2014 Symposium on Radiation Measurements and Applications (SORMA XV)

June 9-12, 2014

THE UNIVERSITY OF MICHIGAN
ANN ARBOR, MICHIGAN, USA

ABSTRACT BOOK

SPONSORED BY

Department of Energy: NNSA NA-22
Defense Threat Reduction Agency (DTRA)
University of Michigan, College of Engineering

Symposium Schedule

Monday June 9	**6:00-8:00 PM Opening Reception – MichiganLeague** 5:00 - 8:00 PM Registration 2nd Floor Concourse - Michigan League **6:00 - 9:00 PM Memorial Service for Prof. Glenn F. Knoll - Ballroom**			
	Rackham Auditorium / Hussey (Sessions)	***Alumni Center***	***Vandenburg***	***Ballroom***
TuesdayJune 10	7:30 AM - 5:00 PM Registration –2nd Floor Concourse (Michigan League)			
8:30 - 8:45	Welcome			
8:45- 9:45	Plenary I			
9:45 - 10:45	Plenary II			
10:45 – 11:00	COFFEE BREAK			*Put Up Posters for Poster Session I*
11:00 – 12:00	Plenary III			
12:00- 1:30	LUNCH *(Put up Posters)*			
1:30 - 3:00		Scintillation Detectors I	Medical Applications I	
3:00 - 4:00				Posters I – New Radiation Detectors
4:00 - 5:30	Room Temperature Semiconductor Materials	AT-TPCs for Exotic Beams and Dark Matter Searches	Silicon Detectors and Photon Readouts	*Remove Posters for Poster Session I*
6:00 -9:00	Conference Reception and Tour – UM football stadium, the “Big House”			
WednesdayJune 11	8:00 AM - 5:00 PM Registration – 2nd Floor Concourse (Michigan League)			
8:00 - 9:30		Scintillation Detectors II	Medical Applications II	*Put Up Posters for Poster Session II*
9:30 - 10:30				Posters II – Radiation Measurement Techniques
10:30 - 12:00		Room Temperature Semiconductor Detectors	Radiation Detection Algorithms and Modeling	*Remove Posters for Poster Session II*
12:00 - 1:30	LUNCH (*Remove and Put Up Posters*)			
1:30 - 3:00		Gamma-Ray and Neutron Imaging Systems	Scintillation Detectors III	*Put Up Posters for Poster Session III*
3:00 - 4:00				Posters III – Physics & Security Applications and Signal Processing
4:00 - 5:30		Nonproliferation, Safeguards, and Homeland Security I	Detector Electronics & Signal Processing	*Remove Posters for Poster Session III*
6:00 - 9:00	Dinner Reception and Museum Tour – University of Michigan Museum of Art			
Thursday June 12	8:00 AM - 5:00 PM Registration –2nd Floor Concourse (Michigan League)			
8:00 - 9:30		Nonproliferation, Safeguards, and Homeland Security II	Unconventional Radiation Detectors	*Put Up Posters for Poster Session IV*
9:30 - 10:30				Posters IV – Medical &Environmental Applications
10:30 - 12:00		Neutron Detectors I	Space Applications	
12:00 - 1:30	LUNCH			
1:30 - 3:00		Active Interrogation Techniques	Low Energy Exotic Beam Facilities	
3:00 - 3:30				COFFEE BREAK
3:30 - 5:30		Contemporary Topics & Closing Announcement	Neutron Detectors II	*Remove Posters for Poster Session IV*

2014 Symposium on
Radiation Measurements
and Applications (SORMA XV)

Greetings from the Chairman

Welcome to the 15th Symposium on Radiation Measurements and Applications (SORMA XV) – this marks our 50th anniversary. While SORMA has been traditionally held every four years, it has been only two years since the previous Symposium was held at the University of California. This increased frequency has largely been due to the step change in the world following the attacks on the U.S. World Trade Center. Radiation detection and measurement science has always been an active field because of the large number of applications that depend upon our measurements, but the new emphasis on security has added demands on our technologies that were unimaginable more than a decade ago.

The program that you are about to experience is the culmination of dedicated work of a few hardy volunteers. The Organizing Committee has been passionate about ensuring this forum remains open and accessible to all practitioners who are dedicated to our craft. Please join us in gratefully acknowledging the generosity of our Symposium Sponsors who understand the importance of our science and the value of this Symposium. Our exhibitors also would like to invite you to peruse their newest technologies and measurement tools. Again, we were not able to accommodate all of the exhibitors who wished to attend SORMA – we want to keep the cozy atmosphere and have placed a priority on the scientific program instead. The technical program before you is scientifically strong and shows remarkable innovations in critical technology areas, including semiconductors, scintillators, gas-filled detectors, ultra-high resolution devices, electronics, and the concepts that exploit them. The Program Committee has selected the technical papers, split approximately evenly between poster and oral presentations, which span the rich spectrum of our field.

For your social program, we have chosen activities that will hopefully rival the successful programs of the past symposia. Please join us for the reception at the University of Michigan Museum of Art (UMMA) where you will be treated with food while being guided through the museum's fine exhibits. Another reception will be held at the famous "Big House" – Michigan's legendary football stadium. On Thursday night, for those of you staying overnight for the MSU FRIB tour or the MCNP-Polimi workshop, there are many other sites worth seeing: watching the Detroit Tigers play a professional baseball game under the stars, taking in wild night life in Windsor, Canada, or even a fast kayak trip down our local Huron River. We hope you will take full advantage of Michigan hospitality while you are with us.

On a sad note, this is the first SORMA that will not be presided over by our dear colleague, friend, and technical leader, Professor Glenn F. Knoll. Early on Easter morning, Glenn passed away unexpectedly and his loss has been an emotional and professional tsunami. SORMA will host a public memorial that honors Glenn's life on Monday evening, 6-9 p.m., in parallel with the Welcoming Reception. All of Glenn's extended family will be present, and they encourage all those whose lives were touched by Glenn, to attend and share their feelings. There will be invited speakers, a musical interlude, an open microphone period, and then a closing reception.

In closing, we welcome you to this wonderful opportunity to interact with superb colleagues and dear friends ... our community is linked by common interests and pursuits, and you will undoubtedly find the technical presentations by your colleagues to be stimulating and rewarding.

Welcome!

David.

Table of Contents

Exhibitors

CAEN Technologies, Inc.	ADIT Electron Tubes
Naval Research Laboratory	Scionix
Canberra Industries	H3D
Niowave, Inc.	W-IE-NE-R Plein & Baus Corp.
Eljen Technology	XIA LLC
Hilger Crystals	Hellma Materials GmbH
Saint-Gobain Crystals	Kromek

Social Programs

Monday 6:00 pm - 8:00 pm ***Opening Reception – Michigan League***

The Opening Reception will be held at the Michigan League in the Vandenberg rooms, on the second floor next to the Registration Table. Buses will pick up attendees staying in north campus hotels. Others will need to make their way there. The League is just a short walk from the Campus Inn and Bell Tower Hotel.

Light refreshments and appetizers will be served. Socializing with new and old friends will be the order of the day. Those interested will also be able to pick up their registration information at the Registration Table. Buses will return participants to the North Campus hotels after the event. The buses will be available until 8:30 pm for transportation back to the North Campus hotels.

Tuesday 6:00 pm - 9:00 pm ***Reception – University of Michigan Football Stadium***

There will be a reception at the University of Michigan Football Stadium "The Big House" on the South Campus of the University. A strolling dinner, refreshments, and dessert will be served. Come and plan on spending the full time eating, drinking, and enjoying the view from the Jack Roth Stadium club. Also there will be the opportunity to spend time down on the football field itself. The buses will be available until 9:30 pm for transportation back to the North Campus hotels. Plenty of free parking for those wishing to drive themselves to and from the event is also available.

Wednesday 6:00 pm - 9:00 pm ***Reception – University of Michigan Museum of Art***

There will be a reception at the University of Michigan Museum of Art (UMMA) on the Central Campus of the University, which is two blocks away from the Michigan League. A strolling dinner, refreshments, and dessert will be served. Come and plan on spending the full time eating, drinking, and looking at world class art. It should be a fun event. The buses will be available until 9:30 pm for transportation back to the North Campus hotels.

Instructions for Presenters

Oral Presentations

- Most oral presentation slots in the main symposium sessions are 12 minutes in length (which includes **presentation and discussion**). Please plan on preparing a **10 minute oral presentation**. Invited speakers will be given a 20 minute slot for presentation and discussion.

- **Presentation order** within sessions is specified on the My Papers page and is also listed in the program. Please note that presentation order *may be changed* any time prior to the start of the symposium.

- All technical material will be presented with a digital projector and a PC running Microsoft Powerpoint. There will be **a ready room available** (Kalamazoo) for testing your presentation. Please create your presentation using the most recent version of software available.

- All files should be loaded onto presentation machines by **07:45 am** in the morning on the day you are to present, or one session prior to the one in which you are to present at the latest.

- **Backup your presentation** on several forms of media. You may wish to use a USB drive, recordable CD, or upload / email your presentation for online access.

- Slide and transparency / overhead projectors will **not** be available.

- A monitor switch will be available should you wish to present from your own laptop via standard 15-pin VGA connector. The resolution of the projectors is 1024x768. Please test your laptop with the projector **at least one session prior** to the one in which you are to present.

Poster Presentations

- There will be 4 poster sessions which highlight a group of papers. Authors are **required to be present** near their posters for discussion with symposium attendees during the prescribed times.

- All poster abstracts will be listed in the abstract book. Poster board locations will be identified by your **assigned poster index** and your previously assigned **paper number** (found at My Papers). Please note that poster indexes may be changed any time prior to the start of the symposium.

- All poster boards will be located in the Ballroom of the Michigan League. All Posters **must be put up before the individual poster session** starts, and **must be removed after each poster session**. Please make sure to put up/remove your posters timely, to meet the conference schedule.
  - Posters for Session I can be put up in the morning of Tuesday, June 10. These posters should be removed by Tuesday evening.
  - Posters for Session II can be put up in the morning of Wednesday, June 11, and should be removed by lunchtime
  - Posters for Session III can be put up in the afternoon of Wednesday, June 11, and should be removed by the evening.
  - Posters for Session IV can be put up in the morning of Thursday, June 12, and should be removed after coffee break.

- Poster boards are **3 feet wide** and **4 feet tall** (portrait orientation). Pushpins will be provided for affixing materials to poster boards.

Shuttle Bus

Transportation during the conference will be provided to and from the Holiday Inn - North Campus, the Michigan League and the Special Event sites.

- **Monday, June 9**
  For Registration and Reception 3:00pm - 8:20pm

- **Tuesday, June 10**
  Into Campus 7:00am - 8:20am
  Back to Hotels 5:30pm - 9:00pm

- **Wednesday, June 11**
  Into Campus 7:00am - 8:20am
  Back to Hotels 5:30pm - 9:00pm

- **Thursday June 12**
  Into Campus 7:00am - 8:20am
  Back to Hotels 5:00pm - 6:00pm

Travel and Area

Parking

- Parking is available in Ann Arbor City parking structures for $1.50 per hour. Several suggested structures for symposium parking are:

  - *Maynard Street Public Parking*
    Located on Maynard Street between E. William and E. Liberty with an additional entrance off Thompson between E. Liverty and E. William
  - *Liberty Square Public Parking*
    Located on Washington Street between Division and State.
  - *S. Forest Public Parking*
    Located on S. Forest between S. University and Willard (1/2 mi from Michigan League).

- Parking is NOT available in University of Michigan staff parking structures. Parking in downtown Ann Arbor and on the University of Michigan campus is very limited. Public safety officials and Parking officials are diligent in issuing tickets to improperly parked vehicles. Any tickets you receive are *your* responsibility.

Currency Exchange

- There is a currency exchange booth in the lobby of the Detroit Metropolitan Airport International Terminal. A limited selection of foreign currencies may be exchanged. Participants are advised to purchase traveler's checks in U.S. dollars or to exchange money before arriving in the United States.

MSU FRIB Tour

Tour of the MSU Facility for Rare Isotope Beams:

- following SORMA XV on June 13th, 2014, at Michigan State University, East Lansing, MI

- Our colleagues at Michigan State University (MSU) and the Facility for Rare Isotope Beams (FRIB) (East Lansing, 1 hr from Ann Arbor) have kindly offered to provide buses for SORMA XV participants on Friday, June 13th and give a tour, with lunch, of the rare isotope beam facilities at MSU. These include the existing coupled cyclotron facility (NSCL) as well as the new LE re-accelerated beam facility (ReA), and the Facility for Rare Isotope Beams (FRIB) now under construction. The present plan is for buses to leave Ann Arbor around 9 AM and return by 3 pm (or earlier). More details including a sign-up sheet for those interested in taking the tour will be provided at the SORMA meeting.

Polimi Workshop

4th MCNPX-PoliMi Workshop

-following SORMA XV on June 13th, 2014, at UM North Campus

- The fourth training workshop of MCNPX-PoliMi will be held by the Detection for Nuclear Nonproliferation group at the University of Michigan on Friday, June 13th, 2014. The workshop will take place at the University of Michigan's North Campus.

Program View of Papers – Tuesday (1/4)

* indicates invited author

Day	Time	Session Title
Tue (6/10)	8:45-9:45 am	**Plenary I** (*pg. 27*) – Rackham Auditorium
		▪ * A Personal Fifty-Five Year Life and Perspective in Fundamental and Applied Atomic and Nuclear Radiation Physics - John Palms (*United States*)
	9:45-10:30 am	**Plenary II** (*pg. 28*) – Rackham Auditorium
		▪ * History of the bubble chamber and active-target imaging detectors. - Fred Becchetti (*USA)*
	11:00-12:00 pm	**Plenary III** (*pg. 28*) – Rackham Auditorium
		▪ * Imaging Challenges in Proton Beam Therapy - Sung Yong Park (*USA*)
	1:30-3:00 pm	**Scintillation Detectors I** (*pg. 29*) – Alumni Center
		▪ * Review of Advances in Inorganic Scintillators for Gamma Ray and Neutron Detection - Kanai Shah (*USA*) - **494**
		▪ * New ideas for better inorganic scintillators - Gregory Bizarri (*USA*) - **503**
		▪ ACs2LiYCl6:Ce3+-based Advanced Radiation Monitoring Device - Brent Budden (*United States*) - **172**
		▪ Linearity of Ca2+-Doped CeBr3 Scintillating Materials - Paul Guss (*USA*) **-022**
		▪ Gamma Spectrometers Employing SrI2(Eu), GYGAG(Ce) and Bi-Plastic - Nerine Cherepy (*USA*) - **078**
		▪ Theoretical and experimental investigation of solid-solution scintillator material properties and performance in the model system of Tl^+ activated $NaBr_xI_{(1-x)}$ and $Na_{(1-x)}K_xI$ - Qi Li (*USA*) **-021**
	1:30-3:00 pm	**Medical ApplicationsI** (*pg. 33*) – Vandenburg
		▪ Limiting factors for timing precision in time-of-flight PET - Stephen Derenzo (*U.S.A.*) - **234**
		▪ Design, development, and initial operation of BabyScan, an in-vivo counter for children around Fukushima - Frazier Bronson (*USA*) - **365**
		▪ Using Neutron for In-situ Measurement of Li Transportation in Li-ion Battery - L. Raymond Cao (*USA*) - **137**
		▪ Impact of system resolution of image quality in PET imaging - Andrej Studen (*Slovenia*) - **297**
		▪ Edge illumination X-ray phase-contrast imaging: enhanced phase sensitivity for synchrotron and laboratory applications - Paul Claude Diemoz (*United Kingdom*) - **356**
		▪ Improvement in Molecular Breast Imaging from advances in CdZnTe technology - Tim Garcia (*United States*) **-431**
		▪ A feasibility study of a PET/MRI insert detector using strip-line and waveform sampling data acquisition - Heejong Kim (*USA*) **-469**
	3:00-4:00 pm	**Posters I – New Radiation Detectors**(*pg. 37*) – Ballroom
		01. Fast Neutron Spectroscopy with CLYC and CNYC Detectors up to 20 MeV - Lakshmi Soundara Pandian (*USA*) - **050**
		02. Development of a Thick Gas Electron Multiplier Based Multi-element Microdosimetric Detector - Zahra Anjomani (Canada) - **053**
		03. High-resolution room-temperature electron spectroscopy - Irshad Ahmad (*USA*) - **068**
		04. The Development of Using CdS sensor Radiation Detection based on liquid crystal cell and Electro-optical Light Modulation Method - Ye Ji Heo (*republic of korea*) - **462**
		05. Characterization of cadmium manganese telluride ($Cd_{1-x}Mn_xTe$; x=0.05) crystals grown by the floating zone method - Anwar Hossain (*USA*) - **211**
		06. Exploring surface processing steps for improving the performance of CdZnTe radiation detectors - Anwar Hossain (*USA*)
		07. Fundamental properties of Transparent RUbber SheeT (TRUST) $LiCaAlF_6$ neutron scintillator - Dai Sugimoto (*Japan*) - **212**
		08. Wavelength-shifting fiber signal readout from Transparent Rubber SheeT (TRUST) type LiCaAlF6 neutron scintillator - Kenichi WATANABE (*Japan*) - **247**

Tuesday (2/4)

Day	Time	Session Title	
Tue (6/10)	3:00-4:00 pm	**09.** Tomographic imaging from one-side using backscattered X-ray - Kenichi WATANABE (*Japan*)	**- 248**
		10. MINER – A mobile imager of neutrons for emergency responders - Mark Gerling (*USA*)	**- 272**
		11. The readout research of large area neutron sensitive MCP detector - Yiming WANG (*China*)	**- 325**
		12. Developments in 3D Diamond Detector Development - Michael Richardson (*United States*)	**- 339**
		13. A Prototype of CVD Diamond based Beam Loss Monitoring Detector For the SSRF and the NSRL - Ming Zeng (*China*)	**- 363**
		14. A scalable ^{3}He-free neutron detector system for use in a wide range of applications - Matt Dallimore (*United States*)	**- 372**
		15. A FASTSCAN WHOLE BODY COUNTER THAT IS INDEPENDENT OF SUBJECT SIZE FOR SMALL CHILDREN TO LARGE ADULTS - Babatunde Oginni (*U. S. A.*)	**- 390**
		16. Evaluation of Optical Response and Noise Properties of AlAs and AlxGa1-xAs Epilayers for use in a Solid-State Photomultiplier - Taehoon Kang (*United States*)	**- 384**
		17. Radiation hardness of single crystal CVD diamond detector for MeV energy protons - Yuki Sato (*Japan*)	**- 425**
		18. Light output and pulse shape characteristics for the novel EJ 299-33 plastic scintillator for γ-rays, neutrons and charged particles - Sheth Nyibule (*USA*)	**- 195**
		19. The recent study of Glass GEM - Yuki Mitsuya (*Japan*)	**- 484**
		20. The Polaris-H Imaging Spectrometer - Christopher Wahl (*USA*)	**- 501**
		21. Informatics based design of garnet host lattices and dopant chemistries for high light yield scintillator materials - Scott Broderick (*USA*)	**- 123**
		22. Development of an Ultra-Low Noise CMOS Preamplifier for Point Contact HPGe Detectors at 77K - Xuezhou Zhu (*China*)	**- 284**
		23. Characterization of an ASIC readout technique for HPGe double-sided strip detectors - Benjamin Sturm (*USA*)	**- 415**
		24. Synthesizing Conjugated Polymers with High Scintillation Light Yield - David Kishpaugh (*United States*)	**- 016**
		25. Scintillation properties of SrI2(Eu2+): Investigations of non-proportionality as a function of temperature and at high gamma-ray energies in comparison to $LaBr_3(Ce^{3+})$ - Rose Perea (*United States*)	**- 090**
		26. The effect of LaBr3:Ce aliovalent co-doping on its mechanical strength - Alessandro Benedetto (*France*)	**- 094**
		27. Band Gap Determination of Promising Halide Scintillators - Will McAlexander (*USA*)	**- 099**
		28. Revisiting index-matched composite scintillators - Drew Onken (*USA*)	**- 115**
		29. Optically Stimulated Luminescence in X-ray irradiated xSnO-(25-x) SrO-75B2O3 Glass - Hidehito Nanto (*Japan*)	**- 127**
		30. Scintillation properties of composite ceramic YAG and its capability on pulse shape descrimination - Takayuki Yanagida (*Japan*)	**- 133**
		31. Scintillation properties of two new elpasolite crystals - Victoria Martin (*United States*)	**- 155**
		32. PL & RL properties of MnO-doped SnO-ZnO-P_2O_5 Glasses - Hirokazu Masai (*Japan*)	**- 157**
		33. Crystal growth and scintillation properties of Eu2+ -doped KBa_2I_5 and K_2BaI_4 - Luis Stand (*United States*)	**- 199**
		34. NIR scintillation properties of Nd^{3+}-doped yttrium vanadate single crystals - Yutaka Fujimoto (*Japan*)	**- 207**
		35. Basic properties of undoped calcium orthoborate crystal for radiation dosimetery - Yutaka Fujimoto (*Japan*)	**- 208**
		36. Quench-Resistant and Metal-Loaded Organic Scintillators - Patrick Feng (*USA*)	**- 085**
		37. Temperature dependence of pyrochlore type scintillators - Shunsuke Kurosawa (*Japan*)	**- 250**
		38. Tuning the internal electric field in CdZnTe radiation detectors - Ge Yang (*USA*)	**- 266**
		39. Scintillation properties of CdF_2 crystal - Kentaro Fukuda (*Japan*)	**- 280**
		40. Thermally and optically stimulated radiative processes in Eu and Y codoped $LiCaAlF_6$ crystal - Kentaro Fukuda (*Japan*)	**- 281**

Tuesday (3/4)

Day	Time	Session Title
Tue (6/10)	3:00-4:00 pm	**41.** Co-doping Effects on Luminescence and Scintillation Properties of Ce doped $Lu_3Al_5O_{12}$ scintillator - Kei Kamada (*Japan*) **- 305**
		42. Growth and Scintillation Properties of Ce and Pr-doped $YCa_4O(BO_3)_3$ single crystals - Kei Kamada (*Japan*) **- 326**
		43. Luminescence properties and neutron response of Bi doped $Li(Nb,Ta)O_3$ crystals grown by micro-pulling down method - Kei Kamada (*Japan*) **- 348**
		44. Estimation of the charge transport properties of Bismuth Tri-Iodide semiconductor radiation detectors - Sasmit Gokhale (*USA*) **- 371**
		45 . Czochralski Growth of 2inch $(Gd_{1-x-y}La_xCe_y)_2Si_2O_7$ (Ce:La-GPS) single crystal and its scintillation properties. - Akira Yoshikawa (*Japan*) **- 409**
		46. Monte Carlo Simulation of Liquid Noble Gas Scintillation Detectors - Syed Hassan (*USA*) **- 488**
		47. Performance Test of Stacked Scintillation Detector for Omnidirectional Gamma-ray Imaging - Tone Takahashi (*Japan*) **- 434**
		48. Investigation of time response of CdZnTe crystals under pulsed laser and X-rays irradiation - Yadong Xu (*China*) **- 471**
		49. Development of high resolution alpha spectrometers using a magnetic calorimeter - Yong-Hamb Kim (*S. Korea*) **- 187**
		50. Development of a scintillation light detector for cryogenic rare event search experiments - JUNGHO SO (*Republic of Korea*) **- 221**
		51. Development of a Fast Neutron Activation Counter Using the Cherenkov Effect - Matthew Millard (*United States*) **- 473**
		52. Characteristics of Fabricated Si PIN-type Radiation Detectors on Cooling Temperatures - Han Soo Kim (*Korea*) **- 034**
		53. X-ray Response of Sub-grain Boundaries in CZT Detectors - Giuseppe Camarda (*United States*) **- 254**
		54. Radiation Hardness Characteristics of Si-PIN Radiation Detector - Manhee Jeong (*South Korea*) **- 055**
		55. Scintillation Properties of 1-inch $CsBa_2I_5:Eu^{2+}$ Crystals - Urmila Shirwadkar (*USA*) **- 143**
		56. Development of ceramics insulated ball-anode element for neutron detection - Kentaro Toh (*Japan*) **- 219**
		57. Preliminary results for possibility of multi-energy X-ray imaging with X-ray beam and filter to overcome low count rate in photon-counting method - Daehong Kim (*Korea*) **- 271**
		58. A two-dimensional scintillation neutron detector readout with wavelength-shifting fibers incorporating interpolation method - Tatsuya Nakamura (*Japan*) **- 446**
		59. Isovalent substitution in Elpasolite Halide Scintillators - Pin Yang (*USA*) **- 144**
		60. Optical Spectroscopy and Scintillation Properties of a Cerium Activated Cs_2NaYBr_6 Crystal - Pin Yang (*USA*) **- 146**
		61. Performance of Large Size LYSO Crystal Batches - Fan Yang (*USA*) **- 178**
		62. Co-doping of $SrI_2:Eu^{2+}$ crystal with different group I and group II elements using Multi-growth Vertical Bridgman - Emmanuel Rowe (*United States*) **- 373**
		63. Response of a new pad-based neutron detector developed for coded aperture thermal neutron imaging - Istvan Dioszegi (*USA*) **- 397**
		64. Alternative Scintillation Materials for Radioxenon Detection - Michael Foxe (*USA*) **- 414**
		65. Thermoluminescent analysis of rare earth íons (Tb^{3+} and Eu^{3+}) doped CaSO4 crystal powder - Luiza Souza (*Brazil*) **- 239**
		66. NEODYMIUM AS DOPANT FOR MAGNESIUM TETRABORATE MATRIX AND ITS APPLICABILITY FOR TL DOSIMETRY - Luiza Souza (*Brazil*) **- 237**
		67. Perovskite single crystal scintillating films for high resolution X-ray imaging at synchrotrons - Federica Riva (*Francia*) **- 112**
		68. Surface Passivation of CZT Nuclear Detectors Using Potassium Hydroxide in Hydrogen Peroxide Solution - Stephen Egarievwe (*USA*) **- 244**
		69. Growth and Characterization of $CdTe_xSe_{1-x}$: A Possible Radiation Detector Material - Utpal Roy (*USA*) **- 256**

Tuesday (4/4)

Day	Time	Session Title
Tue (6/10)	3:00-4:00 pm	**70.** Metal and oxygen impurities in zone-refined precursors for halide crystalline scintillators - Stacy Swider (*United States*) **- 387** **71.** Pulse shape discrimination of $Cs_2LiYCl_6:Ce^{3+}$ scintillator up to 180 °C - Kan Yang (*USA*) **- 391** **72.** Ultra Fast Scintillators for High Speed Radiography - Stuart Miller (*United States*) **- 413** **73.** Luminescent properties of BaBrX:Eu (X=F, Cl, Br, I) family as a function of temperature - Ivan Khodyuk (*USA*) **- 426** **74.** Photon density response and picosecond spectroscopy of GYGAG:Ce - Samuel Flynn (*United States*) **- 106** **75.** Investigation the effect of co-dopants in GGAG crystals by making GGAG:Ce pellets with different co-dopants - Fang Meng (*United States*) **- 107** **76.** Growth of Crack Free Strontium Iodide Crystals by Impurity Softening - Amlan Datta (*USA*) **- 386** **77.** Fabrication of transparent ceramics for gamma spectroscopy and x-ray CT - Zachary Seeley (*United States*) **- 126** **78.** Cerium-doped Mixed Elpasolite Scintillators: $Cs_2NaYBr_3I_3$ and $Cs_2NaLaBr_3I_3$ - Hua Wei (*United States*) **- 102** **79.** Improved Crystal Growth and Scintillation Performance of Europium Doped Cesium Calcium Iodide - Adam Lindsey (*United States*) **- 097** **80.** The effect of co-doping on the luminescence centers and charge traps in GGAG:Ce crystals - Fang Meng (*United States*) **- 049** **81.** Pixelated Neutron Imager Using Single Crystal $LiInSe_2$ - Elan Herrera (*USA*) **- 278**
	4:00-5:30 pm	**AT-TPCs for Exotic Beams and Dark Matter Searches** (*pg. 77*) – Alumni Center ▪ * Results from the LUX dark matter experiment - Markus Horn (United States) **- 156** ▪ * Active Target-Time Projection Chambers for Reactions Induced by Rare Isotope Beams: Physics and Technology - Wolfgang Mittig (USA) **- 507** ▪ * Fusion studies with an active-target time projection chamber - James Kolata (USA) **- 316** ▪ * Ionization-phonon nuclear recoil discrimination with 100 mm dia. germanium direct dark matter detectors for use in SuperCDMS-SNOLAB - Allison Kennedy (USA) **- 441** ▪ The Neutron Induced Fission Fragment Tracking Experiment : High-precision Fission Cross Section Measurements with a Time Projection Chamber - Nathaniel Bowden (USA) **- 336** ▪ Low Energy Calibration of Nuclear Recoils in Dual Phase Xenon with the MiX Detector - Scott Stephenson (United States) **- 296** ▪ SπRIT: A time-projection chamber for symmetry-energy studies - Rebecca Shane (USA) **- 337**
	4:00-5:30 pm	**Room Temperature Semiconductor Materials** (*pg. 72*) – Hussey ▪ * Ruggedization of CdZnTe Detectors, Detector Assemblies and Modules for Radiation Detection Applications - Pinghe Lu (*Canada*) **- 077** ▪ Effects of Excess of 6Li on the Properties of 6LiInSe2 Crystals Grown by the Vertical Bridgman Technique - Yevgeniy Tupitsyn (*USA*) **- 041** ▪ Progress in thallium bromide gamma-ray spectrometer development - Leonard Cirignano (*USA*) **- 241** ▪ Visualization of TlBr Ionic Transport Mechanism by the Accelerated Device Degradation Technique - Amlan Datta (*US*) **- 389** ▪ Post-Growth Annealing of Bridgman-Grown CZT and CMT Crystals for Room-Temperature Nuclear Radiation Detectors - Stephen Egarievwe (*USA*) **- 236**
	4:00-5:30 pm	**Silicon Detectors and Photon Readouts** (*pg. 74*) – Vandenburg ▪ Characterization of a fine pitch vertically integrated DNW MAPS - ALESSIA MANAZZA (*ITALY*) **- 400** ▪ Tunable wavelength bi-alkali photocathode via structure engineering for photon detection applications - Junqi Xie (*USA*) **- 502** ▪ Recent progress of MPPC-based scintillation detectors in high precision X-ray and gamma-ray imaging - Jun Kataoka (*Japan*) **- 019** ▪ Experimental study of β spectra using a semiconductor Si detector - Charlène Bisch (*France*) **- 103** ▪ A Microstructure Solid-State Detector for Fast Neutrons - Justin Clinton (*United States*) **- 459**

Wednesday (1/7)

Day	Time	Session Title
Wed (6/11)	8:00-9:30 am	**Medical Applications II** (*pg. 83*) – Vandenburg
		▪ Range assessment in particle therapy based on prompt-gamma timing measurements - Guntram Pausch (*Germany*) **- 226**
		▪ Study, Simulation and Validation of the Read-Out Electronics Design for a High-Resolution Plastic Scintillating Fiber Based Hodoscope - Jose Maria Blasco (*Spain*) **- 045**
		▪ Study of thermal and epithermal neutrons for accelerator based in vivo neutron activation facility using $^{115}In(n, \gamma)^{116}In$ - Chitra Bhatia (*Canada*) **- 104**
		▪ A new technology for fast two-dimensional detection of proton therapy beams - Derek Dolney (*USA*) **- 393**
		▪ Measurement of charged particle yields emitted during irradiation with therapeutic proton and Carbon beams in view of the design of a new tool for the monitoring of hadrontherapy treatments - Michela Marafini (*Italy*) **- 293**
	8:00-9:30 am	**Scintillation Detectors II** (*pg. 81*) – Alumni Center
		▪ * New organic scintillators for wide-energy neutron detection - Natalia Zaitseva (*USA*) **- 264**
		▪ * Detection of multiple modes of radiation with scintillators - Jarek Glodo (*USA*) **- 498**
		▪ Trapping Effects in Scintillator Nonproportionality - Stephen Payne (*USA*) **- 040**
		▪ Origin of improved scintillation efficiency in $(Lu,Gd)_3(Ga,Al)_5O_{12}$:Ce multicomponent garnets: an X-ray absorption near edge spectroscopy study - Yuntao Wu (*US*) **- 007**
		▪ Structure and scintillation properties of Ce^{3+}-activated lutetium sulfide halides - Gautam Gundiah (*USA*) **- 202**
	9:30-10:30 am	**Posters II – Radiation Measurement Techniques** (*pg. 85*) – Ballroom
		01. Neutrons and gamma ray from deuterium plasmas at RFX-mod - Luca Stevanato (Italy) **- 060**
		02. Transit Time of Electrons and Gas Gain in P-10 and $ArCO_2$ Using an Electron Attachment Spectrometer - Gloria Orchard (*Canada*) **- 233**
		03. Real-Time Airborne Gamma-Ray Background Estimation Using NASVD with MLE and Radiation Transport for Calibration - Jonathan Kulisek (*United States of America*) **- 064**
		04. Optimization for a long counter design using MCNP simulation - Raina Park (*Canada*) **- 076**
		05. Novel Ultra-low Electronic Noise HPGe Detector Structure for Record Energy Resolutions - Vlad Marian (*France*) **- 343**
		06. High-Precision Fission Yields Attained From Delayed Gamma-Ray Measurements - Douglas Rodriguez (*United States of America*) **- 259**
		07. Remediating neutron damage in orthogonal-strip planar germanium detectors - Emily Jackson (*USA*) **- 351**
		08. Feasibility and Demonstration of a Cloud-Based RIID Analysis System - Michael Wright (*USA*) **- 122**
		09. Development of a low background liquid scintillation counter for a shallow underground laboratory - John Orrell (*USA*) **- 131**
		10. Characterization of radiation exposure levels in the vicinity of an x-ray tube used in the non-destructive examination of railroad track structure - Jessica Salazar (*USA*) **- 405**
		11. Radiation Sensor Data Fusion for Improved Detection and Localization - Daniel Cooper (*USA*) **- 032**
		12. Microcalorimeter Q-spectroscopy for nuclear materials analysis - Andrew Hoover (*USA*) **- 169**
		13. High resolution alpha particle spectrometry through collimation - Seunghoon Park (*Republic of Korea*) **- 184**
		14. Localization Techniques for Aerial Search of Radiological Sources - Sean Robinson (*USA*) **- 101**
		15. Multiplicity and Recoil Spectrometer for Fast Neutron Background Measurements at Depth - Peter Marleau (*USA*) **- 203**
		16. Adaptively Reevaluated Bayesian Localization (ARBL) – a Novel Technique for Radiological Source Localization - Erin Miller (*USA*) **- 110**
		17. Beam detector for secondary pion beam at SIS18 GSI - Rafal Lalik (*Germany*) **- 235**
		18. Analyzing the responses of conventional and extended neutron detectors in radiation fields of a 150-MeV LINAC - Yu-Chi Lin (*Taiwan*) **- 289**
		19. Time-of-flight neutron response function characterization of 4He scintillation detectors - Ryan Kelley (*USA*) **- 322**

Wednesday (2/7)

Day	Time	Session Title
Wed (6/11)	9:30-10:30 am	**20.** Data fusion for mobile gamma ray and neutron imaging systems using supervised classification algorithms - John Sparger (*United States*) **- 125**
		21. γ-γ coincidence system for low background measurements - Elena Sala (*Italy*) **- 406**
		22. Design of Gating Grid in SπRIT Time Projection Chamber - Suwat Tangwancharoen (*USA*) **- 423**
		23. Proposed enhancement of gamma-ray detectors efficiency transfer implemented in the case of an isotropic radiating axial point source with experimental audition - Mohamed Krar (*Egypt*) **- 017**
		24. Compton Suppressed LaBr3 Detection System for use in Nondestructive Spent Fuel Assay - Sarah Bender (*United States*) **- 154**
		25. Monte carlo calculation of the response function of plastic scintillator using compton kinematics - Chankyu Kim (*South Korea*) **- 184**
		26. Comparison and optimization of neutron spectrum unfolding methods - Haonan Zhu (*USA*) **- 260**
		27. Semi-empirical Determination of Detection Efficiency for Voluminous Source by Effective Solid Angle Approach - Minyoung Kang (*Korea*) **- 291**
		28. Efficiency calibration model fitting with correlated data - William Russ (*USA*) **- 403**
		29. Challenge Spectra performance of the singles gamma spectrometry analysis using a new coincidence analysis package - Martin Keillor (*USA*) **- 442**
		30. Improvements in standardless calibration procedures for micro-XRF - Lucas Sacchini Del Lama (*Brazil*) **- 451**
		31. Calculation of the detection limit in radiation measurements with systematic uncertainties - John Kirkpatrick (*USA*) **- 474**
		32. Time-correlated neutron analysis of a multiplying HEU source - Eric Miller (*USA*) **- 490**
		33. Development of a wavelength shifting fiber Detector Prototype for Thermal Neutrons based on a Chip readout electronic - Ralf Engels (*Germany*) **- 116**
		34. Electronics Upgrade for Position Sensitive Neutron Detectors - Ralf Engels (*Germany*) **- 119**
		35. Compensation of Detector Capacitance via a Charge-Sensitive Preamplifier modified with a Bootstrap Amplifier - Inyong Kwon (*USA*) **- 238**
		36. Detection and Imaging of Pulsed Neutrons with Solid-State Electronics - Syed Hassan (*USA*) **- 366**
		37. Development of a manufacturing capability for stilbene scintillation crystals - Candace Lynch (*USA*) **- 168**
		38. Optimizing operational temperature to minimize polarization effect in TlBr detectors - Sean O'Neal (*United States*) **- 355**
		39. The cosmic ray muon tomography facility based on large scale MRPC detectors - Ming Zeng (*China*) **- 243**
		40. Lifetime Measurements Using Gamma-Ray Imaging in GRETINA - Robert Crabbs (*United States*) **- 440**
		41. Trends in physical and device parameters for electron directional sensitivity for electron track Compton imaging - Brian Plimley (*United States*) **- 475**
		42. Neutron Dose Equivalent Evaluation from the D-D Neutron Generator at the University of Florida - Chae Young Lee (*South of Korea*) **- 438**
		43. Petawatt Laser Based Muon Source and Detector for Rapid High-Z Material Detection - Mark Browder (*US*) **- 252**
		44. Cyclic neutron activation analysis using deuterium-tritium fusion neutrons for half-life analysis and actinide mixture characterization - Bruce Pierson (*United States*) **- 412**
		45. Induced Radioactivity Research for the NSRL Linac - LIJUAN HE (*China*) **- 220**
		46. True coincidence summing correction and mathematical efficiency modeling of a well detector - Henrik Jäderström (*USA*) **- 368**
		47. Electrical field simulation of an ionization chamber of parallel plates and graphite collecting electrode - Felipe Cintra (*Brazil*) **- 445**
		48. Comparative study of neutron and gamma-ray pulse shape discrimination of anthracene, stilbene, and p-terphenyl - Takayuki Yanagida (*Japan*) **- 132**
		49. Response evaluation of a small radiation detector using OSL with optical fiber readout to high energy carbon ions - Kenichi WATANABE (*Japan*) **- 249**
		50. Spectral Anomaly Methods for Aerial Detection using KUT Nuisance Rejection - Rebecca Detwiler (*USA*) **- 148**

Wednesday (3/7)

Day	Time	Session Title
Wed (6/11)	9:30-10:30 am	**51.** ARCIS: Adaptive Rail Cargo Inspection System - Anatoli Arodzero (*USA*) **- 167**
		52. Fast neutron detection efficiency of EJ-313 and BaF2 scintillators by ^{19}F activation - Pawel Sibczynski (*Poland*) **- 258**
		53. Stand-off radiation source localization with multiple directional sensors - Chuanlei Liu (*Canada*) **- 312**
		54. Benchmarking the RadMAP Gamma-Ray Sensors - Joseph Curtis (*United States*) **- 482**
		55. The Muon Portal detector: a double tracker to inspect travelling containers - Cristina Pugliatti (*Italy*) **- 096**
		56. Implementing the Absolute Calibration Method into an Automated Radioxenon Software Platform - Matthew Cooper (*United States*) **- 364**
		57. Energy Resolution Measurement of a Large LaBr3:Ce Detector for Low Energy Gamma Rays - Akhtar A. Naqvi (*Saudi Arabia*) **- 228**
		58. Multiple neutron interaction location reconstruction using a single volume neutron scatter camera - Kyle Weinfurther (*USA*) **- 331**
		59. Performance improvements to Segmented Silicon Drift Detectors : a key for their integration in portable gamma spectroscopy systems and beta monitoring systems - Olivier Evrard (*Belgium*) **- 121**
		60. Radiation Hardness Characteristics of the Preamplifiers Based on Different Substrate Materials - Manhee Jeong (*South Korea*) **- 054**
		61. Development of a data acquisition system for two-dimensional position sensitive detectors with delay line readout - Andrei Hanu (*United States*) **- 149**
		62. Prototypes of the Data Acquisition System for Thomson Scattering diagnostic - Ekaterina Puryga (*Russia*) **- 215**
		63. A High-Speed Electron Beam Profile Monitor for the Synchrotron Radiation Source - Aleksandr Kotelnikov (*Russia*) **- 288**
		64. Utilization of Wavelength-Shifter Fibers Coupled to ZnS(Ag) and Plastic Scintillator for Simultaneous Detection of Alpha/Beta Particles - Yair Ifergan (*Israel*) **- 287**
		65. CLARO-CMOS: a fast, low power and radiation-hard front-end ASIC for single-photon counting in 0.35 micron CMOS technology - Massimiliano Fiorini (*Italy*) **- 416**
		66. Gamma-ray Spectroscopy Performance of a 16-channel Digital Spectrometer - Hui Tan (*USA*) **- 454**
		67. High density processing electronics for superconducting tunnel junction array detectors - William Warburton (*USA*) **- 455**
		68. An Integrated Digital Neutron Monitor and Reactivity Meter - Hwai-Pwu Chou (*Taiwan*) **- 302**
		69. A double-ring oscillator TDC for a GEM array detector - Hwai-Pwu Chou (*Taiwan*) **- 303**
		70. Nonproportionality in the scintillation light yield of bismuth germanate - Matthew Bales (*United States*) **- 417**
		71. Microscale Luminescence Imaging of Secondary Phases, Defects, and Homogeneity in Scintillators - Stephanie Lam (*USA*) **- 333**
		72. Performance of a Pixelated Neutron Spectrometer - Justin Clinton (*United States*) **- 448**
		73. New VME based read-out modules for multi-detector experiments - Andreas Ruben (*USA*) **- 512**
	10:30-12:00 pm	**Room Temperature Semiconductor Detectors** (*pg. 117*) – Alumni Center
		▪ * Compound Semiconductor X- and Gamma-Ray Radiation Detectors - Ralph James (*USA*) **- 506**
		▪ Combining material study with detector technology development using digital 3- dimensional position-sensitive ASIC readout systems for room-temperature semiconductor gamma-ray detectors - Zhong He (*USA*) **- 495**
		▪ Longevity of planar and pixelated TlBr Gamma Spectrometers - Adam Conway (*USA*) **- 378**
		▪ Strengthened electric field technique implemented on CZT detector - Jianqiang Fu (*China*) **- 006**
		▪ Thallium-based ternary compounds for X- and γ-Radiation Detection - J. Archibald Peters (*United States*) **- 142**
		▪ Noise and detector performance studies of TlBr and (Cd,Zn)Te at room temperature with various digital pulse shapers - Markus Dambacher (*Germany*) **- 166**

Wednesday (4/7)

Day	Time	Session Title
Wed (6/11)	10:30-12:00 pm	**Radiation Detection Algorithms and Modeling** (*pg. 120*) – Vandenburg
		▪ Correlated Statistical Uncertainties in Coded Aperture Imaging - Matthew Fleenor (*USA*) **- 377**
		▪ Improved R/N Source Localization in Variable NORM Background: An MLEM Approach with Segmentation Data - Tanya Crowley (*United States*) **- 145**
		▪ Validation of a Bayesian-Based Isotope Identification Algorithm - Clair Sullivan (*USA*) **- 396**
		▪ Network Algorithms for Detection of Radiation Sources - Nageswara Rao (*USA*) **- 051**
		▪ Neutron Pileup Algorithms For Multiplicity Counters - Sean Robinson (*USA*) **- 109**
		▪ OSIRIS—Gamma-Ray Spectroscopy Software for On-Site Inspections under the Comprehensive Nuclear Test-Ban Treaty - A J Caffrey (*USA*) **- 088**
		▪ Coincidence Counting Using Alternative Neutron Detection - Richard Kouzes (*USA*) **- 100**
	1:30-3:00 pm	**Scintillation Detectors III** (*pg. 124*) – Vandenburg
		▪ Fast Neutron Measurements Using CLYC Scintillator - Martin Smith (*Canada*) **- 012**
		▪ Design of a New Cold Neutron Detector for Chromatic Analysis Neutron Diffractometer Or Reflectometer at NCNR - Alon Osovizky (*USA*) **- 197**
		▪ Cross-correlation measurements with the EJ-299-33 plastic scintillator - Mark Bourne (*United States*) **- 392**
		▪ Next Generation of Dual Mode Scintillator Crystals - Rastgo Hawrami (*USA*) **- 105**
		▪ A Study on the Radiation Hardness of BSO Crystals - Fan Yang (*USA*) **- 177**
		▪ Rugged Detectors for Fast, Epithermal and Thermal Neutrons - Rico Chandra (*Switzerland*) **- 309**
	1:30-3:00 pm	**Gamma-Ray and Neutron Imaging Systems** (*pg. 127*) – Alumni Center
		▪ * Applications of Gamma-Ray Imaging - Kai Vetter (*United States*) **- 509**
		▪ Performance and field tests of handy Compton camera using 3D position-sensitive scintillators coupled with MPPC-arrays - Aya Kishimoto (*Japan*) **- 020**
		▪ Event Localization in Bulk Scintillator Crystals Using Coded Apertures - Klaus-Peter Ziock (*USA*) **- 046**
		▪ Investigations into Semiconducting Boron Carbide for Neutron Radiography and Tomography Applications - Thomas Wulz (*USA*) **- 472**
		▪ iPIX: An advanced gamma camera technology for rapid and accurate localization of radioactive hotspots - Vincenzo Paradiso (*France*) **- 301**
		▪ Backscatter Radiography By Selective Detection As a Non-Destructive Examination Tool - James Baciak (*USA*) **- 376**
		▪ High resolution neutron imaging capabilities with MCP/Timepix detector at BOA beamline at PSI - Anton Tremsin (*USA*) **- 354**
	3:00-4:00 pm	**Posters III – Physics & Security Applications and Signal Processing** (*pg. 130*) – Ballroom
		01. Digital Pulse Analyzer for ITER Vertical Neutron Camera - Alina Ivanova (*Russia*) **- 038**
		02. 256-pixel microcalorimeter array for high-resolution γ-ray spectroscopy of mixed-actinide materials - Ryan Winkler (*USA*) **- 430**
		03. Progress in the development of a single-volume neutron scatter camera - Erik Brubaker (*USA*) **- 447**
		04. High pressure xenon TPC radiation background for NEXT experiment - Abdel Bachri (*USA*) **- 042**
		05. Characteristics of miniaturized CsI(Tl) scintillator for mobile radiation detector - Hyunjun Yoo (*Republic of Korea*) **- 163**
		06. Integration of X-ray and neutron radiography data for enhanced discrimination of materials with high atomic number - Andrew Gilbert (*USA*) **- 439**
		07. PERFORMANCE OF A SMALL ANODE GERMANIUM WELL DETECTOR - Aderemi Adekola (*USA*) **- 165**
		08. Radiation Damage Study and Characterization of Hamamatsu Silicon Photo-Multipliers - Massimiliano Fiorini (*Italy*) **- 335**
		09. ARES Topic 1 - HeliSORDS - Hylton Murphy (*USA*) **- 370**
		10. Study on Photon Number Resolution of Silicon Photomultipliers with different sizes of micro cells - Hyoungtaek Kim (*Republic of Korea*) **- 381**

Wednesday (5/7)

Day	Time	Session Title
Wed (6/11)	3:00-4:00 pm	**11.** SWORD (SoftWare for the Optimization of Radiation Detectors) - Chul Gwon (*USA*) **- 117** **12.** Straw Detector for Ultra High Rate Neutron Detection in the Presence of Ultra High Gamma Flux - Liang Sun (*U.S.A.*) **- 444** **13.** DYNAMIC TEST RESULTS OF A TIME-CORRELATED RADIATION PORTAL MONITOR - Rico Chandra (*Switzerland*) **- 310** **14.** Embedded search and ID capability for human portable radiation detectors - Kirill Shokhirev (*USA*) **- 061** **15.** Determination of Penn State Breazeale Reactor Fuel Element Burnup by Nondestructive Assay - Sarah Bender (*United States*) **- 153** **16.** Finding Gaps in Data to Guide Development of a Radiation Threat Adjudication System - Nick Gisolfi (*United States*) **- 435** **17.** Improved Suppression of Background Radiation for Detecting Sources from Large Libraries of Known Threat - Artur Dubrawski (*USA*) **- 458** **18.** Highly Portable HPGe Detector for Safeguards Applications - Jonathan Dreyer (*USA*) **- 367** **19.** New proposals for radiation portal monitor applications - Byoung-Jik Kim (*Republic of KOREA*) **- 161** **20.** Comparison of waveform digitizers for spectroscopy and homeland security applications - Davide Cester (*Italy*) **- 059** **21.** A liquid scintillator fast neutron multiplicity counter - Steven Sheets (*USA*) **- 410** **22.** Development of a digital pulse processing system for a 2-D THGEM-based microdosimetric detector - Sahar Darvish Molla (*Canada*) **- 080** **23.** Performance of a new real time digital pulse processing system for X-ray and gamma ray semiconductor detectors - Leonardo Abbene (*Italy*) **- 139** **24.** Study on Digital Pulse Shape Discrimination in a BF3 detector - Jinhyung Kim (*Korea*) **- 290** **25.** Development of a 32-Channel Digital Gamma-ray Spectrometer - Hui Tan (*USA*) **- 464** **26.** Composition Optimization of Polystyrene Based Plastic Scintillator - Yewon Kim (*South Korea*) **- 067** **27.** Modification of the Developed Code for Isotopic Analysis of Uranium - Jun-Hyuck Kim (*Republic of Korea*) **- 292** **28.** Gamma-neutron imaging system utilizing pulse shape discrimination with CLYC - Chad Whitney (*US*) **- 084** **29.** Development of photon-counting X-ray nondestructive testing system using Si Strip detectors and time-over-threshold ASIC - Yang Tian (*Japan*) **- 304** **30.** Radiation Sources Driven by Superconducting RF Electron Accelerators - Chase Boulware (*United States*) **- 074** **31.** Electrical and Plasma Characteristics of a Pulsed Neutron Generator - Syed Hassan (*USA*) **- 485** **32.** Neutron Time-of-Flight Measurements; Comparison with Monte Carlo Simulations at the Idaho Accelerator Center - MAYIR MAMTIMIN (*United States*) **- 151** **33.** A Liquid Metal Bremsstrahlung Converter for use with High Power Superconducting Electron Linacs - Dyle Henning (*United States of America*) **- 047** **34.** Development of a DAQ system for a Plasma-Display-Panel based X-ray detector (PXD) - Hakjae Lee (*Republic of Korea*) **- 273** **35.** Investigation of the influence of measurement position on the cosmic-ray induced dose inside a learjet-type aircraft - Adriane Prado (*Brasil*) **- 332** **36.** Materials Chemistries for Faster Electron Mobilities in Semiconducting Detection Materials - Kim Ferris (*USA*) **- 065** **37.** Numerical model of electron energy response in CsI:Tl and SrI2:Eu with diffusion coefficient and rate constants dependent on electron temperature and thus time - Xinfu Lu (*USA*) **- 118** **38.** The method research of enhancing the spatial resolution of photoneutron radiography - Yigang Yang (*P.R.China*) **- 010** **39.** Data and software tools for gamma radiation spectral threat detection and nuclide identification algorithm development and evaluation - David Portnoy (*USA*) **- 083**

Wednesday (6/7)

Day	Time	Session Title
Wed (6/11)	3:00-4:00 pm	**40.** Systematic Measurement of Fast Neutron Background Fluctuations in an Urban Area Using a Mobile Detection System - Anagha Iyengar (*USA*) **- 098**
		41. Features of different inorganic scintillators application in neutron-radiation systems for illegal substances detection - Viacheslav Batyaev (*Russia*) **- 129**
		42. Fast Neutron Coded Aperture Imager - Richard Woolf (*United States*) **- 135**
		43. Multiple Scattering Compton Camera System with Neutron Activation for Material Inspection - Wonho Lee (*Korea*) **- 152**
		44. Development of High-Resolution Silicon-Based Particle Sensor with Integrated Amplification - Geehyun Kim (*South Korea*) **- 380**
		45. Design of a Cosmic-ray Muon Radiography System for Dry Storage Cask Imaging - Haori Yang (*United States*) **- 173**
		46. Study on a pulse analysis algorithm based on template-matching for high throughput spectroscopy - Haori Yang (*United States*) **- 174**
		47. Parameters of explosives detection via tagged neutron method - Sergey Belichenko (*Russia*) **- 189**
		48. Coded Aperture Approaches to Thermal Neutron Imaging of SNM - Jennifer Littell (*United States*) **- 231**
		49. Personal Radiation Detector at High Technology Readiness Level for DARPA's SN-13-47 and SIGMA Program Requirements - Dimitry Ginzburg (*Israel*) **- 246**
		50. Real time wide area radiation surveillance system (REWARD) based on 3D silicon and (Cd,Zn)Te for neutron and gamma-ray detection - Markus Dambacher (*Germany*) **- 313**
		51. Gamma-ray and neutron background data collected aboard the MZ-3A airship - Lee Mitchell (*USA*) **- 334**
		52. Gamma-ray and neutron background comparison of US metropolitan areas - Lee Mitchell (*USA*) **- 340**
		53. Impact of uncertainties on 3D source localization for gamma ray imaging with scene data fusion - Ross Barnowski (*United States*) **- 360**
		54. CLYC-SiPM sensor for handheld detection systems - Jarek Glodo (*USA*) **- 401**
		55. A water-based neutron detector as a well multiplicity counter - Alexandra Asghari (*United States*) **- 481**
		56. Modeling Spent Fuel Gamma-Ray Emissions For Measurement and Detector Development - Douglas Rodriguez (*United States of America*) **- 245**
		57. Testing of a Si-PIN Beta-Gamma Radioxenon Detector - Michael Foxe (*USA*) **-422**
		58. Statistical Predictions of the Performance of a Fast Neutron Multiplicity System for Assaying Plutonium - David Chichester (*USA*) **- 433**
		59. Delayed gamma-ray spectroscopy of nuclear materials with lanthanum bromide detectors - Andrea Favalli (*US*) **- 496**
		60. Evaluation of 6Li metal foil neutron detector for well coincidence counter - Andrea Favalli (*US*) **- 460**
		61. Optimization of dual sided readout of plastic pixels for neutron block detectors - Mitchell Laubach (*United States*) **- 489**
		62. Development of Calibration Source for XMASS detector - Nam Young KIM (*Korea*) **- 295**
		63. Testing the Ultracold Neutron Source at the PULSTAR Reactor - Ekaterina Korobkina (*United States*) **- 421**
		64. Characterization of point defect chemistry in scintillator materials by tracer diffusion - Katherine Colbaugh (*United States*) **- 048**
		65. Fast-Neutron and Gamma-Ray Imaging Measurements of Special Nuclear Material - Alexis Poitrasson-Rivière (*United States*) **- 379**
		66. Improving 3D Compton Image Reconstruction with Visual Volumetric Data - Andrew Haefner (*United States*) **- 218**
		67. The University of New Mexico spectrometer for high resolution fission fragment yield data, with preliminary results from LANSCE - Adam Hecht (*USA*) **- 176**
		68. A Fast Spectrum Neutron Source for Material Irradiation Using a Superconducting Electron Linac - Valeriia Starovoitova (*USA*) **- 029**

Wednesday (7/7)

Day	Time	Session Title
Wed (6/11)	3:00-4:00 pm	**69.** Weld radiography image process aided by interpolation functions and wavelet transformation function - MARIANA BURROWES MOREIRA GUIMARÃE (*BRAZIL*) **- 141** **70.** Feasibility of screening fast moving highway traffic for illicit nuclear material. - Matt Dallimore (*United States*) **- 407** **71.** High Yield, Gas Target Neutron Source - Evan Sengbusch (*USA*) **- 402** **72.** Shallow Underground Proportional Counter Characterization and Calibration for Measuring 37Ar - Allen Seifert (*USA*) **- 150** **73.** Development of Fast-Neutron THGEM-based Imaging Detector for Fan-Beam Tomography Applications and Spectroscopy. - Marco Cortesi (*USA*) **- 111** **74.** Stability of Working Reference Standards for Hybrid K-Edge Densitometer Quality Assurance - Tyler Guzzardo (*US*) **- 014** **75.** Cosmic-Ray Scanning of Cargo Conveyances for Nuclear and Conventional Weapons of Mass Destruction - Michael Sossong (*United States*) **- 013**
	4:00-5:30 pm	**Nonproliferation, Safeguards, and Homeland Security I** (*pg. 164*) – Alumni Center ▪ * Can we break the 1% uncertainty barrier for gamma-ray isotopic nondestructive analysis of special nuclear material? - Michael Rabin (*USA*) **- 374** ▪ Application of Fast Liquid Scintillator for SNM Detection using DDA Method - Michael King (*USA*) **- 036** ▪ Neutron Triples Counting Data for Uranium - Stephen Croft (*US*) **- 497** ▪ Memory effect studies of beta-gamma detectors in the IMS radioxenon stations - Amanda Prinke (*United States of America*) **- 399** ▪ LiF/ZnS Neutron Multiplicity Counter - Sean Stave (*USA*) **- 170** ▪ Material Discrimination Using Scattering and Stopping of Cosmic Ray Muons and Electrons: Differentiating Heavier from Lighter Metals as well as Low-Atomic Weight Materials - Gary Blanpied (*USA*) **- 251** ▪ A segmented detector for airborne γ-ray spectroscopy - Paola Garosi (*Italy*) **- 362**
	4:00-5:30 pm	**Detector Electronics and Signal Processing** (*pg. 167*) – Vandenburg ▪ * A data-driven front-end ASIC for charge-interpolating trackers and spectrometry - Gianluigi De Geronimo (*USA*) **- 328** ▪ Study of the impact of the pixel pitch of the Timepix chip integrated to the GAMPIX gamma camera in terms of spectrometric and imaging performances - Hermine Lemaire (*France*) **- 092** ▪ Ultra-Low Noise Front End Electronics for Germanium Based Antineutrino Detection - Paul Barton (*USA*) **- 079** ▪ Electron spectroscopy of 68Ni enabled through digital pulse-shape processing - Scott Suchyta (*USA*) **- 124** ▪ Energy dispersive CdTe and CdZnTe detectors for spectral clinical CT and NDT applications - William Barber (*USA*) **- 263** ▪ Microwave multiplexed readout for large arrays of TES microcalorimeters - Douglas Bennett (*USA*) **- 424** ▪ Design and fabrication of planar 6 cm x 6 cm microchannel plate photodetector for imaging and fast timing applications - Junqi Xie (*USA*) **- 394**

Thursday (1/5)

Day	Time	Session Title
Thu (6/12)	8:00-9:30 am	**Nonproliferation, Safeguards, and Homeland Security II** (*pg. 172*) – Alumni Center
		▪ * Cosmic Ray Muon Imaging - Christopher Morris (*USA*) **- 511**
		▪ A recently deployed intelligent PVT Portal system - Matt Dallimore (*United States*) **- 369**
		▪ Mobile HPGe Detector Array for Remote Gamma Ray Spectroscopy - Vlad Marian (*France*) **- 324**
		▪ Integrated Detection and Localization Algorithms for Aerial Radiation Search Applications - Carolyn Seifert (*USA*) **- 491**
		▪ Field test results from the Multi-Modal Gamma Imager - Morgan Burks (*USA*) **- 033**
		▪ Radiographic Imaging Components for Dose Reduction in Cargoes - Areg Danagoulian (*US*) **- 317**
		▪ Impact of gamma-ray spectral resolution and efficiency on detection of nuclear threats - Simon Labov (*United States*) **- 429**
	8:00-9:30 am	**Unconventional Radiation Detectors** (*pg. 174*) – Vandenburg
		▪ Transition Edge Sensor Electron Capture Spectroscopy: Towards A Neutrino Mass Measurement - Dr. Gerd J. Kunde (*United States*) **- 240**
		▪ First results with a microcavity plasma panel detector - Claudio Ferretti (USA) **- 242**
		▪ LET dependence of bubbles evaporation pulses in superheated emulsion detectors - Angela Di Fulvio (*United States*) **- 253**
		▪ Response measurement of single crystal CVD diamond radiation detector for intense X-rays aiming at burn-history measurement on an inertial confinement fusion with fast ignition. - Takehiro Shiamaoka (*Japan*) **- 483**
		▪ Gamma-ray Spectrometer based on Superconducting Transition Edge Sensor for Nuclear Materials Analysis - Shuichi Hatakeyama (*Japan*) **- 342**
		▪ Novel use of optical crystals for radiation detection - Adam Hecht (*USA*) **- 477**
		▪ Development of microcalorimeters for Q and electron capture spectroscopy - Mark Croce (*USA*) **- 428**
	9:30-10:30 am	**Posters IV – Medical & Environmental Applications** (*pg. 177*) – Ballroom
		01. Radiation dose evaluation of pediatric voiding cystourethrography–phantom study - Kai-Yuan Cheng (*R.O.C.*) **- 181**
		02. Preliminary Tests of a Kerma-Area Product (KAP) Meter to be used as a Monitor Chamber in a Conventional Diagnostic X ray system. - Eduardo Correa (*Brazil*) **- 308**
		03. Monte Carlo simulations and benchmark measurements on the response of TE(TE) and Mg(Ar) ionization chambers in photon and electron beams - Yi-Chun Lin (*Taiwan*) **- 185**
		04. A COMPACT HIGH RESOLUTION SPECTROSCOPY BREAKTHROUGH FOR HARSH ENVIRONEMENTAL CONDITIONS - Vlad Marian (*France*) **- 327**
		05. Optimal energy window selection of a CZT-based small animal SPECT for quantitative accuracy - SuJin Park (*Republic of Korea*) **- 108**
		06. Design of a low background thermal neutron detector - Zhaoming Zeng (*China*) **- 188**
		07. DOSIMETRY IN COMPUTED TOMOGRAPHY USING A SHORT IONIZATION CHAMBER AND A SEMICONDUCTOR DETECTOR - Cinthia Paschoal (*Brazil*) **- 456**
		08. Denoising of High Resolution Small Animal 3D PET Data using the Non-Subsampled Haar Wavelet Transform - Humberto Ochoa (*Mexico*) **- 015**
		09. Feasibility of CT Imaging with Detection Module of High-Resolution CdTe-Semiconductor PET scanner - Yohei Kikuchi (*Japan*) **- 283**
		10. Development of an on-line dose profiler for hadrontherapy treatments - Paola Maria Frallicciardi (*Italy*) **- 300**
		11. Effect of contrast agent administration on dosimetry in radiotherapy planning - TSI-CHIAN CHAO (*Taiwan*) **- 345**
		12. Comparison of timing resolution of novel scintillators coupled to blue-sensitive silicon photomultipliers and fast photomultiplier tubes - Nuray Yavuzkanat (*United Kingdom*) **- 358**
		13. Calibration of mini TEPC using the nitrogen-neutron-capture peak - Meng-Tsung Lin (*Taiwan*) **- 282**

Thursday (2/5)

Day	Time	Session Title
Thu (6/12)	9:30-10:30 am	**14..** Isotope Production Using a Superconducting Electron Linac - Valeriia Starovoitova (*USA*) **- 030**
		15. A High Intensity 10 MeV X-ray Generator to Eliminate High Activity Sources Used for Sterilization - Valeriia Starovoitova (*USA*) **- 031**
		16. Photon-scattering, electron-loss and shadow-effect correction factors calculation for cylindrical free-air chamber - Tseng-Te Huang (*Taiwan*) **- 210**
		17. Feasibility Study on Fiber-optic Cerenkov Radiation Sensor for Radiotherapy Dosimetry: Estimation of Cerenkov Radiation Generated in Optical Glasses Using MCNPX Simulation - JAESEOK KIM (*Korea, South*) **- 182**
		18. X-ray large area detector using thermoluminescence properties of commercial ceramics - Kiyomits SHINSHO (*JAPAN*) **- 268**
		19. Multi-resolution Voxellation Scheme in Full-FOV Iterative CT Reconstruction for Moderating the Computational Cost - Minsik Lee (*Republic of Korea*) **- 008**
		20. Simulation and Experimental Studies of 3D Image Reconstruction from Insufficient Sampling Data for Applications of Low-dose Dental CBCT Imaging - Minsik Lee (*Republic of Korea*) **- 009**
		21. 3D Image Reconstruction for Digital Tomosynthesis with a Circular X-ray Tube Based on Compressed-sensing (CS) Theory - Yeonok Park (*South Korea*) **- 023**
		22. Feasibility Studies on Volumetric Image Reconstruction by Using a Dental Panoramic Detector with a Limited-angle Zigzag Scan Geometry - Dae Ki Hong (*South Korea*) **- 026**
		23. Development of Portable Gamma Imager with Coded Aperture - Kenji Shimazoe (*Japan*) **- 043**
		24. Study on Effective Imaging Conditions in Moving Grid Technique for Elimination of Grid Line Artifacts - Chul Kyu Park (*South korea*) **- 057**
		25. Image Reconstruction of Optical Computed Tomography Using Algebraic Reconstruction Technique for Dose Readout of Polymer Gel Dosimeters - Jay Wu (*Taiwan*) **- 164**
		26. Techniques for leak measurement of the medical diagnostic X-ray machine - Kuo-Wei Lee (*Taiwan (R.O.C)*) **- 217**
		27. Simulation Study on Electrode Structure of Plasma Display-like X-ray Detector - Jongseok Kim (*Republic of Korea*) **- 277**
		28. INTERCOMPARISON OF PHYSICAL PARAMETERS PHANTOM USING FOR DENTAL X-RAYS - FERNANDA C L FERREIRA (*Brasil*) **- 449**
		29. Monte Carlo simulation of a new design of DOI detector with wavelength shifting (WLS) fiber readout - Su Jung An (*South Korea*) **- 159**
		30. Radiation Measurements Onboard Aircraft in the South Atlantic Region - Claudio Antonio Federico (*Brasil*) **- 382**
		31. Characterizing photon propagation and light collection efficiency of extractive scintillating resin in flow-cell detectors - Amy Meldrum (*United States*) **- 383**
		32. Reconstruction of the Spatial Distribution of Radioactive Contamination using an Array of Directional Gamma-Ray Spectrometers - Laurel Sinclair (*Canada*) **- 419**
		33. Environmental monitoring using leaves of Nerium oleander through the technique of X-Ray fluorescence - Ramon Santos (*Brazil*) **- 432**
		34. Fast radiometric method for plutonium monitoring in environmental matrices - Elena Sala (*Italy*) **- 437**
		35. Anthropomorfic Phantom to Investigation of Bladder Dose in Gynaecological HDR Brachytherapy - Rogério Vidal (*Brazil*) **- 198**
		36. Dose evaluation of ANSI/HPS N13.32-2008 for extremity dosimeter - Chun-Liang Chen (*Republic of China*) **- 298**
		37. A Consideration of DAP-based Radiation Dose Management System by the Effect of Scatter Dose - Kim Kyo-tae (*South Korea*) **- 470**
		38. Scintillation properties of Nd-doped fluoride scintillators in the red and near infrared region - Shunsuke Kurosawa (*Japan*) **- 461**
		39. A novel experimental method of in-vivo dosimetry without build-up device on the skin for external beam radiotherapy - Hosang Jeon (*Republic of Korea*) **- 052**
		40. Implementation of a parallel-beam optical-CT apparatus for three-dimensional radiation dosimetry using high-resolution exquisite CCD camera - Yuan-Jen Chang (*Taiwan*) **- 056**

Thursday (3/5)

Day	Time	Session Title
Thu (6/12)	9:30-10:30 am	**41.** Quantitative evaluation of image registration method used for NIPAM gel dosimeter - Chin-Hsing Chen (*Taiwan*) **- 081**
		42. OFFSET3: a large area, scintillation-fiber tracker for real-time particle imaging - Cristina Pugliatti (*Italy*) **- 095**
		43. Study on physical parameters of a breast phantom with silicone implant and their influences to mammography - Divanizia Souza (*Brazil*) **- 349**
		44. RENAL DYNAMIC PHANTOM FOR QUALITY CONTROL IN SPECT - Marcos Alexandre Dullius () **- 463**
		45. ATTENUATION OF BREMSSTRAHLUNG FROM 90Sr-90Y, 147Pm AND 204Tl IN THICK TARGET COMPOUNDS - HC Manjunatha (*India*) **- 224**
		46. Annual doses for the cave deposits around Çatalhöyük Archaeological Site in Turkey - Ülkü Ulusoy (*Turkey*) **- 487**
		47. Improved CCD-based optical computed tomography scanner used in gel dosimetry using a speckle reduction technique - Yuan-Jen Chang (*Taiwan*) **- 091**
		48. The application of 90º scattering charged particle irradiation platform in GBM cancer stem cell research - IChun Cho (*Taiwan*) **- 128**
		49. Evaluation of radiation doses and image quality for anterior-posterior/posterior-anterior kV portal imaging of lung radiotherapy - Shang-Lung Dong (*R.O.C.*) **- 270**
		50. Evaluation of equivalent thickness of BR-12 slab for different age group of Taiwanese women - Shang-Lung Dong (*R.O.C.*) **- 311**
		51. Dose standardization and spectrum verification in Computed Tomography - CHIEN-HAU CHU (*Republic of China*) **- 162**
		52. Evaluation of ABS and PLA Thermoplastics For Use As Tissue Substitute in Radiotherapy With Photons Beams - Rogério Vidal (*Brazil*) **- 200**
		53. Fast convergence method for iterative image reconstruction with gradient total variation (GTV) algorithm in cone-beam computed tomography - Chang-Woo Seo (*Korea*) **- 206**
		54. CT-based Monte Carlo dose calculations for gynecology brachytherapy employing a Henschke applicator - Pei-Chieh YU (*Taiwan*) **- 209**
		55. Denoising of Small Animal PET Images Using Variational Nonconvex Functional - Jose Mejia (*Mexico*) **- 214**
		56. Non-uniformity Correction for Photon-Counting X-Ray Detector Using Multiple Data Points - YUNA CHOI (*Republic of Korea*) **- 216**
		57. Monte Carlo simulations in multi-detector CT (MDCT) for two PET/CT scanner model using adult phantoms MASH and FASH - Walmir Belinato (*Brasil*) **- 225**
		58. Qualitative analysis of Rhodnius prolixus head using synchrotron radiation phase contrast computed microtomography - Gabriela Souza (*Brazil*) **- 229**
		59. Evaluation of dose equivalent in the labyrinth of a 230 MeV proton therapy facility at CGMH using tissue equivalent proportional counter - Kuan-Wei Jin (*Taiwan*) **- 230**
		60. Activation Analysis Study on Li-Ion Batteries for Nuclear Forensic Applications - Erik Johnson (*USA*) **- 388**
		61. Tritium Powered Radiation Sensor Network - Marc Litz (*US*) **- 011**
		62. X-ray microtomography characterization of carbonate microbialites from a hypersaline coastal lagoon in the Rio de Janeiro State – Brazil - Alessandra Machado (*Brazil*) **- 194**
		63. Study of downscaling sandstone rock porosity by x-ray microtomography - Alessandra Machado (*Brazil*) **- 196**
		64. Simulation study of gap supplementation in PET scanner for in-beam PET system - Hyun-Il Kim (*South korea*) **- 269**
		65. GAMMA TRANSMISSION SYSTEM FOR DETECTION OF SCALE IN PIPELINES OF OIL EXPLORATION - Davi Oliveira (*Brazil*) **- 192**
		66. Fiberglass reinforced by epoxy composites: a 3D look inside the bonded joint - Davi Oliveira (*Brazil*) **- 193**
		67. Efficient Interior CT Reconstruction with Compressed-sensing (CS) Framework for Cost-effective, Low-dose Dental Cone-beam CT (CBCT) Imaging - Uikyu Je (*South Korea*) **- 204**
		68. Angle-weighted Filtered Backprojection (FBP) Reconstruction with Noncircular, Truncated Projections for Low-dose, Cost-effective Dental CBCT Design - Uikyu Je (*South Korea*) **- 265**
		69. Quantitative analysis of femur head after chemotherapy treatment for breast cancer using Synchrotron X-ray Microfluorescence and Microtomography - Arissa Pickler (*Brazil*) **- 232**

Thursday (4/5)

Day	Time	Session Title
Thu (6/12)	9:30-10:30 am	**70.** Estimation of radiation dose from dental cone beam CT for three different age groups - Ching-Ching Yang (*Taiwan*) **- 262** **71.** Evaluation of radiation dose and image quality of CT scan for whole-body pediatric PET/CT: a phantom study - Ching-Ching Yang (*Taiwan*) **- 261** **72.** Comparison of reconstruction methods and quantitative accuracy in Siemens Inveon PET scanner - JIN SU KIM (*South Korea*) **- 285** **73.** Determination of energy windows for triple energy windows scatter correction method for I-131 on Siemens SYMBIA gamma camera: GATE simulation study - JIN SU KIM (*South Korea*) **- 330** **74.** Quantification of neuroimaging of brain glioma using statistical probabilistic anatomical maps - JIN SU KIM (*South Korea*) **- 160** **75.** Adaptive PET imaging for quantitative improvement of regional variable activity - Sang-Keun Woo (*Korea*) **- 314** **76.** Internal motion correction of thoracic PET image using marker and MRI image - Sang-Keun Woo (*Korea*) **- 318** **77.** PET/MRI image information based registration with linear interpolation algorithm - Sang-Keun Woo (*Korea*) **- 267** **78.** Preliminary evaluation of a chest digital tomosynthesis (CDT) imaging - Young-Jin Lee (*Korea*) **- 136** **79.** ▪ X-ray spectra optimization in contrast-enhanced digital mammography through Monte Carlo simulations - Lucas Sacchini Del Lama (*Brazil*) **- 452** **80.** ▪ Breast imaging using scattered radiation: A computational study - Lucas Sacchini Del Lama (*Brazil*) **- 453** **81.** ▪ Iridium 192 absorbed dose comparison using the Fricke Xylenol Gel and a brachytherapy planning system - Lucas Sacchini Del Lama (*Brazil*) **- 467** **82.** ▪ Effective atomic numbers for materials of medical interest at low photon energy using the Rayleigh to Compton scattering ratio - Lucas Sacchini Del Lama (*Brazil*) **- 478** **83.** ▪ A modified Fricke gel dosimeter for fast electron blood dosimetry - Lucas Sacchini Del Lama (*Brazil*) **- 479** **84.** ▪ Preliminary performance of Cone-Beam CT (CBCT) system with flat panel detector: Evaluation of radiation dose and image quality - Bo Kyung Cha (*Republic of Korea*) **- 468** **85.** ▪ Perfusion CT dose assessment for acute stroke and tumor: comparison of bismuth shield and organ-based tube current modulation - Hui-Yu Tsai () **- 323** **86.** ▪ Off-center Effects on Radiation Dose Reduction to Superficial Organs in Chest CT Examination: Comparison of Organ-based Tube Current Modulation (OBTCM), Copper Foil Beam Filtration, and In-plane Bismuth Shield - Hui-Yu Tsai () **- 443** **87.** ▪ Sinogram-based material decomposition in computed tomography with an energy-resolved photon-counting detector - Seungwan Lee (*Republic of Korea*) **- 058** **88.** ▪ Applications of ionization chambers in QA of proton therapy - Chih-hsun Lin (*Taiwan*) **- 158** **89.** ▪ Application of Compressed-sensing (CS) Based Reconstruction Algorithm to Breast Tomosynthesis for Accurate, Low-dose X-ray Imaging - Yeonok Park (*South Korea*) **- 025**
	10:30-12:00 pm	**Neutron Detectors I - Gas and Semiconductor Detectors** (*pg. 219*) – Alumni Center ▪ * Progress in Alternative Neutron Detection - Richard Kouzes (*USA*) **- 499** ▪ Advancements in the development of a directional-position sensing neutron detector using acoustically tensioned metastable fluids - Brian Archambault (*United States*) **- 089** ▪ Fast Differential Die-Away Detector Based on Neutron Moderation - Michael King (*USA*) **- 035** ▪ Advancements in the Development of Microstructured Semiconductor Neutron Detector-Based Instruments - Ryan Fronk (*United States of America*) **- 404** ▪ Limits of 3-Dimentional Associated Particle Neutron Elemental Imaging - David Koltick (*United States*) **- 427** ▪ Non-destructive studies of gamma-ray detectors with neutron energy resolved imaging - Anton Tremsin (*USA*) **- 352**

Thursday (5/5)

Day	Time	Session Title
Thu (6/12)	10:30-12:00 pm	**Space Applications** (*pg. 222*) – Vandenburg

- Thin silicon detectors for measuring dE/dx in energetic particle telescopes: development and test results - Mark Wiedenbeck (*USA*) - **361**
- Probing in-situ with neutron and gamma rays (PING) prototype instrument results - Ann Parsons (*USA*) - **307**
- The Upcoming Balloon Campaign of the Compton Spectrometer and Imager (COSI) - JENG-LUN CHIU (*TAIWAN (R.O.C.)*) - **329**
- Quantum efficiency measurements at multiple X-ray energies in Si Hybrid CMOS detectors - Zachary Prieskorn (*United States*) - **375**
- Characterization of the ProtoEXIST2 CZT Detector Plane - Branden Allen (*USA*) - **408**

1:30-3:00 pm **Active Interrogation Techniques** (*pg. 225*) – Alumni Center

- * Review of active interrogation systems - Tsahi Gozani (*USA*) - **504**
- Prompt Gamma-Ray Production Cross Sections Measurement Using a 14.1 MeV Associated Particle Neutron Generator - Haoyu Wang (*United States*) - **450**
- Portable High Power X-ray Source Based on a 10 MeV Superconducting Linac - Valeriia Starovoitova (*USA*) - **028**
- X-ray and neutron interrogation of air cargo for mobile applications - Seth Van Liew (*United States*) - **275**
- Observation of Material and Thickness Dependent Effects in Moderate and High Z Targets in a Gamma Ray LIDAR Experiment - Xiaodong Zhang (*USA*) - **191**

1:30-3:00 pm **Low Energy Exotic Beam Facilities** (*pg. 224*) – Vandenburg

- * The ISAC program at TRIUMF: status and outlook - Ania Kwiatkowski (*Canada*) - **500**
- * The ATLAS/CARIBU facility - Guy Savard (*USA*) - **505**
- * The Facility for Rare Isotope Beams Project* and the ReA Reaccelerator** - Thomas Glasmacher (*USA*) - **508**

3:30-5:30 pm **Neutron Detectors II - Neutron Spectroscopy without Time-of-Flight** (*pg. 228*) – Vandenburg

- * Deuterated Scintillators and Their Application in Neutron Spectroscopy - Michael Febbraro (*United States*) - **480**
- * Performance of a New 6Li-depleted Cs2LiYCl6 Array for Fast Neutron Spectroscopy - Nathan D'Olympia (*USA*) - **347**
- * DESCANT - Vinzenz Bildstein (*Canada*) - **492**
- Neutron Detector based on particles of 6Li Glass Scintillator Dispersed in Organic Lightguide Matrix - KIRIL IANAKIEV (*USA*) - **418**
- Spatial Resolution and Efficiency of Neutron Sensitive Micro-channel Plate Detectors - Edward Cazalas (*USA*) - **175**

3:30-5:30 pm **Contemporary Topics & Closing Announcement** (*pg. 230*) – Alumni Center

- Development of a Neutron Detector Based on a Lithium Glass-Scintillating Plastic Composite - Michael Mayer (*USA*) - **359**
- Effects of Detector Efficiency and Energy Resolution on Gamma-Ray Background Rejection in Mobile Spectroscopy and Imaging Systems - Timothy Aucott (*United States*) - **411**
- Micro-layered thermal neutron scintillator for increased detection efficiency - Peter Menge (*USA*) - **306**
- Day to Day Variations in Neutron and Gamma Ray Background Radiation - Andrew Nicholson (*USA*) - **062**
- Comparing the Response of PSD-capable Plastic Scintillator to Standard Liquid Scintillator - Richard Woolf (*United States*) - **134**
- Flexible composite scintillator based on Eu:LiCAF crystal grains - Joanna Iwanowska-Hanke (*Poland*) - **093**

Abstracts

Tuesday

Plenary I

8:45 AM - 9:45 AM (Rackham Auditorium)

PLENARY I – Atomic and Nuclear Radiation Physics: 1

A Personal Fifty-Five Year Life and Perspective in Fundamental and Applied Atomic and Nuclear Radiation Physics

John M. Palms

The University of South Carolina, Columbia, South Carolina

A Personal Fifty-Five Year Life and Perspective
in Fundamental and Applied Atomic and Nuclear Radiation Physics
John M. Palms*

This presentation reflects on a fifty-five year career in a broad range of experiences and opportunities in fundamental and applied atomic and nuclear radiation physics. Among fundamental studies are the following: The theory, fabrication and applications of radiation detectors in (1) Studies of Rare Nuclei Using Coulomb Excitation with Heavy Ions in a newly constructed Tandem Van de Graaf Accelerator, (2) Using Radioactive Nuclei to Study Inner Shell Ionization and X-Ray-Fluorence Emission Yields and Coster Kronig Transition Probabilities (3) Involvement with the Evolution of Germanium Gamma-Ray Detectors for Double Beta Decay – Neutrino Mass Experiments. Applied Areas Include: (1) Fluid Gauging Using Kr-85 (2) Eye Tumor Characterizations using P-32 Uptake Studies (3) Clinical X-Ray Beam Analysis (4) Using the Radioactive Bioamplification of Periphyton in Aquatic Environmental Monitory (5) Ecological Based Environmental Monitoring after the TMI Accident, Nonproliferation Assurance, Homeland Security Issues, and Pre-operation – Operation Commercial Nuclear Power Plants Releases. (6) Operations and Refueling Monitoring of Utility Nuclear Plants to improve their operational Efficiencies, Dose Reduction in Refueling and Safety.All these experiences and opportunities were made possible by my association with a variety of organizations including the following:

1) Four Major Universities: Emory University, University of NewMexico, University of California Los Alamos Scientific NationalLaboratory, and Georgia State University

2) The Institute for Nuclear Power Operations – Accreditation Board andAdvisory Board

3) The Academy of Natural Sciences Philadelphia – Ruth Patrick Centerfor Environmental Research

4) Several Utilities – Penn Power & Light (PPL), Peco Energy, ExelonCorporation

5) The Institute for Defense Analyses (IDA)

6) ISOE ALARA Symposia(Information System on Occupational Exposure)

*Distinguished President Emeritus, University of South Carolina

*Distinguished Professor Emeritus, University of South Carolina

May 9, 2014

Plenary II

9:45 AM - 10:30 AM (Rackham Auditorium)

PLENARY II - HISTORY OF THE BUBBLE CHAMBER AND ACTIVE-TARGET IMAGING DETECTORS: 1

History of the bubble chamber and active-target imaging detectors

Fred D. Becchetti

Dept. of Physics, University of Michigan, Ann Arbor , MI USA

Donald Glaser, 1960 Nobel laureate in Physics, passed away last year, as did several of his colleagues who were involved with the early development of the first bubble chambers here at the University of Michigan. I will review those early years, and the subsequent wide-spread development of large, active-target (AT) bubble chambers and related detectors, which dominated high-energy physics for many years, and the many important discoveries made with such detectors. Likewise, as will be described, a number of students with a direct connection to Prof. Glaser also went on to receive Nobel prizes.

Plenary III

11:00 AM - 12:00 PM (Rackham Auditorium)

PLENARY III - IMAGING CHALLENGES IN PROTON BEAM THERAPY: 1

Imaging Challenges in Proton Beam Therapy

Sung Yong Park

Proton Therapy Center, McLaren Cancer Institute, Flint, MI, USA

The physical characteristics of proton beams show a very favorable dose distribution in depth represented by spread out Bragg peak. Through their ability to deliver laterally and distally shaped homogenous fields, proton beams have been shown to be a precise and practical method for delivering highly conformal radiotherapy. However, dose coverage of proton therapy is more sensitive than that of conventional radiotherapy to target movement and patient positioning. That is, proton beam treatment requires more accurate patient positioning to take full advantage of its superior conformity of dose. Therefore, we investigated the feasibility of the cone-beam CT (CBCT) and cone beam digital tomosynthesis (CBDT) for the proton therapy system. We further studied the feasibility of proton tomosynthesis which may provide a more accurate method of dose calculation and verifications with less patient dose.Built at McLaren Cancer Institute in Flint, Michigan, the McLaren Proton Therapy Center (MPTC) and existing cancer center will be clinically and operationally integrated. MPTC is comprised of 52,000 sq. ft. of space (42,000 new and 10,000 renovated Cancer Institute space). Exterior construction began in October 2010 and was completed in December 2011. With a total cost of $80 million, the project took shape with less time and less expense than other proton facilities currently in existence.

Scintillation Detectors I

1:30 PM - 3:00 PM (Alumni Center)

SCINTILLATION DETECTORS I - GAMMA-RAY DETECTORS: 1

Review of Advances in Inorganic Scintillators for Gamma Ray and Neutron Detection

Kanai S. Shah

Review of Advances in Inorganic Scintillators for Gamma Ray and Neutron Detection

In this paper, recent advances in the field of inorganic scintillation materials will be reviewed. This will include discovery of new materials as well as optimization of existing materials to achieve enhanced performance. For gamma-ray spectroscopy, improvements in light yield, proportionality and energy resolution will be emphasized. For neutron detection, the focus will be on light yield, neutron-gamma discrimination and efficiency. Trends in multi-mode operation, where the desired features of individual gamma and neutron detectors are fused into a single detector, will also be reviewed. Various materials belonging to elpasolite, rare earth halide, alkaline earth halide and garnet families will be discussed. Most of the discussion will be on single crystal specimens, though in some cases polycrystalline samples will also be covered. Transitioning of selected materials from research to commercial stage will also be presented.

SCINTILLATION DETECTORS I - GAMMA-RAY DETECTORS: 2

New ideas for better inorganic scintillators

Gregory Bizarri, Eric Samulon, Ivan Khodyuk, Martin Gascon, Andrew Canning, Stephen Derenzo, Edith Bourret-courchesne

Lawrence Berkeley National Laboratory, Berkeley, CA, USA

The search for new inorganic scintillators has become much more sophisticated and increasingly successful in recent years, resulting in the discovery of several high-performance scintillators and in numerous advances in understanding the fundamental processes governing scintillation performance. Current properties of modern scintillators are approaching the intrinsic limits imposed by the crystals. Nevertheless, demand continues for better scintillators for specific applications: for example, improved time response for medical imaging applications such as TOF-PET or high energy resolution and low cost material for security applications. After discussing the basic concepts of scintillation in inorganic materials, we will present how advanced models of these phenomena can provide pathways to assist in scintillator development and discovery. The discussion will be rooted in the two main challenges of tailoring scintillator performance by intelligent manipulation of detection mechanisms and of developing a new concept in scintillation with the potential to overcome the current limitation. The former will focus on how intrinsic and/or extrinsic material component alteration can result in improved performance. The latter will describe the concept of the semiconductor scintillator and its potential to supersede the intrinsic limitation inherent to doped insulators. Emphasis will be on experimentally driven models and how they can impact scintillation development. This work was supported by the US Department of Energy/NNSA/NA22 and the US Department of Homeland Security/DNDO and carried out at Lawrence Berkeley National Laboratory under Contract no. DE-AC02- 05CH11231

SCINTILLATION DETECTORS I - GAMMA-RAY DETECTORS: 3

A $Cs_2LiYCl_6:Ce^{3+}$-based Advanced Radiation Monitoring Device

Laura C. Stonehill[1], Nicholas A. Dallmann[1], Brent S. Budden[1], Mark J. Baginski[2], Dave J. Best[2], Corinne Dathy[3], John M. Frank[3], Mickel Mcclish[4], Martin B. Smith[5], Sean A. Graham[5]

[1]*Los Alamos National Laboratory, Los Alamos, NM, USA*
[2]*SCI Technology, a Sanmina-SCI Company, Huntsville, AL, USA*
[3]*Saint-Gobain Crystals, Hiram, OH, USA*
[4]*Radiation Monitoring Devices, Watertown, MA, USA*
[5]*Bubble Technology Industries, Chalk River, ON, Canada*

The $Cs_2LiYCl_6:Ce^{3+}$ (CLYC) scintillator has gained recent interest because of its ability to perform simultaneous gamma spectroscopy and thermal neutron detection. Discrimination between the two incident particle types owes to their fundamentally unique pulse shapes, a consequence of the interaction and subsequent scintillation mechanisms taking place within the crystal. Due to this dual-mode detector capability, we selected CLYC for the development of an Advanced Radiation Monitoring Device (ARMD), a compact handheld instrument for radioisotope identification and localization. ARMD is a completely mobile lightweight device consisting of four CLYC crystals, custom readout electronics, a battery pack, and a companion Android-based tablet for data analysis and display. We herein describe the motivation of the work and the engineering design of the unit, present results, and explain some of the custom algorithms used to enhance performance and comply with ANSI standard regulations for environmental variability.

SCINTILLATION DETECTORS I - GAMMA-RAY DETECTORS: 4

Linearity of Ca^{2+}-Doped $CeBr_3$ Scintillating Materials

Paul Phillip Guss[1], Michael E. Foster[2], Bryan M. Wong[2], F. Patrick Doty[2], Kanai Shah[3]

[1]*Remote Sensing Laboratory–Nellis, P.O. Box 98521, M/S RSL-09, Las Vegas, NV 89193-8521*
[2]*Sandia National Laboratories, California, Materials Chemistry Department, P.O. Box 969*
[3]*Radiation Monitoring Devices, Inc., 44 Hunt Street, Watertown, MA 02472*
[4]*National Security Technologies, LLC, P.O. Box 98521, M/S NLV078, Las Vegas, NV 89193-8521*

The Remote Sensing Laboratory (RSL) developed an aliovalently calcium-doped cerium tribromide ($CeBr_3:Ca^{2+}$) crystal with 3.2% resolution. RSL completed a crystal assessment, and Sandia National Laboratories calculated the predictive performance and physical characteristics using proven density functional theory (DFT) formalism. Results are reported for the work done to map the detector performance, characteristics, calcium doping concentration, and crystal strength. Preliminary scintillation measurements for this aliovalently calcium-doped $CeBr_3$ scintillator exhibit a slight blue shift in fluorescence emission at 371 nm excitation for $CeBr_3$. The structural, electronic, and optical properties of $CeBr_3$ crystals were investigated using DFT within generalized gradient approximation. The calculated lattice parameters are in good agreement with the experimental data. The energy band structures and density of states were obtained. The optical properties of $CeBr_3$, including the dielectric function, were calculated. Specifically, we report excellent linearity with the aliovalently calcium-doped $CeBr_3$ crystal. Proportionality of light yield is one area of performance in which Ce-doped and Ce-based lanthanide halides excel. Maintaining proportionality is key to producing a strong, high-performance scintillator. Relative light yield proportionality was measured for both doped and undoped samples of $CeBr_3$ to ensure no loss in performance was incurred during doping. The light output and proportionality, however, appear to be similar to $CeBr_3$. There was a reduced yield at low energy. Relative light yield proportionality measurements suggest that dopants do not significantly affect proportionality at higher energies. RSL completed additional testing and evaluation of the new crystal and assessed benchmark spectroscopy measurements. Results, which present energy resolution as a function of energy, are summarized. Typical spectroscopy results using a ^{137}Cs radiation source are shown for our crystallite. We obtain 4.5% for the packaged crystallite. More spectra are presented for ^{241}Am, ^{60}Co, ^{228}Th, and background to exemplify $CeBr_3:Ca^{2+}$ over a broader energy range.

SCINTILLATION DETECTORS I - GAMMA-RAY DETECTORS: 5

Gamma Spectrometers Employing SrI2(Eu), GYGAG(Ce) and Bi-Plastic

Nerine J. Cherepy[1], Stephen A. Payne[1], Patrick R. Beck[1], Erik L. Swanberg[1], Zachary M. Seeley[1], Thomas M. Tillotson[1], Robert D. Sanner[1], Peter A. Thelin[1], Scott E. Fisher[1], Kanai S. Shah[2], Rastgo Hawrami[2], Arnold Burger[3], Michael Groza[3], Pijush Bhattacharya[3], Eugene Tupitsyn[3], Lynn A. Boatner[4], Michael Momayezi[5], Joel Kindem[6]

[1]*Lawrence Livermore National Laboratory*
[2]*Radiation Monitoring Devices*
[3]*Fisk University*
[4]*Oak Ridge National Laboratory*
[5]*Bridgeport Instruments*
[6]*Cokiya, Inc.*

The best scintillators for high-resolution gamma ray spectroscopy exhibit high light yield, excellent light yield proportionality, prompt emission decay and high effective atomic number for high photoelectric cross-section. Gamma spectrometers are being developed by LLNL and our partners, implementing optimized optics and electronics to meet specific requirements of several new scintillator materials. Single crystal Europium-doped Strontium Iodide can provide R(662 keV) =2.6%, but in large sizes optical light-trapping by Eu^{2+} degrades the energy resolution, when standard analog readout is employed. With advances in SrI_2(Eu) crystal growth, 1.5" and 2" diameter boules are now available. We report here on the use of pulse digitization with on-the-fly FPGA-based corrections to acquire gamma spectra with R(662 keV) <3% for 4 in^3 crystals. Transparent ceramic Cerium-doped Gadolinium Garnet, GYGAG(Ce), has a peak emission wavelength of 550 nm that is better matched to Silicon photodetectors than to standard PMTs. We have therefore designed a spectrometer based on pixelated GYGAG(Ce) on a Silicon photodiode array that can provide R(662 keV) =3.5%. In comparison, with large 1-2 in^3 size GYGAG(Ce) ceramics we obtain R(662 keV) =4.6% with PMT readout. We also report on measurements of GYGAG(Ce) with a variety of Silicon photodiodes and Silicon PMs. Finally, we are working on new plastic scintillators incorporating a high loading of Bismuth that exhibit decay times of ~10 ns and R(662 keV) ~10%. The latest performance of prototype devices based on SrI_2(Eu), GYGAG(Ce), and Bismuth-loaded plastic will be presented.

SCINTILLATION DETECTORS I - GAMMA-RAY DETECTORS: 6

Theoretical and experimental investigation of solid-solution scintillator material properties and performance in the model system of Tl^+ activated $NaBr_xI_{(1-x)}$ and $Na_{(1-x)}K_xI$

Qi Li[1], Sam Flynn[1], R. T. Williams[1], K. Biswas[2], E. Tupitysn[3], M. Groza[3], P. Bhattacharya[3], E. Rowe[3], A. Burger[3]

[1]*Department of Physics, Wake Forest University, Winston-Salem, NC 27106*
[2]*Department of Chemistry & Physics, Arkansas State University, State University, AR 72467*
[3]*Department of Physics, Fisk University, Nashville, TN 37208*

A. Gektin et al recently directed attention to phenomenological evidence compiled over the last two decades of improved scintillation light yield achieved near the 50% composition point of mixed crystals relative to the two pure-crystal end points. This phenomenon has been noted in at least 10 different solid solution systems. Gektin et al have offered a reason based on limiting hot electron diffusion range so that electrons are more likely to stop within the Onsager radius of the hole, making a geminate pair. Solid solutions such as BaBrI:Eu from the already high-performance family of alkaline earth iodides have been developed and studied by E. Bourret-Courchesne et al. The mixed crystal has higher light yield and improved water resistance and mechanical properties relative to the BaI2 end point. We will discuss a theoretical basis for anticipating improved proportionality as well as light yield in solid solutions of certain systems, particularly alkali iodides, based on considerations of hot-electron group velocity and thermalization introduced previously by our group.[1] Solid solutions based on NaI and similar alkali halides are attractive to consider in more detail because the end point compositions are cheap and easy to grow. If some of this quality can be preserved while reaping improved light yield and possibly improved proportionality of the mixture, the goal of better performance at the low price of NaI:Tl might be attainable by such a route. Early results are presented in this report.We discuss why NaBrxI(1-x) and Na(1-x)KxI were selected for attention among the many other possible alkali halide mixtures. We present results of DFT calculations of band structure versus alloying, and predictions of mixing enthalpy and Tl solubility. Within the context of our predictive model, we discuss the implications of alloying: complexity introduced due to non-identical atoms in the cation and anion sublattices and its effect on band structure, hot electron group velocity, self-trapped hole and exciton formation, and energy transfer to activator. Crystals of the NaI0.5Br0.5:Tl solid solution have been grown in this study with little cracking or apparent segregation. We describe characterization of the crystals including spectroscopic properties, defects, scintillator light yield, and gamma resolution. Acknowledgment: Williams, Biswas, and Burger acknowledge research support from the US Department of Homeland Security, Domestic Nuclear Detection Office, under National Science Foundation competitively awarded contracts ECCS-1348361, 1348341, 1348139 of the Academic Research Initiative (ARI) program. This support does not constitute an express or implied endorsement on the part of the Government.

[1] Qi Li, et al, Phys. Stat. Sol. RRL 6, 346 (2012).

Medical Applications I

1:30 PM - 3:00 PM (Vandenburg)

MEDICAL APPLICATIONS I - RADIATION IMAGING: 1

Limiting factors for timing precision in time-of-flight PET

Stephen E. Derenzo, Woon-seng Choong, William W. Moses

Lawrence Berkeley National Laboratory

We present Monte Carlo computational methods for estimating the coincident timing precision in time-of-flight (TOF) PET and for exploring the limiting factors. The calculations assume double-ended readout, optimized leading-edge trigger levels, and explicitly include the scintillator luminosity, the scintillator rise and decay times, the time dispersion of optical photons in the scintillator, the photodetector quantum efficiency and transit time jitter, the index of refraction of the scintillator, and the uncertainty in the depth of interaction measurement. For LSO (average 2000 photoelectrons (pe) per photodetector, decay time 40 ns), 3 mm fwhm depth of interaction uncertainty, and photodetector transit time jitters of 0, 100, and 200 ps fwhm, the predicted coincident timing precisions are 97, 127, and 163 ps fwhm, respectively. When using LSO it is therefore not possible to achieve a coincident timing precision much below 100 ps fwhm by improving the photodetector time response. For single-ended readout where the depth of interaction is determined by the attenuation of annihilation photons in the LSO these numbers increase to 107, 134, and 169 ps fwhm, respectively, showing the value of dual-ended readout. For $LaBr_3$:Ce (average 4000 pe per photodetector, 17 ns decay time) the corresponding coincident timing precisions are 78, 84, and 95 ps fwhm. For a theoretically possible scintillator (2000 pe per photodetector, 2 ns decay time) the corresponding coincident timing precisions are 26, 34, and 41 ps fwhm. A coincident timing precision of 34 ps will localize the annihilation point between the two coincident detectors to a precision of 5 mm fwhm. For a 200 mm emission region this will improve the effective sensitivity by a factor of 40 over the same positron tomograph operated in non-TOF mode. If this spatial resolution is sufficient, a tomographic reconstruction is unnecessary.This work was supported by Public Health Service grants R01 EB012524 and R21EB012599, and carried out at the Lawrence Berkeley National Laboratory under Contract no. DE-AC02-05CH11231.

MEDICAL APPLICATIONS I - RADIATION IMAGING: 2

Design, development, and initial operation of BabyScan, an in-vivo counter for children around Fukushima

Frazier Bronson[1], Ryugo Hayano[2], Babatunde Oginni[1], Henrik Jaderstrom[1], Gabriella Ile[1], Shunji Yamanaka[3], Isamu Muramatsu[4]

[1]*Canberra Industries, Meriden CT U.S.A*
[2]*Department of Physics, University of Tokyo, Tokyo Japan*
[3]*Department of Mechanical and Biofunctional Systems, University of Tokyo, Tokyo Japan*
[4]*Canberra-Japan KK, Tokyo Japan*

The events following the Fukushima reactor accident released radionuclides into the environment. These were subsequently inhaled and ingested by the surrounding population. An in-vivo monitoring program was instituted by the Fukushima Prefecture to determine the internal deposition of the affected population. Due to prompt action to regulate the food supply, and also due to the local dietary practices, the internal incorporation and subsequent dose is low. However the in-vivo systems deployed were not designed for small children. They were not sensitive enough, and they were not ergonomically suitable. The BabyScan was created to address these issues. The BabyScan is modeled after the FastScan Whole Body Counter, but with improvements for lower background, higher efficiency, suitability for infants, and an appearance that is more pleasing to the parents of small children. The detection system is 4 large NaI detectors, each 7.6 x 12.7 x 40.3 cm. The shield is 10 – 15cm thick of steel, and totally surrounds the subjects except for an opening for the subject to enter but still allowing the child to view and talk to the parent. The shield was also artfully covered with a sculpted shell that visually softens the appearance. The child lies horizontally on a bed with the detectors above. This type of geometry allows the efficiency to stay relatively constant even though the size of the subject changes. The bed has several positions to allow smaller children to be placed closer to the detectors, for higher efficiency and lower detection limits. Calibration was performed with the MCNP code for a wide range of mathematical permutations of the ANSI N13.35 BOMAB phantom. The calibrations were validated by assaying 3 different phantoms with radioactive material. Quantification of K-40 in the initial group of subjects shows the expected amount. MDA calculations and measurements show that the system can reliably measure 20 Bq of Cs-137 and 200 Bq of K-40.

MEDICAL APPLICATIONS I - RADIATION IMAGING: 3

Using Neutron for In-situ Measurement of Li Transportation in Li-ion Battery

Jinghui Wang[1], Danny Liu[2], Jie Qiu[1], Ke Pan[3], Marcello Canova[3], R. Gregory Downing[4], Anne Co[2], L. Raymond Cao[1]

[1]*Nuclear Engineering Program, The Ohio State University*
[2]*Department of Chemistry and Biochemistry, The Ohio State University*
[3]*Department of Mechanical and Aerospace Engineering, The Ohio State University*
[4]*Material Measurement Laboratory, National Institute of Standards and Technology*

Measuring the distribution of lithium atoms in-situ in high capacity Lithium-Ion Battery electrodes is essential to understanding the dynamics of an operating battery to promote the optimization of materials architecture and to gain insights towards materials properties for high rate of Li transport. An in situ measurement of an electrochemical cell is demonstrated in this work by using a nuclear method, termed as neutron depth profiling (NDP). The in-situ NDP investigation was performed at the 500 kW Research Reactor at The Ohio State University for method development and at the National Institute of Standards and Technology (NIST) Center for Neutron Research (NCNR) for the final data acquisition. We have visualized and quantified the lithium atoms transportation in a Sn electrode during battery charging and discharging. The developed in-situ technique is also applicable to Li-ion batteries with thicker anode/cathode. The details on instrumentation and data analysis are presented in this paper.

MEDICAL APPLICATIONS I - RADIATION IMAGING: 4

Impact of system resolution of image quality in PET imaging

Andrej Studen[1], Karol Brzezinski[2], Vladimir Cindro[1], Neal H. Clinthorne[3], Harris Kagan[4], Carlos Lacasta[2], Gabriela Llosa[2], Marko Mikuz[1,5], Carles Solaz[2], Dejan Zontar[1], Peter Weilhammer[4], Milan Grkovski[1]

[1]*Jozef Stefan Institute, Ljubljana*
[2]*IFIC, CSIC-UVEG, Valencia*
[3]*University of Michigan, Ann Arbor, MI*
[4]*Ohio State University, Columbus, OH*
[5]*University of Ljubljana. Ljubljana*

Spatial resolution is one of the most controversial issues in nuclear medicine. With a relatively small number of collected events for a typical examination, the signal to noise ratio (SNR) can be compromised if counts are divided into cells too small. Our group studies benefits of extending a standard PET ring with high resolution silicon detectors (1 mm spatial resolution) called probes. The probes are normally placed inside the conventional detector ring, benefiting from proximity focus of the selected field of view. In such a setup, three different types of events are possible: (1) standard PET events with both interactions in the ring (ring-ring interactions) (2) mixed events with one photon interacting in the ring and the other in the probe (probe-ring) and (3) high resolution probe only events (probe-probe), which arise when probes surround the object under observation.The three event types are recorded with significantly different spatial resolution. This prompted a study on impact of event resolution on final image quality. In absence of a particular application, variance-resolution curves similar to modified Cramer-Rao bound were used to quantitatively compare images reconstructed using different event types.During initial studies, two-dimensional imaging of a single object slice was performed. Data simulated using point-spread-functions (PSF) extracted from point source scans was found to excellently agree with the measurements. Encouraged by the match, data from a state-of-the-art ring detectors (4 mm and 2 mm crystal size) was simulated. Even for such high-resolution detectors, the high resolution event types (probe-ring and probe-probe) still offer significant advantages over bare ring imaging.

MEDICAL APPLICATIONS I - RADIATION IMAGING: 5

Edge illumination X-ray phase-contrast imaging: enhanced phase sensitivity for synchrotron and laboratory applications

Paul C. Diemoz[1,2], Marco Endrizzi[1], Charlotte K. Hagen[1], Thomas P. Millard[1], Fabio A. Vittoria[1,2], Alberto Bravin[3], Ian K. Robinson[2,4], Alessandro Olivo[1,2]

[1]*Dept. of Medical Physics and Bioengineering, UCL, WC1E 6BT London, United Kingdom*
[2]*Research Complex at Harwell, Harwell Oxford Campus, OX11 0DE Didcot, United Kingdom*
[3]*European Synchrotron Radiation Facility, 38043 Grenoble, France*
[4]*London Centre for Nanotechnology, WC1H 0AH London, United Kingdom*

Several X-ray phase-contrast imaging (XPCi) techniques have been developed over the last twenty years. Despite the large differences in the experimental setup and working principles, they all share one common point: the image contrast is mainly derived from the X-ray phase shift induced by the sample, rather than by attenuation like in conventional methods. This enables greatly enhanced detection of weakly absorbing sample features.Among XPCi techniques, edge illumination (EI), currently under development at UCL, has high potential for a widespread application in a number of different fields [1,2]. A key advantage of EI, in particular, is that it is an intrinsically incoherent method, as it does not rely on X-ray interference effects but only on the geometrical refraction of the beam. As a result, a coherent beam is not required. EI is therefore insensitive to broad beam polychromaticity, and can be used efficiently with relatively large X-ray focal spots: it is thus readily applicable with conventional X-ray tubes [2,3]. Besides, the experimental setup is flexible and robust with respect to mechanical and thermal instabilities.Since EI is a strong contender for laboratory applications in a number of different fields of X-ray imaging, the estimation of its angular sensitivity (i.e. the magnitude of the smallest resolvable refraction angle) is of primary importance to predict its potential impact in the different areas of application. For this reason, significant efforts have been recently dedicated to the theoretical modelling of the phase sensitivity of EI and to its experimental measurement. These studies have shown that the simplicity of the EI setup does not come at the expense of the method's sensitivity. On the contrary, results obtained at ESRF (France) and Diamond (UK) synchrotron facilities demonstrated that EI actually enables the achievement of unprecedented sensitivity, with angular resolution down to few nanoradians, an improvement of about one order of magnitude over previously published values for XPCi [4]. Moreover, it was also proven that, when implemented with laboratory sources, the sensitivity of EI is at least comparable to that obtained with grating interferometry (GI) XPCi, despite the simplified setup and employed mask periods about one order of magnitude larger [5].During this talk, I will describe how the phase sensitivity of EI XPCi can be estimated and present possible strategies to optimize it. A newly developed method enabling the retrieval of the sample scattering, which provides information on the sub-pixel sample microstructure, will also be presented [6]. Finally, I will show examples of the applications investigated by our group in several fields, including security, industrial testing, materials science and biomedical studies.

[1] A. Olivo et al., Med. Phys. 28, 1610 (2001).

[2] A. Olivo and R.D. Speller, Appl. Phys. Lett. 91, 074106 (2007).

[3] P.R.T. Munro et al., Proc. Natl. Acad. Sci. USA 109, 13922 (2012).

[4] P.C. Diemoz et al., Phys. Rev. Lett. 110, 138105 (2013).

[5] P.C. Diemoz et al., Appl. Phys. Lett. 103, 244104 (2013).

[6] M. Endrizzi et al., Appl. Phys. Lett. 104, 024106 (2014).

MEDICAL APPLICATIONS I - RADIATION IMAGING: 6

Improvements in Molecular Breast Imaging from advances in CdZnTe technology

Timothy R. Garcia, Bryan R. Simrak, Aleksandr Kivenson, Haris Kudrolli

Gamma Medica Inc., 12 Manor Parkway, Salem, NH, 03038

Advances in material sciences coupled with developments in electronics technology have led to vast improvements in radiation detectors used for medical imaging. Recent advances in cadmium zinc telluride (CZT) semiconductor technology have enabled the development of gamma cameras with superior energy and spatial resolution. In Molecular Breast Imaging (MBI), patients are injected with a low dose of (^{99m}Tc-sestamibi), and imaged with planar gamma cameras. The functional images displayed by these systems are a perfect complement to the anatomical images from x-ray mammography and tomosynthesis systems. Continued improvements in the quality of CZT available from commercial vendors translate to reduction in injection dose to patients and improvements in image quality. This paper presents low-energy (< 140 keV) data from CZT modules built over the past five years and quantifies the improvement in quality of commercially available CZT.

MEDICAL APPLICATIONS I - RADIATION IMAGING: 7

A feasibility study of a PET/MRI insert detector using strip-line and waveform sampling data acquisition

Heejong Kim[1], Chin-tu Chen[1], Neville Eclov[1], Anatoly Ronzhin[2], Erik Ramberg[2], Sergey Los[2], Pavel Murat[2], Alice M. Wyrwicz[3], Limin Li[3], H.t Chen[1], Chien-min Kao[1]

[1]*Department of Radiology, The University of Chicago, Chicago, IL*
[2]*Fermi National Accelerator Laboratory, Batavia, IL*
[3]*NorthShore University HealthSystem Research Institute, Evanston, IL*

We are developing a Time-of-Flight Positron Emission Tomography (PET) detector by using Silicon Photo-multiplier (SiPM) based on strip-line and high speed waveform sampling data acquisition; multiple SiPMs are connected on a single transmission-line and signal waveform on the strip-line are sampled at two ends of the strip to reduce readout channels while fully exploiting fast time response of SiPM. In addition to the deposited energy and time information, the position of the hit SiPM along the strip-line is determined by the arrival time difference from waveform. Due to in-sensitiveness of SiPM under magnetic fields and compact front-end electronics, the detector approach would be suitable for PET insert detector for magnetic resonance imaging (MRI) scanner. To investigate the feasibility of the conceived PET/MRI insert detector, experimental tests using prototype detector modules have been conducted inside a 9.4 Tesla small animal MRI scanner (Bruker Biospec 94/30 imaging spectrometer). On the prototype strip-line board, 16 SiPMs (5.2mm pitch) are installed on two strip-lines, and coupled to 2x8 LYSO scintillators (5.0x5.0x10.0mm^3 with 5.2mm pitch). The signals on the strip-line are transferred to Domino-Ring-Sampler (DRS4) evaluation board for waveform sampling through 5m long cables. Preliminary results from the experimental tests show that the interference on the MRI image due to the PET detector is negligible and the PET detector performances are consistent with the results measured outside the MRI scanner. In this paper, the preliminary results are presented in detail and discussed with future plans.

Posters I – New Radiation Detectors

3:00 PM - 4:00 PM (Ballroom)

POSTERS I - NEW RADIATION DETECTORS: 1

Fast Neutron Spectroscopy with CLYC and CNYC Detectors up to 20 MeV

Lakshmi Soundara-pandian[1], Jarek Glodo[1], Rastgo Hawrami[1], Urmila Shirwadkar[1], Josh Tower[1], Patrick O' Dougherty[1], Kanai Shah[1], Tobias Achtzehn[2], Hugh R. Andrews[2], Edward T. H. Clifford[2], Patrick Forget[2], Harry Ing[2], Martin B. Smith[2]

[1]Radiation Monitoring Devices, Inc., 44 Hunt Street, Watertown, MA 02472, USA
[2]Bubble Technology Industries, Chalk River, ON, Canada K0J 1J0

Advanced neutron detectors that are capable of detecting fast neutrons and providing energy information are desired to build the next generation radioisotope identification systems for homeland security applications or in nuclear physics experiments. Cs_2LiYCl_6 (CLYC) has been developed at RMD for the explicit purpose of dual-mode, gamma-ray, and neutron detection. The CLYC scintillation detector provides distinct signatures in the shape of the scintillation pulse that facilitates the discrimination between gamma-ray and neutron events, which provides an unambiguous separation of the two signals. In addition, CLYC delivers better energy resolution than classical scintillators, such as NaI:Tl, due to the excellent proportionality between the number of emitted photons to the energy of the gamma-ray. Apart from providing good gamma energy resolution (~3.5% at 662 keV, best results) and thermal neutron detection (~80% efficiency for 1.5 cm thick crystal), CLYC can also detect fast neutrons using the neutron capture reaction by the ^{35}Cl nuclei present in the material. We have observed that CLYC shows a fast neutron capture peak due to the $^{35}Cl(n,p)^{35}S$ reaction and the peak position varies linearly as a function of fast neutron energy[1,2] . RMD is also in the process of developing Cs_2NaYCl_6(CNYC) scintillation material to use as an exclusive fast neutron detector, in which lithium is replaced with sodium, making it insensitive to thermal neutrons. As a result, the range of fast neutron energies that can be detected is improved. In collaboration with Bubble Technology Industries (BTI), we continue investigation of the fast-neutron detection properties of CLYC and CNYC detectors (BTI reports on its portion of the work in a complementary abstract for this conference[3]).In this presentation, we report on the fast neutron detection capabilities of CLYC and CNYC elpasolite scintillation crystals up to 20 MeV measured at the Van de Graaff accelerator facility at the University of Kentucky. Discussion of observed results in terms of various reactions will be provided. Fast neutron spectroscopic information such as energy spectra, energy resolution, and pulse shape discrimination to separate fast neutrons from gamma-rays will also be discussed. This work has been supported by the US Defense Threat Reduction Agency, under competitively awarded contract HDTRA1-12-C-0005. This support does not constitute an express or implied endorsement on the part of the Government. DISTRIBUTION A. Approved for public release: distribution unlimited

[1]T. Achtzehn et al., United States Patent Application Publication, US 2011/0266451 A1 (2011)

[2]J. Glodo et al., IEEE Trans. Nucl. Sci. vol. 60, No.2, pp. 864-870, April 2013

[3]M. B. Smith et al., Fast Neutron Measurements Using CLYC Scintillator, abstract for SORMA XV

POSTERS I - NEW RADIATION DETECTORS: 2

Development of a Thick Gas Electron Multiplier Based Multi-element Microdosimetric Detector

Zahra Anjomani[1], Andrei Hanu[2], William V. Prestwich[1], Soo Hyun Byun[1]

[1]Department of Medical Physics and Applied Radiation Sciences, McMaster University, Hamilton, ON, L8S 4K1, Canada
[2]NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

To overcome the complicated fabrication and assembly process required for building multi-element microdosimetric detectors using the traditional proportional counter technology, a versatile multi-element detector based on a THick Gas Electron Multiplier (THGEM) is presented. Owing to the absence of wire electrodes, the THGEM multi-element detector not only enhances neutron detection efficiency but also offers flexible and convenient fabrication processing. Following optimization for detector design through an extensive Monte Carlo simulation study, a prototype detector consisting of 21 gas cavities was built. Its tests with an alpha source showed a promising signal to noise ratio. In order to accomplish a uniform multiplication gain across all gas cavities, an optimization for THGEM fabrication is currently underway. Characterization of the prototype detector in terms of neutron energy and angular responses will be carried out in the near future.

POSTERS I - NEW RADIATION DETECTORS: 3

High-resolution room-temperature electron spectroscopy

Irshad Ahmad, Filip G. Kondev, John P. Greene, Shaofei Zhu

Argonne National Laboratory, Argonne, Illinois 60439, USA

Electron spectroscopy is a powerful technique to measure internal conversion coefficients of γ-ray transitions, thus allowing their multiipolarities to be determined. In the past, cooled 3-mm lithium-drifted silicon detectors, which have resolutions comparable to those of germanium detectors, have been commonly used for electron spectroscopy [1]. However, these detectors need to be kept at liquid nitrogen temperature and, as a consequence, they are difficult to use for measurements where short-lived radionuclides are utilized. In addition, because of their large thickness, these detectors are also sensitive to γ rays, thus making low-energy electron lines difficult to identify. In recent years, silicon PIN diodes with thickness of ~300 μm and energy resolution of 2.4 keV have been used for electron spectroscopy [2]. However, these detectors have edges with slightly different thickness from that of the bulk material, and hence, they have been collimated. We have recently used passivated, implanted, planar silicon (PIPS) detectors for measurements of electron spectra. The commercially produced PIPS detectors are available in thicknesses of 100 μm, 300 μm, and 500 μm, and we have measured their energy resolution as 2.3 keV, which is essentially the same as that of the PIN diodes.The PIPS detectors of optimum thickness can be implemented in precise α, β^-, and conversion electron counting, as well as for end-point measurements in β^- decay. Results from different electron spectra measurements with such detectors and their applications will be presented and discussed.This work was supported by the U.S. Department of Energy, Office of Nuclear Physics, under contract No. DE-AC02-06CH11357.

[1] I. Ahmad and F. Wagner, Nucl. Instr. and Meth. 116, 465 (1974).

[2] I. Ahmad, R. R. Betts, T. Happ, D. J. Henderson, F. L. H. Wolfs, andA. H. Wuosmaa, Nucl. Inst. and Meth. A299, 201 (1990).

POSTERS I - NEW RADIATION DETECTORS: 4

The Development of Using CdS sensor Radiation Detection based on liquid crystal cell and Electro-optical Light Modulation Method

Ye Ji Heo[1,4], Kyo Tae Kim[2,4], Jin Seon Kim[1,4], Si Cheul Noh[3], Sang Hee Nam[1,2,4], Ji Koon Park[3]

[1]*Dept of. Bio medical Engineering, Inje University, inje-ro 197 Gimhae Gyeongsangnam-do Republic of Korea*
[2]*Dept. of Hybrid Medicine and Science, Inje University, inje-ro 197 Gimhae Gyeongsangnam-do Republic of Korea*
[3]*Dept. of Radiological Science , International University of Korea, Donghu-ro 965 Sangmun-ri Munsan-eup Jinju-si Gyeongsangnam-do Republic of Korea*
[4]*International University of Korea, Medical Image Research Center, inje-ro 197 Gimhae Gyeongsangnam-do Republic of Korea*

In this study, Radiation dosimeter which can monitor exposure of radiation in real time using the method of radiation detection of liquid crystal optical modulation method by the CdS radiation monitoring sensor was made. CdS photo conductor is adequate for being used in radiation detecting sensor because it is great in reproducibility, and is enough in the degree of sensitivity by radiation exposure.The principle of radiation detection sensor of liquid crystal optical modulation method used in this study is able to estimate exposure dose, making liquid crystal layer created as multiple layer and X ray exposure at photo conductor layer form electron-hole pair at photo conductor layer, and adjusting the degree of light source of transmission which can be examined from outside according to the angle by twisting liquid crystal allowing applied voltage which is placed below photo conductor layer. As a basic research, the optical, electric feature of a liquid crystal cell, and the distinctive feature of CdS photo conductor are analyzed. Based on the result, the performance on the ability of radiation detection was studied by analyzing the electric optical feature within CdS radiation monitoring sensor.

POSTERS I - NEW RADIATION DETECTORS: 5

Characterization of cadmium manganese telluride ($Cd_{1-x}Mn_xTe$; x=0.05) crystals grown by the floating zone method

Anwar Hossain, Genda Gu, Aleksey Bolotnikov, Giuseppe Camarda, Yonggang Cui, Utpal Roy, Ge Yang, Ralph James

Brookhaven National Laboratory

In this presentation, we demonstrate the material- and radiation detection properties of cadmium manganese telluride ($Cd_{1-x}Mn_xTe$; x=0.05) - a wide-band-gap semiconductor crystal grown by the floating zone method. We investigated the presence of various bulk defects, such as impurities, Te inclusions, twins, and dislocations, of several indium-doped as-grown and annealed CdMnTe crystals using advanced techniques, viz., white-beam x-ray reflection topography, IR microscopy, and chemical etching. We then fabricated several planar detectors from selected CdMnTe crystals, characterized their electrical properties, and tested their performance as room-temperature X- and gamma-ray detectors. Our experimental results show that crystals grown by floating zone method contained significantly lower concentrations of Te inclusions compared to those grown by the Bridgman method. However, we need to optimize our growth parameters to attain high resistivity large-volume single crystal CdMnTe.

POSTERS I - NEW RADIATION DETECTORS: 6

Exploring surface processing steps for improving the performance of CdZnTe radiation detectors

Anwar Hossain[1], Ifechukwude Okwechime[2], Aleksey Bolotnikov[1], Giuseppe Camarda[1], Yonggang Cui[1], Utpal Roy[1], Ge Yang[1], Ralph James[1]

[1]*Brookhaven National Laboratory, Upton, NY 11973*
[2]*Alabama A&M University, Normal, AL 35762*

In this presentation we describe surface processing procedures to delineate the surface properties of CZT crystals, e.g., the surface structure, formation of chemical species and metal-semiconductor interfaces. These surface features are believed to be sources of leakage currents that contribute to the electronic noise in devices, especially advanced read-out and high-aspect ratio detector modules such as Frisch-grid and Co-planar Grid designs. Furthermore, these surface effects are likely very critical in fabricating high-performance radiation detectors. Therefore, it is vital to identify surface processing approaches that leave a smooth non-conductive surface, without adversely affecting other properties. We processed CZT surfaces by mechanical and chemo-mechanical methods using different etchants including the most common bromine-methanol solution. We analyzed the topographic features of the treated surfaces using an atomic force microscope (AFM) and determined the elemental ratio of Te/Cd using energy dispersive x-ray spectroscopy (EDS) and x-ray photoelectron spectroscopy (XPS). We deposited different metal electrodes on oriented CZT surfaces in different configurations designed to maximize the charge collection by engineering the energy band gap. Then we performed spectral response measurements using sealed radioactive sources and a synchrotron x-ray source. The results of utilizing a combination of surface processing and contact configurations in lowering the electronic noise and enhancing the charge collection efficiency will be reported in detail.

POSTERS I - NEW RADIATION DETECTORS: 7

Fundamental properties of Transparent RUbber SheeT (TRUST) $LiCaAlF_6$ neutron scintillator

Dai Sugimoto[1], Kenichi Watanabe[1], Atsushi Yamazaki[1], Tetsuo Iguchi[1], Akira Uritani[1], Kentaro Fukuda[2], Sumito Ishidu[2], Takayuki Yanagida[3], Yutaka Fujimoto[3]

[1]Nagoya University, Furo-cho Chikusa-ku Nagoya Aichi 464-8603 Japan
[2]Tokuyama Corporation, 3-chome shibuya shibuya-ku Tokyo 150-8383 Japan
[3]Kyusyu Institute of Technology, Kawazu Iizuka-shi Fukuoka 820-8502 Japan

Alternatives of He-3 neutron detectors have been required to be developed because of the He-3 shortage. We, therefore, have developed $LiCaAlF_6$ scintillators as a novel alternative neutron detector. This scintillator has various useful properties such as high neutron detection efficiency, no hygroscopicity, high transparency and low mass density. However, single crystal scintillators are generally difficult to fabricate detectors with a large area of several tens of square centimeters. To overcome this difficulty, we propose that Transparent RUbber SheeT $LiCaAlF_6$ neutron scintillator (TRUST LiCAF), which has many small pieces of LiCAF scintillators dispersed in a transparent rubber and forms a flexible sheet type scintillator. In this paper, we investigated detail detector response of the TRUST LiCAF.We obtained the pulse height spectrum from a TRUST LiCAF scintillator with the size of 10×10×5 mm^3 when irradiating neutrons from a ^{252}Cf neutron source located in a polyethylene moderator with the size of 30×30×30 cm^3. We, additionally, obtained the spectrum when the scintillator was surrounded by a Pb shielding to avoid the influence of gamma rays. From these spectra, we recognized the shoulder shape in lower pulse height side of the neutron absorption peak only when the detector was shielded with Pb. This shoulder shape is considered to be a neutron induced component because this component appears only when gamma rays are shielded. One of the candidates of an origin for this component is the wall effects. However the pulse height ratio of the peak and shoulder positions has discrepancy with energy distribution ratio of two particles emitted from the $^6Li(n,t)\alpha$ reaction in LiCAF scintillator. In the wall effect, the shoulder edge positions correspond to the situation that one particle fully escapes out and another one deposits its energy into a scintillator. However, the scintillation light yield is not always proportional to the deposit energy for high stopping power particles, such as alpha and triton. The relationship of the scintillation light yield and stopping power can be estimated by Birks law, which is an empirical formula for the light yield per path length as a function of stopping power of a particle traversing a scintillator. This law gives a non-linear response at high stopping power region. When assuming adequate Birks' constant, the light yield ratio between only α particle stopping and full energy deposition events agrees with the measured shoulder edge position. From these results, the shoulder shape component is concluded to be due to the wall effects. Consequently, 20% of the neutron signals are affected by the wall effect. This finding is quite important to estimate the neutron detection efficiency in the TRUST LiCAF scintillator.

POSTERS I - NEW RADIATION DETECTORS: 8

Wavelength-shifting fiber signal readout from Transparent Rubber SheeT (TRUST) type $LiCaAlF_6$ neutron scintillator

Kenichi Watanabe[1], Takuya Yamazaki[1], Dai Sugimoto[1], Atsushi Yamazaki[1], Akira Uritani[1], Tetsuo Iguchi[1], Kentaro Fukuda[2], Sumito Ishidzu[2], Takayuki Yanagida[3], Yutaka Fujimoto[3]

[1]Graduate School of Engineering, Nagoya University, Nagoya, Japan
[2]Tokuyama Corp., Tokyo, Japan
[3]Kyushu Institute of Technology, Kita-kyushu, Japan

We have been developing the Eu:$LiCaAlF_6$ (Eu:LiCAF) scintillator as one of the candidates for an alternative of the standard ^3He neutron detector. Although this scintillator has high light yield, it suffers from the interference of gamma rays because of its relatively low alpha/beta ratio. In addition, synthesis of Eu:LiCAF single crystals with a large sensitive area requires relatively long time and high cost. In order to solve these problems, we have developed a Transparent RUbber Sheet Type (TRUST) Eu:LiCAF scintillator. This is a transparent rubber sheet with dispersed small pieces of Eu:LiCAF scintillators. This sheet can be fabricated into various geometric shapes. The sizes of small pieces of Eu:LiCAF crystals are controlled to be smaller than the ranges of fast electrons induced by gamma rays and larger than the ranges of alphas and tritons produced by $^6Li(n,t)$ reaction. Consequently, gamma-ray events can be distinguished from neutron events by the simple pulse height discrimination. In order to take advantage of the geometrical flexibility, we try to readout scintillation photons using a wavelength-shifting fiber (WLSF) from a TRUST Eu:LiCAF scintillator. TRUST Eu:LiCAF scintillator with the size of 10x10x5 mm^3 was covered with a WLSF array plate and the end of the WLSFs was connected with the PMT. In order to eliminate higher pulse height events induced by direct interactions between gamma rays and WLSFs, we applied the pulse shape discrimination technique. The signals induced by direct interaction with WLSF have fast decay time of a few ns. On the other hand, the scintillation signals in the TRUST LiCAF have relatively long decay time of micro-second order. We successfully demonstrate that neutron events can be distinguished from gamma-ray events using the WLSF readout with the pulse shape discrimination technique.

POSTERS I - NEW RADIATION DETECTORS: 9

Tomographic imaging from one-side using backscattered X-ray

Kenichi Watanabe, Jin Yoshida, Atsushi Yamazaki, Takayuki Tohyama, Akira Uritani

Graduate School of Engineering, Nagoya University, Nagoya, Japan

The nondestructive internal inspection of the large size structure is required for maintenance of buildings or infrastructures. Although the transmitted X-ray imaging technique has high special resolution, it is unsuitable for large size structures because the object should be sandwiched between a X-ray source and detectors. Backscattering X-ray imaging techniques can be used for internal visualization of large size structures because it can perform from one-side of an object. However, the backscattering X-ray imaging is difficult to obtain tomographic images. We, therefore, proposed a tomography technique available for large size structures using backscattering X-ray from one side. The proposed system consists of a fan-beam X-ray source and X-ray detectors with parallel plate collimators, which can change mounting direction and record the integrated quantity of the backscattering X-rays. The recorded values are indexes of line integral of Compton scattering cross section along the intersection line between the fan-beam and collimated planes. Tomography can be performed by measuring a large number of line integrals from several angles.In this paper, we performed simulation study and basic experiments to verify the principle of the backscattering X-ray tomography. In the simulation study, the proposed system was modelled in the Monte Carlo simulation code EGS5. The object was aluminum rods embedded in an acryl phantom. Maximum likelihood-expectation maximization (ML-EM) method was used as a reconstruction algorithm. We successfully demonstrated that the backscattering X-ray technique can reconstruct a tomographic image of an object shape by one-sided measurements. Although the pixel values at deep area decrease because of the attenuation effect in an object, the proposed technique can be confirmed to reconstruct an internal structure. The proposed imaging technique can be available for internal nondestructive inspection by one-side measurements.

POSTERS I - NEW RADIATION DETECTORS: 10

MINER – A mobile imager of neutrons for emergency responders

Mark D. Gerling, John E. M. Goldsmith, Jim Brennan

Rad/Nuc Detection Systems, Sandia National Laboratories, California

We are developing a mobile fast neutron imaging platform to enhance the capabilities of emergency responders in the localization and characterization of special nuclear material. This mobile imager of neutrons for emergency responders (MINER) is a compact neutron scatter camera that is designed to provide omnidirectional (4π) imaging with only a ~twofold decrease in sensitivity compared to our much larger neutron scatter cameras. The system was designed to optimize its performance for neutron imaging and spectroscopy, but it also functions as a Compton camera for gamma imaging.The detector head is housed in a 36" high, 15" diameter cylinder. The power conditioning module and sixteen-channel digitizer can be mounted on the side of MINER to aid in portability, with power supplied from a wall outlet or a battery. The only other component of the system is a laptop computer. The entire system (including detection electronics and the laptop computer) is transported in a 43"x27"x20" Pelican case and can be set up in a few minutes.During a field campaign at the Idaho National Laboratory (INL), we conducted measurements on three plutonium-containing objects (a metal sphere and two cans that contain plutonium oxide) in a variety of configurations, and with and without various combinations of poly moderator and stainless steel shielding around the objects. For the plutonium sphere surrounded by 3.5" of poly and 2" of stainless steel, located 2 m from the detector, roughly half an hour was needed to generate a good gamma image, but the neutron signature of the object was sufficiently strong that its direction relative to the detector could be determined within the first minute.For neutron double-scatter events, MINER measures energy spectra as the sum of the energy deposited in the first liquid scintillator cell and the kinetic energy of the scattered neutron, the latter determined by its velocity as measured by the time of flight between the two cells. The instrument does introduce some distortions in the spectra (especially at low energies), but these effects do not vary from measurement to measurement. We therefore have good confidence in our ability to detect changes in spectra from sources measured under the same conditions. During the INL campaign, we had the opportunity to measure spectra for the three plutonium sources, plus a Cf source. The spectrum measured from the bare Pu sphere was very similar to the Cf spectrum. The spectra from the two plutonium oxide objects were very similar to each other, but were significantly different than spectra from the Pu sphere or Cf source. Measurements made at Sandia of a Cf source with and without various thicknesses of poly or lead show significantly less variation in spectral shape. We are therefore left with the intriguing possibility that neutron spectra can not only distinguish between fission and alpha-n sources (demonstrated previously), but also possibly between metallic and plutonium oxide, both with and without intervening moderating material.

POSTERS I - NEW RADIATION DETECTORS: 11

The readout research of large area neutron sensitive MCP detector

Yiming Wang[1,2], Yigang Yang[1,2], Xuewu Wang[1,2], Yuanjing Li[1,2]

[1]*Department of Engineering Physics, Tsinghua University, Beijing, P.R.China.*
[2]*Key laboratory of Particle & Radiation Imaging (Tsinghua University), Ministry of Education, Beijing, P.R.China.*

For the study of high-quality neutron imaging, a neutron sensitive detector with good position resolution, large imaging area, as well as high rate capability and good detection efficiency is needed. This detector consists of MCP and relative readout anode. A large area neutron sensitive MCP with 106mm diameter has been developed. In order to test the large area MCP, we combined it with the WSA anode and acquired the image of Gd-mask with the source of X-ray. By this experimental result it is known that the large area MCP is able to work. However, the position resolution of WSA anode will deteriorate when its area is enlarged and hence it cannot fulfill the requirement of large imaging area. So the research with another type of anode is being undertaken. In order to achieve better performances on position resolution (better than 100 micrometers) and high rate capability (higher than 100 kHz), the delay line anode with the sensitive area of 120mm×120mm has been equipped, which is able to typically realize the position resolution of better than 100 micrometers and the rate capability of up to 1MHz. Further experimental results of the delay line anode will be presented at the conference.

POSTERS I - NEW RADIATION DETECTORS: 12 – *WITHDRAWN*

Developments in 3D Diamond Detector Development

M. Dylan Richardson, Eric D. Lukosi, Tom Wulz

Nuclear Engineering, The University of Tennessee, Knoxville, TN

As nuclear and high energy physics experiments move to higher luminosity experiments, the amount of radiation damage that tracking radiation detectors receive could degrade performance immensely. For the planned upgrades to the Large Hadron Collider (LHC), the increased fluence will be enough to prevent conventional semiconductor-based detectors from surviving for the duration of the operational timeline. Because of this, 3D diamond detectors are explored as an alternative particle tracking method. Diamond has excellent properties for radiation detection, such as a wide band gap, excellent charge carrier properties, and a high radiation hardness. Reactive ion etching processes are being explored for efficient fabrication of high aspect ratio columns in diamond. Filling these columns with a conductive material results in a suitable substrate for particle tracking applications. Initial results on our progress pursuing this fabrication scheme will be presented.

POSTERS I - NEW RADIATION DETECTORS: 13

A Prototype of CVD Diamond based Beam Loss Monitoring Detector For the SSRF and the NSRL

Ming Zeng[1,2], Tenglin Li[1,2], Dong Zhang[3], Xunjiang Xu[3], Yuxiong Li[4], Juexin Li[4], Yukai Chen[4], Xiaoping Ouyang[2]

[1]*Key Laboratory of Particle & Radiation Imaging (Tsinghua University), Ministry of Education*
[2]*Department of Engineering Physics, Tsinghua University, Beijing, 100084, China*
[3]*Shanghai Institute of Applied Physics, Chinese Academy of Sciences, Shanghai 201800, China*
[4]*National Synchrotron Radiation Laboratory, University of Science and Technology of China, Hefei, Anhui 230029, China*

A Beam Loss Monitoring System (BLM System) can help to get the beam loss information by measuring the radiation around the beam pipe. It is useful on finding the vacuum leakage, regulating the machine operation parameters, improving the machine performance and so on. In past years, BLM systems have been designed and implemented for the Shanghai Synchrotron Radiation Facility (SSRF) and the National Synchrotron Radiation Laboratory. The Bergoz BLM detector and direct-readout Si-PIN BLM detector were mixed used in the BLM systems, for different monitoring purpose of the linac, the booster and the storage ring. Si-PIN detector is excellent as it can get accurate information of beam loss position, and it is adaptive for the pulse radiation field around the linac and the transportation line which has a very small duty factor. But it encountered the problem of radiation damage. A new prototype of CVD diamond based BLM detector has been designed and under evaluation for the upgrade of those existing BLM systems, which can work in either pulse counting mode for fast monitoring, or in charge measurement mode for slow monitoring, the design and preliminary result will be introduced in this paper.

POSTERS I - NEW RADIATION DETECTORS: 14

A scalable ^{3}He-free neutron detector system for use in a wide range of applications

Matthew Dallimore[1], David Ramsden[2], Mark Foster[2]

[1]*Symetrica, Inc., Maynard, MA USA*
[2]*Symetrica Security, Southampton UK*

Following the successful development of a large-scale neutron detection system for use in cargo portals, we have since scaled that technology down to a level that permits its use in a very compact system that could be incorporated within the carrying handle of the RadSeeker® RID. This has been achieved primarily through the substitution of silicon photomultipliers for the conventional vacuum photomultiplier used in our original design. Other detectors have also been designed that provide an excellent sensitivity to weight ratio. These designs enable new wearable system capabilities and provide the potential for the production of large area arrays with very high efficiency. This paper will provide an outline of the design changes made and the performance achieved with a number of systems that have been subjected to independent testing.

POSTERS I - NEW RADIATION DETECTORS: 15

A FASTSCAN WHOLE BODY COUNTER THAT IS INDEPENDENT OF SUBJECT SIZE FOR SMALL CHILDREN TO LARGE ADULTS

Babatunde M. Oginni, Frazier L. Bronson, Wilhelm F. Mueller

CANBERRA INDUSTRIES INC

The FastScan Whole Body Counter was originally designed by Canberra Industries to determine the amount of radiological uptake in nuclear workers (adults). The system uses two large NaI detectors of 7.62 x 12.7 x 40.64 cm slabs. These two detectors are aligned vertically on the same axis, and parallel to the vertical axis of a standing subject. The subject stands facing the detector with his back against the shield. The response of the FastScan is relatively independent of adult subject sizes, this phenomenon have not been tested in small subject sizes (children). After the event of Fukushima, there was a need to monitor the general population (children and adults) for internal contamination. This study shows the investigation of the FastScan to measure the general population; the goal is to determine if the standard efficiency calibration for the reference man can be used to evaluate uptake activities in all sizes of people. Efficiency calibrations were performed for different sized BOMAB phantoms; the BOMAB sizes were determined based on the ANSI N13.35 recommendations and the average height and weights for children of different sizes. These phantoms are grouped together to have a shape similar to the size of the person of interest. Shapes representing children 65 cm in height to 95th percent adult male were created. These shapes were then evaluated for efficiencies in the FastScan; a special version of the ISOCS software was used for the efficiency calibrations. This version allows complex and multiple geometric sources to be placed in the same measurement scene. Due to the placements of the detectors, if short subjects stand on the floor of the FastScan, the efficiencies will be too low. However, if they stand on a platform, their efficiencies will be approximately the same as for adults. Platforms of different heights [12, 20, 27 and 31 cm] will allow all sizes of children to be counted with the same efficiency calibration curve to be used for all subjects, and keep error less than ±15% for photons in the energy range of 200 – 1000 keV.

POSTERS I - NEW RADIATION DETECTORS: 16

Evaluation of Optical Response and Noise Properties of AlAs and $Al_xGa_{1-x}As$ Epilayers for use in a Solid-State Photomultiplier

Taehoon Kang[1], Inyong Kwon[1], Erik B. Johnson[3], Xiao J. Chen[3], James F. Christian[3], Mark D. Hammig[2]

[1]*Department of Electrical Engineering Computer Science, University of Michigan, Ann Arbor, MI-48109, USA*
[2]*Department of Nuclear Engineering & Rad. Sci., University of Michigan, Ann Arbor, MI-48109, USA*
[3]*Radiation Monitoring Devices Inc., Watertown, MA 02472 USA*

Silicon solid state photomultipliers (SSPMs) have been developed and demonstrated as viable alternatives to the traditional photomultiplier tube for small area applications. However, many advanced scintillation materials, which provide improved neutron-gamma discrimination such as CLYC, require a strong absorption response in the blue and near-UV region of the spectrum in order to minimize the statistical counting noise associated with the photon-to-electron creation process. Furthermore, the sizes of silicon SSPMs are inherently limited by the material's relatively low band-gap (1.12 eV), which governs the dark count rate. We report on the development of a SSPM based on large band-gap $Al_xGa_{1-x}As$ (Eg = 2.09 eV for x = 0.8), upon which an epitaxial AlAs layer is deposited to serve as a window for blue and UV scintillation photons. Photoluminescent spectra of the epitaxially grown layers are measured for material qualification and time-resolved photoluminescence is used to measure the carrier lifetime. We report the quantum efficiency of different epitaxial layer structures to evaluate the effect of the semitransparent AlAs layer.

POSTERS I - NEW RADIATION DETECTORS: 17

Radiation hardness of single crystal CVD diamond detector for MeV energy protons

Yuki Sato[1], Takehiro Shimaoka[2], Junichi H. Kaneko[2], Mitsutaka Isobe[3], Masaki Osakabe[3], Masakatsu Tsubota[2], Akiyoshi Chayahara[4], Hitoshi Umezawa[4], Shinichi Shikata[4]

[1]The Institute of Physical and Chemical Research (RIKEN), 2-1 Hirosawa, Wako, Saitama 351-0198, Japan
[2]Graduate School of Engineering, Hokkaido University, N13, W8, Sapporo 060-8628, Japan
[3]National Institute for Fusion Science, 322-6, Oroshi-cho Toki-city, Gifu 509-5292, Japan
[4]National Institute of Advanced Industrial Science and Technology (AIST), 1-1-1 Umezono, Tsukuba, Ibaraki 305-8568, Japan

Natural diamond detectors (NDD) have been successfully used for neutral particle analyzer (NPA) at tokamaks such as NSTX, JT-60U and the large helical device (LHD) because of their compact size and superior energy resolution. The higher band gap energy and higher displacement energy of diamond crystals makes it possible to operate at high temperatures and high-dose environments. However, the use of NDD is limited by the availability of IIa type natural diamond crystals, which have superior electrical properties.The latest generations of diamond detectors are made using high quality single crystal (sc), which is produced by chemical vapour deposition (CVD). In a previous study, good energy resolution for 5.486 MeV-alpha-particles emitted from ^{241}Am was obtained using a sc-CVD diamond at Hokkaido University, 0.4% (FWHM). Furthermore, energy peaks of 5.486 MeV, 5.443 MeV and 5.389 MeV were separated because of the high energy resolution. CVD diamond crystals are very promising material as a substrate of particle detectors for plasma diagnostics.

In this paper, we fabricated a single crystal (sc) CVD diamond detector and measured the irradiation dose dependence of output pulse height of the diamond detector using 3 MeV protons. The detector has a layer structure of Pt (50 nm)/ sc-CVD diamond (90 μm)/ TiC (50 nm)/ Au (50 nm). A Pt Schottky contact and TiC/Au Ohmic contact as electrodes were created on the surfaces of the diamond crystal by vacuum evaporation method.The pulse height of the output signals from the diamond detector decreases with increase of the amount of irradiation at the count rate of 1.6~8.9 kcps because of the polarization effect inside of the diamond crystal. However, we observed that the polarization effect is cancelled by applying the reverse bias voltage and the pulse heights become normal again. We also confirmed that the diamond detector works under the number of incident protons of ~3.0×10^{12} ion/cm^2. For future study, the reduction of charge-carrier trapping centers will be required for prevention of the polarization effect and for stable operation of the sc-CVD diamond detectors under the high-dose environments.

POSTERS I - NEW RADIATION DETECTORS: 18

Light output and pulse shape characteristics for the novel EJ 299-33 plastic scintillator for γ-rays, neutrons and charged particles

Sheth O. Nyibule[1], Eric Henry[2], Jan Tõke[2], Wolf U. Schröder[1,2], Luis Acosta[3,7], Lucrezia Auditore[4], Giuseppe Cardella[5], Enrico De Fillipo[5], Laura Francalanza[3,6], Sebastiana Gìani[6], Triestino Minniti[4], Emanuele Morgana[4], Emanuele V. Pagano[3,6], Sarah Pirrone[5], Giuseppe Politi[5,6], Lucia Quattrochi[4], Francesca Rizzo[5,6], Paolo Russotto[5], Antonio Trifirò[4], Marina Trimarchi[4]

[1]University of Rochester, Department of Physics, Rochester, NY 14627, USA
[2]University of Rochester, Department of Chemistry, Rochester, NY 14627, USA
[3]Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Sud, Catania, Italy
[4]Istituto Nazionale di Fisica Nucleare, Gruppo Collegato di Messina and Department of Physics, Messina University, Messina, Italy
[5]Istituto Nazionale di Fisica Nucleare, Sezione di Catania, Italy
[6]Department of Physics and Astronomy, Catania University, Catania Italy
[7]Departamento de Fisica Aplicada, Universidad de Huelva, Huelva, Spain

Plastic scintillator EJ 299-33 is shown to posses a remarkable pulse shape discrimination capability between γ-rays, neutrons (protons), α-particles and heavier isotopes in a complex in-beam experiment involving nuclear reactions of ^{12}C on Al target. The quality of H/γ separation is evidenced by the figure of merit (FOM) 0.76, 2.0 and 2.8 at electron-equivalent light outputs 0.2, 0.5 and 0.9 MeVee respectively. The measured light output provides clear resolution of hydrogen-isotopes (p, d, t), lithium-isotopes (^{6}, ^{7}Li), beryllium-isotopes (^{7}, ^{9}Be) and boron-isotopes (^{10}, ^{11}B). The dependencies of the scintillator light output on particle species and energy have been analyzed in the semi-classical framework proposed by Birks. It is found that the hydrogen-isotopes are well described by a single Birks' constant kB = 0.633±0.03 mg MeV^{-1}cm^{-2} and relative scintillation efficiency S = 0.660±0.03. Although the corresponding parameters for other charged particles differ from those deduced for hydrogen, the species dependence is weak.

POSTERS I - NEW RADIATION DETECTORS: 19

The recent study of Glass GEM

Yuki Mitsuya[1], Takeshi Fujiwara[2], Hiroyuki Takahashi[1]

[1]*Department of Nuclear Engineering and Management, School of Engineering, The University of Tokyo*
[2]*Department of Nuclear Professional School, School of Engineering, The University of Toky*

We recently developed a Glass GEM (G-GEM), and it exhibited a superior performance. We also developed a G-GEM with a single-sided guard ring structure, in order to improve its spark tolerance. The guard ring G-GEM also showed good performance. The gas gain reached 7,500 with a single G-GEM setup. Energy resolution was 17.3% at maximum, with the collimated 6 keV X-ray source. Nowadays, large-area micro pattern gaseous detectors are required not only in physics field, but also in medical application or neutron detection application. Therefore, we are currently developing a large-area G-GEM. In this research, we will show the results of the preliminary experiments with it. Gas gain reached up to around 1000. The energy resolution was 33.6% at gain ~1,000. In addition, a new model of operational principle of G-GEM is currently under consideration.

POSTERS I - NEW RADIATION DETECTORS: 20

The Polaris-H Imaging Spectrometer

Christopher G. Wahl, Willy Kaye, Weiyi Wang, Feng Zhang, Jason Jaworski, Alexis King, Zhong He

H3D, Inc., Ann Arbor, MI, USA

During the last few years, H3D has designed, developed, and introduced a gamma-ray imaging spectrometer system named Polaris-H. Originally designed for the nuclear power plant market, Polaris-H integrates a 3D-position-sensitive pixelated CZT detector (20 mm x 20 mm x 15 mm), associated readout electronics, an embedded computer, a 4-hour battery, and an optical camera all within a portable water-proof case. The total mass is about 4 kg. Start-up time is 2 minutes. Additionally, there is a connection for a tablet, which displays a real-time gamma-ray spectrum and isotope-specific images of the radiation distribution in all 4π in real time. All list-mode data is saved to an external USB memory stick. Based on state-of-the-art technology, CZT spectroscopy is routinely better than 1.5% FWHM at 662 keV, and imaging efficiency at 662 keV is within a factor of two for all directions, except through the battery. This new integrated system enables many new measurements and applications not previously feasible. Measurements have been performed in contaminated environments, in high radiation fields, and in cramped quarters.

POSTERS I - NEW RADIATION DETECTORS: 21

Informatics based design of garnet host lattices and dopant chemistries for high light yield scintillator materials

Scott Broderick[1], Amrita Mishra[1], Katherine Colbaugh[2], James Mcguffin-cawley[2], Krishna Rajan[1]

[1]*Department of Materials Science and Engineering, Iowa State University, Ames, IA*
[2]*Department of Materials Science and Engineering, Case Western Reserve University, Cleveland, OH*

The work accelerates the discovery of new scintillator materials through the application of informatics based methods coupled to electronic structure calculations and thermodynamic modeling. From the informatics analysis, we identified four new chemistries (Y2Yb1Al2Ga3O12, Y2Er1Al2Ga3O12, Y2Lu1Al2Ga3O12, and Ho2Y1Al2Ga3O12) with scintillation properties (~40,000 photons/MeV light yield and ~50 ns decay time) exceeding any other garnet systems. We "virtually" screened 486 chemistries and identified a reduced set of eight additional chemistries (Y2TbAl2Ga3O12, Y2DyAl2Ga3O12, Y2HoAl2Ga3O12, Tb3Al2Ga3O12, Dy3Al2Ga3O12, Ho3Al2Ga3O12, Y2TmAl2Ga3O12, Er2YAl2Ga3O12) exhibiting promising characteristics of the dual design criteria of high light yield and fast decay time for targeted computational/experimental investigations. Through the virtual screening, we extracted previously unknown chemical design rules and quantitative structure-property relationship (QSPR) models. The informatics-based approach involves two steps. In the first step, we screened for garnet crystal chemistries that have predicted properties that are suited for scintillator applications. In the second step, for those chemistries that have been predicted to exhibit favorable scintillation properties, we developed QSPR models for predicting their light yield and decay time. Density functional theory (DFT) calculations and thermodynamic modeling were then applied to these new systems to assess the mechanism allowing for improved scintillation performance. From DFT calculations on Tb3Al2Ga3O12, we calculated a band gap of ~3 eV, thus agreeing with our prediction for a light yield greater than 30,000 photons/MeV. Additionally, informatics-based dopant selection strategies for enhancing the scintillation performance

are presented based on targeted defect reaction energies and results for informatics optimization of crystal growth parameters are presented. The computational based design strategy therefore encompasses chemical selection for enhanced scintillation properties, dopant chemistry selection based on defect mechanisms, and processing-property relationships. This new design strategy reduces the scintillator search space, and will help accelerate the discovery of new scintillator materials.

POSTERS I - NEW RADIATION DETECTORS: 22

Development of an Ultra-Low Noise CMOS Preamplifier for Point Contact HPGe Detectors at 77K

Xuezhou Zhu[1,2], Zhi Deng[1,2], Yulan Li[1,2], Yinong Liu[1,2], Qian Yue[1,2], Jin Li[1,2,3]

[1]*Department of Engineering Physics, Tsinghua University, Beijing, China*
[2]*Key Laboratory of Particle & Radiation Imaging, Ministry of Education, Beijing, China*
[3]*Institute of High Energy Physics, CAS, Beijing 100039, China*

A cryogenic ultra-low noise CMOS CSA has been developed for point-contact HPGe detector for CDEX dark matter search experiment. Conventionally JFET transistors are used for HPGe detector readout for its low 1/f noise. As the detector capacitance scales down to ~1pF, the contribution from 1/f noise decreases in proportion. MOS transistor may achieve comparable or even better noise performance than JFET. Several design techniques have been proposed and implemented to meet this very challenging goal, including adjustable biasing for low temperature operation, fast reset circuits without increasing parallel noise. Prototype chips have been fabricated in 0.35μm CMOS technology. ENC noise without detector was measured to be 6.5 electrons. The chip has also been mounted on a home-made point contact HPGe detector. The energy resolution of 0.86% FWHM for Am-241 59.5keV full energy peak was measured with ~3pF detector capacitance and 26.2pA leakage current. Tests of low-noise JFET with the same detector has also been done, showing CMOS CSA has better noise performance at similar test setup.

POSTERS I - NEW RADIATION DETECTORS: 23

Characterization of an ASIC readout technique for HPGe double-sided strip detectors

Benjamin W. Sturm[1], Lucian Mihailescu[1], Gianluigi De Geronimo[2], Mark Amman[1], Chinh Vu[1], Paul J. Barton[1], Ross E. Meyer[1], Cameron Bates[3], Jane Hoberman[4]

[1]*Lawrence Berkeley National Laboratory, Berkeley, CA 94720*
[2]*Brookhaven National Laboratory, Upton, NY 11973*
[3]*Nuclear Engineering Department, University of California, Berkeley, CA 94720*
[4]*Space Sciences Laboratory, University of California, Berkeley, CA 94720*

High-purity Ge (HPGe) double-sided strip detectors (DSSDs) have many attractive properties for gamma-ray detection and imaging, including excellent energy resolution, high efficiency, and good 3-D spatial resolution. Such detector systems have been developed for a variety of applications ranging from nuclear security to astrophysics. This research seeks to replace the discrete component based read-out system currently being used with a highly integrated approach based on ASIC technology. An ASIC developed by Brookhaven National Laboratory was chosen for the readout due to its low-noise and low-power performance and its ability to read out 32 channels. Characterization was done with the ASIC connected to the HPGe DSSD using both an internal pulser and gamma ray sources. An electronic noise of 2.80 keV FWHM and a 662 keV resolution of 3.38 keV FWHM were achieved. The results from this study demonstrate that ASICs can provide a desirable alternative to the discrete readout method for HPGe DSSDs.

POSTERS I - NEW RADIATION DETECTORS: 24

Synthesizing Conjugated Polymers with High Scintillation Light Yield

Tibor Jake Hajagos, David Kishpaugh, Chao Liu, Yunxia Jin, Qi Chen, Qibing Pei

Soft Materials Research Laboratory, Department of Materials Science and Engineering, University of California, Los Angeles

Current radiation detectors are mostly based on single crystal inorganic semiconductors or scintillators, none of which satisfies the demanding requirements of high sensitivity, energy resolution, fieldability, and low cost. Plastic scintillators provide a low-cost solution for detection, however, they have low scintillation light yield and low cross-section for penetrating radiations such as neutron and gamma. We have discovered that conjugated polymer monoliths synthesized by bulk polymerization could have high scintillation light yield. The highest beta light yield we have measured is about 4.6 times that of a commercial plastic scintillator (BC-400, with a measured light yield of approximately 10,000/MeV). We are synthesizing new conjugated polymer monoliths with hopefully even higher light yield. The synthesis will be further tailored to introduce sensitizing additives, such as high atomic number (Z) organometallic compounds for the detection of gamma with high sensitivity and for neutron/gamma pulse discrimination. So far, we have demonstrated the synthesis of a transparent nanocomposite comprising gadolinium oxide nanocrystals uniformly dispersed in bulk-size samples at high loading content. The strategy to avoid luminescence quenching and opacity in the nanocomposite was successfully deployed, which led to the radioluminescence light yield up to 27,000/MeV, about twice as much as standard commercial plastic scintillators. Nanocomposites with 20 wt.% loading of nanocrystals generated a photoelectric peak for Cs-137 gamma (662 keV) with 11.4% energy resolution.

POSTERS I - NEW RADIATION DETECTORS: 25

Scintillation properties of $SrI_2(Eu^{2+})$: Investigations of non-proportionality as a function of temperature and at high gamma-ray energies in comparison to $LaBr_3(Ce^{3+})$

Rose S. Perea[1], Ann M. Parsons[3], Mike Groza[2], Arnold Burger[1,2], Keivan G. Stassun[1,2]

[1]*Vanderbilt University, Nashville TN*
[2]*Materials Science Group, Fisk University, Nashville TN*
[3]*Planetary Nuclear Instrumentation Group, NASA Goddard Space Flight Center, Greenbelt MD*

Strontium iodide doped with europium ($SrI_2(Eu^{2+})$) is a new scintillator material being developed as an alternative to lanthanum bromide doped with cerium ($LaBr_3(Ce^{3+})$). As with all scintillators, the issue of non- proportionality is important because it affects the energy resolution of the detector. In this study, we investigate how the non-proportionality of $SrI_2(Eu^{2+})$ changes as a function of temperature 16 °C – 60 °C by heating the $SrI_2(Eu^{2+})$ scintillator separate from the photomultiplier tube. In a separate experiment, we also investigate the non-proportionality at high energies (up to 6 MeV) of both $SrI_2(Eu^{2+})$ and $LaBr_3(Ce^{3+})$ at a testing facility located at NASA Goddard Space Flight Center. We find that the non-proportionality increases as the temperature of the $SrI_2(Eu^{2+})$ scintillator is increased. We also find that at 6 MeV gamma-ray energies, $SrI_2(Eu^{2+})$ is more proportional than $LaBr_3(Ce^{3+})$.

POSTERS I - NEW RADIATION DETECTORS: 26

The effect of $LaBr_3$:Ce aliovalent co-doping on its mechanical strength

Alessandro Benedetto[1], Serge Valladeau[1], Dominique Richaud[2], Vladimir Ouspenski[1], René Gy[1]

[1]*Saint-Gobain Recherche, 39 quai Lucien Lefranc, 93303 Aubervilliers, France*
[2]*Saint-Gobain Crystals, 104 route de Larchant, Nemours, France*

Lanthanum bromide cerium doped single crystals are a transparent scintillator material that offers outstanding scintillation properties with high light yield, excellent energy resolution, fast emission and excellent proportionality.Although properly packaged detectors are robust enough to withstand operating conditions during geophysical oil logging operations, the material itself is brittle and exhibits low fracture toughness [1].We attempted to modify the composition of the crystals through aliovalent co-doping by Zn, Sr, Zr, Hf, Ca and Ba by using their bromine phases. These elements have been added in concentrations from 100 ppm to 5000 ppm to the growth bath. Ratio of co-doping in the crystalline matrices ranged from no incorporation (for Zn, Zr, Hf) up to 200 ppm for Sr and Ba and 10-20 ppm for Ca. Co-doping resulted in improved scintillation properties, and in particular for the crystals co-doped with Sr and Ba.In this communication we will mainly present the results on the effect of the aliovalent co-doping on the mechanical properties of the crystals and in particular on their mechanical strength, hardness and toughness. As the crystals are extremely hygroscopic this demanded designing customized experiments in anhydrous environment in order to obtain reliable and accurate results.The results on the ultimate strength have been measured by four points bending fracture on small probes will be presented. The cumulate breaking probability does not vary significantly between the reference material and the co-doped crystals.Microindentation experiments were also conducted in dry box in order to make sure that the surface of the studied crystal was not contaminated by a hydrated layer. This kind of

experiments allowed to measure the hardness of the materials and to obtain semi-quantitative comparative data on the fracture toughness. Also in this case, no clear signature of the co-doping on the mechanical properties of the cerium doped-lanthanum bromide could be found.

[1] K.O. Findley, J. Johnson, D.F. Bahr, F.P. Doty, J. Frey, "Fracture and Deformation Behaviour of Common and Novel Scintillating Single Crystals", Proc. of SPIE (2007), Vol. 6707, 670706

POSTERS I - NEW RADIATION DETECTORS: 27

Band Gap Determination of Promising Halide Scintillators

Will Mcalexander, Mariya Zhuravleva, Chuck L. Melcher

Scintillation Materials Research Center, Department of Materials Science and Engineering, University of Tennessee, Knoxville, Tennessee 37916

We report a systematic study of the band gap of several select metal halide scintillators, both intrinsic and extrinsic, which have displayed promising performance upon initial investigations. In order to evaluate the commercial potential of these scintillators, the band gap of pure compounds and the effects of doping must be considered. To determine the gap energy, transmission spectra were recorded for single crystals of each scintillator in an air-tight sample holder to prevent degradation during measurement. Thin slabs, 2mm in thickness, were lapped and polished to minimize effects from scattering. The results were used to estimate the maximum theoretical light output of activated scintillator and can be used as a measure of the quality of produced crystals in further development. Band gap energies for several intrinsic scintillators are reported for the first time.

POSTERS I - NEW RADIATION DETECTORS: 28

Revisiting index-matched composite scintillators

Drew Onken[1], Sam Flynn[1], Xinfu Lu[1], E. Rowe[2], E. Tupitysn[2], M. Groza[2], P. Bhattacharya[2], A. Burger[2], R. T. Williams[1]

[1]*Department of Physics, Wake Forest University, Winston-Salem, NC 27106*
[2]*Department of Physics, Fisk University, Nashville, TN 37208*

The concept of index-matching granular scintillators has been looked at in several versions over the years. In most of the past studies, proportionality was not explicitly addressed or measured and gamma resolution was modest if reported. A crucial question is whether there is a fundamental reason that a segmented and index-matched composite employed as one scintillator cannot approach single-crystal proportionality when the gaps between segments become a negligible fraction of active crystal volume and are properly index-matched. If there is a limit, what is the reason? The earlier patents and papers dealing with index-matched powders, grains, and chunks covered a wide range of grain sizes and interface gaps, but mostly of a scale that the grains and boundaries of random proportion were traversed by the Compton- or photo-electron track in almost every gamma event. We are concentrating on the other end of the size scale, to combine moderate sized pieces of high performance scintillators like SrI_2:Eu that are presently difficult or expensive to grow in larger size. One important issue is that the refractive index of SrI_2 is high, approximately 1.92 at 435 nm. Matching an index of 1.92 with a stable and clear material that will not attack SrI_2 is a significant challenge. We report ongoing work using thermosetting polyufluorocyclobutene (PFCB) for fixing dispersed nanoparticles with sharp absorption resonances instead of dyes, in order to raise the index with respect to PFCB on the low side of the nanoparticle resonance, chosen to be somewhat higher than the scintillation frequency. The optimal use of tiled- or block-construction detectors should take into account the energy range of gamma rays that are expected in a given application, and choose the individual block size to be significantly larger than the mean displacement of photoelectrons from point of creation to stopping. From Geant4 simulations, the mean range of electrons versus starting energy in SrI_2 is 400 μm at 662 keV, 25 μm at 100 keV, and 1.9 μm at 25 keV. We will describe anexperiment intended to test energy resolution experimentally by preparing tiles of a high-resolution scintillator like YAP:Ce and assembling them with index matching fluid and spacers to vary the gaps between tiles. Experimental gamma energy resolution of the assembly versus gap down to sub-μm spacing is to be compared to resolution of a single crystal the same size as the assembly. Acknowledgment: Williams and Burger acknowledge research support from the US Department of Homeland Security, Domestic Nuclear Detection Office, under National Science Foundation competitively awarded contracts ECCS-1348361, 1348139 of the Academic Research Initiative (ARI) program. This support does not constitute an express or implied endorsement on the part of the Government.

POSTERS I - NEW RADIATION DETECTORS: 29

Optically Stimulated Luminescence in X-ray irradiated xSnO-(25-x) SrO-$^{75}B_2O_3$ Glass

Hidehito Nanto[1], Ryota Nakagawa[1], Yoshinori Takei[1], Kazuki Hirasawa[1], Yuka Miyamoto[2], Hirokazu Masai[3], Toshio Kurobori[4], Takayuki Yanagida[5], Yutaka Fujimoto[5]

[1]*Adv. Mater. Sci. R&D Center, Kanazawa Institute of Technology, 3-1 Yatsukaho, Hakusan, Ishikawa 924-0838 JAPAN*
[2]*Oarai Research Center, Chiyoda Technol Corporation, 3681 Narita-cho, Oarai, Ibaraki 311-1313 JAPAN*
[3]*Institute of Chemical Research, Kyoto University, Gokasho, Uji, Kyoto 611-0011 JAPAN*
[4]*Graduate School of Natural Sci. & Tech., Kanazawa University, Kakuma, Kanazawa, Ishikawa 920-1192 JAPAN*
[5]*Kyusyu Institute of Technology, 2-4 Hibikino, Kitakyusyu, Fukuoka 808-0196 JAPAN*

An intense optically stimulated luminescence (OSL) was observed, for the first time, in x-ray irradiated xSnO - (25-x)SrO – $^{75}B_2O_3$ glass. It was found that the peak wavelength of OSL emission spectrum and its stimulation spectrum is about 400nm and 600 nm, respectively. The OSL intensity is depended on the SnO contents (x=0.05 - 1.5) and the most intense OSL was observed in 1.0 mol% SnO doped glass. It was found that the OSL intensity is increased with increasing x-ray absorbed dose. Fairly good fading characteristics were observed in the x-ray irradiated glass, showing that this glass is useful as a candidate for OSL sensor materials for ionizing radiation sensor. The OSL emission and stimulation mechanisms will be discussed in the presentation.

POSTERS I - NEW RADIATION DETECTORS: 30

Scintillation properties of composite ceramic YAG and its capability on pulse shape descrimination

Takayuki Yanagida[1], Kenichi Watanabe[2], Akira Uritani[2], Yutaka Fujimoto[1], Hideki Yagi[3], Takagimi Yanagitani[3]

[1]*Kyushu Institute of Technology*
[2]*Nagoya Univ.*
[3]*Konoshima Chemical*

Scintillators that convert an ionizing radiation to visible photons by quantum cutting have been widely used for radiation detectors. Especially, scintillation detectors for medical applications such as PET, X-ray CT, and SPECT attract much attentions due to the rise of the number of patients of cancer. One of the important techniques in these applications is a collimator that affects the spatial resolution of the detector. On the other hand, collimators are generally passive material and they become a dead area of the detector. Recently, novel unique technique, a functional collimator, was proposed (K. Watanabe, et al., Nucl. Instrum. Methods A 652 582 2011). In this idea, they examined an active collimator that also had a sensitivity to gamma-rays as same as the main scintillator and exhibited better performance from the viewpoint of spatial resolution and detection efficiency than the conventional detectors consisting of scintillators and passive collimators. In the present work, we investigated the transparent ceramic composite Ce:YAG/YAG scintillator aiming to apply functional collimator. Composite ceramic was developed in laser field for higher laser intensity and the advantage of the composite ceramic is to combine different materials in nano-scale so that no optical adhesions are required.Ce-doped and nondoped YAG ceramic composite was prepared by Konoshima Chemical via vacuum sintering. In this sample, basic scintillation properties, including radioluminescence, scintillation decay time, and pulse height were measured. Finally, pulse shape discrimination (PSD) was examined. In PSD, signal waveforms were digitally processed with 50 ns and 500 ns shaping times.In X-ray induced radioluminescence, emission wavelengths of Ce-doped and non-doped YAG layers appeared around 300 and 530 nm, respectively. Primary scintillation decay time of the former one was ~ 1 μs while that of the latter one resulted ~ 100 ns. Finally, two-dimensional histogram of fast (50 ns) and slow (500 ns) emission components for the ceramic composite under 137Cs irradiation was investigated. As a result, events at Ce-doped and non-doped layers were clearly separated in two-dimensional histogram. It was confirmed that the composite ceramic can be applicable for functional collimator application.

POSTERS I - NEW RADIATION DETECTORS: 31

Scintillation properties of two new elpasolite crystals

Victoria Martin[1], Hua Wei[2], Mariya Zhuravleva[2], Charles L. Melcher[2]

[1]*Department of Nuclear Engineering, University of Tennessee, Knoxville*
[2]*Scintillation Materials Research Center, Department of Materials Science and Engineering, University of Tennessee, Knoxville*

The elpasolite family has a wide range of compositions yet to be investigated as novel scintillators. Due to their highly symmetric crystal structure, the crystal growth poses fewer challenges than most other crystal families. Elpasolite halides are also widely studied as thermal neutron detectors due to their capability to hold elements with high neutron cross sections, such as Li and Gd.The optical and scintillation properties of two recently discovered elpasolites, Cs_2KGdCl_6: Ce and Cs_2KLaI_6: Ce, are presented in this work. The crystals were grown in evacuated quartz ampoules via the Bridgman technique. The scintillation properties were evaluated using x-ray excitation, gamma ray excitation, and thermal neutron irradiation. Scintillation light yield, decay time, and luminescence properties were characterized. The light yield of Cs_2KLaI_6:10% Ce was 60,000 Photons/MeV with a primary decay component of 61 ns, yet Cs_2KGdCl_6: 10% Ce had a light yield of 14,000 Photons/MeV with a primary decay component of 1.7 μs. Hygroscopicity measurements were completed as part of a practical handling assessment.

POSTERS I - NEW RADIATION DETECTORS: 32

PL & RL properties of MnO-doped SnO-ZnO-P_2O_5 Glasses

Hirokazu Masai[1], Yusuke Hino[1], Takayuki Yanagida[2], Yutaka Fujimoto[2], Toshinobu Yoko[1]

[1]*Institute for Chemical Research, Kyoto University*
[2]*Kyushu Institute of Technology*

We examined photoluminescent (PL) and radioluminescent (RL) properties of MnO-doped SnO-ZnO-P_2O_5 glasses prepared by conventional melt-quenching method, and discussed those emission mechanisms. PL spectra of MnO-doped SZP glasses containing different amount of MnO shows two emission band. The emission intensity at 4 eV due to emission of Sn^{2+} center decreases with increasing amount of MnO whereas the intensity at 2.0 eV attributed to emission of Mn^{2+} increases. The PL decay curves of Sn^{2+} emission shows that decay constant of Sn^{2+} decreases with increasing MnO amount, which suggests that there is energy transfer from Sn^{2+} to Mn^{2+} during PL process. On the other hand, emission intensity of Mn^{2+} is much higher than that of Sn^{2+} in RL spectra by X-ray irradiation. Although energy transfer from Sn^{2+} to Mn^{2+} was observed, the emission band area is roughly correlated with the MnO concentration. Thus, it can be concluded that the origin of emission is mostly direct activation of Mn^{2+} center. RL Emission decay curves consist of at least three components, and it is expected that the longest decay component is due to Mn^{2+}. The decay constant of Mn^{2+} becomes shorter, suggesting concentration quenching of Mn^{2+}. The observed difference of emission spectra clearly shows the difference of origin between PL and RL process in oxide glasses.

POSTERS I - NEW RADIATION DETECTORS: 33

Crystal growth and scintillation properties of Eu^{2+} -doped KBa_2I_5 and K_2BaI_4

Luis Stand, Mariya Zhuravleva, Adam Lindsey, Charles L. Melcher

Scintillation Materials Research Center, University of Tennessee, Knoxville, USA

We report two new ternary metal halide scintillators, KBa_2I_5 and K_2BaI_4, activated with divalent europium. KBa_2I_5 has a monoclinic crystal structure, confirmed by X-ray diffraction, with a density of 4.52 g/cm^3. Although neither the KI-BaI_2 phase diagram nor the crystallographic information for K_2BaI_4 was found, our initial growth experiments suggest that both compounds melt congruently and have no solid-solid phase transitions. Differential scanning calorimetry indicates a melting point of 566°C for KBa_2I_5 and 579°C for K_2BaI_4. As expected both metal halide scintillators are slightly hygroscopic and have some internal radioactivity due to the presence of ^{40}K. We grew 13 mm diameter single crystals in an evacuated quartz ampoule via the Bridgman technique. In the case of KBa_2I_5 the optimal Eu^{2+} concentration was 4% and 7% for K_2BaI_4. It is assumed that Eu^{2+}ions occupy Ba lattice sites. The X-ray excited emission and the photoluminescence emission of KBa_2I_5:Eu 4% consisted of a single peak at ~444 nm and ~448 nm for K_2BaI_4:Eu 7% as expected from the 5d-4f transition in Eu^{2+}; no emission from $Eu^{3+}$was observed. The

light yield of KBa_2I_5:Eu 4% (~2x2x1 mm3) was ~85,000 photons/MeV with a 2.7% energy resolution. For a similar piece of K_2BaI_4:Eu 7% the light yield was ~57,000 ph/MeV with a 2.9% energy resolution. All of these properties make, KBa_2I_5:Eu4% and K_2BaI_4:Eu 7%, very promising candidates in many gamma ray and X-ray detection applications.

POSTERS I - NEW RADIATION DETECTORS: 34

NIR scintillation properties of Nd^{3+}-doped yttrium vanadate single crystals

Yutaka Fujimoto[1], Takayuki Yanagida[1], Takahiro Kojima[2], Masanori Koshimizu[3], Keisuke Asai[3]

[1]*Kyushu Institute of Technology, 2-4, Hibikino, Wakamatsu-ku, Kitakyushu, 808-0196, Japan*
[2]*OXIDE, 1747-1 Makihara, Mukawa, Hokuto, Yamanashi, 408-0302 Japan*
[3]*Tohoku University, 6-6-04, Aramaki Aza Aoba Aoba-ku, Sendai, Miyagi 980-8579, Japan*

Solid-state scintillation materials are widely used in ionizing radiation detection systems from security inspection to medical imaging, high energy particle physics experiments and radiation monitoring at nuclear power plants. Common systems are based on detection of visible (VIS) and ultraviolet (UV) light emitted by scintillators excited at high energy photons or charged particle. Meanwhile the scintillation light in near-infrared (NIR) is not exploited for the detection systems. Utilization of NIR scintillation can expect to develop new scintillator that is high light output and good energy resolution because the energy of an NIR quantum (1.5-0.5 eV) is small compared to that of a visible photon. By the reason, recently our group has studied NIR scintillation properties of some laser materials activated with rare-earth ions for NIR regions, and they found to show intense $4f^n$-$4f^n$ emission peaks and good irradiation dose response under excited at X-ray. In this work, we report optical and NIR scintillation properties of Nd^{3+}-doped yttrium vanadate (YVO_4) single crystals that is one of the most efficient laser host crystal providing 1064 nm light.By this study, Nd^{3+}-doped YVO_4 crystal was found to exhibit intense emission peaks at 1050-1080 nm under excited at X-ray. In addition, good linear response was confirmed in the dose range from 1 to 1000 mGy. In the conference, Nd concentration and temperature dependency of the scintillation properties will also be discussed.

POSTERS I - NEW RADIATION DETECTORS: 35

Basic properties of undoped calcium orthoborate crystal for radiation dosimetery

Yutaka Fujimoto[1], Takayuki Yanagida[1], Masanori Koshimizu[2], Keisuke Asai[2]

[1]*Kyushu Institute of Technology, 2-4, Hibikino, Wakamatsu-ku, Kitakyushu, 808-0196, Japan*
[2]*Tohoku University, 6-6-04, Aramaki Aza Aoba Aoba-ku, Sendai, Miyagi 980-8579, Japan*

Generally solid-state luminescent dosimetry is based on radiation energy storage in phosphor material with the form of lattice defects which are relating to electron and hole trap levels. Thermoluminescence (TL) and optically stimulated luminescence (OSL) are popular and simple techniques for radiation dosimetry, and unknown irradiation doses can be evaluated because of the intensities of light emitted by the phosphor proportional to the radiation doses. Recent studies have focused on alkali and alkali-earth borate based materials due to its high sensitivity and linearity dose response and tissue equivalent characterizations for alternative radiation monitoring devise in the protection area, medical and industrial applications. Thus in this work, we report basic optical and dosimetric properties of undoped calcium orthoborate ($Ca_3B_2O_6$) crystal.From the result of TL glow curve, at least two glow peaks were observed at 410 and 480 K, and the TL glow peak intensities proportional to irradiation dose can be identify in the range from 0.5 to 1000 mGy. Under stimulated at 410 K, TL spectrum showed a emission band at 380 nm, which is cased by the host emission associated with intrinsic lattice defects. In the conference, the OSL properties will also be reported.

POSTERS I - NEW RADIATION DETECTORS: 36

Quench-Resistant and Metal-Loaded Organic Scintillators

Patrick L. Feng

Sandia National Labs, Livermore, CA 94550

There exists a need for large-volume and low-cost scintillators that provide high sensitivity and modest gamma-ray energy resolution. Previous efforts to achieve this result have focused on loading organic scintillators with soluble, high-Z metal compounds. Although such efforts successfully combined the increased gamma stopping power of heavier elements with the low cost of plastics, these materials suffer from strong light-yield reduction (quenching) at low metal loading ratios.In this paper, we describe the preparation of quench-resistant metal-loaded organic scintillators based upon fundamental photophysical principles. The specific origins of luminescence quenching will be discussed in the context of heavy-atom effects, leading to a rational design approach that combines radiation transport simulations, molecular modeling, and tailored chemical syntheses. Fluorescence measurements and scintillation pulse-height spectra will be presented to illustrate the systematic relationship between steric/electronic structures of the additive and the obtained light yield. Performance metrics comprising light yield, photoelectric sensitivity, and optical absorption properties will be compared against the respective attributes of commercial organic scintillators and NaI(Tl). This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-13-x-B0006-0. This support does not constitute an express or implied endorsement on the part of the Government.

POSTERS I - NEW RADIATION DETECTORS: 37

Temperature dependence of pyrochlore type scintillators

Shunsuke Kurosawa[1,2], Yasuhiro Shoji[3], Toetsu Shishido[1], Akira Suzuki[1], Yuui Yokota[2], Jan Pejchal[2], Kei Kamada[2,3], Akira Yoshikawa[1,2,3]

[1]*Institute for Materials Research, Tohoku University, Sendai, Miyagi, Japan*
[2]*New Industry Creation Hatchery Center, Tohoku University, Sendai, Miyagi, Japan*
[3]*C&A Corp., Sendai, Miyagi, Japan*

Recently, the pyrochlore crystal structure described as $A_2B_2O_7$, have been studied as scintillation materials, where the A and B species are generally rare-earths or transition metal species such as $Gd_2Si_2O_7$(GPS), $Lu_2Si_2O_7$(LPS). These materials have good light outputs or energy resolutions. However, most components are not congruent (e.g. $Gd_2O_3 – SiO_2$ system), and melt growth is difficult. In order to obtain the congruent components, we doped approximately 10-50% La into the host material. Then we succeeded in obtaining a Ce:$(La, Gd)_2Si_2O_7$ (Ce:La-GPS) scintillator grown by floating zone or Czochralski process with a good energy resolution (FWHM) of 5-7% at 662 keV.We show the scintillation properties of these crystals and their tmperature dependence.As results, the luminescence efficiency of Ce:La-GPS remained very high when the temperature increases up to 150 ºC, which is similar as for the Ce:LPS scintillator. Thus, this material can be used in oil well logging.

POSTERS I - NEW RADIATION DETECTORS: 38

Tuning the internal electric field in CdZnTe radiation detectors

Ge Yang, Aleksey E. Bolotnikov, Yonggang Cui, Giuseppe S. Camarda, Anwar Hossain, Utpal N. Roy, Ralph B. James

Brookhaven National Laboratory

Cadmium Zinc Telluride (CZT) radiation detectors offer great potential for applications in national security, medical imaging, astrophysics research, and in monitoring industrial processes, since they operate at room temperature and provide high detection-efficiency and good energy-resolution. An important parameter that substantially affects the transport behavior of charges and, therefore, the performance of CZT detectors, is the distribution of the internal electrical field; a uniform distribution is always desirable. As is well known, its distribution can be changed significantly by the build-up of space-charge, as was demonstrated in detectors made from crystals of Si, Ge, GaAs, and CdTe. This behavior usually results in degraded charge collection and polarization effects as well. In this work, we employed Pockels effect (PE) measurements to reveal the electric field's distribution considering CZT belongs to a group of crystals exhibiting the linear electro-optic effect. Here we used two approaches, i.e., applying external IR light illumination and controlling the operation temperature, to tune the internal electric field of the CZT detector. In this

case, the electrons and holes trapped at deep levels were released due to the de-trapping energy provided by external IR illumination and thermal activation, therefore causing a change of the space charge and deforming the internal electric field. We observed a change of internal electric field, i.e., the width of the space-charge region in CZT was narrowed, and most portions of the electric field were pushed towards the cathode side, once we applied the IR illumination. Furthermore, we noted that the specific configuration of the IR illumination can have a big impact on the electric field, which could be potentially used to focus the internal electric field. The results will be discussed in detail in the presentation. We will also report the effects of the power of IR illumination on the internal electric field. The changes in the corresponding photo-current, recorded during the IR illumination under different operation temperatures, will be presented as well.

POSTERS I - NEW RADIATION DETECTORS: 39

Scintillation properties of CdF_2 crystal

Kentaro Fukuda[1], Takayuki Yanagida[2], Yutaka Fujimoto[2], Masanori Koshimizu[3]

[1]*Functional Fluoride Group, Tokuyama Corporation, Japan*
[2]*Kyushu Institute of Technology, Japan*
[3]*Department of Applied Chemistry, Tohoku University, Japan*

Scintillators are widely used in various ionizing radiation detection applications such as medical, security, and high energy physics. Most common type of inorganic scintillators are rare-earth activated scintillators. They exhibit high light yield with medium fast decay times of several tens nano seconds. On the other hand, intrinsic luminescence of halide scintillators also attracted much attention. The most famous one is Auger-free luminescence (AFL) of BaF_2. AFL of BaF_2 shows sub-ns decay time and BaF_2 was once investigated to apply TOF-PET. In addition to BaF_2, CdF_2 is predicted to show AFL in visible wavelength theoretically. In the present work, we investigated scintillation responses of CdF_2 crystal fabricated by Tokuyama.Transmittance spectrum of CdF_2 was evaluated by using JASCO V670 spectrometer and the absorption edge appeared around 280 nm. In X-ray induced radioluminescence, intense emission peaks were observed around 350 and 420 nm. Theoretical calculation predicted AFL of CdF_2 at 330 nm and the observed result well coincided with the prediction. Then, wavelength resolved scintillation decay time profile was investigated by using pulse X-ray streak camera system. Significant difference was not observed in those two peaks and decay time profile was well reproduced by two exponential assumption. The fast component resulted 1.4 ns and it was a typical decay time of AFL. Temperature dependence of X-ray induced radioluminescence was also studied on a comparison of conventional AFL scintillator, BaF_2. As a result, both AFL of BaF_2 and emission from CdF_2decreased when the temperature increased. In the conference, optical and scintillation properties of CdF_2 will be presented and discussed about the origin of the emission.

POSTERS I - NEW RADIATION DETECTORS: 40

Thermally and optically stimulated radiative processes in Eu and Y codoped $LiCaAlF_6$ crystal

Kentaro Fukuda[1], Takayuki Yanagida[2], Yutaka Fujimoto[2]

[1]*Functional Fluoride Group, Tokuyama Corporation, Japan*
[2]*Kyushu Institute of Technology, Japan*

Luminescent materials have played an important role in radiation detectors. Among such luminescent materials, storage phosphors have attracted much attention for dosimeter applications. In dosimeter applications, optically stimulated luminescence (OSL), thermally stimulated luminescence (TSL), and radiophotoluminescence (RPL) are used to evaluate dose. In this work, we evaluated Eu and Y co-doped $LiCaAlF_6$ crystal on its OSL and TSL properties. Eu 0.5% doped $LiCaAlF_6$ and Eu and Y 0.5% co-doped $LiCaAlF_6$ crystals were fabricated by Tokuyama using μ-PD technique. They were cut to $2 \times 7 \times 1$ mm^3 and wide surfaces were polished. In scintillation responses such as X-ray induced ratdioluminescence and decay time profiles, no significant difference was observed in these samples. On the other hand, OSL and TSL signal intensities of Y co-doped sample was enhanced with several digits. The enhancement would be attributed to a creation of defects by Y^{3+} co-coping to Ca^{2+} site. In the conference, optical, scintillation, OSL, and TSL properties will be presented and discussed.

POSTERS I - NEW RADIATION DETECTORS: 41

Co-doping Effects on Luminescence and Scintillation Properties of Ce doped $Lu_3Al_5O_{12}$ scintillator

Kei Kamada[1,2], Martin Nikl[4], Shunsuke Kurosawa[3], Yasuhiro Shoji[2,3], Jan Pejchal[3], Yuui Yokota[1], Akira Yoshikawa[1,2,3]

[1]*New Industry Creation Hatchery Center, Tohoku University, 6-6-10 Aoba, Sendai 980-8579*
[2]*C&A corporation, 6-6-10 Aoba, Aramaki, Aoba-ku, Sendai 980-8579, Japan*
[3]*Institute for Material Reseach, Tohoku University, 2-1-1 Katahira, Sendai,980-8577 Japan*
[4]*Institute of Physics, AS CR, Cukrovarnická 10, 162 53 Prague, Czech Republic*

In this presentation, AE(=Mg, Ca, Sr) co-doping effects on luminescence and scintillation properties of Ce doped LuAG will be reported. AE co-doped Ce:LuAG single crystal were grown by the micro-pulling down (m-PD) method and characterized as for the structure and chemical composition. By Mg co-doping, light output of Ce:LuAG was increased upto 235% and decay time became faster than non co-doped Ce:LuAG. Details about luminescence and radiation response characteristics will be shown in our presentation.

POSTERS I - NEW RADIATION DETECTORS: 42

Growth and Scintillation Properties of Ce and Pr-doped $YCa_4O(BO_3)_3$ single crystals

Kei Kamada[1,2], Shunsuke Kurosawa[3], Jan Pejchal[3], Yuui Yokota[2], Akira Yoshikawa[1,2,3]

[1]*New Industry Creation Hatchery Center, Tohoku University, 6-6-10 Aoba, Sendai 980-8579*
[2]*C&A corporation, 6-6-10 Aoba, Aramaki, Aoba-ku, Sendai 980-8579, Japan*
[3]*Institute for Material Reseach, Tohoku University, 2-1-1 Katahira, Sendai,980-8577 Japan*

In this work, Ce and Pr doped YCa4O(BO3)3 (YCOB) single crystals were grown by the micro-pulling down (m-PD) method and characterized as for the structure and chemical composition. The expected 300-500 nm emission of Ce3+ 4f-5d have been observed in Ce:YCOB. Pr:YCOB show broad emission spectrum peaking round 320nm and this emission can be well ascribed to the 5d–4f emission of Pr3+. Photoluminescence decays at 370 nm in Ce:YCOB and 330nm in Pr:YCOB are given in Figure 3. Photoluminescence decay time of Ce:YCOB and Pr:YCOB were about 32ns(100%) and 3.0ns (51%) 10ns (49%) , respectively. Details such optical and luminescence properties, neutron response and scintillation decay will be reported in our presentation.

POSTERS I - NEW RADIATION DETECTORS: 43

Luminescence properties and neutron response of Bi doped $Li(Nb,Ta)O_3$ crystals grown by micro-pulling down method

Kei Kamada[1,2], Shunsuke Kurosawa[3], Jan Pejchal[3], Yuui Yokota[2], Akira Yoshikawa[1,2,3]

[1]*New Industry Creation Hatchery Center, Tohoku University, 6-6-10 Aoba, Sendai 980-8579*
[2]*C&A corporation, 6-6-10 Aoba, Aramaki, Aoba-ku, Sendai 980-8579, Japan*
[3]*Institute for Material Reseach, Tohoku University, 2-1-1 Katahira, Sendai,980-8577 Japan*

In solid-state neutron detectors, the presence of ^{6}Li and/or ^{10}B isotopes in neutron-sensitive material is highly desirable. These isotopes determine neutron detection efficiency and the ability of the material to stop and react with the neutrons. In this decade, some novel inorganic scintillators for neutron detection have been reported. According to the above background, it was assumed that $LiTaO_3$ (LT) and $LiNbO_3$ (LN) scintillator is suitable for neutron detection because they contain a considerable amount of Li. Single crystals of LN and LT were widely used as piezoelectric and nonlinear optical materials . However, radiation responses of LT and LN single crystals doping with luminescence center ion have not been reported yet.In the present communication, the results of growth of Bi^{3+} doped LT and LN single crystals by the micro-pulling-down (μ-PD) method and luminesence and scintillation characteristics of these crystals are presented.

POSTERS I - NEW RADIATION DETECTORS: 44

Estimation of the charge transport properties of Bismuth Tri-Iodide semiconductor radiation detectors

Sasmit S. Gokhale[1], Hyuksu Han[2], James E. Baciak[1], Juan C. Nino[2], Kelly A. Jordan[1]

[1]*Nuclear Engineering Program, Department of Material Science and Engineering, University of Florida, Gainesville, FL 32611, USA*
[2]*Department of Material Science and Engineering, University of Florida, Gainesville, FL 32611, USA*

For the purpose of this research, Bismuth Tri-Iodide (BiI_3) radiation detectors were fabricated from large single crystals grown using the modified vertical Bridgman technique; planar gold electrodes were deposited on two opposite sides of the detectors with the room temperature sputtering technique. The detectors were characterized for their spectroscopic response and charge transport properties. The mobility-lifetime product for the charge carriers was estimated by using the planar transverse field (PTF) irradiation technique. The detectors were irradiated by a collimated gamma-ray source; and were subjected to several fine scans between the electrodes with a gamma-ray beam spot of 300 μm diameter. The results were used to estimate the mobility and lifetime of both electrons and holes.

POSTERS I - NEW RADIATION DETECTORS: 45

Czochralski Growth of 2inch $(Gd_{1-x-y}La_xCe_y)_2Si_2O_7$ (Ce:La-GPS) single crystal and its scintillation properties.

Akira Yoshikawa[1,2,3], Shunsuke Kurosawa[1,2], Ikuhiro Shoji[1,3], Kei Kamada[2,3], Yuui Yokota[2,3], Martin Nikl[4]

[1]*IMR, Tohoku University, 2-1-1 Katahira, Aoba-ku, Sendai 980-8577, Japan*
[2]*NICHe, Tohoku University, 6-6-10 Aoba, Aramaki, Aoba-ku, Sendai, 980-8579, Japan*
[3]*C&A corporation, 6-6-10 Aoba, Aramaki, Aoba-ku, Sendai 980-8579, Japan*
[4]*Institute of Physics, AS CR, Cukrovarnická 10, 162 53 Prague, Czech Republic*

A number of halide and oxide scintillator materials have been developed in past decades. Currently, these materials are widely used in various fields including astronomy, medical imaging, and homeland security. Although halide scintillators, such as Tl:NaI, Tl:CsI, and Ce:$LaBr_3$, have high light outputs of more than 30,000 photons/MeV, they are hygroscopic that makes their device application comparatively complicated. On the other hand, most of oxide scintillators are well resistant to moisture and humidity. Ce-doped gadolinium pyrosilicate (or disilicate), Ce:$Gd_2Si_2O_7$ (Ce:GPS) crystals have also high light output of 30,000 photons/MeV and FWHM energy resolution of 6.0% at 662 keV at room temperature. However, Ce:GPS crystals need to be grown with heavy Ce-doping (approximately 10 at.% regarding Gd+ host cations to be substituted) in order to modify the phase diagram and to stabilize the crystal growth process [1]. Such excessive Ce-concentration leads to reduced light output because of self-absorption or concentration quenching. On the other hand, recently, we found substitution of La into Gd site gives positive effect of the phase stability of this pyrosilicate [2]. In this study, the Czochralski growth of $(La,Gd)_2Si_2O_7$ type crystals was examined. The growths were performed from Ir crucible of Ø100x100 mm in dimensions that was surrounded with zirconia and alumina ceramics for thermal insulation. The crucible was heated inductively. The pulling-up rate applied was 0.5 mm/h and the environmental atmosphere installed in the growth chamber was Ar + CO_2. The seed crystal was rotated at 10 rpm, and the crystal diameter was controlled to be about 2 inch. Crack free bulk single crystal is successfully grown. After the crystal growth, PL, PL decay, RL, pulse height spectra and scintillation decay were measured. LY~42,000ph/MeV, ER~7% are obtained at the x=0.01, y=0.24. The relation between the composition and properties will be reported.

Reference

1. S. Kawamura, J. H. Kaneko, M. Higuchi, et.al., IEEE Trans. Nucl. Sci. 54, (2007) 1383.

2. A. Suzuki, S. Kurosawa, A. Yoshikawa, et. al., Appl. Phys. Express 5 (2012) 102601.

POSTERS I - NEW RADIATION DETECTORS: 46

Monte Carlo Simulation of Liquid Noble Gas Scintillation Detectors

Syed M. Hassan[1,2], Eugene L. Clark[1], John Chatzakis[1], Michael Tatarakis[1]

[1]*CPPL, TEI of Crete, 73133 Chania, 74100 Rethymno, Crete, Greece*
[2]*School of Nuclear Engineering, Purdue University, West Lafayette, IN 47907, USA*

Monte Carlo transport codes are used for the developing of novel gamma-ray and neutron detector based on the liquid noble gas as a scintillation medium with scalability to large detector masses. We investigated the liquid noble gas detectors for photon and neutron beams as a function of energy with a specific aim to understand the necessary physics processes of radiation interaction and geometry effects of the detectors with several radiation lengths of depth and high solid angle coverage. The agreements of the codes are shown by the results of the energy deposition from 200 keV up to 11 MeV gamma rays for different liquid krypton/xenon cylinder chamber lengths and beam offsets. Different processes related to the deposition of incident energy within the detector volume are discussed, particularly the ionization process and the production of electron and positron. The possibility of any enhancement in the scintillation light proportional to the incident radiation is also presented.

POSTERS I - NEW RADIATION DETECTORS: 47

Performance Test of Stacked Scintillation Detector for Omnidirectional Gamma-ray Imaging

Tone Takahashi[1], Jun Kawarabayashi[1], Hideki Tomita[1], Tetsuo Iguchi[1], Eiji Takada[2]

[1]*Quantum Engineering, Nagoya University, Nagoya, Japan*
[2]*Toyama National College of Technology, Toyama, Japan*

A gamma-ray imaging with high detection efficiency and wide field of view is quite useful for speedy mapping of radioactive materials released in the environment through nuclear severe accident,etc. For omnidirectional gamma-ray imaging, we are developing a Compton gamma-camera with stacked scintillators. The detector is constructed with some scintillator rods and two position sensitive photo detectors. The interaction position of long axis direction of the scintillator rod is obtained from a ratio of pulse height of the photo detector attached to both sides of the scintillator rod and also the deposited energy at the interaction position from the sum of their pulse heights. By using these three dimensional coordinate of interaction positions and the deposited energies, the gamma-ray source direction can be estimated through a reconstruction algorithm based on Compton scattering kinematics. We have verified the detection principle and the detector performance by a Monte Carlo simulation and basic experiments with a test model detector. For a measurement of 137Cs gamma-ray source with 16x16 stacked GAGG scintillator rods (3x3x48 mm^3) , we have confirmed that the source position could be determined with angular resolution of 28° in all directions as the back projected image by Monte Carlo simulation, and also successfully demonstrated to find the source direction in the experiment with a test model detector of 3x3 GAGG rods.

POSTERS I - NEW RADIATION DETECTORS: 48

Investigation of time response of CdZnTe crystals under pulsed laser and X-rays irradiation

Yadong Xu, Rongrong Guo, Yihui He, Gangqiang Zha, Wanqi Jie

State Key Laboratory of Solidification Processing

CdZnTe (CZT) detectors are becoming more attractive for various hard X-ray and soft γ-ray imaging applications, such as nuclear medicine, space astronomy and homeland security, etc., due to their high energy and spatial resolutions. However, the temporal performance of these detectors is still not well explored. So far, scintillation detectors coupled with photo-detectors have been mostly employed in timing measurements, for example in nuclear physics experiment diagnosis and in positron emission tomography (PET) imaging. Due to its high stopping power and room temperature operation capability, CZT could be used as an alternative to existing scintillator in the corresponding application field. But the dynamic process of carrier relaxation in CZT material upon X or γ-rays absorption is still an issue. A more detailed interpretation of carrier generation and transportation in CZT crystals is needed to fully understand the temporal response, and to provide a guide to optimize CZT material and detector design. In this work, we adopt the pulsed laser and X-rays to study the temporal response of CZT detectors. The photo-response transient currents

of CZT detectors are compared both for anode and cathode irradiation. To evaluate the carrier drift, trapping and de-trapping in CZT detectors, the behaviors of the rising, duration and annihilation processes of the photo-response currents induced by the pulsed laser and X-rays have been evaluated, respectively, as a function of the applied bias and the photons flux.

POSTERS I - NEW RADIATION DETECTORS: 49

Development of high resolution alpha spectrometers using a magnetic calorimeter

W.s. Yoon[1,2,3], C.s. Kang[1], S.r. Kim[1], G.b. Kim[1], H.j. Lee[1], J.h. Lee[2], M.k. Lee[2], J.h. So[1], Y.h. Kim[1,2,3]

[1]*Center for Underground Physics, Institute for Basic Science (IBS), Daejeon, South Korea*
[2]*Korea Research Institute of Standards and Science (KRISS), Daejeon, South Korea*
[3]*University of Science and Technology (UST), Daejeon, South Korea*

We have developed a high resolution alpha spectrometer using a magnetic calorimeter. The detector operates in the principle of calorimetric measurement for temperature increase due to particle absorption in a gold foil absorber at milli-Kelvin temperatures. A magnetic calorimeter made of gold doped with erbium on a superconducting meander pickup coil was adapted to make accurate measurement of the temperature change as an ultra-sensitive thermometer. The detector demonstrated 1.2 keV FWHM equivalent resolution in alpha particle detection with an ^{241}Am source. In the low energy region, many peaks appeared from the absorption of low energy x and γ rays and conversion electrons. An energy resoltuon of 430 eV FWHM was found for 60 keV γ rays measured in the same time with αparticles.

POSTERS I - NEW RADIATION DETECTORS: 50

Development of a scintillation light detector for cryogenic rare event search experiments

H. J. Lee[1], C. S. Kang[1], S. R. Kim[1], G. B. Kim[1], Y. H. Kim[1,2], J. H. Lee[2], M. K. Lee[2], J. H. So[1], W. S. Yoon[2]

[1]*Center for Underground Physics, Institute for basic Science (IBS), Republic of Korea*
[2]*Research Institute of Standards and Science (KRISS), Republic of Korea*

In rare event search experiments, the heat and light measurement at low temperatures of using scintillating crystals as target material can provide high resolution detection and active background rejection mechanism. Low temperature detectors with high energy resolution can be adapted to measure heat signals of the crystal as well as scintillation light signals coming out of the crystal. The ratio between heat and light signals may differ for different event types. We developed a light detector to measure scintillations from a crystal developed for rare event searches. A two-inch Ge wafer was used as the light absorber, while a metallic magnetic calorimeter was to read the temperature increase of the absorber. The light detector was tested in 30-100 mK. The performance in energy resolution, rise time and signal amplitude will be reported and discussed for possible applications to dark matter detection and neutrinoless double beta decay experiment.

POSTERS I - NEW RADIATION DETECTORS: 51

Development of a Fast Neutron Activation Counter Using the Cherenkov Effect

Matthew J. Millard[1], Timothy A. Devol[1], Zane W. Bell[2]

[1]*Clemson University, Environmental Engineering & Earth Sciences*
[2]*Oak Ridge National Laboratory, Nuclear Material Detection and Characterization*

Fast neutron detectors utilizing the Cherenkov effect were exposed to a neutron flux to quantify detector response and applicability as a criticality monitor. The detector consists of an optically clear medium, composed of select target nuclei, coupled to a photomultiplier tube. The beta and gamma radiation from the resultant reaction products of the target nuclide produce Cherenkov photons within the medium which can be detected. Example media include quartz (SiO_2) and sapphire (Al_2O_3) which were irradiated with unmoderated ^{252}Cf. Monte Carlo N-Particle

(MCNP) code simulations were done to quantify the neutron flux incident on the media. The threshold reactions of interest were ^{28}Si (n, p) ^{28}Al and ^{27}Al (n, p) ^{27}Mg which have neutron reaction cross sections of approximately 0.02 barns at 5 MeV up to 0.1 barns and 0.3 barns at 10 MeV, respectively. The average counting efficiency of the quartz disc was 51.9 ± 4.78%, while the average counting efficiency of the sapphire disc was 57.3 ± 3.41%. The neutron response of ZnS and $MgAl_2O_4$ will also be quantified.

POSTERS I - NEW RADIATION DETECTORS: 52

Characteristics of Fabricated Si PIN-type Radiation Detectors on Cooling Temperatures

Han Soo Kim[1], Manhee Jeong[1], Young Soo Kim[1], Seung Yeon Cho[2], Jang Ho Ha[1]

[1]Korea Atomic Energy Research Institute
[2]Environmental Health Center, Yonsei University

Room-temperature semiconductor radiation detectors such as CdZnTe and CdTe are currently being commercialized from several vendors. Although these semiconductors offer very good energy resolution and high efficiency, the stability of mass production is still challenging. Thus, scintillator detectors matched with Si-based semiconductor is still developed by virtue of its compactness, low power consumption and stability of the semiconductor fabrication processes. PIN photodiodes with three different active area (3x3 mm^2, 5x5 mm^2, and 10x10mm^2) were designed and fabricated. In Si-based semiconductor radiation detectors, one of the noise sources is thermal noise, which degrades their performance, such as the energy resolution and unexpected pulse signals. In this study, the temperature effects of fabricated PIN photodiode radiation detectors were investigated. Energy resolutions from 30 keV to 80 keV gamma-ray by using a Ba-133 calibration source and I-V curves were measured at every 10 ℃ interval from room temperature to -40 ℃. Variation of energy resolutions for Cs-137, Co-60, and Na-22 sources were also addressed at the same temperatures by matching with the CsI(Tl) scintillator.

POSTERS I - NEW RADIATION DETECTORS: 53

X-ray Response of Sub-grain Boundaries in CZT Detectors

Giuseppe S. Camarda[1], Aleksey E. Bolotnikov[1], Yonggang Cui[1], Anwar Hossain[1], Kihyun Kim[2], Wonho Lee[2], Utpal Roy[1], Ge Yang[1], Ralph B. James[1]

[1]Brookhaven National Laboratory, Upton, NY, USA
[2]Korea University, Seoul, Korea

Several CZT detectors were evaluated by using the Micron-scale X-ray Detector Mapping (MXDM) system of beamline X27B at the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory (BNL). The goal of this study is to understand the deterioration of detectors' performance in regions near sub-grain boundaries, possibly related to the presence of a higher concentration of impurities than in the rest of the matrix. The uniformity of the X-ray response maps for fabricated detectors is indicative of the performance of the detectors. The results will clarify the defects responsible for the observed non-uniformities.

POSTERS I - NEW RADIATION DETECTORS: 54

Radiation Hardness Characteristics of Si-PIN Radiation Detector

Manhee Jeong, Woo Jin Jo, Han Soo Kim, Young Soo Kim, Jang Ho Ha

Korea Atomic Energy Research Institute, Jeongeup, Jeollabookdo 580-185, South Korea

The Korea Atomic Energy Research Institute (KAERI) has fabricated Si-PIN radiation detectors with low leakage current, high resistivity (>11 kΩ-cm) and low capacitance for the high-energy physics and X-ray spectroscopy. Floating-zone (FZ) 6-inch diameter N-type silicon wafers, with <111> crystal orientation and 675 μm thick, were used in the detector fabrication. The active areas are 3 mm x 3 mm, 5 mm x 5 mm and 10

mm x 10 mm. We used a double deep-diffused structure at the edge of the active area for protection from the surface leakage path. We also compare the electrical performance of the Si-PIN detector with anti-reflective coating (ARC). For a detector with an active area of 3 mm x 3 mm, the leakage current is about 1.9 nA and 7.4 nA at a 100 V reverse bias voltage, and 4.6 pF and 4.4pF capacitance for the detector with and without an ARC, respectively. In addition, to compare the energy resolution in the sense of radiation hardness, we measured the energy spectra with ^{57}Co and ^{133}Ba before the irradiation. Using developed preamplifiers (KAERI-PA1) that have ultra-low noise and high sensitivity, and a 3 mm x 3 mm Si-PIN radiation detector, we obtained energy resolutions with 122 keV of ^{57}Co and 81 keV of ^{133}Ba of 0.221 keV and 2.61 keV, respectively. After 10, 100, 10^4 and 10^5 Gy irradiation, we tested the characteristics of the radiation hardness on the Si-PIN radiation detectors in the sense of electrical and energy spectra performance changes and will present the results in detail.

POSTERS I - NEW RADIATION DETECTORS: 55

Scintillation Properties of 1-inch $CsBa_2I_5:Eu^{2+}$ Crystals

Urmila Shirwadkar, Rastgo Hawrami, Edgar Van Loef, Jaroslaw Glodo, Gary Markosyan, Imad Abselem, John Vaghini, Craig Hines, Jeff Finkelstein, Kanai Shah

Radiation Monitoing Devices, Inc

$CsBa_2I_5:Eu^{2+}$ (CBI) is an exciting material for gamma-ray spectroscopy. Recently, gamma-ray energy resolution of ~ 2.3% @ 662 keV has been reported by scientists at Delft University for a small sample of CBI. Although, excellent results have been obtained for smaller samples, for practical use of this material as a gamma-ray detector, it is important to grow and study larger crystals. At RMD, we have grown 1-inch diameter CBI crystals, up to 4-5 inches in length. The crystals are clear to partly translucent in appearance, and have a very respectable performance. Scintillation properties of 1-inch diameter samples of CBI will be presented in this paper. At 662 keV, we have achieved energy resolution of ~ 4.9 % for a 1" x 1" cone and 5.4 % for a 1" right cylinder. The light output of a 1-inch cylinder was estimated ~ 75,000 ph/MeV. The light output proportionality of the cylinder is excellent over a wide range of energies from 60 keV up to 1274 keV, therefore, yields very good energy resolution of ~ 9.2 % at 60 keV. CBI, similar to other Eu^{2+}-doped materials, has significant self-absorption. This results in light trapping, more prominent for larger crystals. The events affected by light trapping have lower pulse height and longer decay times. This relationship can be exploited to improve energy resolution in larger crystals, as it has been shown for $SrI_2:Eu^{2+}$ by researchers at Lawrence Livermore National Laboratory.

POSTERS I - NEW RADIATION DETECTORS: 56

Development of ceramics insulated ball-anode element for neutron detection

Kentaro Toh[1], Tatsuya Nakamura[1], Kaoru Sakasai[1], Kazuhiko Soyama[1], Hideshi Yamagishi[2]

[1]J-PARC Center, Japan Atomic Energy Agency, Tokai 319-1195, Japan
[2]Nippon Advanced Technology, Tokai 319-1112, Japan

A novel ceramics insulated detector element was developed for neutron measurement, and an irradiation experiment was performed using a Cf-252 neutron source. The developed detector element consists of a ceramics insulator, cathode lines on the insulator, and ball-shaped anodes. The cathode lines are arranged on the surface of the ceramics, and anode lines, which are connected to anode balls, are arranged on the backside of the ceramics. Both electrodes lines are arranged orthogonally. The incident neutrons are usually scattered by the detector element itself because it acts as scatterer. To estimate the effects of scattering, we calculated the amount of neutrons scattered by the developed element. By the calculation results by a Monte Carlo simulation using PHITS, it is found that the developed element is effective to reduce the scattered neutrons. They were detected by the adjacent pixels relative to the incident position and the counting ratio of the pixel to the incident position was 10^{-5}. The ratio was also smaller than that when ceramics was used as insulator. The number of scattered neutrons of the developed element is 40% smaller than that of polymer insulated element, which is widely used in micro-pattern element. Finally, neutron-induced signals were clearly observed using the developed detector element.

POSTERS I - NEW RADIATION DETECTORS: 57

Preliminary results for possibility of multi-energy X-ray imaging with X-ray beam and filter to overcome low count rate in photon-counting method

Dae-hong Kim, Young-jin Lee, Pil-hyun Jeon, Hee-joung Kim

Department of Radiological Science, Yonsei University, Wonju, South Korea

Energy-resolved photon-counting detector has widely been used for multi-energy X-ray imaging. The main advantages of photon-counting detector are reducing dose, compositional analysis, and contrast enhancement. However, the clinical application is limited due to low count rate. In this paper, we presented a method with combinations of filter and tube voltage to overcome the low count rate of photon-counting method. The proposed method was evaluated with ratio of beam hardening. Tungsten anode spectral model using interpolating polynomials (TASMIP) was used to perform the simulation. Filters were selected to achieve the spectral separation considering their K-edge with tube potentials. Mean energy of bean hardening is assessed for PMMA, aluminum, and iodine. In PMMA, beam hardening effect was not shown for each tube voltages. Therefore, all tube voltage and filter can be used in PMMA. In Aluminum, combinations of 80 kVp and filter from Z=68 to Z=75 is useful for energy selective imaging. In iodine, combinations of 50 kVp and filter Z=57 and Z=58 can be used to select for multi-energy X-ray imaging. From these results, multi-energy imaging can be achievable for PMMA material. However, high density materials such as aluminum and iodine need to be carefully selected for securing both image quality and patient dose.

POSTERS I - NEW RADIATION DETECTORS: 58

A two-dimensional scintillation neutron detector readout with wavelength-shifting fibers incorporating interpolation method

Tatsuya Nakamura[1], Kentaro Toh[1], Takuro Kawasaki[1], Masumi Ebine[2], Atsushi Birumachi[2], Takaaki Hosoya[3], Kaoru Sakasai[1], Kazuhiko Soyama[1], Masaki Katagiri[3]

[1]J-PARC center, Japan Atomic Energy Agency
[2]Nuclear science institute, Japan Atomic Energy Agency
[3]College of engineering, Ibaraki University

A two-dimensional scintillation neutron detector incorporating an interpolation method readout by wavelength-shifting (WLS) fiber was developed to make an effective pixel size smaller than the physical pitch of the WLS fibre array. The detector that was made with the crossed arranged WLS fiber arrays where the fibers were placed in a regular pitch of 2.5 mm in x and y directions. The dedicated signal processing algorithms that calculated an incident position of neutron with a base length of the same, half and quarter of the physical WLS fiber pitch were developed for the detector operated in a photon-counting method. The paper demonstrates feasibility of the developed interpolation methods using a collimated neutron beam.

POSTERS I - NEW RADIATION DETECTORS: 59

Isovalent substitution in Elpasolite Halide Scintillators

Pin Yang, F. Patrick Doty, Xiaowang Zhou, Marlene Bencomo

Sandia National Laboratories, Albuquerque, New Mexico

The effects of alloying in lanthanide based elpasolite hailde (A_2BLnX_6; X halogen) scintillators have been investigated. These compounds can outperform other halide-based scintillators in terms of their proportionality response, making them particularly attractive for un-cooled gamma-ray spectroscopy applications. However, their luminosity still cannot rival against state-of-the-art lanthanide tri-halide compounds such as LaBr3 and CeBr3. This study focuses on the effects of anion mixing (Cl^- and Br^-) and cation (La^{3+} and Gd^{3+}) substitution on their scintillating performance, especially on the alloying effects on the light yield and energy resolution. The substitution of a smaller size anion (Cl^-) in the bromide compounds is aimed to modify the crystal field around activators at their octahedral sit; therefore, it could potentially broaden detectors' spectroscopy response and enhance the total photon count. In addition, the mixing of different size anions can induce localized lattice distortion, break the degeneracies

of electronic orbital states, and potentially enhance the amount of light yield. On the cation side, the substitution of Gd^{3+} with La^{3+} is to exploit the potential energy transfer from host Gd^{3+} to Ce^{3+} activator centers to enhance the output of the detector. Based on these promises, single crystals of four alloying systems, including $Cs_2LiLaCl_xBr_{6-x}$, $Cs_2LiYCl_xBr_{6-x}$, and $Cs_2NaYCl_xBr_{6-x}$, $Cs_2LiLa_{1-x}Gd_xBr_6$, were grown and studied. Their photoluminescence and radioluminescence responses will be reported and compared to shed lights on the effects of alloying on scintillating performance. A total of 17 different isovalent substitution elpasolite halide single crystals were grown for this study. Optical quality crystals of 1.27 cm diameter X ~1.0 cm were cut from the boules and used for scintillation characterization. Optical spectroscopy results show a similar excitation and a characteristics emission due to Ce^{3+} 5d-to-4f [2F5/2,2F7/2] transition. The emission spectra exhibit a systematic blue shift as smaller Cl- ions substitute larger Br- in the host lattice. Substitution of Gd+ in these compounds can slightly boost the optical quantum efficiency. Based on these alloyed systems, it appears both cation and anion substitutions will shift their emission spectrum as predicted by the change of crystal field around activators. However, these isovalent substitutions do not appear to be effectively broadening their emission spectrum suggesting alloying might not significantly alter the electron-phonon coupling in the elpasolite lattice. Results from gamma energy spectra indicate that alloying can result in a lower energy resolution, which can in part be attributed to the decrease in the light yield. However, these results can also be confounded by the slight difference in optical quality of these crystals. Furthermore, the substitution of isovalent ion in the host crystal slightly increases the fast decay component, but does not affect significantly in their proportionality responses. These results will be compared with well-established scintillators and mechanisms contribute to the decay behavior will be discussed.

This work is supported by the NNSA/DOE Office of Nonproliferation Research and Development, Proliferation Detection Program, Advanced Material Portfolio. Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

POSTERS I - NEW RADIATION DETECTORS: 60

Optical Spectroscopy and Scintillation Properties of a Cerium Activated Cs_2NaYBr_6 Crystal

Marlene Bencomo, Pin Yang, F. Patrick Doty, Xiaowang Zhou

Sandia National Laboratories, Albuquerque, New Mexico

The quest for high performance scintillators is crucial in supporting the development of advanced gamma ray spectroscopy and radiation detection applications. New scintillators should have high light yield, good proportionality and stopping power. Scintillators with these characteristics can ultimately replace benchmark scintillators such as NaI(Tl) and CsI(Tl) while providing better energy resolution. In this study, the material and scintillation properties of a cerium doped Cs_2NaYBr_6 crystal are reported. A 10 mm sample of a cerium doped Cs_2NaYBr_6 single crystal (12.7 mm dia.), grown by a Bridgeman method, was used for scintillation characterization. Luminescence and scintillator properties, including photo-excitation and emission, optical quantum yield, gamma energy spectrum, radioluminescence decay time, and linearity response, were investigated. . Photoluminescence response shows an excitation peak at 346.0 nm and two emission peaks at 369.75 nm and 401.25 nm which can be attributed to the cerium doping. The measured energy resolution for this new compound is 7% (at 662 keV) which is compatible to the NaI(Tl) and better than CsI(Tl) and BGO scintillators. The crystal also shows a dominant fast decay component at 44.0 ns (99.98%), which is slightly longer than the optical decay time of 31.46 ns, presumably due to the additional relaxation processes following ionization. The proportionality of light yield for the cerium doped Cs_2NaYBr_6(Ce) is less than 6% between 60 keV and 1597 keV, which is substantially better than many well established scintillators such as NaI:Tl (14%), CsI:Tl (10%), and LSO (11%), With further improvement in crystal quality, this new scintillator can be an alternative detector material for radiation detection applications. This work is supported by the NNSA/DOE Office of Nonproliferation Research and Development, Proliferation Detection Program and Advanced Material Portfolio. Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy

POSTERS I - NEW RADIATION DETECTORS: 61

Performance of Large Size LYSO Crystal Batches

Fan Yang, Rihua Mao, Liyuan Zhang, Renyuan Zhu

California Institute of Technology,1200 E California BLVD, Pasadena, CA 91125, USA

Because of their high stopping power and fast and bright scintillation light, cerium doped lutetium oxyorthosilicate (Lu_2SiO_5:Ce, LSO) and lutetium-yttrium oxyorthosilicate ($Lu_{2(1-x)}Y_{2x}SiO_5$:Ce, LYSO) crystals have attracted a broad interest in the physics community pursuing precision electromagnetic calorimeter for future high energy physics experiments. Their excellent radiation hardness against gamma-rays, neutrons and charged hadrons also makes them a preferred material for calorimeters to be operated in a severe radiation environment. Twenty-five LYSO crystals with a slightly tapered shape 20×23×200 mm grown by Saint-Gobain, SIC and SIPAT for the SuperB experiment. Ten rectangular LYSO crystals with dimension of 30×30×130 mm and two hexagonal LYSO crystals of 18.6×130 mm grown by SIC for the Mu2e experiment.Optical properties, including excitation, emission and transmittance spectra, and scintillation properties, including light output, decay time and light response uniformity, were measured in the Caltech HEP Crystal Laboratory. Correlations between optical and scintillation properties were investigated. Results of these investigations indicate that the quality of large size LYSO crystals grown in industry is adequate for future HEP calorimeters at both the energy and intensity frontiers.

POSTERS I - NEW RADIATION DETECTORS: 62

Co-doping of $SrI_2:Eu^{2+}$ crystal with different group I and group II elements using Multi-growth Vertical Bridgman

Emmanuel Rowe[1], Pijush Bhattacharya[1], Eugene Tupitsyn[1], Vladimir Buliga[1], Michael Groza[1], Arnold Burger[1,2]

[1]*Fisk University, Dept. of Life and Physical Sciences Nashville, TN U.S.A.*
[2]*Vanderbilt University, Nashville, TN, U.S.A.*

The importance of gamma ray spectroscopy in the age of nonproliferation can hardly be overstated. While the industrial use of gamma ray spectroscopy is constantly changing, what remains is the need for crystals with high energy resolution and non proportional. Devoid of native radioactive isotopes, europium doped strontium iodide is a prime for commercialization. In this report we plan to co-dope as a fine tuning for lattice hardening and scintillation properties. It has been shown with $LaBr_3:Ce^{3+}$that co-doping with divalent strontium or calcium that the scintillator was a factor of three more tolerant towards high ionization density recombination. In this comparative study of the substitution effect of univalent and divalent ions substituted at the strontium site of an iodide doped with 2.5m% europium iodide matrix by measuring the energy resolution and light yield.The starting material for the strontium iodide doped with 2.5m% europium iodide were 99.999% pure anhydrous SrI_2 beads and 99.999% EuI_2. This material was synthesized using quick Bridgman then partitioned for the use of the co-dopants. The co-dopants used in this experiment were NaI, KI, MgI_2, and CaI_2 with a selected molar percentage of 0.1%. Using a steel cartridge machined in the shape of a revolver cylinder, five ingots were grown simultaneously in one Bridgman run. The boules where created from a quick Bridgman 60g of $SrI_2:Eu^{2+}$ (2.5 mol %). The boule was partitioned into 10g charges and then co-doped as followed; $SrI_2:Eu^{2+}/Ca^{2+}$ (2.5/0.1 at %); $SrI_2:Eu^{2+}/K^{1+}$ (2.5/0.1 at %); $SrI_2:Eu^{2+}/Na^{1+}$ (2.5/0.1 at %); and $SrI_2:Eu^{2+}/Mg^{2+}$ (2.5/0.1 at %).The scintillation light yields of the samples were measured using a ^{137}Cs γ source. The setup for the γ-ray testing consisted of a Hamamatsu R6231-100 PMT biased at 900V, connected to an Ortec 113 preamplifier, an Ortec 671 spectroscopic amplifier, and a Canberra MP2 multichannel amplifier.We have carried out the growth of Strontium iodide co-doped with group I and group II elements. The co-dopants used in this experiment were NaI, KI, MgI_2, and CaI_2 with a selected molar percentage of 0.1%. The initial $SrI_2:Eu^{2+}$ (2.5 m%) was synthesized using quick Bridgman then partitioned for the charge material for the co-dopant growth. Using a steel cartridge, five samples were grown simultaneously in one Bridgman run. The best energy resolution of 2.9%, and crystal quality of the grown boules was obtained for the magnesium the co-dopants.

POSTERS I - NEW RADIATION DETECTORS: 63

Response of a new pad-based neutron detector developed for coded aperture thermal neutron imaging

Istvan Dioszegi, Bo Yu, Neil Schaknowski, Jack Fried, Peter E. Vanier, Cynthia Salwen, Leon Forman

[1]*Brookhaven National Laboratory, Upton, New York 11973-5000 USA*
[2]*Ion Focus Technology Inc., Miller Place, New York 11764 USA*

A new coded aperture thermal neutron imager system is being developed at Brookhaven National Laboratory. The camera utilizes a position-sensitive ^{3}He-filled ionization chamber, in which an anode plane is composed of an array of pads with independent acquisition channels. The charge is collected on each of the individual 5x5 mm^{2} anode pads, (48x48 in total, corresponding to 24x24 cm^{2} sensitive area) and read out by application specific integrated circuits (ASICs). The new design has several advantages for coded-aperture imaging applications in the field, compared to the previous generation of wire-grid based neutron detectors. Among these are its rugged design, lighter weight and use of non-flammable stopping gas. The pad-based readout occurs in parallel circuits, making it capable of high count rates, and also suitable to perform data analysis and imaging on an event-by-event basis. The spatial resolution of the detector can be better than the pixel size by using a charge sharing algorithm. In this paper we will report on the development and performance of the new pad-based neutron camera and describe a simulation software tool developed to model the response of the detector in order to optimize the pad geometry and achieve a sub-pixel resolution.

POSTERS I - NEW RADIATION DETECTORS: 64

Alternative Scintillation Materials for Radioxenon Detection

Michael Foxe[1], Ted W. Bowyer[1], Matthew W. Cooper[1], Anthony R. Day[1], James H. Ely[1,2], Derek A. Haas[1], James C. Hayes[1], Justin D. Lowrey[1], Justin I. Mcintyre[1], Amanda M. Prinke[1]

[1]*Pacific Northwest National Lab, Richland, WA, USA*
[2]*International Atomic Energy Agency, Vienna, Austria*

Radioxenon beta–gamma coincidence detectors are employed worldwide to monitor nuclear explosions. The current generation of these detectors utilizes a scintillating plastic to detect the electron emissions from radioxenon. This plastic has been previously shown to retain a portion of the gas sample, creating a "memory effect" that must be corrected for in subsequent measurements. We report on the effectiveness of three materials that are expected to have much less memory effect. The three materials covered in this study are scintillating glass, yttrium aluminum perovskite (YAP), and Stilbene.

POSTERS I - NEW RADIATION DETECTORS: 65

Thermoluminescent analysis of rare earth íons (Tb^{3+} and Eu^{3+}) doped $CaSO_4$ crystal powder

Danilo Oliveira Junot, Luiza Freire Souza, Divanizia Souza Nascimento

Federal University of Sergipe

Since the thermoluminescence started to be applied to the dosimetry of ionizing radiation in 1940 different materials detectors have been proposed, and one of the most common is $CaSO_4$, which has been doped with various rare earth (RE) elements recently. The motivation of this work was to produce crystals of $CaSO_4$ doped with an unusual combination of RE elements such as terbium (Tb) and europium (Eu) in different concentrations. The interest in the production of $CaSO_4$:Tb,Eu was to investigate other methods of production of thermoluminescent materials. In the growth route, the crystals were produced from calcium carbonate ($CaCO_3$), by incorporating the dopants (Tb_2O_3 and Eu_2O_3) in a solution of sulfuric acid, that is evaporated leaving just $CaSO_4$:Tb,Eu crystal powder. X-ray diffraction and radioluminescence techniques were used to characterize samples. The composites showed TL emission glow curves with three peaks centered around 165 °C, 255 °C and 347 °C, after irradiated with a $_{90}Sr/^{90}Y$ source. Thermoluminescent (TL) characteristics such as linearity, reproducibility, fading, kinetics order, and activation energy were evaluated. Samples produced with concentration ratio of 5:1 of Tb and Eu have show the highest TL intensity and were compared with commercial TLDs (TLD-100, TLD-900). The new route for the preparation of samples were shown to be viable.

POSTERS I - NEW RADIATION DETECTORS: 66

NEODYMIUM AS DOPANT FOR MAGNESIUM TETRABORATE MATRIX AND ITS APPLICABILITY FOR TL DOSIMETRY

Luiza Freire Souza, Marcos Couto Santos, Rogério Matias Vidal, Rene Rojas Rocca, Divanizia Nascimento Souza

Physics Department , Federal University of Sergipe , São Cristovão

The MgB_4O_7 doped with lanthanides such as, Dy^{3+} and Tm^{3+} are phosphors very well established in personal dosimetry routine. Some characteristics such as, linearity to a broad range of dose, low energy dependence, Zeff = 8.5, high sensitivity and a thermoluminescent emission curve relatively simple,make the MgB_4O_7 a good material for thermoluminescent dosimetry. With the aim of analyze other doping possibilities, this paper present some preliminary results for the use of Nd^{3+} dopant in MgB_4O_7matrix. In the present work the phosphor was produced trough solid state synthesis and the X-ray diffraction and scanning electronic microscopy confirmed the technique success. It was also observed that MgB_4O_7:Nd when irradiated with photons and beta radiation has significant TL response and for the dose range of few grays the TL response is linear. It was also verified the influence on varying the dopants concetration for TL emission.The sensitivity of material was compared with TLD-100 (LiF:Mg,Ti) and the comercial MgB_4O_7:Dy .The results show that the sensitivity of the produced material is greater than the MgB_4O_7:Dy but is less compared to TLD-100.

POSTERS I - NEW RADIATION DETECTORS: 67

Perovskite single crystal scintillating films for high resolution X-ray imaging at synchrotrons

Federica Riva[1,2], Paul-antoine Douissard[1], Thierry Martin[1], Ashot Petrosyan[3], Christophe Dujardin[2]

[1]*European Synchrotron Radiation Facility ESRF, 6 rue Jules Horowitz, Grenoble 38000 France*
[2]*Institut Lumière Matière, Universitè Lyon 1 - CNRS, Villeurbanne cedex 69622 France*
[3]*Institute for Physical Research, Armenian National Academy of Science, 378410 Ashtarak-2, Armenia*

X-ray detectors for high spatial resolution imaging are mainly based on indirect detection. The detector consists of a converter screen, light microscopy optics and a cooled charged-coupled device (CCD). The screen converts part of the absorbed X-rays into a visible light image, which is projected onto the CCD by means of the optics. The detective quantum efficiency of the detector is strongly influenced by the properties of the converter screen (X-ray absorption, spread of energy deposition, light yield and emission wavelength). In order to obtain detectors with micrometer and sub-micrometer spatial resolution, thin (1-50 μm) single crystal film (SCF) scintillators are required. These scintillators are layers grown on a substrate by liquid phase epitaxy (LPE). The critical point for these layers is their weak absorption, especially at energies exceeding 20 keV. At the European Synchrotron radiation Facility (ESRF), X-ray imaging applications can exploit energies up to 120 keV. Therefore, the development of new scintillating materials is currently investigated. The aim is to improve the contradictory compromise between absorption and spatial resolution, to increase the detection efficiency while keeping a good image contrast even at high energy.We developed a "simulation tool" in order to find the optimal combination of scintillating screen (in terms of thickness and material) and visible light optics for different energy ranges. We chose to combine a Montecarlo approach (Geant4 Montecarlo toolkit) with analytical calculations for the optics.The aim of these simulations is guiding the choice of the materials that will be grown by LPE. Alumina perovskites and Lutetium oxide (Lu_2O_3) are good candidates because of their high density compared to garnet or silicates that are currently used at ESRF. We simulated the energy deposition and we identify different materials for different energy ranges: Lu_2O_3 for energies lower than 51 keV, $GdAlO_3$ (GAP) in the range 51 keV-65 keV, $LuAlO_3$ (LuAP) for higher energies.We successfully started the development of GAP by liquid phase epitaxy on $YAlO_3$ (YAP) substrates and we demonstrated the feasibility of X-ray imaging with this material.Unfortunately, the lattice mismatch between YAP and GAP does not allow the growth of layers with good optical quality. In order to overtake this problem we are currently studying a mixed composition $Gd_xLu_{1-x}AlO_3$ to reduce the lattice mismatch with the substrate and study the effect on the layer quality.

POSTERS I - NEW RADIATION DETECTORS: 68

Surface Passivation of CZT Nuclear Detectors Using Potassium Hydroxide in Hydrogen Peroxide Solution

Ifechukwude O. Okwechime[1], Stephen U. Egarievwe[1], Anwar Hossain[2], Zaveon M. Hales[1], Ralph B. James[2]

[1]*Nuclear Engineering and Radiological Science Center, Alabama A&M University, Normal, AL 35762, USA*
[2]*Nonproliferation and National Security Department, Brookhaven National Laboratory, Upton, NY 11973, USA*

Surface damages caused during cutting and polishing in the fabrication of cadmium zinc telluride (CZT) nuclear detectors often result in high leakage current that limits the spectral performance of the material. Chemical treatment is an effective technique for removing the surface damages and thus reducing the leakage current. In this study, we report the effects of chemo-mechanical polishing with a mixture of hydrogen bromide in hydrogen peroxide and ethylene glycol solution, followed by passivation with potassium hydroxide in hydrogen peroxide on CZT detector performance. The treatment effects were studied using current-voltage (I-V) measurements, spectral response and x-ray photoelectron spectroscopy (XPS). The resistivity of the CZT samples is in the order of 10^{10} ohms-cm. The currents in the I-V measurements increased rapidly following the chemo-mechanical polishing and passivation and decreased steadily over a 14-day period. The spectral response results show that the 59.5-keV peak of Am-241 was stable under the same channel over the 14-day period.[This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA award number 2012-DN-077-ARI065-03. This work has also been supported by the US Nuclear Regulatory Commission through award number NRC-27-10-514. These supports do not constitute an express or implied endorsement on the part of the Government.

POSTERS I - NEW RADIATION DETECTORS: 69

Growth and Characterization of CdTexSe1-x: A Possible Radiation Detector Material

Utpal N. Roy[1], Aleksey E. Bolotnikov[1], Giuseppe Camarda[1], Kisung Lee[1,2], Wonho Lee[1,2], Ge Yang[1]

[1]*Brookhaven National laboratory*
[2]*Korea University, Seoul, Korea*

CdZnTe (CZT) is the leading material for high-resolution gamma-ray spectrometers that operate at ambient temperature for applications in homeland security/non-proliferation, and in medical imaging. But despite the current success of CZT, most security applications demand large area/volume detectors, and herein, their deployment is seriously impeded because of several disadvantages related to growing large CZT crystals. Ultimately, these problems result in the high cost and scarcity of large-volume detectors. The main drawbacks that lower the charge-transport characteristics of CZT materials comprise the segregation coefficient of Zn in the CdTe matrix that causes a compositional gradient in a large-volume detector, along with a fairly large concentration of sub-grain boundaries, and of Te inclusions/precipitations. However, CdTexSe1-x offers several advantages that negate the defects mentioned above, and hold promise for tremendous potential in improving the charge-transport characteristics of large-volume detectors. The main benefit is the near-unity segregation coefficient of Se in the CdTe matrix that assures a highly uniform composition in the grown ingot, resulting in a higher yield of satisfactory crystals, and thus, is expected to lower the production costs of such detectors compared to those manufactured from CZT crystals. The results of our growth experiments confirm the near-unity segregation of Se for ingots grown by the vertical Bridgman growth technique. We also have grown CdTexSe1-x samples by the Traveling Heater Method. We examined the crystals for the presence of defects, such as Te inclusions/precipitations and sub-grain boundaries that govern charge-transport characteristics. The concentrations of the former were five-to eight-fold times lower than those in the typical CZT material presently available; similarly, the concentration of sub-grain boundaries in our material also was much less extensive than in present-day CZT materials. In this presentation, we will discuss the growth of CdTexSe1-x with different compositions and describe our detailed evaluations of its basic material properties. Also, we will discuss the initial results of our measurements of charge-transport characteristics and of the properties of the fabricated devices.

POSTERS I - NEW RADIATION DETECTORS: 70

Metal and oxygen impurities in zone-refined precursors for halide crystalline scintillators

Stacy E. Swider, Stephanie Lam, Shariar Motakef

CapeSym, Inc., Natick, MA

Successful growth of halide scintillator crystals depends on a supply of ultra-high purity (UHP) precursor materials. Metallic interstitials and substitutions may cause strain in the lattice and /or provide bandgap states that quench luminescence. Oxygen impurities can create competing compounds within a matrix, such as oxyhalides, that disrupt crystallinity and nucleate cracks. Using mass spectroscopy and thermo-gravimetric analysis, we analyzed impurities in SrI_2, EuI_2, and YCl_3 precursors before and after zone refining. The data show suitable metallic segregation, achieving < 10 ppm total, excluding barium and calcium. Most of the alkali, alkali earth, and transition metals segregated well, while the metalloids often displayed poor segregation. Oxygen concentrations as low as 7 ppm were achieved. Additional oxygen was measured in nitrates and sulfates, via ion chromatography. This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract HSHQDC-13-C-00080. This support does not constitute an express or implied endorsement on the part of the Government.Corresponding author: swider@capesym.com; 508-653-7100

POSTERS I - NEW RADIATION DETECTORS: 71

Pulse shape discrimination of $Cs_2LiYCl_6:Ce^{3+}$ scintillator up to 180 °C

Kan Yang, Peter R. Menge

Saint-Gobain Crystals, Hiram, Ohio, USA

In this study, we investigate the possibility of using Ce^{3+} doped Cs_2LiYCl_6 (CLYC) as a neutron-gamma dual mode detector from room temperature to temperatures up to 180 °C. We revisited the pulse shape discrimination (PSD) of CLYC at various temperatures. Previously, it had been shown that PSD based on Core-Valence-Luminescence fades away at temperatures >120° C. However, it has been discovered that there is a secondary mechanism which can be utilized for neutron-gamma Pulse Shape Discrimination in addition to the well-known Core-Valence-Luminescence (CVL). Moreover, this mechanism is found to be insensitive to temperature change in contrast to CVL. Temperature dependent PSD algorithms have been developed to enable reliable neutron-gamma PSD up to 180 °C.

POSTERS I - NEW RADIATION DETECTORS: 72

Ultra Fast Scintillators for High Speed Radiography

Zsolt Marton, Stuart R. Miller, Harish B. Bhandari, Elena E. Ovechkina, Vivek V. Nagarkar

Radiation Monitoring Devices, Inc., 44 Hunt Street, Watertown, MA 02472, USA

With the development of high speed imaging systems comes an ever increasing need for scintillator films with faster decay properties. We have developed several scintillator materials exhibiting nanosecond decay times for ultra-fast radiography applications. Here we report on LuI_3:Ce and $CeBr_3$ materials that have been deposited as polycrystalline, structured films using our hot wall epitaxy (HWE) method. The $CeBr_3$ films have demonstrated 6 ns primary decay compared to 25 ns measured in crystalline material. LuI_3:Ce films have shown a 13 ns decay compared to the 28 ns reported for crystals.Here we report on the scintillation properties of films compared to corresponding crystalline materials. The films were integrated into our high-speed CMOS imaging system to demonstrate high-speed radiography capability.

POSTERS I - NEW RADIATION DETECTORS: 73

Luminescent properties of BaBrX:Eu (X=F, Cl, Br, I) family as a function of temperature

Ivan Khodyuk, Eric Samulon, Gautam Gundiah, Martin Gascon, Stephen Derenzo, Edith Bourret, Gregory Bizarri

Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

The BaBrX:Eu^{2+} family (where X=F, Cl, Br, I) has been a long-standing subject of research in various fields of luminescent materials. BaBrF and BaBrCl were the focus of medical imaging attention for their remarkable storage properties [1]. More recently, BaBrI:Eu has raised the interest of the gamma-ray detection community for its very high light yield of 97,000 photons/MeV and its good energy resolution of about 3% at 662 keV [2]. While aspects of individual mechanisms have been studied and partly understood, no attempt has ever been made to explain the overall behavior among the family or to underline specific factors governing it. For instance, while there is a significant change of the material band gap going from BaFBr (8.3 eV) to BaBrI (5.3 eV), this cannot account for the light output variation between the two materials. Using temperature dependent X-ray and optical spectroscopy measurements as well as spectrally resolved thermo-stimulated luminescence and afterglow emission, the individual properties of the compounds will be discussed. Based on these results, an overall model explaining the family properties will be proposed with respect to the constituents of each material.

[1] Schweizer, Phys. Stat. Sol. (a) 187/2 (2001) 335.

[2] Bizarri et al., IEEE TNS 58 (2011) 3403.

POSTERS I - NEW RADIATION DETECTORS: 74

Photon density response and picosecond spectroscopy of GYGAG:Ce

Sam Flynn[1], Qi Li[1], K. B. Ucer[1], R. T. Williams[1], K. Biswas[2], Z. M. Seeley[3], N. J. Cherepy[3]

[1]*Department of Physics, Wake Forest University, Winston-Salem NC*
[2]*Department of Chemistry & Physics, Arkansas State University, State University AR*
[3]*Lawrence Livermore National Laboratory, Livermore CA*

Gallium Aluminum Garnet activated with Cerium [$(Gd,Y)_3(Ga,Al)_5O_{12}$:Ce, hereafter called GYGAG:Ce] has been prepared in a transparent ceramic form with demonstrated gamma resolution of 4% (662 keV).[1,2] Gadolinium-based garnet ceramics as well as single crystals exhibit light yields of about 50,000 photons/MeV, unprecedented for Ce-doped oxide scintillators.[3,4] Laser interband photon density response (PDR) experiments at Wake Forest that have proven useful for determining the kinetic order and rate constants of nonlinear quenching in halide and some oxide scintillators[5] are applied in this work to measure nonlinearity of light yield in GYGAG:Ce crystals. Picosecond absorption induced by interband excitation of GYGAG:Ce exhibits a strong signal in the infrared at 0.59 and 0.95 eV, with additional spectral measurements in progress over the 0.45 to 3.6 eV range and 0.5 ps to 200 ps time range. The time-resolved and kinetic order data from these experiments test concepts of carrier and exciton transport in GYGAG, where carrier transport in engineered conduction and valence bands[4] and Frenkel exciton transport in the Gd sublattice[1,2] are in consideration. We report GYGAG and GGAG electronic structures calculated by DFT PBE0 hybrid functional method, incorporating the special quasi-random structure (SQS) approach. In GYGAG, we find a 6.5 eV band gap (free-carrier gap at T=0 K). Taking excitons and room-temperature shifts into account, this value of the band gap seems well-positioned for probing excitons created at varying density in z scan, at different internal states in the 5.9-6.4 eV range of our femtosecond laser, and capture of initial excitons, cool free carriers, and hot free carriers using picosecond absorption spectroscopy with two-photon excitation.Acknowledgment: Research supported by the U.S. Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contracts NSF ECCS-1348361(WFU), 1348341(ASU) of the ARI program, and IAA HSHQDC-09-x-00208/P00002 (LLNL). This support does not constitute an express or implied endorsement on the part of the Government.

References

1. N. J. Cherepy, Z. M. Seeley, S. A. Payne, et al, IEEE Trans. Nucl. Sci. 60, 2330 (2013).

2. N. J. Cherepy, S. A. Payne, B. W. Sturm, et al, Proc. SPIE 2011, LLNL-PROC-497351.

3. N.J. Cherepy, S.A. Payne, B.W. Sturm, J.D. Kuntz, Z.M. Seeley, B.L. Rupert, R.D. Sanner, O.B. Drury, T.A. Hurst, S.E. Fisher, M. Groza, L. Matei, A. Burger, R. Hawrami, K.S. Shah, L.A. Boatner, IEEE Nuc. Sci. Symp. Conf. Record, p. 1288 (2010).

4. P. Prusa, K. Kamada, M. Nikl, A. Yoshikawa, J. A. Mares, Rad. Meas. 56, 62 (2013).

5. Joel Q. Grim, K. B. Ucer, A. Burger, P. Bhattacharya, E. Tupitsyn, E. Rowe, V. M. Buliga, L. Trefilova, A. Gektin, G. A. Bizarri, W. W. Moses, and R. T. Williams, Phys. Rev. B 87, 125117 (2013).

POSTERS I - NEW RADIATION DETECTORS: 75

Investigation the effect of co-dopants in GGAG crystals by making GGAG:Ce pellets with different co-dopants

Fang Meng[1,2], Merry Koschan[1], Charles L. Melcher[1,2]

[1]*Scintillation Materials Research Center, University of Tennessee, Knoxville, TN, UAS*
[2]*Materials Science and Engineering Department, University of Tennessee, Knoxville, TN, USA*

This work was focused on comparing the properties of sintered pellets with single crystals of cerium doped $Gd_3Ga_3Al_2O_{12}$(GGAG) grown via the Czochralski method. The aim of the study was to develop a simple and cost effective technique of using sintered pellets to investigate co-doping of GGAG:Ce and to identify the optimal composition for best scintillator performance. Pellets co-doped with various elements including B, Ba, and Ca were prepared via solid-state synthesis. X-ray diffraction, radioluminescence (RL), photoluminescence, reflectivity and transmittance measurements were carried out to characterize the polycrystalline pellets. Boron and barium co-doped GGAG:Ce pellets were found to have higher RL intensity than non-co-doped pellets, while Ca co-doping reduced the RL intensity in GGAG:Ce pellets. This is correlated with the performance of these co-dopants in GGAG:Ce single crystals. The light output of the GGAG:Ce crystals co-doped with B or Ba was measured to be ~50300 and 49700 photons/Mev respectively which is ~15% higher than the light output of the GGAG:Ce single crystal with no co-doping. On the other hand, calcium co-doping in single crystals results in lower light output but faster decay time (43 ns vs. 56 ns).

POSTERS I - NEW RADIATION DETECTORS: 76

Growth of Crack Free Strontium Iodide Crystals by Impurity Softening

Amlan Datta, Stephanie Lam, Stacy Swider, Shariar Motakef

Capesym, Inc.

We report on growth of crack free SrI_2:4%Eu^{2+} crystals through addition of impurities to reduce the hardness of the host matrix. SrI_2:Eu^{2+} and a large number of halide crystals have a very high ductile-brittle transition temperature, and experience brittle fracture during crystal growth caused by formation of surface or bulk flaws and/or second phase impurities. A number of impurities were investigated to reduce the hardness of SrI_2:Eu^{2+} and thereby enhance plastic deformation of the crystal in response to the unavoidable thermal strains present during growth. An impurity that resulted in close to 50% reduction in the hardness of SrI_2:Eu^{2+} was identified. We have repeatedly grown a number of crack-free 1-inch diameter SrI_2:Eu^{2+} crystals doped with this softening impurity. No crystal doped with the softening impurity has cracks or other structural flaws, whereas undoped control crystals and crystals doped with other types of impurities, all dehydrated and grown under identical conditions, were cracked. The addition of the softening dopant is found to have no material impact on the light output and energy resolution of the grown SrI_2:Eu^{2+} crystals.

POSTERS I - NEW RADIATION DETECTORS: 77

Fabrication of transparent ceramics for gamma spectroscopy and x-ray CT

Zachary M. Seeley, Nerine J. Cherepy, Stephen A. Payne

Chemical Sciences Division, Lawrence Livermore National Lab, Livermore CA 94550

As a relatively new class of optical materials, fabrication of transparent polycrystalline ceramics with high optical transparency and production of large, commercial-size ceramic optics is an evolving field of research. Compared to single crystals, transparent ceramics offer improved mechanical properties, and fabrication cost is significantly reduced, due to lower process temperatures and briefer heat treatments. At Lawrence Livermore National Laboratory, we are developing scalable fabrication techniques for two transparent ceramic scintillators, with applications in gamma spectroscopy and X-ray computed tomography imaging. For MeV X-ray computed tomography imaging, lutetium-based bixbyites doped with europium, $Gd_{2-x}Lu_xO_3(Eu)$ or GLO(Eu), were selected for their high light yield, density and effective Z [1,2]. In comparison to CsI(Tl) and $CdWO_4$, much larger, optically contiguous plates can be obtained by ceramics processing. Transparent ceramic GLO provides a combined improvement in stopping power and light yield, compared to scintillator glasses, the other option for large optically transparent windows.Gadolinium based garnets, $Gd_{3-x}Y_x(Ga,Al)_5O_{12}(Ce)$, or GYGAG(Ce) were down-selected from a broad list of cubic oxide candidates as a high-performing scintillator for gamma spectroscopy, offering high light yield, high effective Z, and fast decay time [3,4]. Transparent ceramics offer a route to highly uniform doping throughout the volume of even very large size samples. As a result, we obtain energy resolution of R(662 keV) = 4.6% for >1 in^3 size GYGAG(Ce) ceramic scintillators. Further scale-up is in progress.Despite the different chemistries and crystal structures of these materials, both transparent ceramics are processed in a similar fashion. Nanopowder of the custom oxide composition is synthesized by flame spray pyrolysis, providing a uniform and non-agglomerated starting material with high surface area, ideal for sintering [3]. Through a series of steps, the powder is dispersed into an aqueous solution, coated with organic processing agents, and formed into a 30-50% dense green body compact.ransparent ceramics with minimal optical scatter may be formed by vacuum sintering followed by hot isostatic pressing to full density (accompanied by ~50% volumetric shrinkage) for ~1 cm^3-scale samples. However, upon scaling up the procedure to larger sizes (>10 cm^3), the volumetric shrinkage during sintering becomes increasingly difficult to accommodate without accumulated stress and eventual cracking. To overcome this dimensional obstacle, we implemented an intermediate hot pressing step which applies pressure and temperature simultaneously as the green body compact is formed, allowing the first stages of sintering to occur while under pressure and resulting in a compact density closer to 75%. Thus volumetric shrinkage and cracking is reduced during the subsequent densification. Using this technique we have successfully produced a 10 inch transparent bixbyite ceramic window and a highly transparent 2.5 cubic inch garnet.

Acknowledgment: The authors appreciate help from Patrick Beck, Erik Swanberg, and Nanocerox Inc. (Todd Stefanik). This work was performed under the auspices of the U.S. DOE by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, and was supported by the U.S. Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded IAA HSHQDC-12-X-00149, and the US DOE, Office of NNSA, Enhanced Surveillance Subprogram. This support does not constitute an express or implied endorsement on the part of the Government. LLNL-ABS-649236

References

1. Z. M. Seeley, Z. R. Dai, J. D. Kuntz, N. J. Cherepy, S. A. Payne, Opt. Mater. 35, 74 (2012).

2. Z. M. Seeley, N. J. Cherepy, S. A. Payne, Optical Materials Express 3, 908 (2013).

3. Z. M. Seeley, N. J. Cherepy, S. A. Payne, J. Crystal Growth 379, 79 (2013).

4. N. J. Cherepy, Z. M. Seeley, S. A. Payne, et al, IEEE Trans. Nucl. Sci. 60, 2330 (2013).

POSTERS I - NEW RADIATION DETECTORS: 78

Cerium-doped Mixed Elpasolite Scintillators: $Cs_2NaYBr_3I_3$ and $Cs_2NaLaBr_3I_3$

Hua Wei[1], Victoria Martin[2], Luis Stand[1], Fang Meng[1], Mariya Zhuravleva[1], Charles Lee Melcher[1]

[1]*Scintillation Materials Research Center, Department of Materials Science and Engineering, University of Tennessee, Knoxville*
[2]*Department of Nuclear Engineering, The University of Tennessee, Knoxville*

Elpasolite scintillators are promising candidates for gamma-ray and neutron spectrometer applications due to their high performance and potentially low cost. Their cubic or pseudo-cubic isotropic structure reduces the impact of thermo-mechanical stress during crystal growth. This work is motivated by the shortcomings of available elpasolite scintillators, which fail to provide high light yield due to the wide bandgap in the case of chlorides and bromides, or cloudiness and high cost in the case of iodides. We recently discovered that mixed Br-I elpasolite scintillators, $Cs_2NaYBr_3I_3$:Ce and $Cs_2NaLaBr_3I_3$:Ce, have promising performance. $Cs_2NaYBr_3I_3$ with 2% Ce doping shows excellent energy resolution of 3.3% at 662 keV, despite a relatively modest light yield of 43,000 ph/MeV. The major decay component is 43 ns (76%), which is considerably faster than

most elpasolite scintillators. $Cs_2NaLaBr_3I_3$ with 5% Ce has a light yield of 59,000 ph/MeV, and its energy resolution can achieve 4.3% at 662 KeV (3% for a small sample), which is better than both endpoint compounds of the Br-I solid solution, i.e. $Cs_2NaLaBr_6$: Ce [1] and Cs_2NaLaI_6: Ce [2]. Non-proportionality of the mixed Br-I compounds were measured using gamma-ray sources ranging in energy from 14 keV to 835 keV. The better energy resolution of $Cs_2NaYBr_3I_3$:Ce appears to be related to its more proportional gamma-ray response.The electronic bandgaps of undoped $Cs_2NaYBr_3I_3$ and $Cs_2NaLaBr_3I_3$ were determined from optical tranmittance and absorption measurements. The bandgaps of both compounds are ~4.3 eV. The crystal structures of $Cs_2NaYBr_3I_3$:Ce and $Cs_2NaLaBr_3I_3$:Ce are cubic and tetragonal respectively. The high symmetry leads to fewer cracks during crystal growth and minimizes light scattering at grain boundaries. The ease of crystal growth is promising for the scale-up of the growth process to larger sizes. Reference:[1] G. Gundiah, K. Brennan, Z. Yan, E.C. Samulon, G. Wu, G.A. Bizarri, S.E. Derenzo, E.D. Bourret-Courchesne, J. Luminescence, 2013, ISSN 0022-2313, [2] J. Glodo, E. van Loef, W. Higgins, K. Shah, 2006 IEEE Nuclear Science Symposium Conference Record, Vol 1-6 2006, 1208-1211.

POSTERS I - NEW RADIATION DETECTORS: 79

Improved Crystal Growth and Scintillation Performance of Europium Doped Cesium Calcium Iodide

Adam C. Lindsey, Mariya Zhuravleva, Charles L. Melcher

Scintillation Materials Research Center - Materials Science And Engineering Department, The University of Tennessee, Knoxville, TN - USA

As part of a broad study to explore the feasibility of select novel metal halide scintillation materials for further development beyond the laboratory, we present new results obtained from single crystals of $CsCaI_3$:Eu grown with the Bridgman method. Our recent efforts have placed a focus on the pre-synthesis handling procedures, as well as growth techniques, in order to improve the quality of single crystals grown from the melt. While crystals grown at small diameters are adequate for performance characterization, larger diameter growth approaching detector sizes of 25-50mm diameter are necessary for a practical use and consideration for further development in commercial applications. As an approach to this growth scale, 15mm diameter crystals were grown in silica ampoules within a two-zone transparent furnace to observe the growth process and rapidly determine appropriate zone settings to carefully control the crystal/melt interface and produce large, highly transparent single crystals. Ampoules incorporating a necked capillary geometry were used to promote the formation of a singular randomly oriented seed prior to growth. Improvements to the attainable light yield and energy resolution were made possible through improved growth and handling protocols with an increase to 45,000 ph/MeV and 4% energy resolution at 662 keV respectively. The proportionality of the gamma response is reported for the first time. The growth and handling of highly transparent crystals of this material at 15mm diameter is illustrated.

POSTERS I - NEW RADIATION DETECTORS: 80

The effect of co-doping on the luminescence centers and charge traps in GGAG:Ce crystals

Fang Meng[1,2], Merry Koschan[1], Hua Wei[1,2], Harold Rothfuss[1,3], Charles L. Melcher[1,2]

[1]*Scintillation Materials Research Center, University of Tennessee, Knoxville, Tennessee, USA*
[2]*Materials Science and Engineering Department, University of Tennessee, Knoxville, TN, USA*
[3]*Siemens Medical Solutions Molecular Imaging, Knoxville, Tennessee, USA*

Single crystals of $Gd_3Ga_3Al_2O_{12}$ doped with 0.2 at % Ce (GGAG:Ce) and co-doped with Ca, B, or Ba (in all cases 0.2 at % with respect to rare earth in the melt) were grown by the Czochralski (CZ) technique. A flowing atmosphere of nitrogen mixed with a small amount of oxygen was used. The boule size was ~80 mm tall and ~32 mm diameter. The effect of the co-doping on Ce luminescence centers was investigated via

photoluminescence (PL), radioluminescence (RL), and temperature dependent PL lifetime measurements. Excitation bands were observed in PL spectra at 345 and 450 nm due to the 4f-5d transition of Ce^{3+}ions. An emission band in PL spectra was observed at 550 nm, which was consistent with the RL spectra. Ca co-doping significantly suppressed the higher energy excitation band, while B and Ba co-doping slightly increased this band relative to the 450 nm band. The RL spectra were similar for all co-dopants. The temperature dependence of the photoluminescence lifetime spectra showed that co-dopants did affect the thermal quenching behavior; for the codopants studied the thermal quenching temperature ranged from ~275 to 375 K and the thermal activation energy ranged from ~ 460 to 600 meV. The effect of co-doping on charge traps was investigated with thermoluminescence (TL) and afterglow measurements. TL spectra showed that Ca co-doping significantly reduced the trapped charge population around room temperature, which was correlated with reduced afterglow. Thus, the scintillation and PL decay time of the Ca co-doped scintillator was shortened and afterglow was suppressed relative to GGAG:Ce, and GGAG:Ce co-doped with B or Ba. On the other hand, B co-doping reduced the concentration of electron trap centers and improved the scintillation light output. Ba co-doping also increased the scintillation light output. In addition, room temperature traps can affect the afterglow of GGAG crystal. Trap parameters as determined from fits of the TL glow curves showed a strong correlation between the lifetime of the traps and the afterglow decay time at room temperature.

POSTERS I - NEW RADIATION DETECTORS: 81

Pixelated Neutron Imager Using Single Crystal LiInSe_2

Elan H. Herrera[1], Eric D. Lukosi[1], M. Dylan Richardson[1], Ashley Stowe[2]

[1]Nuclear Engineering, The University of Tennessee, Knoxville, TN
[2]Y12 National Security Complex, Oak Ridge, TN

A novel radiation detection system is being developed for thermal neutron detection. The detector consists of single crystal LiInSe_2 grown by the collaborating team at the Y12 National Security Complex. The ternary semiconducting crystal is enriched in neutron sensitive 6Li and is intended for use as a pixelated, position sensitive imaging system. Having the neutron sensitive isotope embedded in the detection crystal permits direct charge capture without the necessity of a conversion layer. The high Q-value of the lithium, neutron interaction will create a significantly larger number of electron-hole pairs in this system compared to its helium and boron based analogs. This property should offer the additional benefit of direct gamma discrimination without relying on signal processing techniques. A custom, low-noise front-end electronics chain will be fabricated to match the operational characteristics of LiInSe2. Various characterization techniques will be employed including deep-level transient spectroscopy (DLTS), transient current technique (TCT), cathodoluminescence (CL) and photoluminescence (PL). Based on these results, crystal growth will be optimized to achieve a stoichiometric composition ideal for thermal neutron detection. Initially, the system will be calibrated and tested for a single output channel. Then the system will be scaled from a single channel to a 16-channel system using an analog preamplifier and signal processing chain. Final development will prepare the system for conversion to a 64-channel, application specific integrated circuit (ASIC) based digital system that will incorporate the detector and detection circuit into a system on a chip (SoC).

Room Temperature Semiconductor Materials

4:00 PM - 5:30 PM (Hussey)

ROOM TEMPERATURE SEMICONDUCTOR MATERIALS: 1

Ruggedization of CdZnTe Detectors, Detector Assemblies and Modules for Radiation Detection Applications

Pinghe Lu, Henry Chen, Patrick Gomolchuk, Dave Beitz, Adam W. Grosser

Redlen Technologies, Saanichton, BC V8M 0A5, Canada

This paper describes improvements in ruggedization of CZT detectors for use in medical, imaging, and security applications. Research included experimenting with various isotropic and anisotropic conductive adhesives and underfill material systems suitable for CZT substrates. A bumping method using solder mask was developed to control spacing between CZT substrate and cathode/anode carrier printed circuit boards (PCBs). Detector attachment strategies involved considerations on whether monolithic or multiple tiles were attached to a single carrier board, whether a thin cathode board was required, and various detector anode configurations such as pixel pitches from large (2.5 mm) to small (0.5 mm) for pixelated detectors. Attachment process optimizations were conducted to improve reliabilities of attached detector modules. Procedures for burn-in test and highly accelerated and demanding stress testing were developed for detector module screening and quality assurance on selected detector products. Detectors, detector assemblies, and modules were subjected to varying levels of drop/shock, vibration, and aggressive temperature cycling to assess and improve their ruggedness. Detector and module performance was evaluated at various stages of attachment under the following sources: Co-57, Cs-137 and Am-241. In conclusion, significant progress has been made in the ruggedization of CZT detectors for medical, imaging, and security applications.

ROOM TEMPERATURE SEMICONDUCTOR MATERIALS: 2

Effects of Excess of ^{6}Li on the Properties of $^{6}LiInSe_2$ Crystals Grown by the Vertical Bridgman Technique

Eugene Tupitsyn[1], Pijush Bhattacharya[1], Emmanuel Rowe[1], Liviu Matei[1], Yunglong Cui[1], Vladimir Buliga[1], Michael Groza[1], Brenden Wiggins[1,2], Arnold Burger[1,2], Ashley Stowe[2,3]

[1]*Fisk University, Nashville, TN*
[2]*2Vanderbilt University, Nashville, TN*
[3]*Y-12 National Security Complex, Oak Ridge, TN*

The lithium based chalcogenide 6LiInSe2 semiconductor has recently received much attention due to possible application in neutron detection. 6LiInSe2 possess both high resistivity and wide band gap, which makes it an attractive candidate for semiconductor radiation detector. The crystals grown from stoichiometric starting material are red with an absorption edge around 2.2 eV due to the intrinsic defect induced donor acceptor pair recombination. The ideal color of the crystal is chartreuse green. In this investigation we have introduced 4% excess lithium from stoichiometry during synthesis of the 6LiInSe2 charge materials in an attempt to grow green crystals by reducing the intrinsic defects.The growth of 6LiInSe2 crystals were carried out using a vertical Bridgman method. The composition was stoichiometric for one growth and 4% Li excess for another. The initial 6LiIn synthesis was carried out in a Pyrolitic Boron Nitride (PBN) crucible in an argon environment. Due to high reactivity of lithium, the metals were loaded in an Argon filled glove box. The 6LiInSe2 charge materials were synthesized with selenium vapor transported to LiIn while continuous rotation of the ampule at 950 °C.The synthesized charge materials were loaded inside the PBN growth ampoule for vertical Bridgman method in a two zones furnace (Mellen) in Argon pressure of 0.5 Bar. The temperatures of the top and bottom zones were kept at 940 °C and 740 °C with a temperature gradient of 10 °C. The growth rate of these crystals was 7 mm/day. The wafers from different ingots were cut and polished for photoluminescence and radiation detection measurements. For electrical measurements, all the wafers were etched for 1 minute in 5% Br:Methanol for 1 minute and then gold contacts were deposited using sputtering on both sides of the wafer. Low temperature photoluminescence measurement of red crystals clearly showed a high defect induced absorption around 2.2 eV, consistent with previous work for the red crystal an lower than yellow crystals with a band edge of 2.8 eV [1, 2].The resistivity of red and yellow 6LiInSe2 crystals was found in the range of 1-3 x1012 ohm-cm with having a significant effect of excess lithium concentrations. The alpha particle detection measurements were carried out using pulsed height measurement. In case of red 6LiInSe2 wafers, the alpha particle detection as well photoconductivity was not observed. Low carrier mobility due to the presence of intrinsic defect clusters in these wafers was the reason for no

radiative recombination. On the other hand yellow and greenish yellow wafers showed photoconductivity and as well as alpha particle detection.Acknowledgement:This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC 2013-DN-077-ER00002. This support does not constitute an express or implied endorsement on the part of the Government.References:

1. L. Isaenko, I. Vasilyeva, A. Merkulov, A. Yelisseyev, S. Lobanov, J. Cryst. Growth 275, 217-223 (2005).

2. E. Tupitsyn, P. Bhattacharya, E. Rowe, L. Matei, M. Groza, B. Wiggins, A. Burger,and A. Stowe, Applied Physics Letters 101, 202101 (2012)

ROOM TEMPERATURE SEMICONDUCTOR MATERIALS: 3

Progress in thallium bromide gamma-ray spectrometer development

Kanai Shah[1], Hadong Kim[1], Alexei Churilov[1], Yaroslav Ogorodnik[1], Alireza Kargar[1], Guido Ciampi[1], Leonard Cirignano[1], Andrey Gueorguiev[1], Suyoung Kim[1], Zhong He[2], Crystal Thrall[2], William Koehler[2]

[1]Radiation Monitoring Devices Inc., 44 Hunt St, Watertown, MA, 02472, USA
[2]Department of Nuclear Engineering and Radiological Sciences, University of Michigan, Ann Arbor, MI, 48103, USA

Thallium bromide (TlBr) has emerged as a candidate semiconductor for gamma ray spectroscopy at or near room temperature due to its intrinsic properties (wide band gap (2.68 eV), high density (7.5 g/cm^3), and high Z (81, 35)) and recent improvements in crystal growth and detector processing. Due to its low melting point (460 °C), cubic crystal structure and congruent melting with no solid-solid phase transitions between the melting point and room temperature, TlBr can be grown by relatively simple melt based methods. TlBr with electron mobility-lifetime products ($\mu\tau$) in the mid 10^{-3} cm^2/V range has been obtained enabling the fabrication of TlBr gamma ray spectrometers with thickness exceeding 1-cm. Energy resolution < 1% has been obtained at 662 keV with TlBr detector arrays after depth correction.Due to its ionic nature, long term stability of TlBr detectors operated at room temperature has been an issue. To address this, modest cooling (~ - 20 °C) has been implemented and found to be an effective method for improving long term stability. Surface processing, contacts and annealing have been found to affect the stability of TlBr detectors operated at room temperature. One detector, operated at room temperature and under continuous bias for more than 400 days, continues to exhibit a photopeak under ^{241}Am (60 keV photons) irradiation. In this paper we present an overview of our latest detector highlights and recent progress in TlBr detector development.This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract HSHQDC-08-C-00140. This support does not constitute an express or implied endorsement on the part of the Government.

ROOM TEMPERATURE SEMICONDUCTOR MATERIALS: 4

Visualization of TlBr Ionic Transport Mechanism by the Accelerated Device Degradation Technique

Amlan Datta, Piotr Becla, Shariar Motakef

Capesym, Inc.

Thallium Bromide (TlBr) is a wide bandgap, compound semiconductor with high gamma-ray stopping power and promising physical properties. However, performance degradation and the eventual irreversible failure of TlBr devices can occur due to “polarization”, caused by the electro-migration of Tl^+ and Br^- ions to the electrical contacts across the device. In this paper, we present results on the Accelerated Device Degradation technique which allows direct observation of creation and propagation of ionic transport channels within the crystal under applied bias. The channels are observed to be initiated both directly under the electrode as well as away from the electrode. The growth direction is always towards the anode indicating that Br^- is the mobile diffusing species within the channels. The presence of these channels clearly suggests that ionic transport through pre-existing crystalline defects such as grain boundaries dominates molecular diffusion. The Accelerated Device Degradation technique is a quick and reliable tool for research into the failure mechanism of TlBr devices, as well as evaluating and optimizing crystal growth and detector fabrication processes. This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contracts HSHQDC-13-C-00082. This support does not constitute an express or implied endorsement on the part of the Government.

ROOM TEMPERATURE SEMICONDUCTOR MATERIALS: 5

Post-Growth Annealing of Bridgman-Grown CZT and CMT Crystals for Room-Temperature Nuclear Radiation Detectors

Stephen U. Egarievwe[1], Ifechukwude O. Okwechime[1], Rachel C. Powel[1], Justin Gray[1], Anwar Hossain[2], Ge Yang[2], Ralph B. James[2]

[1]Nuclear Engineering and Radiological Science Center, Alabama A&M University, Normal, AL 35762, USA
[2]Nonproliferation and National Security Department, Brookhaven National Laboratory, Upton, NY 11973, USA

Cadmium zinc telluride (CZT) and cadmium manganese telluride (CMT) are some of the semiconductor materials that have proven to be good candidates for room-temperature nuclear radiation detection applications. Bridgman-grown CZT and CMT crystals often have Te inclusions that limit their performances as X-ray and gamma-ray detectors. Post-growth thermal annealing under Cd vapor and/or under temperature gradient has been the approach to removing performance-limiting Te inclusions from CZT and CMT detectors. Annealing under a mixture of Cd and Zn vapor has also been effectively used for CZT crystals. This paper presents results of post-growth annealing of CZT and CMT crystals under Cd vapor and/or under temperature gradient. For CZT samples annealed at 700 ^{o}C in a 10 ^{o}C/cm temperature gradient, we observed Te inclusions migration from low to high temperature region at 2.2 x 10^{-4} m/s. The sizes of Te inclusions were reduced up to 80% in a 60-hour annealing of CZT at 510^{o}C under Cd vapor. Tellurium inclusions were completely eliminated in CMT samples annealed at 570 ^{o}C in Cd vapor for 26 hours.[This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA award number 2012-DN-077-ARI065-03. This work has also been supported by the US Nuclear Regulatory Commission through award number NRC-27-10-514. These supports do not constitute an express or implied endorsement on the part of the Government.]

Silicon Detectors and Photon Readouts

4:00 PM - 5:30 PM (Vandenburg)

SILICON DETECTORS AND PHOTON READOUTS: 1

Characterization of a fine pitch vertically integrated DNW MAPS

Alessia Manazza[1], Luigi Gaioni[1], Massimo Manghisoni[1,2], Lodovico Ratti[1,3], Valerio Re[1,2], Gianluca Traversi[1,2]

INFN, Sezione di Pavia, Via Bassi 6, I-27100 Pavia, Italy

This work presents the characterization results of a Deep N-well (DNW) active pixel sensor fabricated in a vertically integrated technology, where two 130 nm CMOS homogeneous tiers are processed in order to obtain a 3D monolithic integrated circuit (3D-IC). Analog and digital blocks belonging to different wafers are in communication through face-to-face bonding pads and a thinning process step is applied on the top tier to expose through silicon vias (TSV), therefore making connection to the buried circuits possible. The 3D technology has been used to design a fine pitch CMOS MAPS with sparsification capabilities, in view of vertexing applications to experiments in high luminosity colliders. Results from the characterization of different kind of test structures, including single pixels, 3x3 and 8x8 matrices, are presented. In particular, measurements have been performed with an infrared laser source to evaluate the charge collection properties of the proposed vertically integrated sensors.

SILICON DETECTORS AND PHOTON READOUTS: 2

Tunable wavelength bi-alkali photocathode via structure engineering for photon detection applications

Junqi Xie, Marcel Demarteau, Robert Wagner, Xing Wang

High Energy Physics, Argonne National Laboratory, Argonne, IL

In a standard photon detection device, photocathode is the initial photon to electron converting material, determining the response sensitivity of the device to photons along the detection range. At Argonne National Laboratory (ANL), the Large Area Picosecond Photo Detector (LAPPD) project is developing detector modules with 8"x8" active area, a spatial resolution of 1-3mm, and a time resolution of 1-10ps. We report on the engineering design, fabrication and characterization of bi-alkali photocathodes with tunable wavelength, enhanced quantum efficiency and low dark current. Sequential growth process of bialkali photocathode was investigated. The growth parameters, especially thickness of antimony layer, were optimized. By adding an antireflection oxide layer between the glass substrate and photocathode, the light loss is reduced. Due to the enhanced reduction at long wavelength, the photocathode detection range was tuned to longer wavelength. The theory and experiment results will be reported and future direction for tunable wavelength photocathode development will be discussed.

SILICON DETECTORS AND PHOTON READOUTS: 3

Recent progress of MPPC-based scintillation detectors in high precision X-ray and gamma-ray imaging

Jun Kataoka[1], Takuya Fujita[1], Takahiro Ambe[1], Toru Nishiyama[1], Aya Kishimoto[1], Kenshiro Takeuchi[1], Yosuke Kurei[1], Takayuki Tsujikawa[1], Takuya Kato[2], Shinji Ohsuka[2], Sigeyuki Nakamura[2], Masato Hirayanagi[2], Shunsuke Adachi[2], Tetsuya Uchiyama[2], Hiroki Suzuki[2]

[1]*Research Institute for Science and Engineering, Waseda University, Tokyo*
[2]*Hamamatsu Photonics, K. K., Hamamatsu*

The Multi-Pixel Photon Counter (MPPC), known as part of the silicon photomultiplier family produced by Hamamatsu Photonics K.K, is a promising light sensor for various applications not only in physics experiments but also in nuclear medicine, manufacturing, industry, homeland security, and even in high-energy astronomy satellite missions. In particular, the MPPC can replace conventional photomultiplier tubes (PMTs) in number of applications to read out weak scintillation light signals. In this paper, we provide the current status and most recent progress of the MPPC-based scintillation detectors being developed in collaboration with Hamamatsu, such as (1) a high-precision X-ray and Gamma-ray spectral image sensor, (2) next-generation positron emission tomography (PET) detectors having time-of-flight (TOF), magnetic resonance imaging (MRI), and depth-of-interaction (DOI) measuring capability, and (3) a compact Gamma camera for environmental radiation surveys. We first present a new method of fabricating an ultra-fine resolution (0.2 mm/pixel) Ce:GAGG scintillator plate 1 or 2-mm thick, cut using a dicing saw for micro-grooves 50-um wide. When the plate is optically coupled with the 4×4 MPPC-array, each having a sensitive area of 3×3 mm2, excellent spatial resolution of 0.48 mm (FWHM) and energy resolution of 13% (FWHM) were obtained for 122-keV gamma rays. Hence, the detector can act as a convenient "multi-color" imaging device that can be potentially used for future photon-counting/spectral CT. We then show a prototype system for a high-resolution MPPC-based PET scanner and a dedicated analog ASIC that can realize ≃1 mm (FWHM) spatial resolution, as well as 489 ps (FWHM) TOF measurement capability. We also describe various attempts at using MPPCs to realize MRI and DOI-PET applications. Finally, we present the concept of a two-plane Compton camera consisting of Ce:GAGG scintillator arrays coupled with thin MPPC arrays. Thanks to the thin and compact features of the MPPC device, the camera not only realizes small size (14×14×15 cm3) and light weight (1.9 kg) but also achieves sensitivity about 10 times higher than that of the conventional PMT-based pinhole camera used in Fukushima. We also present the prospects and various applications of the MPPC-based cameras for use in monitoring radiation in the near future.

SILICON DETECTORS AND PHOTON READOUTS: 4

Experimental study of β spectra using a semiconductor Si detector

Charlène Bisch[1], Xavier Mougeot[1], Marie-martine Bé[1], Christophe Dulieu[1], Mark A. Kellett[1], Abdel-mjid Nourreddine[2]

[1]*CEA, LIST, Laboratoire National Henri Becquerel, Gif-sur-Yvette, F-91191, France.*
[2]*Institut Pluridisciplinaire Hubert-Curien, UMR7178 CNRS-IN2P3 and Université Louis Pasteur, 23 rue de Loess, F-67037 Strasbourg cedex 02, France.*

The study of the shape of β spectra is experiencing a resurgence of interest having been little studied since the late 1970s. Precise knowledge of the shape of energy spectra, coupled with well established uncertainties, are sought by users from the nuclear power industry (decay heat calculations), medical care sector (dose calculations) or ionizing radiation metrology (reduction of uncertainties in activity measurements using the liquid scintillation technique). As the primary laboratory for measurement of radioactivity in France, the Laboratoire National Henri Becquerel (LNHB) requires a computer code to meet the demands of users. Indeed, calculations are necessary to supply the lack of data and because some half-lives of radionuclides are too short to be measured. The existing computer codes only reproduce well allowed transitions and must rely an experimentally measured form factor for transitions of higher orders of forbiddenness. Our computer code BetaShape calculates beta spectra for allowed and fordidden unique transitions including the screening effect, finite nuclear size effect and radiative corrections. Moreover, developments are in progress to improve screening corrections and to take into account atomic exchange effects. Obviously, measurements are needed to constrain and to validate these calculations. Hence, an operational device using a semiconductor Si detector has been developed in order to measure spectral shapes and to quantify the uncertainties. In addition to superior energy resolution, Si detectors also have a number of other desirable features, such as a linear response function and a compact size that meet our requirements. The entire setup has been designed in an attempt to measure the true spectral shape, by limiting the sources of deformation, i.e. ultra-thin source, ultra vacuum, detector cooled to liquid nitrogen temperature, low scattering materials and limitation of microphonics. This paper describes the experimental setup and the source preparation method. Measured ^{60}Co spectra, used to validate the Monte Carlo modelling of the experimental device, are presented. Finally, the experimental deformation function extracted from the measured spectra is given along with the resulting experimental shape factor.

SILICON DETECTORS AND PHOTON READOUTS: 5

A Microstructure Solid-State Detector for Fast Neutrons

Justin Clinton[1], Nicholas Li Causi[2], Yaron Danon[3], Ishwara Bhat[2]

[1]*Department of Engineering Physics, Air Force Institute of Technology, Wright-Patterson AFB, Ohio*
[2]*Department of Electrical, Computer, and Systems Engineering, Rensselaer Polytechnic Institute, Troy, NY*
[3]*Department of Mechanical, Aerospace, and Nuclear Engineering, Rensselaer Polytechnic Institute, Troy, NY*

Semiconductor neutron detectors (SCND) devices have undergone dramatic improvements over the last ten years; the addition of microstructures have resulted in single detector thermal intrinsic efficiencies approaching 50%. In this work we investigated replacing the thermal neutron converter with a proton radiator to create an improved SCND for direct detection of fast neutrons. Simulations using the GEANT4 toolkit indicated that an intrinsic efficiency of 0.88% was possible with optimized microstructure geometries; this represents a 4-fold increase over current planar SCND's for fast neutrons. A proof of principal device was constructed; a high-purity n-type silicon substrate was etched with an array of 28 um deep hexagonal hole-type microstructures using deep reactive ion etching (DRIE). Following this, a spin-on p-type dopant was applied to create a continuous p-n junction throughout the microstructures, which were then filled with parylene. The detector was tested with an unmoderated ^{252}Cf neutron source, where an intrinsic efficiency of 0.11±0.03% was measured. The actual microstructure dimensions, measured with an SEM, were used to run an updated simulation; this resulted in a calculated efficiency of 0.14%, slightly higher but within the experimental error of the measured data.

AT-TPCs for Exotic Beams and Dark Matter Searches

4:00 PM - 5:30 PM (Alumni Center)

AT-TPCS FOR EXOTIC BEAMS AND DARK MATTER SEARCHES: 1

Results from the LUX dark matter experiment

Markus Horn

Yale University, New Haven, CT

The LUX (Large Underground Xenon) experiment aims at the direct detection of dark matter particles via their collisions with xenon nuclei. The 350 kg two-phase liquid xenon time projection chamber measures simultaneously the scintillation and ionization from interactions in the target. The ratio of these two signals provides very good discrimination between potential nuclear recoil signals and electronic recoils to set limits on WIMP-nucleus scattering cross sections. The LUX detector operates at the Sanford Underground Research Facility (Lead, South Dakota, USA) since February 2013. First results were presented in late 2013. An overview of those results, together with new calibration techniques and background studies will be presented and an outlook given on the upcoming 300 live-days WIMP search starting in 2014.

AT-TPCS FOR EXOTIC BEAMS AND DARK MATTER SEARCHES: 2

Active Target-Time Projection Chambers for Reactions Induced by Rare Isotope Beams: Physics and Technology

Wolfgang Mittig

Michigan State University-NSCL, E. Lansing MI 48824

Weakly bound nuclear systems can be considered to represent a good testing-ground of our understanding of non-perturbative quantum systems. These systems can be studied by reactions using rare isotope beams. Great progress in experimental sensitivity has been attained by increase in rare isotope beam intensities and by the development of new high efficiency detectors. It is now possible to study reactions leading to bound and unbound states in systems with very unbalanced neutron to proton ratios. Application of Active Target-Time Projection Chambers to this domain of physics will be illustrated by experiments performed with existing detectors. The NSCL is developing an Active Target-Time Projection Chamber (AT-TPC) to be used to study reactions induced by rare isotope beams at the National Superconducting Cyclotron Facility (NSCL) and at the future Facility for Rare Isotope Beams (FRIB). The AT-TPC counter gas acts as both a target and detector, allowing investigations of fusion, isobaric analog states, cluster structure of light nuclei and transfer reactions to be conducted without significant loss in resolution due to the thickness of the target. The high efficiency and low threshold of the AT-TPC allows investigations of fission barriers and giant resonances with fast fragmentation rare isotope beams. A large number of electronic channels (order of magnitude 10,000) and a high speed DAQ are needed. The AT-TPC detector was commissioned in March 2014. A short description of other detectors of this type under development will be given.

AT-TPCS FOR EXOTIC BEAMS AND DARK MATTER SEARCHES: 3

Fusion studies with an active-target time projection chamber

James J. Kolata

Nuclear Science Lab, University of Notre Dame, Notre Dame, IN 46556 - USA
Fusion Studies with an Active-Target Time Projection Chamber.

J.J. Kolata (University of Notre Dame) and the NSCL AT-TPC Collaboration

Near- and sub-barrier fusion of a radioactive ^{10}Be with ^{40}Ar has been studied at the TwinSol facility of the University of Notre Dame, using the prototype active-target time projection chamber (AT-TPC) developed at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University. Preliminary results from this experiment will be presented, and the lessons learned in the data analysis will be discussed. A proposed experiment to study possible proton-transfer effects on fusion in the ^{47}K+40Ar system using the full AT-TPC at the ReA3 low-energy exotic beam facility at the NSCL, and application of the method to fusion in other systems involving low-rate radioactive beams, will be discussed in the light of these lessons.

Work partially supported by the US NSF under Contract No. PHY09-69456

AT-TPCS FOR EXOTIC BEAMS AND DARK MATTER SEARCHES: 4

Ionization-phonon nuclear recoil discrimination with 100 mm dia. germanium direct dark matter detectors for use in SuperCDMS-SNOLAB

Allison Kennedy[1], Daniel A. Bauer[2], Daniel Brandt[3], Paul L. Brink[3], Blas Cabrera[4], Hassan Chagani[1], Matt Cherry[3], Georghe A. Codoreanu[1], Eduardo Do Couto E Silva[3], Priscilla Cushman[1], Gary L. Godfrey[3], Jeter Hall[2], Sten Hansen[2], Jasmine Hasi[3], Michael Kelsey[3], Chris J. Kenney[3], Steven Leman[5], Vuk Mandic[1], Nader Mirabolfathi[6], Sergey Monin[1], Daniel Nagasawa[4], Larry Novak[4], Richard Partridge[3], Chris Phenicie[1], Kedar Page[7], Matt Pyle[6], Roxanne Radpour[1], Wolfgang Rau[7], Rudy Resh[3], Bernard Sadoulet[6], Dennis N. Seitz[6], Bruno Serfass[6], Benjamin Shank[4], Astrid Tomada[3], Anthony Villano[1], Jeff Yen[4], Betty A. Young[8], Jianjie Zhang[1]

[1]*School of Physics & Astronomy, University of Minnesota, Minneapolis, MN 55455, USA*
[2]*Fermi National Accelerator Laboratory, Batavia, IL 60510, USA*
[3]*SLAC National Accelerator Laboratory/Kavli Institute for Particle Astrophysics and Cosmology, 2575 Sand Hill Road, Menlo Park 94025, CA*
[4]*Department of Physics, Stanford University, Stanford, CA 94305, USA*
[5]*Department of Physics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA*
[6]*Department of Physics, University of California, Berkeley, CA 94720, USA*

The next phase of the Super Cryogenic Dark Matter Search experiment, SuperCDMS-SNOLAB, will operate newly developed 1.37 kg (100 mm diameter, 33.3 mm thick) germanium detectors with interleaved phonon and charge channels. With the excellent expected nuclear recoil discrimination to low recoil energies, the SuperCDMS-SNOLAB experiment is expected to achieve an order of magnitude better sensitivity to the WIMP-nucleon elastic scattering cross section than the current best limits in the field. Initial results of tests with prototype 100 mm detector are presented here, demonstrating their potential for use in SuperCDMS-SNOLAB.

AT-TPCS FOR EXOTIC BEAMS AND DARK MATTER SEARCHES: 5

The Neutron Induced Fission Fragment Tracking Experiment : High-precision Fission Cross Section Measurements with a Time Projection Chamber

Nathaniel Bowden[1,2]

[1]*NIFFTE Collaboration*
[2]*Lawrence Livermore National Laboratory*

The goal of the Neutron Induced Fission Fragment Tracking Experiment (NIFFTE) is to measure fission cross sections with unprecedented precision. The NIFFTE Collaboration has designed and built a Time Projection Chamber (TPC) for this purpose. The exquisite tracking capabilities of this device allow for the full reconstruction of charged particles produced by neutron beam induced fissions from a thin central target. The wealth of information gained from this approach will allow cross section systematics to be controlled at the level of 1%. Here we present the current status of the NIFFTE TPC, describe the wide variety of systematic studies being performed, and outline preliminary results from measurements performed at the Los Alamos Neutron Science Center (LANSCE) facility. LLNL-ABS-650701This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

AT-TPCS FOR EXOTIC BEAMS AND DARK MATTER SEARCHES: 6

Low Energy Calibration of Nuclear Recoils in Dual Phase Xenon with the MiX Detector

Scott Stephenson

University of Michigan, Ann Arbor, MI

Astrophysical evidence suggests that 25% of our universe consists of dark matter (DM) that has yet to be observed through direct means. The most promising technique for detection of Weakly Interacting Massive Particles (WIMPs) is that of large scale liquid xenon (LXe) target detectors. At low WIMP mass the likelihood for an event to occur within the detector target volume follows an exponentially decreasing function of energy, causing the bulk of dark matter events to be found at lower energies. Due to this effect, finding the low energy response of LXe is crucial in determining the sensitivity of the most promising dark matter experiments. The MiX (Michigan Xenon) detector is the first high light yield, 3D position sensitive, compact, liquid xenon time projection chamber (TPC) designed to probe the response of LXe to WIMP-like events in this regime. The detector will be irradiated with monoenergetic neutrons to produce events which deposit a known energy into the target, allowing determination of the crucial light and charge yield parameters at various electric fields.

AT-TPCS FOR EXOTIC BEAMS AND DARK MATTER SEARCHES: 7

SπRIT: A time-projection chamber for symmetry-energy studies

R. Shane[1], A. B. Mcintosh[2], T. Isobe[3], J. Estee[1], G. Jhang[4], N. Nakatsuka[5], W. Powell[6], S. Tangwancharoen[1], H. Baba[3], Z. Chajecki[1], M. Famiano[7], F. Lu[8], W. G. Lynch[1], T. Murakami[5], R. Olsen[2], H. Sakurai[3], A. Taketani[3], M. B. Tsang[1], R. Wang[9], S. Yennello[2], J. Yurkon[1]

[1]*National Superconducting Cyclotron Laboratory and Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan, 48824-1321, USA*
[2]*Cyclotron Institute, Texas A&M University, College Station, TX 77843, USA*
[3]*RIKEN Nishina Center, Hirosawa 2-1, Wako, Saitama, Japan*
[4]*Department of Physics, Korea University, Anam-ro 145, Seongbuk-gu, Seoul 136-713, Korea*
[5]*Department of Physics, Kyoto University, Kita-shirakawa, Kyoto 606-8502, Japan*
[6]*Department of Physics, University of Liverpool, Liverpool, Merseyside L69 3BX, UK*
[7]*Department of Physics, Western Michigan University, Kalamazoo, Michigan, 49008-5252, USA*
[8]*Shanghai Institute of Applied Physics, CAS, Shanghai 201800, P. R. China*
[9]*Department of Physics, Tsinghua University, Beijing 100084, P. R. China*

A Time-Projection Chamber called the SAMURAI Pion-Reconstruction and Ion-Tracker (SπRIT) has recently been developed at Michigan State University as part of an international effort to constrain the symmetry-energy term in the nuclear Equation of State (EoS). The SπRIT TPC will be used in conjunction with the SAMURAI spectrometer at the Radioactive Isotope Beam Facility (RIBF) at RIKEN to measure yield ratios for pions and other light isospin multiplets produced in central collisions of neutron-rich heavy ions, such as ^{132}Sn + ^{124}Sn. The SπRIT TPC can function both as a TPC detector and as an active target. It has a vertical drift length of 53 cm, parallel to the magnetic field. Gas multiplication is achieved through the use of a multi-wire anode. Image charges are produced in the 12096 pads of the pad plane, located 4 mm below the anode, and are read out using the new Generic Electronics for TPCs. This work is supported by the Department of Energy under Grant DE-SC0004835.

Abstracts

Wednesday

Scintillation Detectors II

8:00 AM - 9:30 AM (Alumni Center)

SCINTILLATION DETECTORS II - CERAMIC & NEW ORGANICS: 1

New organic scintillators for wide-energy neutron detection

Natalia Zaitseva, Andrew Glenn, Leslie Carman, H. Paul Martinez, Stephen Payne

Lawrence Livermore National Laboratory

Efficient detection of special nuclear materials (SNM) requires instruments which can sensitively detect and characterize uranium and plutonium isotopes in a wide range of energies, having at the same time the extremely important ability to discriminate among different types of radiation. For many decades, neutron detection technology has been based on 3He proportional counters that are sensitive primarily to thermal neutrons. The most common methods for direct detection of fast neutrons have been based on liquid organic scintillators with PSD properties. The recent shortage of 3He and handling issues with liquid scintillators stimulated a search for efficient solid-state PSD materials. A broad survey of organic single crystals conducted in the present work provided large number of new materials, which became available for studies of PSD phenomena. New organic crystals [1] with excellent PSD have been developed for fast neutron detection. Knowledge obtained in the studies with single crystals led to development of the first plastic scintillators with efficient fast neutron/gamma PSD [2]. More advantages have been introduced by the next generation of plastics doped with neutron capture agents. Loading with 10B resulted in a new type of organic scintillators useful for combined detection of both thermal and fast neutrons discriminated from gamma radiation background. The most recent development produced the first ever 6Li-loaded plastic scintillators that, in addition to simultaneous detection of fast and thermal neutrons, offer a unique "triple" PSD for signal separation between fast neutrons, thermal neutrons, and gamma-rays. Among new materials developed for commercial production are large-scale (>10 cm) stilbene single crystals grown by the inexpensive solution growth technique, and different types of new PSD plastics which, due to the deployment advantages and ease of fabrication, create a good basis for the replacement of liquid scintillators and widespread use as future large-volume and low-cost neutron detectors.

Lawrence Livermore National Laboratory is operated by Lawrence Livermore National Security, LLC, for the U.S. Department of Energy, National Nuclear Security Administration under Contract DE-AC52-07NA27344.This work has been supported by the U.S. Department of Energy NA-22 and DTRA, and by the US Department of Homeland Security, DNDO, under competitively awarded IAA HSHQDC-09-X-00743. This support does not constitute an express or implied endorsement on the part of the Government.

1. N. Zaitseva, et al, IEEE Trans. Nucl. Sci., 58, (2011) 3411-3420.

2. N. Zaitseva, et al, Nuclear Inst. and Methods in Physics Research, A (2012) pp. 88-93

SCINTILLATION DETECTORS II - CERAMIC & NEW ORGANICS: 2

Detection of multiple modes of radiation with scintillators

Jarek Glodo, Rastgo Hawrami, Edgar Van Loef, Lakshmi Soundara Pandian, Urmila Shirwadkar, Gary Markosyan, Joshua Tower, Kanai S. Shah

Radiation Monitoring Devices, Inc

Detection of multiple modes of radiation, or multi-mode detection, is becoming more common due to the development of new scintillation materials capable of pulse shape discrimination (PSD). While in the past the detection of gamma-rays and neutrons (generating charged particles), for example, was often achieved using two separate detectors, currently there are choices available that can achieve this with a single detector. This outcome is possible due to the different responses of these materials to gamma-rays (electrons) and charged particles (alphas, protons, etc.) that can be analyzed to derive a particle's species. PSD relies on the fact that scintillation processes are not uniform for different particles producing pulses that are a function of excitation (density).

Materials with pulse shape discrimination have been known since the 1950s, when the differences in decay times generated by electrons and alpha particles were observed in organic compositions such as anthracene. In time, PSD became more prevalent in liquid scintillators due to their larger sizes over organic crystals. In recent years, PSD capable materials are experiencing a revival due to the development of elpasolite crystals and, more recently, PSD capable plastics. In this presentation we will discuss current developments in the PSD materials, their capabilities, and applications.

SCINTILLATION DETECTORS II - CERAMIC & NEW ORGANICS: 3

Trapping Effects in Scintillator Nonproportionality

Stephen A. Payne, Nerine J. Cherepy, Steven Hunter, Larry Ahle, Erik Swanberg, Zachary Seeley

Lawrence Livermore National Laboratory

We have studied the impact of traps on scintillator nonproportionality by recording its temperature dependence for several scintillators and by varying the processing conditions used to fabricate cerium-doped gadolinium garnet ceramics. This data was obtained with the SLYNCI facility (Scintillator Light Yield Nonproportionality Characterization Instrument), where the normalized light yield is recorded against the electron energy that is released via the Compton interaction with a 662 keV gamma ray. Here we report the nonproportionality curves as a function of temperatures (+400C, 00C, and -400C), as was obtained for CsI(Na), CsI(Tl), NaI(Tl), $LaBr_3$(Ce), CeBr3, undoped SrI_2 and a Gadolinium garnet, and are currently working on additional scintillators. We also report on six Gadolinium garnet transparent ceramics of identical composition that have been processed differently in terms of the sintering and post-annealing steps; at this juncture, our interpretation of the large changes in the nonproportionality curves is discussed in terms of changes in the carrier trap distribution that is induced. We fit the data to a model which takes into account the presence of traps, generation of both free carriers and "born" excitons, Onsager-mediated recombination of electrons and holes, and exciton-exciton annihilation. We will discuss the differences among scintillators by way of interpreting the model parameters.

SCINTILLATION DETECTORS II - CERAMIC & NEW ORGANICS: 4

Origin of improved scintillation efficiency in $(Lu,Gd)_3(Ga,Al)_5O_{12}$:Ce multicomponent garnets: an X-ray absorption near edge spectroscopy study

Yuntao Wu[1,2], Guohao Ren[1], Martin Nikl[3]

[1]*Shanghai Institute of Ceramics, Chinese Academy of Sciences, No.215 Road, Jiading, Shanghai, 201899, P.R. China*
[2]*Scintillation Materials Research Center, Department of Materials Science and Engineering, University of Tennessee, Knoxville, Tennessee 37996, USA*
[3]*Institute of Physics, Academy of Sciences of the Czech Republic, Cukrovarnická 10, 16253 Prague 6*

In the recent successful improvement of scintillation efficiency in $Lu_3Al_5O_{12}$:Ce driven by Ga^{3+} and Gd^{3+} admixture, the "band-gap engineering" and energy level positioning have been considered the valid strategies so far. This study revealed that this improvement was also associated with the cerium valence instability along with the changes of chemical composition. By utilizing XANES technique, tuning the Ce^{3+}/Ce^{4+} ratio by Ga^{3+} admixture was evidenced, while it was kept nearly stable with the Gd^{3+} admixture. Ce valence instability and Ce^{3+}/Ce^{4+} ratio in multicomponent garnets can be driven by the energy separation between 4f ground state of Ce^{3+} and Fermi level.

SCINTILLATION DETECTORS II - CERAMIC & NEW ORGANICS: 5

Structure and scintillation properties of Ce^{3+}-activated lutetium sulfide halides

Gautam Gundiah, Edith D. Bourret, Stephen E. Derenzo

Lawrence Berkeley National Laboratory, Berkeley, CA. USA.

In our quest for dense, fast and bright lutetium-containing scintillators for time-of-flight PET, we investigated the scintillation properties of the lutetium sulfide halide family LuSX with X= F, Cl, Br or I. While the scintillation properties of Ce^{3+}-activated lutetium halides and lutetium sulfide have been explored, those of lutetium sulfide halides have not been reported. All compounds in this system crystallize in layered/lamellar structures. While LuSCl, LuSBr and LuSI form isomorphous, orthorhombic FeOCl-type crystal structures, LuSF crystallizes in a trigonal crystal system. All compounds can be activated by Ce^{3+} and show the characteristic 5d-4f transition with emission maximum between 490 and 545 nm (FWHM ~150 nm), on excitation with UV or X-rays. The materials show a primary decay component between 23 and 32 ns accounting for 26-77% of the emitted light under X-ray excitation. Scintillation light yields were obtained using X-ray excitation by comparison to a single crystal with known luminosity, emission in a similar wavelength range and measured under id The highest luminosity obtained was for LuSI and is ~20,000 ph/MeV.entical conditions.

Medical ApplicationsII

8:00 AM - 9:30 AM (Vandenburg)

MEDICAL APPLICATIONS II - RADIATION THERAPY AND NUCLEAR MEDICINE: 1

Range assessment in particle therapy based on prompt-gamma timing measurements

Christian Golnik[1], Fernando Hueso González[1], Aleksandra K. Biegun[3], Peter Dendooven[3], Wolfgang Enghardt[1,2], Fine Fiedler[2], Thomas Kormoll[1], Andreas Müller[1], Reint Ostendorf[3], Johannes Petzoldt[1], Katja Römer[2], Guntram Pausch[1]

[1]*OncoRay, Technische Universität Dresden, Germany*
[2]*Helmholtz-Zentrum Dresden-Rossendorf, Germany*
[3]*KVI – CART, University of Groningen, The Netherlands*

Proton and ion beams open up new vistas for the curative treatment of tumors, but adequate technologies for monitoring the compliance of dose delivery with treatment plans in real time are still missing. Range assessment, meaning the monitoring of therapy-particle ranges in tissue during the treatment, is still a key challenge for tapping the full potential of particle therapy. In this context, the paper verifies an unconventional concept of range assessment by using prompt-gamma timing (PGT) measurements[1], which is based on an elementary physical effect: Therapy particles penetrating tissue move very fast, but still need a measurable time – about 1 to 2 ns in case of protons with a 5 to 20 cm range – from entering the patient's body until stopping in the target volume. Particles with a longer range have to travel a longer path and need more time. Since prompt gamma rays can be emitted all along the particle track, the period of (potential) prompt gamma emission is longer. Timing spectra, measured with a setup technically resembling usual time-of-flight (TOF) techniques, thus exhibit a broader distribution of prompt events and, consequently, a distinct shift of the center of gravity reflecting an (on average) later emission due to the longer range. PGT distributions encode the emission times of prompt gammas with respect to the particle entrance in tissue rather than their time of flight to the detector. In contrast to conventional TOF applications, the detector(s) can therefore be arranged close to the target at distances just large enough to ensure a manageable detector load. Timing spectra comprising some hundred thousand events can thus be collected within seconds. Supposed a time resolution of 1 ns FWHM, this statistics is sufficient for detecting peak shifts around 10 ps corresponding to range variations of 1-2 mm. A fast, robust, and very simple range assessment, solely based on straight timing spectroscopy with common gamma detectors of reasonable efficiency and time resolution, seems to be feasible. The concept was verified by retrospective analysis of data taken with other objectives at the AGOR accelerator at KVI-CART Groningen. A $Gd_3Al_2Ga_3O_{12}$ (GAGG:Ce) scintillation detector had gathered energy deposition and timing data of gamma rays produced by a pencil beam of 150 MeV protons hitting thick PMMA (and other) targets, using the cyclotron RF as time reference. PGT spectra extracted for different target configurations clearly show the expected peak shifts and broadenings depending on the track length of protons in the target, in spite of a moderate system time resolution (1 ns FWHM). Measured data are well reproduced by model calculations, which allow further exploring the prospects and limitations of PGT.

[1] Patents applied for.

MEDICAL APPLICATIONS II - RADIATION THERAPY AND NUCLEAR MEDICINE: 2

Study, Simulation and Validation of the Read-Out Electronics Design for a High-Resolution Plastic Scintillating Fiber Based Hodoscope

Jose María Blasco[1], Enrique Sanchis[1], Domingo Granero[2], Jose David Martín[1], Vicente González[1], Diego Barrientos[1], Francisco Javier Egéa[1], Enrique Sanchis-sánchez[1], María Clara Blasco[1]

[1]*Universitat de València*
[2]*Eresa Grupo Médico*

This work presents a study, simulation and validation of the read-out proposed for a high-resolution Plastic Scintillating Fiber based hodoscope prototype, which is used for beam positioning and beam calibration. Concretely, it has been based on a 128 PhotoDiode array from Hamamatsu. The goal is making possible the validation of the proper functioning of the complete detection system (detector plus read-out). In order to achieve this, a sound comparison between the experimental results obtained with a radioactive source versus the ones obtained from Geant4 simulations of the PSF detector was carried out.
Additionally, a set of simulations were also conducted to assess the system under several conditions with the following goals: first, to evaluate its feasibility for proton applications (such as protontherapy) and second, to study its behavior for a configuration with two PSF detection planes.

MEDICAL APPLICATIONS II - RADIATION THERAPY AND NUCLEAR MEDICINE: 3

Study of thermal and epithermal neutrons for accelerator based in vivo neutron activation facility using $^{115}In(n, \gamma)^{116}In$

Chitra Bhatia

Medical Physics and Applied Radiation Sciences, McMaster University, Hamilton, ON, Canada, L8S 4K1

Thermal and epithermal neutron fluence estimations for the in vivo irradiation cavity located at the Tandetron accelerator, McMaster University [1,2] using $^{7}Li(p,n)^{7}Be$ as a neutron production reaction are presented. The measurejments were carried out by the use of the neutron activation method with the $^{115}In(n, \gamma)^{116}In$ reaction. The phantoms, prepared using $InCl_3$ and dil. HNO_3, were irradiated at five different proton energies between 1.95 to 2.3 MeV. The measurements were done with bare phantoms and with a Cd wrap of 0.5 mm. The induced activities in the In phantoms were recorded using a HPGe detector and reaction rates were calculated to determine the ratio of epithermal to thermal neutrons. The measured ratios at different energies were used to estimate the epithermal neutron contribution for other in-vivo elements studied like Al, Na, Mg, Ca and Mn. The preliminary results show that the epithermal neutrons contribution is < 4 % of the total neutron fluence. Details of the measurements will be discussed. A benchmark study to compare experimental results using MCNP is underway.

References

[1] A Pejovic-Milic, S H Byun, D R Chettle, F E McNeill, W V Prestwich, J. Radioanal. Nucl. Chem. 269 (2006) 417–20.
[2] S H Byun, A Pejovic-Milic, S McMaster, W Matysiak, Aslam, Z Liu, L M Watters, W V Prestwich, F E McNeill and D R Chettle, Phys. Med. Biol. 52 (2007) 1693–703.

MEDICAL APPLICATIONS II - RADIATION THERAPY AND NUCLEAR MEDICINE: 4

A new technology for fast two-dimensional detection of proton therapy beams

Derek Dolney[1], Mitch Newcomer[2], Godwin Mayers[2], Gaurav Shukla[2], Doug Bollinger[2], Eli Pollock[2], Niral Desai[2], Justin C. Wong[2], Richard Maughan[1], Robert Hollebeek[2]

[1]*Department of Radiation Oncology, University of Pennsylvania, Philadelphia, PA 19104*
[2]*Department of Physics, University of Pennsylvania, Philadelphia, PA 19104*

Purpose: The authors have developed a novel detector technology for proton therapy dosimetry with fine spatial and time resolution and wide dynamic range. New technology tailored to proton therapy will reduce the uncertainties in beam characteristics, assist in the development of new and advanced therapy-supporting technologies, facilitate more rapid delivery and commissioning of new particle therapy facilities, and allow more comprehensive Quality Assurance measurements.Methods: The Micromesh Gaseous Structure, or Micromegas, is a technology developed for high count-rate applications in high-energy physics experiments. The investigators have designed and assembled a Micromegas chamber, specially designed amplifiers, and readout electronics adapted to the requirements of the proton therapy environment and providing both excellent time and high spatial resolution. The chambers were operated with ionization gains between 10 and 200. Several iterations of Micromegas prototypes have been fabricated and assembled. Data has been collected with these prototypes not only in proton therapy beams to demonstrate the capabilities and limitations of this new technology.Results: The digitized ionization signal, representing the instantaneous dose rate per detector channel, is found to be reproducible to better than 0.8%. Spatial resolution is determined to be 75 μm (1σ) at 1 ms time resolution. Our system resolves the high dose rate within a proton Bragg peak and measurements agree with a parallel-plate ionization chamber (PTW 34070) to better than 1%. The unique time resolution of this system is leveraged to resolve the dynamic elements of proton beam delivery (rotating range modulator wheel and magnetically-scanned beams). Conclusion: An adaptation of Micromegas is demonstrated as a beam monitor for proton therapy, and the data indicates that Micromegas holds promise as a high spatial and time resolution measurement device. Systems of this type will be useful in future treatment methods involving beams that change rapidly in time and spatial position.

MEDICAL APPLICATIONS II - RADIATION THERAPY AND NUCLEAR MEDICINE: 5

Measurement of charged particle yields emitted during irradiation with therapeutic proton and Carbon beams in view of the design of a new tool for the monitoring of hadrontherapy treatments

Vincenzo Patera[1,3], Michela Marafini[1,3], Adalberto Sciubba[3], Luca Piersanti[3], Paola Maria Fralliccardi[1,3]

[1]Museo Sotrico della Fisica e Centro Studi e Ricerche Enrico Fermi,
[2]Dipartimento di Fisica, Sapienza Università di Roma, Roma, Italy
[3]INFN Sezione di Roma, Roma, Italy

Posters II – Radiation Measurement Techniques

9:30 AM - 10:30 AM (Ballroom)

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 1

Neutrons and gamma ray from deuterium plasmas at RFX-mod

Stevanato Luca[1], Cester Davide[1], Viesti Giuseppe[1], Nebbia Giancarlo[2], Martinez Emilio[3], Zuin Matteo[3], Winder Gonzalez[3], Cavazzana Roberto[3], Valisa M.[3]

[1]Dipartimento di Fisica ed Astronomia dell' Università di Padova, Padova, Italy
[2]INFN Sezione di Padova, Padova, Italy
[3]Consorzio RFX, Padova, Italy

Results of the first experimental measurements of neutron and gamma ray productions in RFX-mod Deuterium plasmas is discussed. The nuclear reaction under consideration is: D + D -> ^{3}He(0.82MeV) + n (2.45 MeV).RFX-mod is a toroidal device (R_0=2m, a=0.459 m, major and minor radius, respectively), where plasmas of thermonuclear interest are produced and magnetically confined. Two magnetic configurations have been explored in this work: tokamak and reversed-field pinch (RFP).The diagnostic system is made of a spectrometer based on a cylinder 2"x2" of EJ-301 liquid scintillator coupled to a flat-panel photomultiplier. The advantages in using flat-panel to read scintillation light is the lower power consumption relative to normal PMT and the possibility of operating the instjrument under magnetic fields.The sensor has been installed on a

vertical top window, above the main toroidal axis of the machine at about 260 mm above the outer window surface in a high magnetic field and surrounded by a Polyethylene shield. The read-out consists of two CAEN desktop DT5751 (digitizer) and DT5780 (HV supply). In DT5751, a DPP algorithm is implemented inside a FPGA providing online, for each event, the discrimination between neutron and gamma-ray. Results from the first campaign of measurements will be discussed.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 2

Transit Time of Electrons and Gas Gain in P-10 and $ArCO_2$ Using an Electron Attachment Spectrometer

Gloria M. Orchard, Anthony J. Waker

Faculty of Energy Systems and Nuclear Science, University of Ontario Institute of Technology, Oshawa, Ontario, Canada

An Electron Attachment Spectrometer (EAS) has been designed to measure the transit time and electron attachment in different gases. The aim of the EAS is to observe how electron parameters including the drift velocity, pulse formation time, multiplication gain and electron attachment depend on the gas composition. Current research interests include the measurement of the time between the generation of the electron-ion pairs and arrival of the electrons at the wire anode in P-10 and $ArCO_2$ gases. Additionally, the study of the multiplication properties of the detector as a function of pulse formation time in the two gases as a function of applied electric field will be presented. The overall objective of this work is to investigate if the gas-gain of a proportional counter can be optimized by minimizing electron attachment with oxygen to improve the measurement of tritium in air. The EAS is a cylinder with a length of approximately 92 mm and diameter of 41 mm comprised of cylindrical hollow brass electrodes and Teflon spacers. A uniform electric field within the tube is applied and guides electrons and/or ions towards their respective electrodes. A proportional counter with a 50 μm diameter wire anode was used to detect the electrons and/or ions created by an Am-241 source located at the opposite end. Currently a Thick Gas Electron Multiplier (THGEM) is under development to replace the anode wire of the EAS and the design and electric field pattern within the EAS with a THGEM will be presented.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 3

Real-Time Airborne Gamma-Ray Background Estimation Using NASVD with MLE and Radiation Transport for Calibration

Jonathan A. Kulisek, John E. Schweppe, Sean C. Stave, Bruce E. Bernacki, David V. Jordan, Trevor N. Stewart, Carolyn E. Seifert, Warnick J. Kernan

Pacific Northwest National Laboratory, Richland, WA 99352

Helicopter-mounted gamma-ray detectors can provide law enforcement officials the means to quickly and accurately detect, identify, and locate radiological threats over a wide geographical area. The ability to accurately distinguish radiological threat-generated gamma-ray signatures from background gamma radiation in real time is essential in order to realize this potential. This problem is non-trivial, especially in urban environments for which the background may change very rapidly during flight. This exacerbates the challenge of estimating background due to the poor counting statistics inherent in real-time airborne gamma-ray spectroscopy measurements. To address this, we have developed a new technique for real-time estimation of background gamma radiation from aerial measurements. This method is built upon on the noise-adjusted singular value decomposition (NASVD) technique that was previously developed for estimating the potassium (K), uranium (U), and thorium (T) concentrations in soil post-flight. The method can be calibrated using K, U, and T spectra determined from radiation transport simulations along with basis functions, which may be determined empirically by applying maximum likelihood estimation (MLE) to previously measured airborne gamma-ray spectra. The method was applied to both measured and simulated airborne gamma-ray spectra, with and without man-made radiological source injections. Compared to schemes based on simple averaging, this technique was less sensitive to background contamination from the injected man-made sources and may be particularly useful when the gamma-ray background frequently changes during the course of the flight. This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-12-R-00065. This support does not constitute an express or implied endorsement on the part of the Government.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 4

Optimization for a long counter design using MCNP simulation

Raina J. Park, Soo Hyun Byun, William V. Prestwich

Research Group of Soo Hyun Byun, Department of Medical Physics and Applied Radiation Sciences, McMaster University, 1280 Main St W, Hamilton, ON, Canada, L8S 4L8

We present a design for a neutron long counter using the MCNP Monte Carlo code. The long counter has been conveniently used for monitoring fast neutron fluence and ideally an energy independent flat response is desired over a wide energy range [1]. A long counter is normally composed of a central slow neutron detector surrounded with a moderator. In order to accomplish a response close to the ideal case, it is vital to optimize the geometry of the moderator. In this study, the long counter response is optimized using the MCNP Monte Carlo code. As a benchmark test, we first carried out the efficiency simulation for a BF3 detector [2], which showed an excellent agreement with the experimentally reported data. MCNP simulations for various moderator geometries are systematically compared.

[1] H. Tagziria, D.J. Thomas, Nucl. Instr. Meth. A 452 (2000) 470.

[2] T.E. Sampson, D.H. Vincent, Nucl. Instr. Meth. 95 (1971) 563.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 5

Novel Ultra-low Electronic Noise HPGe Detector Structure for Record Energy Resolutions

Vlad Marian, Benoit Pirard, Pascal Wendling, Pascal Quirin, Jeremy Flamanc, Marie Odile Lampert

Canberra France

This paper reports on improvements, characteristics, detection performances and prospective applications of recently developed ultra low noise HPGe detectors for a large set of applications, ranging from fundamental research to industrial activities.The design and optimization of the noise figure of the detector as a whole is described. The combined developments carried out on all detector subsystems (crystal, cryostat, pulsed reset cold preamplifier, as well as warm preamplifier) allowed to reach record energy resolution (FWHM) on large detectors (≥1kg).

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 6

High-Precision Fission Yields Attained From Delayed Gamma-Ray Measurements

Douglas C. Rodriguez[1], Luke W. Campbell[1], Steve Reese[2], Russell Williford[2], Edward T. Reedy[3,4], Heather A. Seipel[3,4], Michael Smith[3,4], Vladimir V. Mozin[5], Bernhard A. Ludewigt[6], Andrea Favalli[7], Medodi Iliev[7], Alan W. Hunt[3,4]

[1]*Pacific Northwest National Laboratory, Richland, WA*
[2]*Oregon State University, Corvallis, OR*
[3]*Idaho State University, Pocatello, ID*
[4]*Idaho Accelerator Center, Pocatello, ID*
[5]*Lawrence Livermore National Laboratory, Livermore, CA*
[6]*Lawrence Berkeley National Laboratory, Berkeley, CA*
[7]*Los Alamos National Laboratory, Los Alamos, NM*

Fissile and fissionable materials can be discriminated based on their unique fission yields and the corresponding delayed beta or gamma ray signatures. However, the yields of short-lived isotopes (<1 hour half-life) in current nuclear databases exhibit large uncertainties. We present recent delayed gamma-ray measurements of uranium and plutonium isotopes under thermal neutron and reactor-spectrum neutron irradiation and the impact on the analyzed fission yields.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 7

Remediating neutron damage in orthogonal-strip planar germanium detectors

Emily G. Jackson[1], Ethan Hull[2], Christopher J. Lister[1], Richard Pehl[2]

[1]*Physics Department, University of Massachusetts Lowell, Lowell, MA 01854*
[2]*PHDs Company, 3011 Amherst Road, Knoxville, TN 37921*

Germanium detectors have proven to be the best gamma-ray spectrometers for five decades. Their excellent energy resolution, even in very large crystals, is due to uniform charge-carrier mobility and efficient charge collection at the electrodes. However, radiation damage from neutron sources can cause preferential hole trapping and result in position-dependent pulse-height deficits that degrade the energy resolution of the detector. Mitigating this radiation damage is critical to the further development of very large segmented planar germanium gamma-ray detectors and their widespread use. To this end, two detectors with 16 x 16 orthogonal amorphous germanium contacts were deliberately subjected to a non-uniform neutron irradiation to cause considerable degradation of performance. The radiation damage was produced using the ^{7}Li(p, n)^{7}Be reaction at the UMass Lowell Van de Graaff accelerator with a 3.7-MeV proton beam incident on a natural Li target. The energy of the emitted neutrons at zero degrees was 2.0 MeV and each detector was exposed to a flux greater than 5 x 10^{9} n/cm^{2} in about two hours. The irradiation was deliberately non-uniform, with the central region receiving an order of magnitude greater flux. The neutron damage caused the central area of the detector to have many more charge-trapping centers which down-shifted the charge collected from gamma rays. The charge trapping was enhanced for the "holes" so that there was significant difference in the electron and hole charges collected from each side of the detector. A 2D energy difference plot shows a central hole of missing events, where the charge matching was very poor, surrounded by a "donut" of relatively undamaged detector. A software 3D "trap-corrector" gain-matching algorithm considerably restored the overall performance. After characterizing the neutron damage, several methods were used to attempt to regain the performance of the detectors. The bias voltage was increased and significant improvements were seen in the charge-matching between both sides of the detector. The detectors were then annealed, both at room-temperature and at 70 C. We will illustrate the improvement in resolution and charge collection seen with increasing bias voltage on neutron-damaged detectors and will discuss the progress being made with moderate and high-temperature annealing.This work was sponsored by DOE NP Phase I SBIR Award number: DE-SC0009639

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 8

Feasibility and Demonstration of a Cloud-Based RIID Analysis System

Michael C. Wright[1], Kristin L. Hertz[2], William A. Johnson[2], Eric D. Sword[1], James R. Younkin[1], Lorraine E. Sadler[2]

[1]*Oak Ridge National Laboratory*
[2]*Sandia National Laboratories*

A significant limitation in the operational utility of handheld and backpack radioisotope identifiers (RIIDs) is the inability of their onboard algorithms to accurately and reliably identify the isotopic sources of the measured gamma-ray energy spectrum. Improved algorithms exist but are not implemented on RIIDs due to insufficient computational power or classification, export controls, or other sensitivities. They also have limited ability to use additional contextual information in making an assessment. A possible solution is to move the spectral analysis computations to an external device whose capabilities can be greatly enhanced and whose algorithms can be kept secure. A Cloud-based analysis system can provide this capability. Cloud computing is becoming ubiquitous and affords the radiation detection community an opportunity for tremendous leverage of private sector developments. The goal of this project was to determine if the operational performance of RIIDs could be improved by applying these developments in a way that meets the needs of the national security community.Direct linking of RIIDs to the Cloud offers a number of advantages over the built-in capabilities currently available on the detectors, including improved analysis, streamlined operation, easy updating, customizable analysis, data fusion, monitoring of RIIDs, and information security. A systems study was performed to look at the radiation detection mission architecture and determine the benefits, risks, and costs, as well as a guide for development, of a Cloud-based RIID system. Various potential users of the system were interviewed and observed in order to assess the potential benefits and impacts on field operations of a Cloud-based analysis system. A small-scale Cloud-based analysis system demonstrating most of the features of the architecture was implemented to show its feasibility and to gain practical experience. The system was demonstrated using a number of widely deployed commercial off-the-shelf (COTS) systems, as well as a custom-built detection system, to take data and send it to the Cloud for analysis. The DHSIsotopeID and HPGeFSA algorithms were used to analyze the data with detector characterizations specialized for the individual detectors that submitted the data. Analysis results were then returned to the detector, in the case of the Falcon and the custom device, which had the ability to receive results onboard. For the other systems, the results could be viewed on smartphones, tablets, or laptop computers. Using a web interface, additional information could be added to the analysis, the

full-spectrum regression fits could be viewed, and the data could be downloaded for further analysis.The implementation and demonstration of a prototype Cloud-based RIID analysis system have shown this type of system to be feasible with currently available communication and computational technology. The system study has shown that the potential user community could derive significant benefits from an appropriately implemented Cloud-base analysis system and has identified the design and operational characteristics required by the users and stakeholders for such a system.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 9

Development of a low background liquid scintillation counter for a shallow underground laboratory

Craig E. Aalseth, Bruce E. Bernacki, Matthew Douglas, Erin S. Fuller, Martin E. Keillor, Shannon M. Morley, John L. Orrell, Mark E. Panisko, Sarah M. Shaff, Glen A. Warren, Michael E. Wright

Radiation Detection & Nuclear Sciences, Pacific Northwest National Laboratory, Richland, WA 99352 USA

Pacific Northwest National Laboratory has recently opened a shallow underground laboratory intended for measurement of low-concentration levels of radioactive isotopes in samples collected from the environment. The development of a low-background liquid scintillation counter is currently underway. Liquid scintillation counting is especially useful for pure beta-emitting isotopes or beta emitters with low gamma-ray yields. The combination of high-efficiency detection of the beta emission in a liquid scintillation cocktail coupled with the low-background environment of an appropriately-designed shield located in a clean underground laboratory provides the opportunity for increased-sensitivity measurements of a range of isotopes. To take advantage of the 35-meter water water-equivalent overburden of the shallow underground laboratory, a series of benchmarked simulations have evaluated the instrumental shield design requirements to assess the possible background rate achievable. Evaluation and assay of the shield construction materials provides a robust basis for the shield design development. Of particular interest is the background associated with the light detection instruments, typically photomultiplier tubes. Alternative light detection concepts are investigated whilst balancing the competing desires for low background and high light collection efficiency.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 10

Characterization of radiation exposure levels in the vicinity of an x-ray tube used in the non-destructive examination of railroad track structure

Jessica E. Salazar[1], Michael Liesenfelt[1], Harry Cui[1], Edward Dugan[1], Jeb Belcher[2], Jim Baciak[1]

[1]*Nuclear Engineering Program, University of Florida, Gainesville, FL 32611, USA*
[2]*Georgetown Rail Equipment Company, Georgetown, TX 78626, USA*

The need for subsurface flaw detection in railroad structural components has led to the recent development of a mobile radiography unit mounted on a hi-rail platform. The design enlists an 1800-Watt tube oriented such that it throws a static fan beam at a tangential angle to the surface of the track. Since the operation of this system in populated areas will result in exposure to the general public, a thorough understanding of the backscatter radiation field is necessary. Due to the fan beam geometry and use of scattered X-rays for image formation, this system poses several unique challenges to shielding requirements. Exposure rate measurements were taken around the track under normal tube operation, and with the collimator plates completely closed. The field mapping led to the discovery of a height-dependent exposure rate due to the shielding and scattering from the low-lying steel rail. Leakage was also identified from the center of the housing and from gaps in the shielding that surrounds the cables at both ends of the tube. Additional measurements indicated that the maximum leakage from the tube could be reduced to less than 5.3 mR/hr with approximately 0.5 inches of lead.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 11

Radiation Sensor Data Fusion for Improved Detection and Localization

Daniel A. Cooper, Robert J. Ledoux, Krzysztof Kamieniecki, Stephen E. Korbly, James B. Costales, Joyoni Dey, Rustam Niyazov, James Batcheler, Jeffrey Thompson, Aaron Smith

Passport Systems, Inc., 70 Treble Cove Rd., N. Billerica, MA 01862

Data fusion methodologies hold the potential for increasing the utility of otherwise isolated discrete detectors through the intelligent sharing and integration of multiple data sources. In recent years there has been a concerted effort on the part of government agencies and contractors to apply data fusion principles and techniques to the radiation sensing problem. Under the Intelligent Radiation Sensor System (IRSS) Advanced Technology Demonstration (ATD) program [1] sponsored by DHS DNDO, Passport Systems, Inc. developed a generalized Bayesian framework for performing fusion of data from a variety of sensors. In the context of the IRSS ATD program, data from non-co-located spectroscopic radiation detectors was fused to demonstrate increased detection performance and enable emergent capabilities, like source localization and tracking, which are not available to individual detectors. Subsequent to the IRSS ATD program the same data fusion framework has been extended to demonstrate the fusion of auxiliary sensor measurements with the radiation data to improve system search and tracking capabilities. Two different government programs have explored fusion with embedded inertial sensors with portable radiation sensors (Small Business Innovative Research program) [2] and adjunct video data fusion with fixed radiation monitors (Exploratory Research Program). The data fusion framework developed by Passport Systems will be discussed and examples from the various programs will be used to illustrate the utility of data fusion in a variety of operation settings. Additionally, performance of the fusion algorithms using data from Passport's commercial sensors will be discussed.This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contracts/IAAs HSHQDC-09-C-00123, HSHQDC-12-C-00092, and HSHQDC-13-C-B0034. This support does not constitute an express or implied endorsement on the part of the Government. All claims and representations contained herein are those of the author alone.

REFERENCES

[1] D. Cooper, et al., "Intelligent Radiation Sensor System (IRSS) Advanced Technology Demonstrator (ATD)", SORMA West, May 2012

[2] D. Cooper, et al., "Integration of Inertial Measurement Data for Improved Localization & Tracking of Radiation Sources", IEEE Conference on Technologies for Homeland Security, November 2013

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 12

Microcalorimeter Q-spectroscopy for nuclear materials analysis

Andrew Hoover[1], Evelyn Bond[1], Mark Croce[1], Gerd Kunde[1], Michael Rabin[1], Brad Alpert[2], Douglas Bennett[2], Jason Hayes-wehle[2], Dan Schmidt[2], Joel Ullom[2]

[1]Los Alamos National Laboratory, Los Alamos, NM, USA
[2]National Institute of Standards and Technology, Boulder, CO, USA

Microcalorimeter Q-spectroscopy is a new measurement technique for the analysis of nuclear material from facility swipes, environmental samples, and bulk samples, supporting safeguards and forensics goals. We are developing instrumentation and methods to measure the total reaction energy (Q-value) of Pu, Am, and Cm isotopes. The method represents a new, maximally efficient, and relatively rapid analysis tool ultimately aimed at analysis of single particles. Q-spectroscopy has benefits over traditional mass-spectrometry, which normally requires elemental chemical separation and has problems with certain isobaric interferences. There are also benefits over alpha-spectroscopy, which requires careful electroplating of samples and lacks sufficient resolution to resolve closely spaced spectral peaks. Compared to these conventional methods of isotopic analysis, Q-spectroscopy has the potential for significantly reduced sample preparation chemistry and spectral complexity. It also provides a new method for determination of material chemical age (time since purification) using the $^{241}Am/^{241}Pu$ isotope ratio via simultaneous measurement of the low-energy ^{241}Pu beta particles and high-energy ^{241}Am Q-value. Q-spectroscopy is non-consumptive, allowing for reanalysis of the sample material by other methods. Q-spectroscopy relies on embedding the sample material inside an absorber connected by a thermal link to a highly sensitive, low-temperature (~0.1 K) transition-edge-sensor (TES) thermometer. Energy from particle interactions in the absorber is precisely measured as a temperature change in the device, allowing for high-resolution spectroscopy in theory a factor of ten better than current alpha-particle detection technologies (silicon detectors). Due to the high efficiency of the embedded source geometry (essentially unity), measurement times can be minimized.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 13

High resolution alpha particle spectrometry through collimation

Seunghoon Park, Sung-woo Kwak, Il-jin Park

Technology Development Division, Korea Institute of Nuclear Non-proliferation and Control, Republic of Korea

Alpha particle spectrometry has been used in the measurement of nuclear materials in various fields, such as safeguard verification, nuclear security, nuclear decay data and environmental surveys. In order to verify nuclear experiments or reprocessing, it is important to identify nuclear materials in a radioactive source, which exist in very small portions in the environment or atmosphere. A collimator between a radiation source and a detector plays a crucial role in identifying specific radionuclide among various species in a radioactive source collected from the atmosphere or environment. In general, without collimation system, the energy distribution measured by a detector is broadened by background effects. Since particles with a high angle have a longer path than particles with a low angle, collision with the background increases. Therefore, collimation by cutting out particles with a high angle is one of the solutions to obtaining an energy distribution with high resolution. The mesh type collimator is not only optimally designed (through the Monte Carlo simulation method, Geant4) but it can be experimentally implemented. By applying a collimator, the resolution and the efficiency can be controlled by adjusting the mesh diameter and thickness of the collimator. As a result, the designed geometry can be found by maximizing both resolution and efficiency. Therefore, a target particle, such as ^{235}U, can be distinguished by a detector with a collimator under a mixture of various nuclides, for example: ^{232}U, ^{238}U, and ^{232}Th.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 14

Localization Techniques for Aerial Search of Radiological Sources

Sean Robinson, Erin Miller, Amanda Prinke, Kevin Anderson, Jennifer Webster, Jon Mccall, Carolyn Seifert

Pacific Northwest National Laboratory, Richland, WA

A numerical technique for localization has been developed by PNNL for the purpose of searching for and locating radiological sources in urban or rural environments from an aerial platform. This technique is based on a Bayesian framework and is employed using a localized methodology that restricts likelihood map updates to the local detector field of view. This modification allows the detection method to operate in real time for efficient search operations, and to locate multiple sources of interest over a wide area. A large multi-element scintillation detector is used onboard a helicopter platform to provide search operations. Results from the localization technique are shown for real and simulated helicopter data, and the capability of the localization methodology to locate radioisotopes is estimated for several test cases. This likelihood-based technique for localization is shown to facilitate urban search by allowing quick and adaptive estimates of source location. In particular, this method represents a significant advancement from earlier methods like full-field Bayesian likelihood (which is not generally fast enough to allow for broad-field search in real time) and highest-net-counts estimation (which has a localization error that depends strongly on flight path and cannot generally operate without exhaustive search). This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-12-X-00376. This support does not constitute an express or implied endorsement on the part of the Government.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 15

Multiplicity and Recoil Spectrometer for Fast Neutron Background Measurements at Depth

Peter Marleau[1], Mark Gerling[1], Melinda Sweany[1], Adam Bernstein[2], Nathaniel Bowden[2], Steven Dazeley[2], Caleb Roecker[3]

[1]*Radiation and Nuclear Detection Systems, Sandia National Laboratories, Livermore, CA*
[2]*Rare Event Detection, Livermore National Laboratory, Livermore, CA*
[3]*Department of Nuclear Engineering, UC Berkeley, Berkeley, CA*

An important and poorly understood background for underground experiments is that of fast neutrons induced by muogenic interactions in cavern walls. Current estimates of the absolute flux and spectral shape of the neutron background 10-1000 MeV are not well constrained. For this reason, we have designed and constructed a Multiplicity and Recoil Spectrometer (MARS) to measure the neutron spectrum above ~10 MeV and

to characterize the backgrounds relevant for the future development of a kiloton scale Gadolinium doped water Cherenkov based antineutrino detector. The project, dubbed WATCHMAN (WATer Cherenkov Monitor of AntiNeutrinos) has the ultimate goal of demonstrating the feasibility of monitoring nuclear reactors remotely. The MARS detector is currently deployed at the Kimballton Underground Research Facility (KURF) run by Virginia Tech to measure the neutron spectrum at multiple depths between ~350-1500 meters water equivalent (m.w.e.). We will present the MARS design and preliminary results from these measurements.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 16

Adaptively Reevaluated Bayesian Localization (ARBL) – a Novel Technique for Radiological Source Localization

Erin A. Miller[1], Sean M. Robinson[2], Amanda M. Prinke[1], Kevin K. Anderson[1], Jennifer B. Webster[1], Jon D. Mccall[1], Carolyn E. Seifert[1]

[1]*Pacific Northwest National Laboratory, Richland, WA, USA*
[2]*Pacific Northwest National Laboratory, Seattle, WA, USA*

A novel technique for the localization of radiological sources using a moving detector has been developed for the purpose of aerial search. This technique is based on a Bayesian likelihood technique for localization, in which measured count rates in a time series are compared with predicted count rates from a series of test sources to define likelihood. This technique is expanded by using a localized treatment with a limited field of view, coupled with a likelihood ratio reevaluation, allowing this technique to be used in real time on commodity hardware. Several other advancements for speed have been made, including the use of a quadratic approximation to the likelihood, in order to arrive at a fast algorithm that can localize distant sources in real time. This technique is presented as a method for general source localization and represents a significant advancement to techniques based on iteration of the likelihood function alone. This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-12-R-00065. This support does not constitute an express or implied endorsement on the part of the Government.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 17

Beam detector for secondary pion beam at SIS18 GSI

Rafal Lalik[1,2]

[1]*Excellence Cluster Universe, Garching, Germany*
[2]*E12, Physics Department, TU Munich, Germany*

High energy physics experiments with secondary beams require not only infrastructure to produce such beams but also beam diagnostics devices to determine properties of the beam particles event by event. The second feature is specially required for exclusive analyses of the studied reactions.

For the upcoming pion beam experiment with the HADES spectrometer with the SIS18 accelerator at GSI in Darmstadt, Germany, the pion beam detector for determining individual particles momenta has been developed. It consists of two silicon detectors placed in carefully selected positions along the beam line. Both detectors provide position information of incoming pions allowing to calculate their momenta from beam optics transport formalism.

One of the location is close to the secondary production target. The silicon sensor experiences there high particle rate of $\approx 10^8$part./s where only 1% of it are actually pions. Presence in the beam line requires also in vacuum operation. Due to large distances between the first station of beam detector and the HADES experiment, also the timing properties of the system are crucial. In this presentation details about measuring of the pion momenta with use of beam transport optics, construction of the silicon tracker including radiation hard silicon sensors performance, the n-XYTER front-end readout chip and TRB3 readout electronics and detector commissioning results in the laboratory and with beams will be presented.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 18

Analyzing the responses of conventional and extended neutron detectors in radiation fields of a 150-MeV LINAC

Yu-chi Lin[1], Rong-jiun Sheu[2], Ang-yu Chen[3], Kuo-wei Lee[4]

[1]*National Synchrotron Radiation Research Center, Hsinchu, Taiwan*
[2]*Institute of Nuclear Engineering and Science, National Tsing Hua University, Taiwan*
[3]*Department of Engineering and System Science, National Tsing Hua University, Taiwan*
[4]*Institute of Nuclear Energy Research, Longtan, Taoyuan, Taiwan*

Two sets of high-sensitivity neutron detecting system were assembled for monitoring neutrons outside the shielding of a 150-MeV LINAC. Each set consisted of two neutron detectors: one was a conventional moderated-type neutron detector based on a large cylindrical He-3 proportional counter and another was an extended version by embedding a layer of lead in the moderator to increase its sensitivity to high-energy neutrons. Neutron measurements were conducted simultaneously at the downstream and lateral locations of the LINAC because of their different radiation fields. Note that, not only neutrons but also high-energy gamma rays (>5-10 MeV) could potentially cause counts to the detectors through photonuclear reactions with the detector materials. This part of contribution largely depends on the high-energy tail of the gamma-ray spectrum in the radiation field and the amount of heavy metal inside the detector. Detector response functions to both neutrons and high-energy gamma rays were calculated using MCNPX. Neutron and gamma-ray spectra at the locations of measurement were estimated using the FLUKA Monte Carlo simulations. Neutron counting rates estimated by folding the spectra with response functions were analyzed and compared with measurements. Based on a reasonable beam lost scenario, the estimated results were generally consistent with the measurements. For neutron measurements outside the LINAC shielding, high-energy neutrons (>10 MeV) were negligible in this case, but photoneutrons caused by interactions of high-energy gamma rays with the detector structure could be significant. In particular, at the downstream of the LINAC where high-energy photons were abundant, approximately 50% of the registered counts of the extended neutron detector were coming from photoneutrons as a result of the detector itself rather than the radiation field. Caution should be taken in interpreting the dose rate reading of the extended detector in such a situation.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 19

Time-of-flight neutron response function characterization of ^{4}He scintillation detectors

Ryan P. Kelley[1], Lucas M. Rolison[1], Jason M. Lewis[1], Andreas Enqvist[1], Kelly A. Jordan[1], David Murer[2]

[1]*Nuclear Engineering Program, University of Florida, Gainesville, FL 32611, USA*
[2]*Arktis Radiation Detectors Ltd, Räffelstrasse 11, 8045 Zürich, Switzerland*

Using the tandem Van de Graaff generator at Ohio University, the neutron light response function was measured for pressurized ^{4}He scintillation detectors over the energy range from several hundred keV to 10 MeV. These high accuracy measurements were compared to previous ^{4}He characterization experiments, allowing for the development of a highly accurate response matrix. The response matrix can be used to unfold the detected neutron spectrum to determine the incident spectrum. This has several important applications, including detection of special nuclear material, non-destructive assay of spent fuel, and medical applications.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 20

Data fusion for mobile gamma ray and neutron imaging systems using supervised classification algorithms

John E. Sparger[1], Jason P. Hayward[1,2]

[1]*University of Tennessee Knoxville*
[2]*Oak Ridge National Laboratory*

Supervised classification algorithms and dimensionality reduction techniques were applied to simulated and measured data from four mobile radiation detector systems with the goal of increasing alarm performance for nuclear threat sources. Data was analyzed from two real world gamma ray coded aperture imaging systems, one gamma ray and neutron counting system, and one simulated neutron and gamma ray coded aperture system.

Supervised classification algorithms including Random Forest, support vector machines, and neural networks were trained using simulated source injection to differentiate threat sources from urban and rural background. Classifier and ensemble results were compared to previously employed, single metric criteria using 10-fold cross validation. The supervised classifiers showed significant improvement in detection performance over the previous methodology, especially when deployed in ensembles.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 21

γ-γ coincidence system for low background measurements

Elena Sala[1,2], Ezio Previtali[1,2], Massimiliano Clemenza[1,2], Massimiliano Nastasi[1,2]

[1]*University of Milano-Bicocca*
[2]*INFN Milano-Bicocca section*

High Purity Germanium (HPGe) detectors have been develop for many years reaching competitive features to perform material high sensitivity measurements needed in various applications. Gamma-ray spectroscopy with HPGe is one of the most powerful tool to detect low level contaminations in samples thanks to the excellent energy resolution of these detectors and the possibility to build them with a low intrinsic background.One feasible application of this method is the material selection for rare physics event experiment in which all the experimental component should have high radiopurity. These demanding searches need to detect a very low rate event distinguishing it from the background, for this reason the source of background due to the apparatus contaminations should be reduced, in particular those due to primordial radionuclides.In Radioactivity Laboratory of Milano-Bicocca a system composed of two Low Background HPGe operating in coincidence was developed. All the components materials were selected with HPGe gamma spectroscopy and Monte Carlo simulations in order to use materials with the lowest possible contamination in primordial radionuclides and a consequent low intrinsic background. The changes needed to reach this goal has led to a detector configuration, GMX 100-95 LB with a mechanical cooling system that avoids the use of cryogenic liquids and the electronics placed far away from the crystal. The developed system differs respect to the one available on market, HPGe Reduced Background ,making the developed system quite unique. Furthermore the system is placed in a specific shielding composed of an external layer of Lead and one internal of Copper to reduce the external background. Coincidence measurements can reach a high sensitivity for some radionuclides that decay emitting gamma radiations in coincidence. It was therefore mandatory the deep study of such decay schemes to choose the most probable coincidendes, suitable isotopes for this measurements are ^{60}Co, ^{232}Th and ^{228}Ac from ^{232}Th chain and ^{214}Bi from^{238}U chain. This peculiar measurements are performed with two GMX detectors connected to a dedicated DAQ with an external trigger and the analysis were realized using dedicated software for coincidence study. This active method of background reduction allows the rejection of spurious counting for radionuclides that decay through a gamma rays cascade allowing a gamma-gamma coincidence. The system composed of the two GMX detectors had been used to performed measurements of materials in order to select them for experiments of rare events search.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 22

Design of Gating Grid in SπRIT Time Projection Chamber

Suwat Tangwancharoen[1], William G. Lynch[1], Takumi Usukura[3], Nori Nakatsuka[4], Genie Jhang[6], Hidetada Baba[2], Tadaaki Isobe[2], Rensheng Wang[5]

[1]*National Superconducting Cyclotron Laboratory and Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan 48824, USA*
[2]*RIKEN Nishina Center, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan*
[3]*Rikkyo University*
[4]*Department of Physics, Kyoto University, Kyoto 606-8502, Japan*
[5]*Department of Physics, Tsinghua University, Beijing 100084, P. R. China*
[6]*Department of Physics, Korea University, Anam-ro 145, Seongbuk-gu, Seoul 136-713, Korea*

Distortion of the electric field in the detection volume of a TPC can result from the introduction of positive ions which are produced in an electron avalanche near the anode wires. A gating grid is used to prevent these ions from drifting back into the detection volume. When the gating grid is open, all wires are set to match the potential in the detector, making the wires almost invisible to the drifting electrons which pass into the multiplication region. To close the gating grid, alternate wires are biased up or down by 80 V (to -25 V and -185 V), creating an electric field between the wires so that no electrons pass to the anode plane. There is a "dead" region near the gating grid, in which ionization electrons drift into the gating grid before it has opened. The size of this dead region is governed by the electron drift time and the time needed to open the gate. The former

is determined by the gas, pressure, and electric field, and is difficult to change without sacrifice performance somewhere else. Therefore, we have investigated how to optimize the latter by matching the impedance of the driving circuit, estimating the inductance of the system and tuning the RLC values so that the gating grid is slightly underdamped. Using our optimized gating-grid driver, the gating grid takes 120 ns to open and 600 ns to discharge.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 23

Proposed enhancement of gamma-ray detectors efficiency transfer implemented in the case of an isotropic radiating axial point source with experimental audition

Mohamed E. Krar, Mahmoud I. Abbas

Department of Physics, Alexandria University, 21511 Alexandria, Egypt

In gamma-ray spectroscopy using HPGe or NaI(Tl) detectors of any geometrical shape, one usually needs to know the total and the full-energy peak efficiencies for any specific source–detector configuration of concern. Because the experimental work is tedious and even difficult for extended sources, much research has been focused on the development of computational techniques to determine these efficiencies. The efficiency transfer (ET) comes as a very useful tool to calibrate the gamma-ray detectors. The efficiency transfer is treated with the fact that the ratio of the full-energy peak efficiency (FEPE) to effective solid angle for a given gamma ray energy is source independent. However, this ratio is dependent on the direction and position of the incident photon in accordance to the detector surface; we propose a detector specific factor to overcome this dependency using the GEANT4 Monte Carlo toolkit developed at CERN (version 10.00). Audition of the assumption was conducted using Cs-137 point source mounted axially to 3"x3" NaI (Tl) scintillation detector in different elevations.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 24

Compton Suppressed $LaBr_3$ Detection System for use in Nondestructive Spent Fuel Assay

Sarah Bender, Brenden Heidrich, Kenan Ünlü

Radiation Science and Engineering Center, Pennsylvania State University, University Park, PA 16802-2304

Nuclear material accountancy is of continuous concern for the regulatory, safeguards, and verification communities. In particular, spent nuclear fuel reprocessing facilities pose one of the most difficult accountancy challenges: monitoring highly radioactive, fluid sample streams in near real-time. Current accountancy methods for nuclear fuel reprocessing facilities are resource intensive and time-consuming. The adaptation of passive gamma-ray detection coupled with multivariate analysis techniques could reduce the personnel requirements and processing time of samples. In measured gamma-ray spectra from spent nuclear fuel, the Compton continuum from dominant fission product photopeaks obscure the lower energy lines from other isotopes. The application of Compton suppression to gamma-ray measurements of spent fuel may reduce this effect and may allow other less intense, lower energy peaks to be detected, potentially improving the accuracy of analysis algorithms. Compton suppressed spectroscopic measurements of spent nuclear fuel using $LaBr_3$ and HPGe primary detectors were performed at Penn State. Irradiated fuel was measured in two configurations: either as intact fuel elements viewed through a collimator or as feed solutions in a laboratory to simulate the measurement of a dissolved process stream. These two configurations allowed the direct assessment and quantification of the differences in measured gamma-ray spectrum from the application of Compton suppression. For the first configuration, several irradiated fuel elements of varying cooling times from the Penn State Breazeale Reactor spent fuel inventory were measured using three collimated Compton suppression systems that utilized different primary detectors: HPGe, $LaBr_3$, and NaI(Tl). In the second case, samples of two Approved Test Material (ATM) commercial fuel elements were obtained from Pacific Northwest National Laboratory. These samples had been processed using the beginning stages of the PUREX method. They represented an unseparated feed solution from a reprocessing facility process stream. Compton suppressed measurements of the ATM fuel samples were recorded inside the guard detector annulus, to simulate the siphoning of small quantities from the main process stream for long dwell measurement periods. The measurements of the collimated intact fuel rods show that the $LaBr_3$ and HPGe based Compton suppression systems were able to resolve several additional peaks in the freshly irradiated fuel element and the fuel element that had cooled for one year. The $LaBr_3$ based Compton suppression system recorded a higher average suppression factor than the HPGe based system. Using the collimated geometry, photopeak losses due to suppressed accidentally coincident interactions were minimal due to the very small solid angle of detection. However in measurements of the dissolved ATM fuel samples, significant photopeak losses were observed because spectra were recorded with the source in very close proximity

to the primary and annular guard detectors, so the coincidence detection probability was very high. No additional photopeaks were detected using Compton suppression with this geometry. These experiments show that LaBr3-based Compton suppression systems would improve measured spectral results if oriented such that the gamma-ray photons are collimated to impinge the primary detector face as a beam. While HPGe-based Compton suppression systems resolve many more photopeaks, LaBr3 is suitable for applications that require room-temperature operation and less opportunity to perform maintenance.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 25

Monte carlo calculation of the response function of plastic scintillator using compton kinematics

Chankyu Kim[1], Hyunjun Yoo[1], Yewon Kim[1], Hyoungtaek Kim[1], Jong Yul Kim[1,2], Gyuseong Cho[1]

[1]*Department of Nuclear and Quantum Engineering, KAIST, Daejeon, Republic of Korea*
[2]*Neutron Science Division, Korea Atomic Energy Research Institute, Daejeon, Republic of Korea*

Plastic scintillators have been far away from gamma-ray due to low light yield in spite of their desired characteristics like fast decay time, low cost, availability in large scale and tissue-equivalence. Nevertheless, several attempts have been continued to use plastic scintillators for gamma-ray detection, especially in the field of dosimetry and homeland security.The Monte Carlo simulation is a general method used for predicting characteristics of a radiation detection system and analyzing of measured result. Particularly, the Gaussian Energy Broadening (GEB) option in MCNP is useful to simulate the energy-broadening effect of the detector, and makes the simulation result close to the measured spectra. To compute the input parameters for the GEB option, the full width at half maximum (FWHM) of each photoelectric peak are generally used. However, in case of organic scintillators including plastic, with gamma energies exceeding 50keV, the cross-section for photoelectric effect is lower than that for Compton scattering so that it is hard to find any photoelectric peak in the spectrum. From this reason, other method to estimate the energy broadening effect is required for the application of GEB when the organic scintillators are used.This research suggests the method to simulate the response function of plastic scintillator close to the real spectra using Compton kinematics. Both methods to evaluate the energy broadening effect with the photoelectric peak and Compton kinematics will be compared using inorganic scintillator. And finally, it applied to the plastic scintillators and the simulated result will be compared with the measured gamma spectra.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 26

Comparison and optimization of neutron spectrum unfolding methods

Haonan Zhu[1], Michael Febbraro[1], Christopher Lawrence[2], Frederick Becchetti[1], Ramon Torres-isea[1]

[1]*University of Michigan, Dept. of Physics, Ann Arbo MI, 48109, USA*
[2]*University of Michigan, NERS, Ann Arbor MI, 48109, USA*

In organic scintillators, neutron spectrum unfolding is the process of obtaining the energy spectrum of neutrons from a light response spectrum from the detector. The process can be mathematically interpreted as a procedure to solve an ill-posed inverse matrix problem. However, the traditional methods based on step-by-step loops is a time-consuming process. In this paper, we present implementation of vectorization techniques and a comparative analysis of Maximum-Likelihood Expectation Maximization (MLEM), Conjugate Gradient Normalized Equations (CGNE), Dynamic Systems (DS), and Neural Networks algorithms. Our results demonstrate that with effective vectorization, the computation speed of spectrum unfolding is significantly improved with identical unfolding performance.

This work is supported by NSF grant PHY 0969456 and the University of Michigan Undergraduate Research Opportunity Program (UROP)

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 27

Semi-empirical Determination of Detection Efficiency for Voluminous Source by Effective Solid Angle Approach

M. Y. Kang[1], J. H. Kim[1], Jinhyeong Kim[1], H. D. Choi[1], G. M. Sun[2]

[1]*Department of Nuclear Engineering, Seoul National University, Seoul, Korea*
[2]*Neutron Utilization Technology Division, Korea Atomic Energy Research Institute (KAERI), Daejeon, Korea*

In the field of γ-ray measurements, the determination of full energy (FE) absorption peak efficiency for a voluminous sample is difficult, because the preparation of the standard sample with the same chemical composition and the geometrical configuration about a voluminous sample is not easy. So simulation or semi-empirical methods are preferred in many cases. Effective Solid Angle (ESA) Code which includes semi-empirical approach has been developed by the Applied Nuclear Physics Group in Seoul National University. ESA code converts FE absorption peak efficiency determined by using reference point γ-ray sources into that for a volume source such as cylinder or Marinelli beaker shapes.In this study, we validated ESA code by using two Marinelli type voluminous KRISS (Korea Research Institute of Standards and Science) CRM (Certified Reference Materials) sources and IAEA standard γ-ray point sources. An Ortec n-type HPGe detector with a relative efficiency of 31.7% was used. IAEA point sources (Co-60, Eu-152, Am-241 and Cs-137) were measured at the distance of 25 cm away from the detector window. KRISS CRM sources were measured on top of the detector head. Radioactive source of CRM is contained in 450 mL Marinelli beakers filled with diluted HCl solution or solid medium (agar). CRM sources contain Am-241, Cd-109, Co-57, Ce-139, Cr-51, Sn-113, Sr-85, Cs-137, Co-60 and Y-88. HyperGam code was used to analyze the area of peak in spectra. The calculated FE efficiency curve for a voluminous shape from point sources was compared with experimentally determined FE efficiency obtained with voluminous CRM sources.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 28

Efficiency calibration model fitting with correlated data

William R. Russ, John M. Kirkpatrick, Kara E. Morris, Brian M. Young

Canberra Industries, Meriden, CT USA

Peak efficiency calibrations for spectrometric analysis have traditionally ignored correlations in the input data when fitting analytical models and propagating associated errors. During fitting the calibration data points have been treated as independent. The computational process for performing linear least square fitting with correlated data has been established and is well understood. However, a practical implementation requires that inputs to the computation that determine the correlative associations must be provided and interpreted. A software interface that performs this task is shown and validated and the underlying process is discussed. The impact of explicitly treating the correlations of the calibration data is evaluated. A normalized correlation matrix is used as an abstraction that allows for different forms of the fitted polynomial model. During fitting, the correlation matrix is converted to the data covariance matrix appropriate for the particular functional form. The software interface provides for specifying the input calibration data manually or automatically from analyzed spectra and the calibration source certificate file. A global uncertainty can be specified that is associated with the source preparation aliquot volume that would correlate with all of the nuclides. Nuclide-specific correlated line uncertainties can be specified that are associated with the activity uncertainty for multi-line nuclides. Some knowledge of the attribution of component source certificate uncertainties as provided by source manufacturer documentation is required to appropriately apportion components in this scheme. However, the software also provides for direct entry of the correlation matrix values for cases not accommodated by this default approach. Once the calibration data and correlation matrix are specified, the software interface allows for performing the fit. Currently two standard function models are available: Linear and Dual. The form can be selected along with the desired fit order of the polynomial. A plot displays the model overlaid by the input calibration data points for evaluation and modification of the fit selections. Finally, the software provides for injecting the output model coefficients and covariance matrix error calculation terms into a spectral file for use during analysis. A software utility designed to explicitly treat correlated calibration data when fitting and propagating error has been developed and validated. Providing an accurate and convenient method of handling such correlated data can be important when such correlations are significant. An example of the relative error as a function of energy for a Eu-152 multi-line calibration source is shown to exhibit up to approximately 30% change in the uncertainty when correlations are considered.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 29

Challenge Spectra performance of the singles gamma spectrometry analysis using a new coincidence analysis package

Martin E. Keillor, Luke E. Erikson, Timothy J. Stavenger

Pacific Northwest National Laboratory

The Pacific Northwest National Laboratory (PNNL) is developing a custom software suite capable of automating many of the tasks required to accurately analyze coincident signals within detector arrays. This capability is required to enable rapid analysis of data collected with a new low-background intrinsic germanium array at PNNL. To utilize data collected from this system, PNNL has developed the gamma spectroscopy software "Melusine" to support the efficient analysis of list-mode data from multi-element detector arrays. We have performed initial tests to validate the "singles" analysis results produced by Melusine, which are thus far consistent with current industry-standard analysis tools such as Genie 2000. This work will provide an overview of the architecture and analysis capabilities of Melusine, and compare challenge spectra analysis results to those recorded by the Provisional Technical Secretariat of the Comprehensive Nuclear Test Ban Treaty Organization for their 2005 Proficiency Test Exercise.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 30

Improvements in standardless calibration procedures for micro-XRF

C. M. Sosa[1], V. M. Sbarato2[2], L. S. Del Lama[3], M. E. Poletti[3], R. D. Perez[1,2]

[1]*IFEG-CONICET, (X5016LAE) Ciudad Universitaria, Córdoba, Argentina*
[2]*Universidad Nacional de Córdoba (X5016LAE) Ciudad Universitaria, Córdoba, Argentina*
[3]*Departamento de Física - Faculdade de Filosofia Ciências e Letras de Ribeirão Preto. Universidade de São Paulo, Ribeirão Preto, Brazil*

The XRF emission from a bulk sample has not a linear dependence with elemental concentrations because of the so called matrix effects. The most versatile approach to correct matrix effects consists of the application of the Fundamental Parameter method (FP) which requires few calibration standards for the quantification of a wide range of matrices. For FP method, the physical processes in the sample leading to the XRF emission are described by a set of analytical equations. It requires a database of fundamental parameters and the spectral distribution of the excitation radiation as well. For the Microanalysis by XRF (micro-XRF), the high intensity and anisotropy of the photon flux at the output of the focalization lens difficult a direct determination of the emergent spectrum.Different techniques have been used in the past to estimate the excitation spectrum using indirect measurements, such as attenuation of the primary intensity, x-ray scattering and induced x-ray fluorescence in targets. The former methods are based on approximated theoretical models, which produces limitations in accuracy. The induced x-ray fluorescence in targets technique consists of the measurement of the x-ray fluorescence intensity from several thick targets covering the emission energy interval of the x-ray source. The method has the advantage that it not requires approximations or any assumption about the physical characteristics of the x-ray source keeping the accuracy less than 10%. A drawback is that the result of the method is the cumulative spectral distribution which is the energy integral of the spectrum x-ray source. However, the comparison of the cumulative spectral distribution determined with and without the lens by micro-XRF can be employed to characterize its focalization lens. In this work the development of an analytical approach employing this idea is presented and applied to characterize the focalization lens of our laboratory. After that a standardless calibration of the micro-XRF spectrometer by FP was developed and validated by quantification of reference standards.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 31

Calculation of the detection limit in radiation measurements with systematic uncertainties

John M. Kirkpatrick, William Russ, Ram Venkataraman, Brian M. Young

Canberra Industries, Inc., Meriden CT USA

A new, accurate, and robust numerical method has been developed for calculating detection limits for radiation measurements. A well established concept in the field of ionizing radiation measurements, the detection limit (L_D) or Minimum Detectable activity (MDA) is an a priori estimate of measurement sensitivity based on straightforward principles of classical hypothesis testing as originally set out by L. A. Currie in his landmark 1968 paper on the subject. In the past, calculations of the detection limit have almost universally relied on the asymptotic Gaussian approximation to Poisson counting statistics; they have also typically neglected to treat systematic uncertainties, such as those related to calibration parameters, which can nevertheless be significant components of the total measurement uncertainty and thus important contributors to an evaluation of measurement sensitivity. One recent attempt to update the detection limit formalism was described in the ISO 11929:2010 standard, which sought to set the problem of detection limits on a rigorous Bayesian theoretical footing, while also extending the standard method to incorporate systematic uncertainties in calibration parameters. A shortcoming of that method is that it fails to make use of significant prior information available in the form of obvious physical constraints on the measurement problem, and as a result utilizes inappropriate assumptions of Gaussian behavior to approximate the posterior distributions of the calibration parameters. The result was the development of an approximate formula that works best only for small values of the relative systematic uncertainty, for which such a modification of Currie

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 32

Time-correlated neutron analysis of a multiplying HEU source

Eric C. Miller[1], Jeff M. Kalter[1], Chris M. Lavelle[1], David L. Chichester[2], Scott M. Watson[2], Matt T. Kinlaw[2], William A. Noonan[1]

[1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD
[2]Idaho National Laboratory, Idaho Falls, ID

The ability to quickly identify and characterize special nuclear material remains a national security challenge. In counter proliferation applications, identifying the neutron multiplication of a sample can be a good indication of the level of threat. Currently neutron multiplicity measurements are performed with moderated He-3 proportional counters. These systems rely on the detection of thermalized neutrons, a process which obscures both energy and time information from the source. Fast neutron detectors, such as liquid scintillators, have the ability to detect events on nanosecond time scales providing more information on the temporal structure of the arriving signal and provides an alternative method for extracting information from the source. To explore this possibility, a series of measurements were performed on the Idaho National Laboratory's MARVEL assembly, a configurable HEU source. The source assembly was measured in a variety of different HEU configurations and with different reflectors, covering a range of neutron multiplications from 2 to 8. The data was collected with liquid scintillator detectors and digitized for offline analysis. A novel approach for identifying the bursts of detected neutrons associated with the same fission chain was used. Using this approach we are able study various statistical properties of individual fission chains. One of these properties is the distribution of neutron arrival times within a given burst. We have observed two interesting empirical trends. First, this distribution exhibits a weak, but definite, dependence on source multiplication. Second, there are distinctive differences in the distribution depending on the presence and type of reflector. Both of these phenomena might prove to be useful when assessing an unknown source. The physical origins of these phenomena can be illuminated with help of MCNPX-PoliMi simulations.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 33

Development of a wavelength shifting fiber Detector Prototype for Thermal Neutrons based on a Chip readout electronic

Ralf Engels, Uwe Clemens, Andreas Erven, Willi Erven, Hubert Gorke, Johannes Heggen, Guenter Kemmerling, Tobias Kollmann, Heinz Loevenich, Jakob Schelten, Christian Wesolek, Stefan Van Waasen

Forschungszentrum Juelich GmbH - ZEA-2

A neutron detector prototype based on wavelength shifting fibers and a LiF/ZnS scintillator plate has been developed as an alternative to He-3 gas detectors. The development of alternative technologies for pure and applied neutron science has been driven by the foreseen He-3 shortage. Neutron scintillators are an important class of neutron detectors, in particular for scattering experiments with thermal neutrons. For this applications the scintillators have to be optimized in thickness for absorption, position resolution and light re-emitting properties. In our prototype a LiF/ZnS, from the company Eljen, has been selected as scintillator. Each WLS-fiber is mounted to a pixel of a multi-anode photomultiplier (MaPMT, H7546

300 from Hamamatsu) collecting the light individually from 64 fibers, with a photocathode structured as a mask of 8 x 8 pixels. The prototype consists of 32 WLS fibers per layer and of new chip based readout electronic for such a multi-anode photomultiplier. The idea is to sort the multi¬ anode signals to the pins from the MAROC chip (from Omega), connected with the second board, called MAROC board, via one connector. Here the MAROC is placed on bottom layer and the top layer is holding connectors for the Pre FPGA board. The FPGA board is connected via an optical link to the DAQ system, a standard computer with software environment. In this paper the properties of the components of such a detector setup are studied with a prototype, which aims at an efficient light detection by photomultipliers and the Chip readout electronic.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 34

Electronics Upgrade for Position Sensitive Neutron Detectors

Guenter Kemmerling, Uwe Clemens, Ralf Engels, Hubert Gorke, Johannes Heggen, Tobias Kollmann, Heinz Loevenich, Jakob Schelten, Christian Wesolek, Stefan Van Waasen

Forschungszentrum Juelich GmbH - ZEA-2

There is a long-lasting experience with scintillation detector systems for neutron scattering experiments at the Central Institute of Engineering, Electronics and Analytics ZEA 2 Electronic Systems. An in house developed readout electronics, which was designed in early 2000, for high resolution position sensitive neutron detectors, is in continuous operation at the research reactor FRM II in Munich. Nevertheless, it is necessary to upgrade the electronic, since the instruments require more flexible measure modes e.g. on time of flight and on special region of interest, namely on different sections on the sensitive detector area. At present a 5-inch position sensitive photomultiplier with a Li-glass scintillator in front is used for this purpose. Another detector setup is based on a H8500 multi-anode-photomultiplier (MaPMT). The MaPMT is a 12 stage vacuum photomultiplier with a squared input window of the flat panel with a matrix of 8 x 8 anodes (also referred as pixels) for charge collection and position sensing. Due to the low collection efficiency in the inter-pixel regions the high-effective area is approximately 49 mm2. The new readout electronics of the MaPMT based scintillation detector has already been tested in the lab with a light source. Both detector systems allow a detailed analysis of Bragg peaks, which often is required to define an advanced background separation and to reveal and evaluate double peaks. This is also useful in reflection and refraction experiments where a narrow beam hits a sample surface at glancing angles. A multi detector with high spatial resolution is mandatory. For all instruments, which are actually using 5-inch neutron detector, a new flexible readout electronics was designed with an analogue board as a common mezzanine card (CMC), hooked on an in house developed Compact-PCI card. The same readout electronics is also useful for the H8500 based detector system. Characterization of the data acquisition board, studies of the neutron event recognition and measurements of gamma sensitivity and neutron detection efficiency, will be carried out at a neutron beam at FRM II and will be presented in this paper.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 35

Compensation of Detector Capacitance via a Charge-Sensitive Preamplifier modified with a Bootstrap Amplifier

Inyong Kwon, Taehoon Kang, Mark D. Hammig

University of Michigan, Ann Arbor, MI, USA

We describe an integrated circuit design for a modified charge-sensitive amplifier (CSA) that compensates for the effect of capacitance presented by nuclear radiation detectors. For applications that require large area semiconductor detectors or for those semiconductor sensors derived from high permittivity materials such as PbSe, the detector capacitance can degrade the voltage gain and increase the noise during pulse formation. In order to suppress the effect of sensor capacitance, we applied a bootstrap technique into a traditional CSA. The technique exploits the Miller Effect by reducing the voltage difference between the two sides of a radiation detector which minimizes the capacitance presented to the differential common-source amplifier. This new configuration is successfully designed to produce effective gain even at high detector capacitance. The entire circuit, including a core CSA with feedback components and a bootstrap amplifier, are implemented in a 0.18 μm CMOS process with a 3.3 V supply voltage.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 36

Detection and Imaging of Pulsed Neutrons with Solid-State Electronics

John Chatzakis[1], Hercules Rigakis[1], Syed M. Hassan[2,3], Eugene L. Clark[2], Paul Lee[4]

[1]*Department of Electronics, TEI of Crete, Chania 73133, Crete, Greece*
[2]*Center for Plasma Physics and Lasers, TEI of Crete, Chania 73133, Crete, Greece*
[3]*School of Nuclear Engineering, Purdue University, West Lafayette, IN 47907, USA*
[4]*NSSE, National Institute of Education, Nanyang Technological University, Singapore 637616, Singapore*

Efficient fast and thermal neutron detectors are generally required to detect the special nuclear materials. For many applications the neutron and gamma-ray detectors must have fast response, portable, low cost, and should be deployed with large or small detection area. A solid-state detector based on materials activation caused by neutrons, and detection of the secondary particle emission of their decay is presented. The detector utilizes a micro-controller capable to communicate using the I^2C protocol. An image sensor can be made by using a number of these detectors, capable to communicate with an interface unit and pass an image to the personal computer. The low-noise semiconductor neutron detector is initially designed to detect the fast neutron pulses emit by a pulsed neutron generator based upon the dense plasma focus device. When deuterium gas is used, up to 10^6 neutrons per shot are produced by the plasma focus with a temporal pulse width of a few tens of nanoseconds. Measurements of the space- and time-resolved characteristics of the pulsed neutrons require large area detection materials and fast circuitry that processes the electronic pulse readout from each semiconductor detecting layer or pixel. Numerical simulations are used to find the electrical characteristics of the plasma device including the scaling of bank energies with total current and focus pinch current and the scaling of neutron yields with energies and currents. Monte Carlo simulations are used to determine the detector's efficiency and the optimal design parameters values. In addition to neutron detection, this detector can be used as a radiation monitor in the medical industry.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 37

Development of a manufacturing capability for stilbene scintillation crystals

Candace Lynch, Sergey Selin, Anthony Inzalaco, Thomas Caughey

Inrad Optics, Northvale, NJ

We report on the commercial production of the organic scintillation crystal stilbene. Stilbene has long been recognized as an excellent material for detection of fast neutrons in a gamma-ray background, but material availability has limited its widespread use. Recently, solution crystal growth was proposed as a potentially cost-effective route for production of organic scintillators. Solution growth is appealing compared to the conventional melt growth process – it is often simpler and less expensive, and can be scaled up to produce large, high quality crystals. Challenges include the need for hardware which resists attack by organic solvents and the requirement for high purity raw materials. We have leveraged our existing commercial solution growth capability at Inrad Optics to demonstrate the viability of solution growth for production of large stilbene boules. Stilbene crystals grown at Inrad Optics have dimensions suitable for production of parts up to 4" in diameter. Boules have been fabricated into a variety of geometries, such as cylinders, bars, and thin plates. The pulse shape discrimination figure of merit of Inrad Optics stilbene is 4.7, which is equivalent to stilbene grown from the melt and superior to liquid and plastic organic scintillators.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 38

Optimizing operational temperature to minimize polarization effect in TlBr detectors

[1]*Department of Nuclear Engineering, University of Michigan, Ann Arbor, MI*
[2]*Radiation Monitoring Devices, Watertown, Massachusetts*

Due to a high stopping power and large band gap, thallium bromide (TlBr) is an attractive semiconductor material for room-temperature gamma ray spectroscopy. Previous results have shown that 5 mm thick pixelated TlBr detectors can achieve <1% FWHM energy resolution at 662 keV for single pixel events. However, after days to months of room-temperature operation, these devices fail, or polarize. Research is ongoing to minimize polarization effects in TlBr. Two successful approaches are to (1) cool the detector to -20ºC and (2) use Tl electrodes while periodically changing the polarity of the bias. Method 2 is not ideal for stable operation. Historically, -20°C was chosen for convenience because it is achievable

by conventional freezers. This work uses temperature dependent leakage currents to predict a more optimal operating temperature. Results are presented for temperatures just above 0°C where the leakage current is close to minimal and significant condensation does not occur. These results are compared to the behavior of typical detectors at room-temperature and -20ºC to determine if polarization occurs near 0ºC.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 39

The cosmic ray muon tomography facility based on large scale MRPC detectors

Xuewu Wang[1,2], Ming Zeng[1,2], Jianping Cheng[1,2], Zhi Zeng[1,2], Yi Wang[1,2], Ziran Zhao[1,2], Xiaoguang Yue[1], Zhifei Luo[1], Hengguan Yi[1], Baihui Yu[1]

[1]*Department of Engineering Physics, Tsinghua University, Beijing, 100084, China*
[2]*Key Laboratory of Particle & Radiation Imaging (Tsinghua University), Ministry of Education, Beijing, 100084, China*

Cosmic ray muon tomography is a novel technology for high-Z material detection with high penetration and intrinsic safety feature developed recently. Since 2011, Tsinghua University Cosmic Ray Muon Tomography Group have developed the prototype cosmic ray muon tomography facility with 73.6 cm × 73.6 cm large scale 2D position sensitive MRPC detectors, and the double-fine multiplex readout electronics have been developed to deal with the 2880 channels of induced signals. The images of cosmic ray muon tomography with experiment data was reconstructed based on PoCA reconstruction algorithm. The experiment results are well consistent with the simulation data. This prototype will provide a platform for further studies of the physical characteristics and the performances of cosmic ray muon tomography.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 40

Lifetime Measurements Using Gamma-Ray Imaging in GRETINA

Robert Crabbs[1,2]

[1]*Nuclear Engineering, University of California at Berkeley, Berkeley*
[2]*Applied Nuclear Physics, Lawrence Berkeley National Laboratories, Berkeley*

GRETINA is an array of segmented, position-sensitive HPGe detectors housed in a spherical frame. Its 7 modules cover approximately 1π steradian of the central cavity, and offer 40% peak-to-total for ^{60}Co. I seek to use this array and its Compton imaging capabilities to measure the lifetimes of short-lived nuclear states produced in accelerators. Theoretically, Compton Imaging can extract these lifetimes "for free", using the same data taken during spectroscopy runs. This is extremely attractive for beam scheduling. The current lifetime measurement approach – the "Recoil Distance Method", or RDM – requires dedicated, labor-intensive experiments and a great deal of beamtime.Compton Imaging attempts to reconstruct the decay curve for the recoil nuclei traveling down the beam axis. Under ideal conditions, it becomes straightforward to compute the lifetime using a simple exponential fit. However, imaging is limited both by statistics and by the position-sensitivity within GRETINA

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 41

Trends in physical and device parameters for electron directional sensitivity for electron track Compton imaging

Brian C. Plimley[1], Amy Coffer[1], Kai Vetter[1,2]

[1]*Nuclear Engineering Department, University of California at Berkeley, Berkeley, CA*
[2]*Applied Nuclear Physics, Lawrence Berkeley National Laboratory, Berkeley, CA*

Electron track Compton imaging can show increased detection sensitivity over conventional Compton imaging through a reduction in background. The background reduction corresponds to the precision in measuring the initial trajectory of the Compton-scattered electron in the detection system. However, precise direction measurement is challenging due to the tortuous path typical of electrons.Silicon charge-coupled devices (CCDs) are one compromise between detection efficiency and a longer electron scattering length scale. Silicon CCDs offer excellent energy

resolution (<1%) and position resolution in two spatial dimensions (10.5 μm), with a significant active thickness (650 μm). We have previously demonstrated electron track Compton imaging with a CCD, benchmarked our models used to evaluate the electron direction sensitivity, and presented preliminary simulated sensitivity for modeled devices with different parameters of pixel pitch and device noise.In this paper, we examine more fundamental physical and technical limits to electron trajectory reconstruction. The parameters we analyze include electron energy, angle of inclination relative to the device plane, device pixel pitch (position resolution), device noise, and lateral diffusion in the device. The relationships among parameters are apparent when the parameters are normalized to the basic length and energy scales in the measurement. The basic length scales are the extrapolated range of electrons and the position resolution of the detector, while the basic energy scale is the amount of energy deposited by the electron in a distance equal to the position resolution of the detector. We show that the relationships among these parameters are consistent over the range of parameter values studied.nAlthough the analysis has been performed with our own direction reconstruction algorithm and modeled CCD responses, the resulting relationships have a broader relevance. Any high-resolution device measuring electron trajectories, particularly those measuring a two-dimensional projection of the electron trajectory, might be expected to show very similar relationships between parameters.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 42

Neutron Dose Equivalent Evaluation from the D-D Neutron Generator at the University of Florida

Heejun Chung[1], Chae Young Lee[2], Yong Hyun Chung[2], Kelly Alexander Jordan[1]

[1]University of Florida, Department of Materials Science and Engineering, Gainesville, FL 32611, U.S.A
[2]Yonsei University, Department of Radiological Science, Won-ju, S. Korea

A D-D neutron generator with a maximum intensity of 4 x 10^9 neutrons/sec was newly designed and installed at the University of Florida for nuclear science and security applications. For safety monitoring, the average dose equivalent rate was measured by a bonner ball neutron detector at 19 monitoring points, and resulted in less than 1 mrem/hr at the restricted area and 0.5 mrem/hr to the public.However, the question of reliability about these measured data still remains since the indicated value on a bonner ball is not clearly readable (analogue) and the generated neutron yield is not constant due to variations in the high voltage and current supplies to the generator. Therefore, a validation study of the measured average dose equivalent rate is required to ensure that these measured values meet regulatory requirements given in 10CFR20 and part IV of Florida Administrative Code.The average dose equivalent rate is typically estimated by Monte Calro simulation codes, MCNP and GEANT4. Each simulation tool has been developed based on different nuclear libraries and statistical models so the final result possibly varies. Some studies have already reported the difference between MCNP and GEANT4 is existed, and sometimes it is significantly different even though the simulation condition and geometry are the exactly same.To evaluate more accurate estimates, both MCNPX and GEANT4 simulations with the same condition and geometry were performed at the 5 highest dose points from the 19 monitoring points. The values from each simulation tool and the experimental results were almost overlapped with each others within 5 % at the restricted areas. However, the simulation results to public showed lower dose, almost a factor of 10, than the experimental data. The averaged simulation values are 0.49 mrem/hr at the restricted areas and 0.03 mrem/hr to public.Additionally, partial dose equivalent rates for 5 major organs of an operator were simulated with ORNL adult male phantom via MCNPX. In the simulation, the flux-to-dose conversion coefficients were obtained from the NCRP-38, the phantom was faced towards the generator room, and the max neutron generation yield was assumed (4x10^9 neutrons/sec). The simulation results respectively showed 0.56, 0.82, 0.96, 0.48, and 0.83 mrem/hr for skin, liver, stomach, brain, and heart.This study was performed based on the Brain Korea 21 project (BK 21) and the memorandum of understanding for a joint research agreement between the University of Florida and Yonsei University.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 43

Petawatt Laser Based Muon Source and Detector for Rapid High-Z Material Detection

Todd Ditmire[1], J. Andrew Green[2], David Schwellenbach[2], Wendi Dreesen[2], J. Rick Wood[3], Mark K. Browder[3]

[1]National Energetics
[2]National Security Technologies
[3]Lockheed Martin

This paper presents the experimental design and analysis for a proof of principle test of a Petawatt laser based muon source and associated detector system for the purpose of rapid high-Z material detection. The objective system can be used as a precursor scan for a more thorough x-ray system scan, or ultimately, as a stand-alone "muon radiography" system. The work is exploratory and utilizes a Petawatt short pulse laser system to generate a burst of muons well above background rates. The muons are expected to behave as a point source with some directionality. A well-known point source location eliminates the requirement for an initial detector array to establish entry into the target volume, and requires only one detector array behind the target inspection volume. Initial production rates, energy spectrum, and estimates of angular distributions are presented. The detector system based on a gas-tube combined with scintillator material is also presented along with our approach to differentiating the muons from the expected high energy gammas and secondary's. The success of the experiment will be based on the ability to differentiate gammas and muons, confirming muon angular distribution, and data indicative of the number of muons generated.*

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 44

Cyclic neutron activation analysis using deuterium-tritium fusion neutrons for half-life analysis and actinide mixture characterization

Bruce David Pierson, Marek Flaska, Sara A. Pozzi

Detection for Nuclear Nonproliferation Group, University of Michigan, Ann Arbor

Cyclic neutron activation analysis (CNAA) using deuterium-tritium fusion neutrons is an uncommon method of material characterization when compared to mass spectroscopic techniques, with exception to a few material impurities such as oxygen. Alternative techniques such as prompt gamma neutron activation and mass spectroscopy are, generally, capable of satisfying the needs of commercial/research entities. However, the complexity and cost of building facilities to utilize these broadly applicable material-analysis techniques may be unnecessary in cases where 14-MeV neutrons can be used to induce threshold reactions with high specific activities; this approach, coupled with lower cost, improved performance, and considerable emission intensity of fusion-neutron sources, makes material analysis using fusion-neutrons a more viable alternative for several applications.The University of Michigan's Neutron Science Laboratory has completed a pneumatic transfer system designed to perform relative impurity measurements and half-life measurements of high specific activity activation products. An irradiation of zirconium-fluoride was performed to measure the half-lives of 16N, 19O, and 90mZr. Finally, samples of depleted-uranium and highly-enriched uranium encapsulated at 50 parts-per-million in silica glass were cyclically irradiated and counted using a single high-purity germanium detector acquiring data in list-mode.Results of the half-life estimates of 16N, 19O, and 90mZr, and spectral comparisons of the depleted and highly-enrich uranium will be presented and discussed in detail to assess CNAA's performance.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 45

Induced Radioactivity Research for the NSRL Linac

Lijuan He, Weimin Li, Yuxiong Li, Yukai Chen, Guangyi Ren

NSRL, USTC, Hefei, Anhui, China

The 200-MeV electron linac of NSRL located in Hefei is one of the earliest high-energy electron linear accelerators in China. The electrons are accelerated to 200MeV by five acceleration tubes and collimated by the scrapers. The scraper aperture is smaller than the acceleration tube one, so some electrons will hit the materials when passing through them. These lost electrons will cause induced radioactivity mainly due to photonuclear reaction. The measurements showed that electrons were lost mainly at the scraper. So the induced radioactivity of the NSRL Linac is mainly produced here. The radionuclide types have been simulated using FLUKA and measured with HPGe γ spectrometer. The linac mentioned above had been retired because of upgrading yesteryear. The components removed are used to study induced radioactivity. The research will provide the theoretical basis for the similar accelerator decommissioning plan, and is significant for accelerator structure design, material selection and radiation protection design.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 46

True coincidence summing correction and mathematical efficiency modeling of a well detector

Henrik Jäderström[1], Wilhelm F. Mueller[1], Valery Atrashkevich[2], Aderemi S. Adekola[1]

[1]*Canberra Industries, Inc., 800 Research Parkway, Meriden, CT, 06450, USA*
[2]*Stroiteley street 4-4-52, Moscow, Russia*

True coincidence summing (TCS) occurs when two or more photons are emitted from the same decay of a radioactive nuclide, and are detected within the resolving time of the gamma ray detector. TCS changes the net peak areas of the affected full energy peaks in the spectrum and the nuclide activity is rendered inaccurate if no correction is performed. TCS is independent of the count rate, but it is strongly dependent on the peak and total efficiency, as well as the characteristics of a given nuclear decay. The TCS effects are very prominent in the well detectors because of the high efficiencies, and makes accounting for TCS a necessity. For Canberra's recently released Small Anode Germanium (SAGe) well detector, an extension to Canberra's mathematical efficiency calibration method (In Situ Object Calibration Software or ISOCS, and Laboratory SOurceless Calibration Software or LabSOCS) has been developed that allows for calculation of peak and total efficiencies for well detectors. The extension also makes it possible to calculate TCS corrections for well detectors using the standard algorithm previously developed for Canberra's Spectroscopy software Genie-2000. The peak and total efficiencies from ISOCS/LabSOCS have been compared to MCNP with agreements within 3% for peak efficiencies and 10% for total efficiencies for energies above 30 keV for samples inside the well. The TCS correction factor have been compared to MCNP-CP for over 2000 lines and the majority of the correction factors agree within 20%. Samples within the well have been measured and analyzed with and without TCS correction and the applying the correction factor shows significant improvement of the activity determination. The implementation of ISOCS/LabSOCS for well detectors offers a powerful tool for efficiency calibration for these detectors. The automated algorithm to correct for TCS effects in well detectors makes nuclide specific calibration unnecessary and offers flexibility in carrying out gamma spectral analysis.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 47

Electrical field simulation of an ionization chamber of parallel plates and graphite collecting electrode

Fernanda Beatrice Nonato, Felipe Belonsi Cintra, Linda Viola Ehlin Caldas

Gerência de Metrologia das Radiações, Instituto de Pesquisas Energéticas e Nucleares (IPEN), São Paulo - Brasil

Some ionization chambers of different types were designed and built to be applied in different radiation beams at the Calibration Laboratory of IPEN/CNEN. An ionization chamber of parallel plates was developed for use in electron beams of linear accelerators. This ionization chamber presents simple construction, its body is made of acrylic and the collecting electrode is painted with graphite powder mixed with nail polish. The sensitive volume of the ionization chamber is 0.34 cm^3 and the collecting electrode diameter is 1.7 cm. The ionization chamber was developed according to the TRS 398 and TRS 381 recommendations (IAEA, 1995; IAEA, 2009). The Maxwell 2D software was used to simulate the electric field and its behavior, specially at the extremes of the nominal sensitive volume. The applied electric potential was 300 V between the electrodes. The electrical field outside the parallel plates, at the acrylic bulk was also studied. Finally, a radiation transport characterization was used with the MCNP5 code to estimate the charge created inside the sensitive volume. Using the Hetch formula, it is possible to estimate a saturation curve of this ionization chamber that can be compared with experimental data.IAEA (International Atomic Energy Agency), 1995. The use of plane-parallel ionization chambers in high-energy electron and photon beams. An international code of practice for dosimetry.Technical Report Series No. 381, IAEA, Vienna.IAEA (International Atomic Energy Agency), 2009. Absorbed dose determination in external beam radiotherapy: An international code of practice for dosimetry based on standards of absorbed dose to water. Technical Report Series No. 398 (v. 12) IAEA, Vienna.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 48

Comparative study of neutron and gamma-ray pulse shape discrimination of anthracene, stilbene, and p-terphenyl

Takayuki Yanagida[1], Kenichi Watanabe[2], Yyutaka Fujimoto[1]

[1]*Kyushu Institute of Technology*
[2]*Nagoya Univ.*

Organic scintillators have played a major role in ionizing radiation detectors. In this study, conventional bulk organic crystalline scintillators, anthracene, stilbene, and p-terphenyl were investigated on their basic scintillation properties and neutron/gamma discrimination capabilities. Sample crystals were products and had sizes of 30 mmϕ x 10 mmt (anthracene) and 10 mmphiϕ x 10 mmt (other two crystals). At first, basic scintillation properties including X-ray induced radioluminescence and scintillation light yields were studied. Scintillation wavelengths under X-ray excitation of anthracene, stilbene, and p-terphenyl were 450-520, 400-500, and 350-450, respectively. Scintillation light yields of anthracene, stilbene, and p-terphenyl under 137Cs gamma-ray irradiation were 20100, 16000, and 19400 ph/MeV, respectively. Scintillation decay times of these organic scintillators were investigated under neutrons from 252Cf and under gamma-rays from 60Co irradiations. All scintillation decay time profiles were well reproduced by two components exponential assumption. Decay times under neutron irradiation of anthracene, stilbene, and p-terphenyl were 32+370, 5.3+50, and 4+31 ns, respectively. Differences of neutron/gamma events were observed in slower component. In neutron induced scintillation decay time profiles, relative ratio of the slower component became lower compared under gamma-ray excitation. Neutron/gamma events were clearly separated by using pulse shape discrimination technique based on the ratio two different components (fast/slow) in these organic scintillators.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 49

Response evaluation of a small radiation detector using OSL with optical fiber readout to high energy carbon ions

Kenichi Watanabe[1], Hidefumi Miyamae[1], Atsushi Yamazaki[1], Akira Uritani[1], Yusuke Koba[2], Naruhiro Matsufuji[2]

[1]*Graduate School of Engineering, Nagoya University, Nagoya, Japan*
[2]*National Institute of Radiological Sciences, Inage, Japan*

Radiotherapy is one of the most important treatments of cancer. Recently many irradiation methods have been developed, which can locally concentrate radiation dose into tumors such as IMRT (intensity modulated radiation therapy) and particle radiotherapy. In order to assure treatment procedures, a radiation detector is required to be inserted into an affected part in a patient body. Therefore, detectors are desired to be miniaturized as small as possible. We, therefore, have developed a small size radiation detector using an optically stimulated luminescence (OSL) material with optical fiber readout. We aim to apply our detector to quality assurance in heavy particle radiotherapy. For practical use, the detail response of the detector should be characterized. In this paper, we evaluate the detector response for high energy carbon ions at HIMAC facility of National Institute of Radiological Sciences. We fabricated a prototype small detector using a small Eu:BaFBr as an OSL material with an optical fiber readout with less than 1 mm diameter. Through the optical fiber, stimulation laser light was irradiated onto the OSL material and stimulated fluorescence was detected with a photomultiplier tube mounted at another end of the optical fiber. The fabricated small detector head was set in a water equivalent phantom. High energy carbon ions with the energy of 290 MeV/n were irradiated into the water phantom. The depth profile of the detector output was evaluated. Although the Bragg-curve can be confirmed, the sensitivity, defined as the ratio of outputs of the evaluated detector to a standard ion chamber, decreases near the Bragg-curve. The relationship between the sensitivity and the stopping power was evaluated. The stopping power dependence of the detector sensitivity can be useful to correct the detector output for the dose monitoring. We, additionally, evaluated the uncertainty of the detector output. The uncertainty per readout was evaluated to be 0.6 mGy, which is independent of the dose rate. This means that fluctuation origins independent of the dose rate, such as electrical noise, are dominant under the current situation.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 50

Spectral Anomaly Methods for Aerial Detection using KUT Nuisance Rejection

Rebecca Detwiler, David Pfund, Mitchell Myjak, Carolyn Seifert

Pacific Northwest National Laboratory, 902 Battelle Boulevard, Richland, WA 99352 USA

This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-12-X-00376. This support does not constitute an express or implied endorsement on the part of the Government.This work discusses the application and optimization of a spectral anomaly method for the real-time detection of gamma radiation sources from an aerial helicopter platform. Aerial detection presents several key challenges over ground-based detection. For one, larger and more rapid background fluctuations are typical due to higher speeds, larger field of view, and geographically induced background changes. Any large variation in altitude or stand-off distance can cause significant steps in background count rate as well as spectral changes due to increased gamma-ray scatter with detection at higher altitudes. The work here details the adaptation and optimization of the PNNL-developed algorithm NSCRAD (Nuisance-Rejecting Spectral Comparison Ratios for Anomaly Detection), a spectral anomaly method previously developed for ground-based applications, for an aerial platform. The algorithm has been optimized for two multi-detector systems; a NaI(Tl) detector based system and a CsI detector array. The optimization here details the adaptation of the spectral windows for a particular set of target sources to aerial detection and the tailoring of the spectral windows and background tracking parameters for the specific detectors. As well, the methodology and results for background rejection methods optimized for the aerial gamma-ray detection using Potassium, Uranium and Thorium nuisance rejection is shown. Results indicate that use of a realistic KUT nuisance rejection may eliminate rises in the NSCRAD metric due to background magnitude and spectral steps encountered in aerial detection due to altitude changes and geographically induced steps such as at land-water interfaces.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 51

ARCIS: Adaptive Rail Cargo Inspection System

Anatoli Arodzero, Salime Boucher, Luigi Faillace, Mark Harrison, Scott Stroms

RadiaBeam Technologies, LLC, Santa Monica, CA

Existing requirements for high throughput rail cargo radiography inspection include high resolution (better than 5 mm line pair), penetration beyond 400 mm steel equivalent, material discrimination (organic, inorganic, high Z), high scan speeds (>10 kph, up to 60 kph), low dose and small radiation exclusion zone. To meet and exceed these requirements, research into a number of new radiography methods, new detector materials and design has been initiated.RadiaBeam Technologies is developing an innovative rail cargo X-ray scanning technique that promises dramatically improved penetration and imaging capability. Our Adaptive Rail Cargo Inspection System, ARCIS, will be able to provide radiographic scanning with material discrimination at speeds consistent with normal commercial operation.Novel concepts relying on Linac-based, adaptive, modulated energy X-ray sources, new types of fast X-ray detectors (Scintillation-Cherenkov detectors), and fast processing of detector signals are being developed. Crystalline inorganic detector materials, which may be suitable for these applications, will be discussed. These materials should combine a balance of scintillation and Cherenkov light and allow using Silicon Photomultipliers (SiPM, MPPC) for signal readout.This work has been partly supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-13-C-B0019. This support does not constitute an express or implied endorsement on the part of the Government.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 52

Fast neutron detection efficiency of EJ-313 and BaF_2 scintillators by ^{19}F activation

Pawel Sibczynski[1], Jan Kownacki[2], Marek Moszyński[1], Joanna Iwanowska[1], Agnieszka Syntfeld-każuch[1], Aneta Gójska[1], Frédérick Carrel[3]

[1]*National Centre for Nuclear Research, PL 05-400 Otwock, Poland*
[2]*Heavy Ion Laboratory, Warsaw, Poland*
[3]*CEA LIST Institute, Department of Metrology, Instrumentation & Information, Gif-Sur-Yvette, France*

Through the last years, detection of fast neutrons by means of ^{19}F activation in the scintillator medium plays an important role in Homeland Security. The method was proposed to detect prompt neutrons emitted due to photofission of Special Nuclear Materials (SNMs). The idea of this method relies on the fact that when the $^{19}F(n,\alpha)^{16}N$ or $^{19}F(n,p)^{19}O$ reactions occur, the ^{16}N and ^{19}O nuclei undergo β^- decay within few seconds after interaction. Then, it is possible to acquire β^- particles separately from accelerator's Bremsstrahlung flash and determine the presence of nuclear materials.In the present study /Phi/ 5" × 3" EJ-313 liquid fluorocarbon and /Phi/ 2" × 3" BaF_2 scintillators were exposed on neutron sources in order to compare the scintillators responses to detection of β^- particles with maximum energy of 10.4 MeV. After background subtraction and setting the energy gate between 6 – 10.5 MeV, fast neutron detection efficiency obtained by means of ^{19}F activation for the mentioned scintillators were estimated. Preliminary measurements showed that the fast neutrons detection efficiency of the side oriented /Phi/2" × 3"BaF_2 is only two times lower that that obtained for the front oriented /Phi/5" × 3" EJ-313.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 53

Stand-off radiation source localization with multiple directional sensors

Chuanlei Liu[1], Marc Desrosiers[2], Pierre-luc Drouin[1], Guillaume St-jean[3], David Waller[2]

[1]*Royal Military College of Canada, Kingston ON K7K, Canada*
[2]*Defence Research and Development Canada, Ottawa K1A 0Z4, Canada*
[3]*Communications Research Centre Canada, Ottawa K1A 0Z4, Canada*

Two algorithms have been developed to localize radioactive sources using a system of two or more directional radiation detectors. One is a point-of-closest-approach algorithm, while the other is a maximum likelihood algorithm. In order to test the performance of these algorithms, a variety of real and simulated scenarios have been studied with various gamma radiation sources. Two defence and security applications are of particular interest: one is the monitoring of a crossroads by a wireless radiation sensor network; the other is the deployment of a mobile radiation detection system that can differentiate a point source of radiation from an extended source of radioactive contamination. Results from both experimental and simulated data are presented. The maximum likelihood algorithm is shown to have superior performance (range and accuracy) for source localization. Comparing the ratios of detector counts for the mobile system application allows a differentiation of an extended, line source from a point source.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 54

Benchmarking the RadMAP Gamma-Ray Sensors

Joseph C. Curtis[1], Mark S. Bandstra[2], Victor Negut[2], Timothy J. Aucott[1], Daniel H. Chivers[2], Kai Vetter[1,2]

[1]*Nuclear Engineering, University of California Berkeley, USA*
[2]*Applied Nuclear Physics, Lawrence Berkeley National Laboratory, USA*

Mobile radiation detection platforms offer unique analysis and reconstruction opportunities including natural gamma-ray background analysis and radioactive source location reconstruction in the platform's surroundings. In order to characterize the detection hardware and algorithms used, precise understanding of the platform's response to known sources in required. The Radiological Multi-sensor Analysis Platform (RadMAP), originally built at the Naval Research Laboratories (NRL), contains sodium iodide and high-purity germanium detectors for the detection of gamma-rays. Two approaches were implemented to characterize the 10x10 sodium iodide array and 24 germanium detectors: A model was built using the NRL GEANT4 front-end SWORD to simulate the full spectral response of each detector including down-scattering sources like the ground between the source and detector. Additionally, a Python-based ray-tracing model was written to find an efficiency (linear attenuation) response to a source located at any point on a unit sphere around the vehicle (so-called "4π response"). Using experimental data from controlled scenarios with known sources, the simulation strategies are used to benchmark the efficiency and spectral response of the RadMAP vehicle.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 55

The Muon Portal detector: a double tracker to inspect travelling containers

V. Antonuccio[3], M. Bandieramonte[1,3], U. Becciani[3], F. Belluomo[6], M. Belluso[3], S. Billotta[3], A. Blancato[1], D.l. Bonanno[1], G. Bonanno[3], A. Costa[3], G. Fallica[4], S. Garozzo[3], V. Indelicato[1], P. La Rocca[1,2], E. Leonora[2], F. Longhitano[2], S. Longo[5], D. Lo Presti[1,2], P. Massimino[3], C. Petta[1,2], C. Pistagna[3], C. Pugliatti[1,2], M. Puglisi[6], N. Randazzo[2], F. Riggi[1,2], S. Riggi[3], G. Romeo[3], G.v. Russo[1,2], G. Santagati[1,2], G. Valvo[4], F. Vitello[3], A. Zaia[5], G. Zappalà[1]

[1]*University of Catania, Department of Physics and Astronomy, Catania, Italy*
[2]*INFN, Catania, Italy*
[3]*INAF – Astrophysics Observatory, Catania, Italy*
[4]*STMicroelectronics - Catania, Italy*
[5]*Insirio SPA, Messina, Italy*
[6]*Meridionale Impianti Welding Technology, Catania, Italy*

The "Muon Portal Project" aims at the design and construction of a working detector prototype in scale 1:1, to inspect the content of travelling containers by means of the secondary cosmic-ray muon radiation and recognize high-Z hidden materials (U, Pu or other fissile samples). The radiographic image is obtained by reconstructing the input and output trajectories of each muon and consequently the scattering angle, exploiting two trackers placed above and below the container. The scan is performed without adding any external radiation, in a reasonable time (a few minutes) and with a good spatial and angular resolution. The detector consists of 8 planes segmented in 6 identical modules. Each module is made of scintillating strips with two wavelength shifting (WLS) fibers inside, coupled to Silicon photomultipliers. The customized read-out electronics employs trading programmable boards. Thanks to a smart read-out system, the output channels are reduced by a factor 10. The signals from the front-end modules are sent to the read-out boards, where an adapter module is devoted to the convertion of the analog signal to a digital signal, by a comparison to a threshold. The data are pre-analyzed and stored into a data acquisition PC.Actually, an intense measurement and simulation campaign is in progress to characterize carefully the detector components. The first detection modules (1 x 3 m^2) is now under construction. The detector architecture with a particular attention to the used electronics, the main preliminary results will be presented.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 56

Implementing the Absolute Calibration Method into an Automated Radioxenon Software Platform

Matthew W. Cooper[1], James H. Ely[2], James C. Hayes[1], Justin I. Mcintyre[1], Brian T. Schrom[1], Thomas J. Suckow[1]

[1]*Pacific Northwest National Laboratory*
[2]*International Atomic Energy Agency*

Systems capable of performing automated field chemistry and then making an accurate measurement of the resulting radioactive components have many challenges. One of the challenges is maintaining confidence that the nuclear measurement is accurate, which requires calibration and quality control (QC) checks. The noble gas systems deployed for the International Monitoring System (IMS) have initial calibrations performed using radioxenon gases and have a QC source that is routinely measured to ensure system stability. Ideally, routine calibration audits would be performed to verify the calibration; however, this is not logistically possible for fielded systems. An absolute calibration method can be employed to provide a more holistic approach.PNNL is developing a software package called the Standalone Calibration Tool (SCT) to aid in the nuclear detector calibrations. As part of the automation process, SCT requires the system operator to use isotopically pure radioxenon samples for three of the four-radioxenon isotopes. A separate modeling and spectral generation program called the Beta-Gamma Simulator (BGSim) was developed to test and verify the absolute calibration technique, as well as to investigate radiometric interference between the four-radioxenon isotopes of interest. SCT can also be used to verify and correct detection efficiencies from radioxenon measurements taken during normal system operation. This may give analysts an additional tool to verify reported data and increase the overall data quality that is reported by the International Data Center to the National Data Centers.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 57

Energy Resolution Measurement of a Large LaBr3:Ce Detector for Low Energy Gamma Rays

Akhtar Abbas Naqvi[1], Fatah Zuhair Khiari[1], Mohammad M. Maslehuddin[2], Mohammad Ashraf Gondal[1], Omar S. Baghabra Al-amoudi[3]

[1]*Physics Department, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia*
[2]*Center for Engineering Research, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia*
[3]*Civil Engineering Department, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia*

Response of a large 100 mm x 100 mm (diameter x height) LaBr3:Ce detector has been measured for 0.2-1.0 MeV prompt gamma rays using a D(d,n) portable neutron generator-based PGNAA setup. Due to its large size, the LaBr3:Ce detector has higher intrinsic activity, thereby a higher dead time and smaller count rate handling capability. However due to larger solid angle, it still allows to reduce the counting time for better statistics. Performance tests of the large $LaBr_3$:Ce detector were carried out by measuring prompt gamma ray yields covering 0.2- 1.0 MeV gamma rays from cadmium acetate, boron oxide, and mercuric nitrate samples. Theoretical yield of prompt gamma rays was calculated from the samples using Monte Carlo simulation. Inspite of interference of detector and sample-associated prompt gamma rays, an excellent agreement between experimental yields and the theoretical yield of the prompt gamma rays has been achieved. This indicates the excellent performance of the $LaBr_3$:Ce detector in prompt gamma analysis of the bulk samples in spite of large intrinsic intensity. Results of this study will be presented.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 58

Multiple neutron interaction location reconstruction using a single volume neutron scatter camera

Kyle Weinfurther[1], John Mattingly[1], Erik Brubaker[2]

[1]*North Carolina State University, Raleigh NC*
[2]*Sandia National Laboratories, Livermore CA*

Dual plane neutron scatter cameras have been in operation for almost a decade. However, the requirement for a scatter in both planes causes dual-plane cameras to exhibit low counting efficiencies. An alternative to the dual plane design utilizes a single volume of scintillation material with pixelated photodetectors on at least two opposing faces. At a minimum, the neutron must scatter twice in the scintillator volume to reconstruct its incident direction. Previous results demonstrated that the scintillation position can be reconstructed with sub-millimeter accuracy and precision for a single interaction in the detector volume. Single interaction reconstruction results indicate that multiple interactions can be resolved at small distances between each interaction. In this paper, we will show the characterization of multiple interaction location reconstruction using time-integrated pixel intensity distributions. We will characterize the errors, uncertainties, and computational expense associated with the position reconstruction. We will also present the methodology used to determine initial guesses for scintillation locations supplied to the non-linear optimization algorithm. Errors in reconstruction as a function of photodetector pixel size will be shown. Finally, we will determine the minimum distance between interactions that can be resolved. The minimum distance will dictate the gain in detector efficiency the single volume neutron scatter camera can achieve relative to a dual-plane camera.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 59

Performance improvements to Segmented Silicon Drift Detectors : a key for their integration in portable gamma spectroscopy systems and beta monitoring systems

Olivier R. Evrard[1], Marijke Keters[1], Chaitanyia Cherukuri[1], Mathieu Morelle[1], Jason Pavlick[2], Bob Zakrezewski[2], Nabil Meena[2], Brett Robertson[2], Frazier Bronson[2], James Cocks[2]

[1]*CANBERRA Semiconductors*
[2]*CANBERRA Industries*

Performance improvements to Segmented Silicon Drift Detectors : a key for their integration in portable gamma spectroscopy systems and beta monitoring systems Evrard O., Keters M., Bronson F ,Cherukuri C., Morelle M., Pavlick J., Zakrzewski B., Meena N., Robertson B., Cocks. J.Recent progresses obtained in the consolidation of the leakage current densities and in the reduction of the series noise of LA-SSD – Linear Anode Silicon Drift Detectors (SSDDs) at room temperature have allowed the reaching of a resolution of 3.5 % @ 662 keV on a 0.9" LASDD detector (area 4 cm2) coupled to a 0.9" x1.2" LaBr3 scintillator. Resolutions of 4.5 % were reached at 45 °C without any need for cooling the detector with Peltiers. The analog charge Sensitive Amplifiers and the DSP-MCA Digital Signal Processing – Multi Channel Analysers systems that were used for this evaluation were the I-TRP (Integrated – Transistor Reset Pulse Charge Sensisitve Amplifier) and the LYNX of CANBERRA.nThese results and the compact nature of LA-SSDD devices combined with easy interfacing to mainstream read-out electronics qualifies them for being integrated in robust and cost efficient industrial compact spectroscopy systems for monitoring gamma rays. Some of their attributes are their mechanical robustness (no vacuum needed, no fragile glass parts or fragile electrodes), compatibility with interconnects technologies, and their absence of temperature dependency of the gain. This make them interesting alternatives to Photomultiplier Tubes (PM) for medium to high range energies applications where robustness, compactness and gain stability are required.In addition, the 4 cm2 LA-SSDD can be used as a beta detector. The measurement of C-14 sources can be carried out with excellent efficiencies since the noise thresholds of such devices is 7.2 keV for a segment of 3.55 cm2 at 20°C. Similar PIN diodes generally give thresholds of 27 keV. Combined gamma-beta systems can therefore be devised if small sized electronics can be coupled to the LA-SSDDs.The LA-SDD detector was developed for scintillation applications. The design of this detector minimises the number of collection anodes and therefore of segments and keeps the drift lengths minimal. Recent improvements in the anodes design described in this article allowed the upscaling of SSDDs from 0.7 " to 0.9",while keeping the same resolution of 3.5 % @662 keV. The reduction of the series noise when transitioning from ring linear anodes to the newly developed micro-linear anodes explains the progress made, allowing an upscaling of detector size. Uscaling to a detector diameter of 1" will be possible by further optimising the design of the micro-linear anodes.The industrialisation of the LA-SDDs will required smaller sized CSAs such as the VERDI ASIC realised by Polytechnico de Milano. This ASIC is made of 8 charge sensitive amplifiers-shapers on a chip size of 3 mm by 3 mm. Smaller sized LA-SDDs having a diameter of 0.7 " were coupled to the VERDI and to a compact low power back end, resolutions of 4.3 % for Cs-137 have been reached. The total power consumption of the system was under 2 Watts. This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-07-C-00033 & HSHQDC-10-C-00174. This support does not constitute an express or implied endorsement on the part of the Government.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 60

Radiation Hardness Characteristics of the Preamplifiers Based on Different Substrate Materials

Manhee Jeong, Woo Jin Jo, Han Soo Kim, Young Soo Kim, Jang Ho Ha

Korea Atomic Energy Research Institute, Jeongeup, Jeollabookdo 580-185, South Korea

We developed ultra-low noise single charge sensitive amplifiers (CSAs) based on a different type of substrate materials such as FR4, Teflon and ceramics with different design as KAERI-PA1 and KAERI-PA2. Different types of CSAs were tested to see the effects of noise from dielectric loss of substrate capacitance before and after irradiation. If the electronic noise on the CSAs is to be minimized and the energy resolution enhanced, it needs optimized shaping time to the detector and small feedback capacitance of the CSA for a better SNR. Teflon and ceramic based KAERI-PA1 have better noise performance than an FR4 based one, but Teflon based KAERI-PA1 shows better sensitivity than a ceramic based one. In KAERI-PA2, the equivalent noise and sensitivity were 0.52 (keV FWHM of Si) and 7.2 (mV/fC) with 2 μs peaking time and 0.1 pF detector capacitance, respectively. After 10, 100, 10^4 and 10^5 Gy irradiation the ENC and sensitivity characteristics of the developed CSAs based on three different substrate materials will be presented.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 61

Development of a data acquisition system for two-dimensional position sensitive detectors with delay line readout

Andrei R. Hanu[1,2], William V. Prestwich[1], Soo-hyun Byun[1]

[1]*Department of Medical Physics and Applied Radiation Sciences, McMaster University, Hamilton, ON, Canada*
[2]*NASA Goddard Space Flight Center, Greenbelt, MD 20771*

We present the development of a digital data acquisition (DAQ) system for position sensitive detectors that rely on the delay line method for two-dimensional readout. The DAQ system consists of a commercially available field-programmable gate array (FPGA) carrier board and a custom made time-to-digital converter (TDC) plugin card. During an acquisition, the TDC digitizes the elapsed time between a global start signal and four delay line signals. Position reconstruction is accomplished in the FPGA by calculating the time difference between pulse pairs corresponding to a common delay line. Based around the TDC-GPX application-specific integrated circuit (ASIC), the TDC plugin card features one common START channel, four independent STOP channels, a typical timing resolution of 81 ps, and a 17-bit measurement range. The DAQ system has been successfully tested with periodic event rates up to 1.8 MHz while the integral and differential non-linearities are better than 0.2 % and 1%, respectively. Output images are made up of 1024 x 1024 square pixels with a pixel depth of 32-bits and a timing resolution of 162 ps per pixel. Recently, the DAQ has been successfully applied to our general-purpose THGEM imaging detector using a two-dimensional delay line readout. The construction, operation, and limitations of the DAQ will be presented in detail.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 62

Prototypes of the Data Acquisition System for Thomson Scattering diagnostic

Ekaterina A. Puryga[1,2], Svetlana V. Ivanenko[1,3], Alina A. Ivanova[1], Aleksander I. Kotelnikov[1], Peter V. Zubarev[1], Andrey N. Kvashnin[1], Aleksander D. Khilchenko[1]

[1]*Budker Institute of Nuclear Physics, 630090, Novosibirsk, Russia*
[2]*Novosibirsk State Technical University, 630092, Novosibirsk, Russia*
[3]*Novosibirsk State University, 630090, Novosibirsk, Russia*

To determine plasma parameters in fusion devices with a time resolution, the approach of Thomson scattering is widely used. In diagnostic systems based on the method of Thomson scattering, plasma is probed by a high power pulsed laser beam. The task is to measure the intensity and spectrum of the scattered light signal. The intensity of radiation scattered on plasma electrons, is proportional to the electron density. When collective effects can be neglected, the scattered light spectrum is uniquely determined by the electron distribution function, which is characterized by the temperature in a case of Maxwellian plasmas.
This paper describes the prototype of the data acquisition system for a laser Thomson scattering diagnostic on GOL-3 and GDT magnetic mirror traps (BINP SB RAS, Novosibirsk, Russia), Globus M spherical tokamak (Ioffe Institute, St. Petersburg, Russia). The developed complex is also proposed for ITER (Cadarache, France). The measurement system developed for GOL-3 multi-mirror linear magnetic trap, is based on the digitizer unit with the ADC having the sampling frequency of 500 MHz and the amplitude resolution of 12 bits. The further evolution of the above-mentioned instrument is a prototype of the 48-channel data acquisition system with the sampling frequency of 2 GHz and the 10-bit digital resolution, which was designed recently. It is planned to be used on Globus M and ITER. Both data acquisition systems operate in an oscillographic mode of recording of the scattering signals. In parallel, another version of the data acquisition system for ITER is under development, where a method of time integration of signals is implemented instead of high-speed direct conversion. The basic module of this type for ITER has eight detection channels. The distinctive feature of this approach is a serial measurement of the light emission background and the composition of background and the laser signal. Subtracting them, an integral of the desired scattered signal over the detection time can be delivered independently in every measurement channel.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 63

A High-Speed Electron Beam Profile Monitor for the Synchrotron Radiation Source

Aleksandr I. Kotelnikov, Aleksandr D. Khilchenko, Andrey N. Kvashnin, Oleg I. Meshkov, Alina A. Ivanova, Ekaterina A. Puryga, Svetlana V. Ivanenko, Peter V. Zubarev

Budker Institute of Nuclear Physics, Novosibirsk, Russian Federation

The real-time processing of the electron beam parameters is a necessary procedure to optimize the key characteristics of the synchrotron radiation source using feedback loops. The actual problem is to study multi-bunch beam instabilities. To solve this problem a high-speed electron beam profile monitor is developed. This device includes a photodetector unit and signal recorder. The photodetector unit is bult on a photodiode strip consisting of 16 integrated avalanche photodiodes. Electric pulses from the photodiodes are fed to inputs of analog integrators. The integrator is designed for input pulse repetition rate of 200 MHz. The 16-channel signal recorder fixes the integrals values, performs their 16-bit analog-to-digital conversion and buffering in the internal 3 Gb memory. The accumulated data is transferred via Ethernet 100BASE-T. The device described must continuously implement 15625000 measurements of the vertical or horizontal electron beam profile at 16 points with a time resolution of 5 ns.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 64

Utilization of Wavelength-Shifter Fibers Coupled to ZnS(Ag) and Plastic Scintillator for Simultaneous Detection of Alpha/Beta Particles

Yair Ifergan[1], Shay Dadon[1], Itamar Israelashvili[2], Alon Osovizky[3], Ehud Gonen[1], Dvir Smadja[1], Yakir Knafo[3], Dmitry Ginzburg[3], Yagil Kadmon[1], Yosef Cohen[1], Tzachi Mazor[1]

[1]*Electronics & Control Laboratories, Nuclear Research Center- Negev, Beer-Sheva, Israel*
[2]*Physics Department, Nuclear Research Center of the Negev, P.O. Box 9001, Beer Sheva, Israel*
[3]*Radiation Detection Department, Rotem Industries Ltd, Israel*

Low level radioactive surface contamination measurements require lightweight, large area and high efficiency detector. In most existing scintillation detectors there is a tradeoff between effective area and scintillation light collection. Direct coupling of the Photomultiplier tube (PMT) to the scintillator would limit the effective detection area to that of the PMT's dimensions. On the other hand, Indirect coupling of the PMT to the scintillator would reduce the quality of light collection, and hence would reduce the signal to noise ratio and minimum detectable activity (MDA). By using wavelength shifting (WLS) fibers the scintillation light may be collected efficiently also in a large area detector.In this study, 32 WLS fibers (BCF-91A, 1mm-diameter and 330mm-length) were coupled to a beta sensitive plastic scintillator layer (BC-400, 50x200x1mm thick) on one side, and to a alpha sensitive ZnS(Ag) layer (25mg/cm^3 thickness) on both sides, for detecting both alpha and beta particles. The WLS fibers collect the emitted light from the plastic scintillator (emission peak at 423nm) and ZnS(Ag) (emission peak at 450nm), convert it to 490 nm and transfer it to the PMT. This first prototype unique configuration enables monitoring radioactive contaminated surfaces by both sides of the detector and provides high gamma rejection.In this paper, the detector structure, as well as the detector's measured linear response, will be described. The measured detection efficiency of ^{238}Pu alpha particles (5.5MeV) is ~63%. The measured detection efficiency for beta particles is ~89% for^{90}Sr-^{90}Y (195.8keV, 934.8keV), ~50% for ^{36}Cl (251.3keV), and 35% for ^{137}Cs (156.8keV).Geant4 simulation optimization results, including both the ionization stage and the WLS light collection, will be also presented. Other scaled up effective area configurations are being under investigation.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 65

CLARO-CMOS: a fast, low power and radiation-hard front-end ASIC for single-photon counting in 0.35 micron CMOS technology

Massimiliano Fiorini[1], Mirco Andreotti[1], Wander Baldini[1], Roberto Calabrese[1], Paolo Carniti[2], Lorenzo Cassina[2], Angelo Cotta Ramusino[1], Andrea Giachero[2], Claudio Gotti[2], Eleonora Luppi[1], Matteo Maino[2], Roberto Malaguti[1], Gianluigi Pessina[2], Luca Tomassetti[1]

[1]*Universitàdegli Studi di Ferrara and INFN Sezione di Ferrara, Italy*
[2]*Universitàdegli Studi di Milano Bicocca and INFN Sezione di Milano Bicocca, Italy*

The CLARO-CMOS is a prototype ASIC that allows fast photon counting with 5 ns peaking time, a recovery time to baseline smaller than 25 ns, and a power consumption of about 1 mW per channel. This chip is capable of single-photon counting with multi-anode photomultiplier tubes (Ma-PMTs), and finds applications also in the read-out of silicon photomultipliers and microchannel plates. The prototype is realized in AMS 0.35 micron CMOS technology. In the LHCb RICH environment, over ten years of operation at the nominal luminosity expected after the upgrade in Long Shutdown 2, the ASIC must withstand a total fluence of about $6x10^{12}$ 1 MeV n_{eq}/cm^2 and a total ionizing dose of 400 krad. A systematic evaluation of the radiation effects on the CLARO-CMOS performance is therefore crucial to ensure long-term stability of the electronics front-end.The results of multi-step irradiation tests with neutrons up to the fluence of 10^{14} 1 MeV n_{eq}/cm^2, with protons up to the dose of 8 Mrad and with X-rays up to the dose of 8 Mrad are presented, including measurement of single event effects during irradiation and chip performance evaluation before and after each irradiation step.In addition, systematic tests have been done on the single-photon counting performance of the CLARO-CMOS coupled to a Hamamatsu R11265 Ma-PMT, that is the baseline solution for the upgraded LHCb RICH photo-detectors. Such results are presented as well.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 66

Gamma-ray Spectroscopy Performance of a 16-channel Digital Spectrometer

Hui Tan, Wolfgang Hennig, Mark Walby, Jackson Harris, Dimitry Breus, Peter Grudberg, William K. Warburton

XIA LLC, 31057 Genstar Rd., Hayward, CA 94544 USA

We present the gamma-ray spectroscopy performance of a 16-channel digital spectrometer. The recently redesigned Pixie-16 spectrometer now has the capability to incorporate different types of pin-compatible analog-to-digital converters (ADCs) with sampling speeds up to 500 MSPS and resolution up to 16 bits while keeping the back-end of the spectrometers compatible. Thus, a large digital data acquisition system can be built with the Pixie-16 modules with different ADCs to read out a large mix of radiation detectors that have significantly different requirements for digitization rates and precisions. Gamma-ray spectroscopic measurements, including energy resolution, integral nonlinearity, differential nonlinearity, and timing resolution, have been performed on Pixie-16 modules with 14-bit/100MHz, 12-bit/250MHz, 14-bit/250MHz, and 12-bit/500MHz ADCs, respectively. All of these spectrometers achieved excellent energy resolution, ~1.8 keV FWHM at 1332.5 keV with a 40% coaxial HPGe detector. Excellent linearity was also achieved by these spectrometers with integral nonlinearity less than 0.6 LSB/14-bit or 0.5 LSB/12-bit (equivalent to 2 LSB in 14-bit) for a dynamic range of 2.6 MeV and differential nonlinearity less than 0.4 LSB. Sub-nanosecond timing resolution was readily achieved using $LaBr_3$ detectors. Detailed results from these measurements will be presented.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 67

High density processing electronics for superconducting tunnel junction array detectors

William K. Warburton[1], Jackson T. Harris[1], Stephan Friedrich[2]

[1]*XIA LLC Hayward, CA 94544 USA*
[2]*Lawrence Livermore Laboratory, Livermore CA 94550*

Superconducting tunnel junction (STJ) detectors are being developed as soft x-ray (100 – 2,000 eV) detectors, particularly for synchrotron applications, because of their advantages in obtaining sub-10 eV energy resolution at count rates approaching 10 kcps. However, their small sizes, typically less than 250 μm square, means that they need to be deployed in arrays to achieve effective solid detection angles. Arrays of 100+ elements are being produced and of 1000 elements contemplated. We have recently completed a 5 year effort to develop compact, cost effective, computer controlled processing electronics for such STJ detector arrays. In this paper we review the development effort, focusing on the major issues encountered and our solutions to them. Of particular interest are our preamplifier design, which can achieve 2 eV energy resolution and set the STJ operating points under computer control; our low noise power supply which supplies the preamplifier

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 68

An Integrated Digital Neutron Monitor and Reactivity Meter

Shin-yu Chen, Hwai-pwu Chou

Institute of Nuclear Engineering and Science, National Tsing-Hua University

This paper describes an integrated digital neutron monitor and reactivity meter for Tsing-Hua Open-Pool Reactor (THOR). The monitoring system is based on the field programmable gate array (FPGA) technology to facilitate the development effort, which provides a real time estimation of operating parameters for the THOR reactor. A self-verification mechanism is implemented to assure operational reliability. From the measurement result, the on-line tested digital system shows a better performance compared with the existing THOR analog system.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 69

A double-ring oscillator TDC for a GEM array detector

W. W. Yen, H. P. Chou

Department of Engineering and System Science, National Tsing Hua University

A data acquisition system has been developed for using with a GEM array detector. The data acquisition system is implemented using commercial field programmable gate arrays (FPGA) to measure particle trajectory and energy information using TDC units. The TDC units are based on a two-ring oscillator algorithm working as a circular vernier delay line. Preliminary tests using simulated signals indicated that the FPGA-based data acquisition system has a good linearity and is flexible for parameter adjustment for various experimental conditions.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 70

Nonproportionality in the scintillation light yield of bismuth germanate

Matthew J. Bales[1], Herbert Breuer[2], Timothy E. Chupp[1], Kevin J. Coakley[3], Robert L. Cooper[4], Thomas R. Gentile[5], Jeffrey S. Nico[5]

[1]*University of Michigan, Ann Arbor, MI 48109 USA*
[2]*University of Maryland, College Park, MD 20742 USA*
[3]*National Institute of Standards and Technology, Boulder, CO 80305 USA*
[4]*Indiana University, Bloomington, IN 47408 USA*
[5]*National Institute of Standards and Technology, Gaithersburg, MD 20899 USA*
[6]*Arizona State University, Tempe, AZ 85287 USA*

We present measurements of nonproportionality in the scintillation light yield of bismuth germanate (BGO) for gamma-rays with energies between 23 keV and 662 keV. The scintillation light was read out by avalanche photodiodes (APDs) with both the BGO crystals and APDs operated at a temperature of 90 K. Data were obtained using radioisotope sources to illuminate a single BGO crystal in a small test cryostat and a 12-element detector in a neutron radiative beta-decay experiment. In addition one datum was obtained in a 4.6 T magnetic field based on the bismuth K x-ray escape peak produced by a continuum of background gamma rays in this apparatus. Our data combined with previous results for allow accurate parameterization of the nonproportionality of BGO response.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 71

Microscale Luminescence Imaging of Secondary Phases, Defects, and Homogeneity in Scintillators

Stephanie Lam, John Fiala, Stacy Swider, Amlan Datta, Shariar Motakef

Capesym, Inc., Natick, MA 01760, USA

Crystallinity and emission homogeneity are essential to scintillator performance, which is typically described by light yield and energy resolution, both of which are bulk properties. However, methods for visualizing and examining quality on the microscale have yet to be well-explored. In this study, a novel microscale luminescence system was designed to excite scintillators in the VUV range and capture their emission on the microscale. The system includes a mercury lamp, and a spectrometer. Custom software and a motorized XYZ stage allow for automated mapping with a spot size as small as 200 microns. The 2D capabilities of the system include the capture of reflection, emission, transmission and birefringence image mosaics, as well as mosaics of emission peak centroid and magnitude. 3D imaging, mapping, and statistics of secondary-phase distributions are also available in transmission mode. Thus, this system can be used to determine the presence of secondary phases, precipitates and inclusions, strain, and emission uniformity. The capabilities of this system were tested on polished and etched samples of $CsBa_2I_5$(2%Eu), CsI (5%Ba, 3% Eu), and SrI_2(5% Eu). Emission images obtained during sample excitation reveal features that cannot be seen using typical reflection microscopy. In the $CsBa_2I_5$ and CsI samples, 0.1 mm sized rod-like and cubic features were observed, respectively. These secondary phases are suggested result from stoichiometric imbalance, the presence of eutectics, immiscibility, or unoptimized growth conditions. For SrI_2(Eu), an emission map of a 1-cm cross-section showed high uniformity, suggesting uniform dopant distribution. These studies demonstrate the suitability of the microscale luminescence imaging system as an instrument for analyzing the microscale luminescence properties of scintillators. By scanning cross sections or along the length of a crystal boule, one can use this tool successfully and efficiently to assess crystal uniformity, singularity, and homogeneity. This information provides useful feedback for crystal growth optimization.This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract HSHQDC-12-C-00048. This support does not constitute an express or implied endorsement on the part of the Government.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 72

Performance of a Pixelated Neutron Spectrometer

Justin Clinton, Benjamin Kowash, Steven Mc Hale, John Mc Clory

Department of Engineering Physics, Air Force Institute of Technology, Wright-Patterson AFB, Ohio

The neutron spectrometer presented in this work was designed to not only identify the neutron energy spectrum of an unknown source, but also to provide directional information for locating said source. The spectrometer consists of 10 alternating layers of thermal neutron detectors, high-density polyethylene (HDPE), and cadmium filters. Each detector layer consists of a 10 cm diameter silicon wafer that has been etched with 55 hexagonal microstructured pixels containing ^{6}LiF. The GEANT4 toolkit was used to optimize the thickness of the HDPE moderator layers, necessary to thermalize incident fast neutrons, to provide enhanced neutron energy discrimination. Further simulations produced a library of spectrometer responses to mono-energetic neutrons spanning 10 keV to 10 MeV. The spectrometer was tested using two reference sources, ^{252}Cf and PuBe; neutron spectra were unfolded from the measured spectrometer responses and compared to the true spectra. The ^{252}Cf spectra demonstrated excellent agreement, while the PuBe diverged considerably above ~6 MeV. Additional experiments were conducted to determine the spectrometer's angular resolution for determining source location; accuracies of 1 ± 1.7^{0} and 3 ± 2.8^{0}were calculated for the ^{252}Cf and PuBe sources, respectively.

POSTERS II - RADIATION MEASUREMENT TECHNIQUES: 73

New VME based read-out modules for multi-detector experiments

Andreas Ruben[1], Gregor Montermann[2], Robert Schneider[2]

[1]W-IE-NE-R Plein & Baus Corp., Springfield OH USA
[2]MESYTEC GmbH, Putzbrunn Germany

30 years after the introduction of VME it is still the most commonly used bus standard for nuclear physics experiment data acquisition systems. Many laboratories even still use the much older CAMAC standard which is facing the problem of obsolete components and discontinued modules and computer interfaces. Further today's nuclear physics experiments often tend to be more complex by measuring many parameters simultaneously with high precision which often requires combinations and arrays of detectors. To read-out these detectors synchronized multi channel analog-to- digital converters are needed. A new line of "classic" nuclear physics read-out modules, i.e. a peak-sensing and charge-integrating

analog to digital converter (ADC/QDC) as well as a time to digital converter (TDC) is presented. Using matching highly integrated analog NIM front-end modules a variety of radiation detectors can be read out in very compact setups. The application for high precision gamma ray spectroscopy as well as for different types of neutron detectors is shown. For these pulse shape discrimination for neutron gamma discrimination is discussed and results are presented.

Room Temperature Semiconductor Detectors

10:30 AM - 12:00 PM (Alumni Center)

ROOM TEMPERATURE SEMICONDUCTOR DETECTORS: 1

Compound Semiconductor X- and Gamma-Ray Radiation Detectors

Ralph B. James[1], Aleksey E. Bolotnikov[1], Giuseppe S. Camarda[1], Yonggang Cui[1], Genda Gu[1], Anwar Hossain[1], Kihyun Kim[2], Kisung Lee[2], Wonho Lee[2], Utpal N. Roy[1], Ge Yang[1]

[1]*Brookhaven National Laboratory*
[2]*Korea University*

Compound semiconductors are under investigation by many organizations for detecting and imaging X- and gamma-ray radiation. Among the different crystals available today, Cadmium Zinc Telluride (CdZnTe or CZT) is the most extensively studied due to its band-gap, high atomic number, availability of large crystals, and good charge-carrier transport properties. In the past decade, there has been a two-pronged approached approach to advance the technology, (1) Identify defects in the material and fix the material deficiencies therein, and (2) Use the best material available today for fabricating suitable detectors and incorporating them into deployed instruments. Most engineering approaches to develop CZT detectors have focused on designing different configurations of the electrodes and using pulse processing, mainly to minimize the effects of carrier trapping and to improve the spectroscopic and imaging performance. This approach has been very successful, and novel detectors, such as small-pixel, co-planar grid, and Frisch-grid detectors, have emerged. We will report on the progress towards development of new high-granularity CZT detectors that provide high performance using average-grade and relatively low-cost crystals. Despite the important progress on developing electron-transport-only detectors and correction algorithms, crystal defects in CZT materials still limit the yield and cost of detector-grade commercial crystals, and they often dominate the detectors' performance, especially for large-volume devices used to detect and image radiation above 200 keV. Over the past years, materials research at BNL was extended to characterizing these CZT materials at the micro-scale level, and correlating the crystal's defects with the detector's performance. We built a set of dedicated tools for this research, including automated infrared (IR) transmission microscopy, X-ray micro-scale mapping using a synchrotron light source, X-ray transmission / refraction tomography, current deep level transient spectroscopy (I-DLTS), and photoluminescence measurements. In addition, we used state-of-art instruments at BNL's Center for Functional Nanomaterials (CFN) to measure some of the electrical, optical and micro-structural properties. This presentation will report some of our recent findings to improve the crystal growth and fabrication processes, improve the methods for purification, distinguish various crystal defects and their effects on carrier trapping, study the internal electrical field in CZT detectors, and clarify the effects of annealing on the material's properties. In addition to our CZT crystal/device characterization, our group has worked to develop alternative detector materials (e.g., CdMnTe, CdMgTe, InI, and CdTeSe); short descriptions of some of the R&D highlights on alternative materials will also be provided.

ROOM TEMPERATURE SEMICONDUCTOR DETECTORS: 2

Combining material study with detector technology development using digital 3- dimensional position-sensitive ASIC readout systems for room-temperature semiconductor gamma-ray detectors

Zhong He, Feng Zhang, Yuefeng Zhu, Michael Streicher, William Koehler

Department of Nuclear Engineering and Radiological Sciences, University of Michigan, Ann Arbor, Michigan 48109-2104, USA

The advancement on digital charge-sensitive application specific integrated circuits (ASICs), combined with 3-dimensional position-sensitive readout technology, has enabled a number of unique capabilities for advancing room-temperature semiconductor gamma-ray detectors. This paper summarizes advancements in identifying and characterizing material defects invisible to conventional inspection techniques, revealing electrode fabrication and attachment problems, observing changes of internal electric field separate from charge trapping-detrapping effects during conditioning and polarization periods in TlBr detectors, achieving optimum gamma-ray spectroscopic performance, and performing sub-pixel position resolution for improved gamma-ray imaging resolutions. Experimental measurements have shown that it is feasible to achieve better than 0.5% FWHM energy resolution at 662 keV using CdZnTe detectors with 3-dimensional position-sensitive digital ASIC readout technology at ambient temperatures. Sub-pixel position sensing enabled by the digital ASIC improves gamma-ray imaging resolution. Improvements on reconstructed gamma-ray images using digital 3-D CdZnTe detectors will be reported.

ROOM TEMPERATURE SEMICONDUCTOR DETECTORS: 3

Longevity of planar and pixelated TlBr Gamma Spectrometers

Adam M. Conway[1], Erik L. Swanberg[1], Lars F. Voss[1], Robert T. Graff[1], Art J. Nelson[1], Rebecca J. Nikolic[1], Steven A. Payne[1], Len Cirignano[2], H. Kim[2], K. Shah[2]

[1]*Lawrence Livermore National Lab*
[2]*Radiation Monitoring Devices, Inc*

TlBr is a material of interest for use in room temperature gamma ray detector applications due to its wide bandgap, 2.7 eV, and high average atomic number (Tl 81, Br 35). Researchers have achieved energy resolutions of <1.3 % at 662 keV, demonstrating the potential of this material system. However, these detectors are known to polarize at room temperature using conventional configurations. Much progress has been made to increase the usable room temperature lifetime from days to months. Continued improvement of room temperature, high-resolution gamma ray detectors based on TlBr requires further understanding of the degradation mechanisms. We have found that material resistivity, surface etching and electrode metal all play an important role in determining detector longevity at room temperature. In this work will we present our most recent results on both planar and pixelated TlBr detectors with different electrode metals, including Cr, Mo and Pt. Using a combination of highly concentrated HCl and Pt pixel, good energy resolution (<3% at 662 keV) was achieved for over 3 months of continuous operation at room temperature. Comparisons of planar and pixelated degradation mechanisms will be discussed.
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, LLNL-ABS-555751. This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded IAA HSHQDC-09-X-0751. This support does not constitute an express or implied endorsement on the part of the Government. LLNL-ABS-649652

ROOM TEMPERATURE SEMICONDUCTOR DETECTORS: 4

Strengthened electric field technique implemented on CZT detector

Jianqiang Fu[1,2], Yulan Li[1,2], Lan Zhang[3], Libo Niu[1,2], Hao Jiang[1,2], Yuanjing Li[1,2]

[1]*Dept. of Engineering Physics, Tsinghua University, Beijing 100084, China*
[2]*Key Laboratory of Particle & Radiation Imaging (Tsinghua University), Ministry of Education, China*
[3]*Nuctech Company Limited, Beijing 100084, China*

CZT detector has attracted much interest as a room-temperature solid-state X-ray and gamma ray detector. We make efforts to develop an electrode structure which requires only a single readout channel and is suit for large cube CZT crystal, especially for $10\times10\times10mm^3$ crystal. In this paper, a novel strengthened electric field (SEF) technique is proposed to improve the performance of our designs. By this technique, the average intensity of the electric field in the detector is increased, so the drift time of carriers is shorter and the trapping is reduced. While the maximum intensity of the electric field is reduced, the intensity of the electric field is more uniform and higher bias can be applied.We have designed SEF Line Anode and SEF Point Anode detectors by implementing SEF technique. Simulation indicates that with SEF technique, the performances of detectors are improved greatly. A self-developed Induced Current Calculator (ICC) package is used to develop an understanding of how energy spectrum is formed, and the parameters of the detectors are optimized.A SEF Line Anode prototype and a SEF Point Anode prototype are fabricated and tested. Experimental results demonstrate the effectiveness of SEF technique. SEF Line Anode detector achieves FWHM @ 662keV of 1.9% and SEF Point Anode 1.8% when electric noise is 4.0keV. Efforts will be made to improve the fabrication process and to reduce the low energy tail and improve P/C ratio.

ROOM TEMPERATURE SEMICONDUCTOR DETECTORS: 5

Thallium-based ternary compounds for X- and γ-Radiation Detection

John Archibald Peters, Zhifu Liu, Maria Sebastian, Bruce W. Wessels, Jino Im, Arthur J. Freeman, Sandy Nguyen, Peng Wang, Mercouri G. Kanatzidis

Northwestern University, Evanston, IL 60208, USA

For efficient hard radiation detection at room temperature, wide band gap semiconductor compounds with high average atomic numbers, high mass density, and high resistivity are sought after for potential replacement of conventional semiconductor detectors. Here, we report on the photoconductive properties of highly dense, semi-insulating, and semiconducting thallium-based ternary compounds, including Tl_6I_4S, Tl_6I_4Se, and $Tl_4Cu_2I_6$ for radiation detection. These compounds are grown by the modified Bridgman method. Tl_6I_4Se has shown particular promise for hard radiation detection as previously reported, with mobility–lifetime products of 7.1×10^{-3} and 5.9×10^{-4} cm^2/V for electron and hole carriers, respectively. Room temperature detector response of these materials to x-ray and γ-ray radiation was measured. Our studies show that their mobility-lifetime products and radiation spectral response are comparable to the benchmark material CdZnTe.Likewise Tl_6I_4S has shown considerable promise. For example, a Tl_6I_4S detector clearly resolved the 122 keV peak of a ^{57}Co γ-ray source as well as the 22.0 and 22.2 keV peaks that are characteristic of the Kα lines of Ag x-rays. Most recently we have been synthesizing $Tl_4Cu_2I_6$, a transition metal halide with a bandgap of 2.3 eV and a resistivity of $\sim4 \times 10^{10}$ Ω-cm. Photoconductivity measurements were used to determine mobility–lifetime (μτ) products for electron and hole carriers. For $Tl_4Cu_2I_6$ μτ products for electrons and holes are of the order of 10^{-4} and 10^{-5} cm^2/V, respectively. In these thallium-based ternary compounds carrier lifetimes have also been measured using transient photoconductivity measurements while experimental defect studies were performed to provide important understanding and insights to the performance of these detector materials. Photoluminescence (PL), photoconductivity (PC) spectroscopy, and photo-induced current transient spectroscopy (PICTS) were carried out to determine the nature of shallow and deep level point defects. The results indicate the presence of shallow defect levels in undoped Tl_6I_4Se while both shallow and deep level defects were observed in Tl_6I_4S and $Tl_4Cu_2I_6$. The identification and characterization of these defects and the understanding of their effects on electrical properties are of great importance to control and to improve γ-ray detection properties of these thallium-based ternary compounds. This would lead to semi-insulating semiconductors with higher resistivity and larger μτ products, resulting in high efficiency radiation detectors that operate at room temperature.

Acknowledgements: This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-2010-DN-077-ARI042-02.

ROOM TEMPERATURE SEMICONDUCTOR DETECTORS: 6

Noise and detector performance studies of TlBr and (Cd,Zn)Te at room temperature with various digital pulse shapers

Markus Dambacher[1], Keitaro Hitomi[3], Christian Disch[2], Alex Fauler[1,2], Michael Fiederle[1,2]

[1]*X-Ray Imaging Europe, Stefan-Meier-Str. 21, 79104 Freiburg, Germany*
[2]*Freiburg Materials Research Center, Stefan-Meier-Str. 21, 79104 Freiburg, Germany*
[3]*Department of Quantum Science and Energy Engineering, Graduate School of Engineering, Tohoku University, Sendai 980-8579, Japan*

Digital signal processing offers the possibility to realize advanced shaping algorithms with improved signal to noise ratio at higher count rates. They allow superior performance compared to analog systems that are usually equipped with Gaussian pulse shapers in terms of energy resolution and throughput. The paper shows detailed analysis of the series and parallel noise contributions of TlBr and (Cd,Zn)Te detectors by comparing the energy resolution with various gamma sources and the ENC by adding pulser signals of two advanced pulse shapers, such as Cusp and Trapezoidal, to a standard Gaussian shaper at various peaking times and with changing plateaus. The measurements with both detectors were performed at room temperatures, detector pulses were digitized with A/D converters at high amplitude resolutions. For both detectors an increase in detector performance could be achieved with the two advanced digital shapers due to the lower sensitivity to both serial and parallel noise. Although the results were achieved with digitized detector signals and signal processing was performed by software, all filters can also be used in real-time spectroscopic systems. The different scenarios that the detectors can be used in and which pulse shapers may deliver the best performance will also be discussed.

Radiation Detection Algorithms and Modeling

10:30 AM - 12:00 PM (Vandenburg)

RADIATION DETECTION ALGORITHMS AND MODELING: 1

Correlated Statistical Uncertainties in Coded Aperture Imaging

Matthew C. Fleenor[1], Matthew A. Blackston[2], Klaus P. Ziock[2]

[1]*Physics Group, Roanoke College, VA*
[2]*Nuclear Materials Detection and Characterization Group, Oak Ridge National Lab, TN*

Coded aperture and other radiation imagers are presently being developed to address a number of nuclear safeguards and security applications. In order for coded aperture imaging technology to be used to maximum utility, it is necessary to provide statistically meaningful information about the radioactive components of the imaged objects. To address the deficiency of quantifiable errors in coded aperture imaging of gamma-ray sources, we present uncertainty matrices containing covariance terms between image pixels. We calculated these correlated uncertainties as functions of variation in mask rank, mask pattern over-sampling (sampling a single mask element with multiple detector pixels), and whether or not anti-mask data is included. Utilizing simulated datasets, we find that correlations (and inverse correlations) arise when the data from two or more image pixels are summed. Furthermore, we find that the presence of correlations (and their inverses) is heightened by the process of over-sampling, while correlations are suppressed by the inclusion of anti-mask data and with increased mask rank. For double-sampled data, correlations are most noticeable in the eight nearest neighboring pixels to the image pixel under consideration. Lastly, we find that uncertainties in the observed data are incorrectly estimated when correlations are not considered. Therefore, the statistical confidence of source detection is overestimated (sometimes by almost a factor of 2) when the covariance terms are not included for a summed region of image pixels.

RADIATION DETECTION ALGORITHMS AND MODELING: 2

Improved R/N Source Localization in Variable NORM Background: An MLEM Approach with Segmentation Data

Tanya A. Crowley, Barbara M. Gardner, Myron J. Mandell, Robert D. Penny

Leidos Corp., 10260 Campus Pt. Dr., San Diego, CA 92121

A novel approach and algorithm have been developed to rapidly detect and localize both moving and static radiological/nuclear (R/N) point-like sources from an airborne platform. Current aerial systems with radiological sensors are limited in their ability to compensate for variable NORM (Naturally Occurring Radioactive Material) background, resulting in reduced performance. The proposed approach suppresses the effects of NORM background by incorporating additional video data to track objects and gather terrain information which is used to segment the surveyed area into regions where activity is likely to be uniform. The algorithm produces Source Activity Maps (SAMs) of both target and background isotope activity over the pixelated survey area. The task of producing the SAMs requires two major steps: 1) The development of a forward model which describes the transformation of isotope activity to detector measurements, and 2) The solution of the associated inverse problem, the estimation of the isotope activity from the measurements, which is the focus of this paper. The forward model is the full isotope-spatial model as described by Wahl [1], and consists of a system matrix which transforms a pixelated survey region of emission sources to detector responses. The inverse problem is ill-posed as there are fewer measurements than unknown variables, and the measurements are subject to Poisson noise. The well-known Maximum Likelihood Expectation Maximization (MLEM) algorithm (Lange [2]) for emission sources with Poisson statistics has been selected to solve the inverse problem as it is well-suited for underdetermined problems and has a remarkably simple iterative scheme that is guaranteed to converge. Segmented terrain information is incorporated by constraining NORM background activity within a segment to be uniform, improving performance. The MLEM algorithm with segmentation constraints is implemented in MATLAB and examples of the performance are given.

[1] Wahl, Christopher, "Imaging, Detection, and Identification Algorithms for Position-Sensitive Gamma-Ray Detectors," University of Michigan, Ann Arbor, MI, PhD Thesis 2011.

[2] Lange K, Carson R., "EM Reconstruction Algorithms for Emission and Transmission Tomography," J. Comput. Assist. Tomogr., 1984; 8:306–316.

This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-12-C-00096. This support does not constitute an express or implied endorsement on the part of the Government.

RADIATION DETECTION ALGORITHMS AND MODELING: 3

Validation of a Bayesian-Based Isotope Identification Algorithm

Jacob Stinnett, Clair J. Sullivan

Department of Nuclear, Plasma, and Radiological Engineering, The University of Illinois at Urbana-Champaign, Urbana, IL

Handheld radio-isotope identifiers (RIIDs) are widely used in Homeland Security applications, however most commercially-available devices have serious problems in their ability to correctly identify isotopes. It has been reported that this flaw largely is because of overly-simplistic isotope identification algorithms on board the RIIDs. This paper reports on the experimental validation of a new isotope identification algorithm using Bayesian statistics to identify the source while allowing for calibration drift and shielding. We present here results on further testing of this algorithm and on a study on the impact of variation of gamma peak energies and areas.

RADIATION DETECTION ALGORITHMS AND MODELING: 4

Network Algorithms for Detection of Radiation Sources

Ngeswara S. V. Rao[1], Satyabrata Sen[2], Nicholas J. Prins[3], Richard R. Brooks[4]

[1]*Computer Science and Mathematics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831*

[2]*Computer Science and Mathematics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831*
[3]*Global Security Directorate, Oak Ridge National Laboratory, Oak Ridge, TN 37831*
[4]*Department of Electrical and Computer Engineering, Clemson University, SC 29634*
[5]*Department of Computer Science, University of Memphis, Memphis, TN 38152*

In support of national defense, Domestic Nuclear Detection Office's (DNDO) Intelligent Radiation Sensor Systems (IRSS) program supported the development of networks of radiation counters for detecting, localizing and identifying low-level, hazardous radiation sources. Industry teams developed the first generation of such networks with tens of counters, and demonstrated several of their capabilities in indoor and outdoor characterization tests. Subsequently, these test measurements have been used in algorithm replays using various sub-networks of counters. Test measurements combined with algorithm outputs are used to extract Key Measurements and Benchmark (KMB) datasets. We present two selective analyses of these datasets: (a) a notional border monitoring scenario that highlights the benefits of a network of counters compared to individual detectors, and (b) new insights into the Sequential Probability Ratio Test (SPRT) detection method, which lead to its adaptations for improved detection. Using KMB datasets from an outdoor test, we construct a notional border monitoring scenario, wherein twelve 2"*2" NaI detectors are deployed on the periphery of 21*21meter square region. A Cs-137 (175 uCi) source is moved across this region, starting several meters from outside and finally moving away. The measurements from individual counters and the network were processed using replays of a particle filter algorithm developed under IRSS program. The algorithm outputs from KMB datasets clearly illustrate the benefits of combining measurements from all networked counters: the source was detected before it entered the region, during its trajectory inside, and until it moved several meters away. When individual counters are used for detection, the source was detected for much shorter durations, and sometimes was missed in the interior region. The application of SPRT for detecting radiation sources requires choosing the detection threshold, which in turn requires a source strength estimate, typically specified as a multiplier of the background radiation level. A judicious selection of this source multiplier is essential to achieve optimal detection probability at a specified false alarm rate. Typically, this threshold is chosen from the Receiver Operating Characteristic (ROC) by varying the source multiplier estimate. ROC is expected to have a monotonically increasing profile between the detection probability and false alarm rate. We derived ROCs for multiple indoor tests using KMB datasets, which revealed an unexpected loop shape: as the multiplier increases, detection probability and false alarm rate both increase until a limit, and then both contract. Consequently, two detection probabilities correspond to the same false alarm rate, and the higher is achieved at a lower multiplier, which is the desired operating point. Using the Chebyshev's inequality we analytically confirm this shape. Then, we present two improved network-SPRT methods by (a) using the threshold off-set as a weighting factor for the binary decisions from individual detectors in a weighted majority voting fusion rule, and (b) applying a composite SPRT derived using measurements from all counters. This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded IAA HSHQDC-13-X-B0002. This support does not constitute an expressed or implied endorsement on the part of the Government.

RADIATION DETECTION ALGORITHMS AND MODELING: 5

Neutron Pileup Algorithms For Multiplicity Counters

Sean Robinson, Sean Stave, Azaree Lintereur, Edward Siciliano, Richard Kouzes, Mary Bliss

Pacific Northwest National Laboratory, Richland, WA

The shortage of helium-3 (^{3}He) has created a need to identify alternative neutron detection options for a variety of nuclear nonproliferation applications. One application that may be affected by ^{3}He replacement technology is that of mass accountancy, which utilizes coincidence and multiplicity counters to verify special nuclear material declarations. The use of neutron scintillation materials, such as LiF-ZnS sheets, as an alternative to ^{3}He proportional tubes in multiplicity counters requires novel techniques for Pulse Shape Discrimination to distinguish between neutrons and gamma rays. These techniques must work under high count rates, as the maximum momentary rate for incoming neutrons from multiplicity events can be quite large. We have created a fast and accurate neutron discrimination algorithm based on time window filtering and signature comparison that can operate quickly on data with high degrees of gamma ray and neutron pileup. This algorithm is evaluated for its capability to separate signals as the pileup rate increases, and the possibility for implementation on fast hardware (e.g., FPGA hardware) for real-time operation is explored.

RADIATION DETECTION ALGORITHMS AND MODELING: 6

OSIRIS—Gamma-Ray Spectroscopy Software for On-Site Inspections under the Comprehensive Nuclear Test-Ban Treaty

Augustine J. Caffrey[1], Ann E. Egger[1], Sarah M. Kelly[1], Kenneth M. Krebs[1], C. Jayson Wharton[1], Brian D. Milbrath[2], David V. Jordan[2], Jeter C. Hall[2], Theodore W. Bowyer[2], Nathan G. Wimer[3], Stephen W. Padgett[3], Steven A. Kreek[3]

[1]Idaho National Laboratory, Idaho Falls, Idaho, USA
[2]Pacific Northwest National Laboratory, Richland, Washington, USA
[3]Lawrence Livermore National Laboratory, Livermore, California, USA

We are designing and testing software for the acquisition and analysis of high-resolution gamma-ray spectra during on-site inspections under the Comprehensive Nuclear-Test-Ban Treaty (CTBT). The On-Site Inspection RadioIsotopic Spectroscopy—OSIRIS—software contains an "information barrier" limiting the displayed information to selected gamma-ray peaks. OSIRIS gamma-ray energy spectra are not visible to the user; instead, the displayed information is limited to radioisotopes relevant to CTBT on-site inspections, e.g. iodine-131.[1]OSIRIS is based on the GAUSS nonlinear least-squares spectrum analysis algorithms[2] to process the spectra, and it can be energy-calibrated automatically using either gamma-ray check sources or natural background radiation. An ORTEC Trans-SPEC-DX-100T mechanically-cooled HPGe spectrometer[3] serves as the OSIRIS prototype instrument.A set of over 200 fission-product spectra has been assembled for OSIRIS testing, measured where possible, or generated by modeling.[4,5] The testing spectral compositions include CTBT treaty-compliant scenarios, for example, a severe nuclear reactor accident, and CTBT non-compliant scenarios such as a vented underground nuclear explosion. The spectra in non-compliant scenarios span the time range from 1 to 100 weeks after an event. We will report the OSIRIS code performance by comparing its computer-based automated analysis to gamma-spectroscopy expert analysis of the test spectra.

References

1. OSIRIS is programmed to report these fission-product isotopes: ^{140}Ba, ^{141}Ce, ^{144}Ce, ^{134}Cs, ^{131}I, ^{132}I, ^{140}La, ^{99}Mo, ^{95}Nb,^{147}Nd, ^{144}Pr, ^{106}Rh, ^{103}Ru, ^{99m}Tc, ^{132}Te, ^{95}Zr.

2. R.G. Helmer, M.H. Putnam, and C.M. McCullagh, "GAUSS VII, a computer program for the analysis of γ-ray spectra from Ge semiconductor spectrometers", Nuclear Instruments and Methods in Physics Research A206 (1983) 477, http://dx.doi.org/10.1016/0167-5087(83)90385-X

3. http://www.ortec-online.com/Solutions/gamma-spectroscopy.aspx

4. X-5 Monte Carlo Team, February 2008. MCNP — A General Monte Carlo N-Particle Transport Code, Version 5, Los Alamos National Laboratory Report LA-UR-03-1987.

5. Agostinelli, S.; et al., "GEANT4 – A Simulation Toolkit", Nuclear Instruments and Methods in Physics Research A506 (2003) 250, http://www.dx.doi:10.1016/S0168-9002(03)01368-8

RADIATION DETECTION ALGORITHMS AND MODELING: 7

Coincidence Counting Using Alternative Neutron Detection

Richard T. Kouzes, Azaree T. Lintereur, Edward R. Siciliano

Pacific Northwest National Laboratory

Due to the worldwide shortage of ^{3}He, future safeguards instrumentation will have to utilize alternative technologies for neutron detection. Previous projects and testing at Pacific Northwest National Laboratory (PNNL) have shown that there are a number of commercially available alternatives to ^{3}He, including ^{10}B-lined proportional counters. One of instruments used most widely by the International Atomic Energy Agency (IAEA) for safeguards measurements of fresh nuclear fuel is the Uranium Neutron Coincidence Collar (UNCL). An Alternative Boron-based Uranium Neutron Coincidence Collar (ABUNCL) has been developed and tested under a Coincidence Counting With Boron-Based Alternative Neutron Detection Technology project. Results indicate that such an alternative may be a viable replacement for safeguards measurements with the UNCL. An overview of this alternative system and results from the testing program will be presented.

Scintillation Detectors III

1:30PM - 3:00 PM (Vandenburg)

SCINTILLATION DETECTORS III - NEUTRON-SENSITIVE DETECTORS: 1

Fast Neutron Measurements Using CLYC Scintillator

Martin B. Smith[1], Tobias Achtzehn[1], Hugh R. Andrews[1], Edward T. H. Clifford[1], Patrick Forget[1], Harry Ing[1], Jarek Glodo[2], Rastgo Hawrami[2], Patrick O' Dougherty[2], Kanai Shah[2], Urmila Shirwadkar[2], Lakshmi Soundara - Pandian[2], Josh Tower[2]

[1]Bubble Technology Industries, Chalk River, ON, Canada
[2]Radiation Monitoring Devices, Watertown, MA, USA

The elpasolite scintillator Cs_2LiYCl_6:Ce (CLYC) originally became a material of interest for radiation detection because of its ability to simultaneously detect gamma rays and thermal neutrons. More recently, researchers at Bubble Technology Industries discovered[1,2] that CLYC can also detect high-energy (fast) neutrons. This capability is due to the presence of ^{35}Cl in CLYC, enabling it to act as a fast-neutron spectrometer through interactions such as $^{35}Cl(n, p)^{35}S$. The advent of fast-neutron detection with CLYC enables tri-mode systems that can perform gamma-ray spectroscopy, thermal-neutron detection, and fast-neutron spectroscopy using a single detector.In collaboration with Radiation Monitoring Devices (RMD), investigation of the fast-neutron detection properties of CLYC has continued (RMD reports on its portion of the work in a complementary abstract for this conference[3]). A range of CLYC crystals have been studied using a Van de Graaff accelerator. These cylindrical crystals have dimensions (thickness × diameter) 1" × 1", 1" × 2", and 2" × 2", and include samples with natural concentrations of Li isotopes and crystals that are enriched in 6Li. The linearity of the response and the efficiency of fast-neutron detection have been investigated as a function of neutron energy for a variety of crystal sizes and compositions. The data show that the gamma-equivalent energy of both known fast-neutron peaks[2]varies linearly with the energy of the incoming neutron, and that the fast-neutron detection efficiency scales with crystal size, as expected. This work has been supported by the US Department of Defense, Defense Threat Reduction Agency, under competitively awarded contract HDTRA1-12-C-0005. This support does not constitute an express or implied endorsement on the part of the Government. DISTRIBUTION A. Approved for public release: distribution unlimited.

[1]T. Achtzehn et al., United States Patent Application Publication, US 2011/0266451 A1 (2011)

[2]M.B. Smith et al., IEEE Trans. Nucl. Sci. 60(2), 855 (2013)

[3]Lakshmi Soundara-Pandian et al., Fast Neutron Spectroscopy with CLYC and CNYC Detectors up to 20 MeV, abstract for SORMA XV

SCINTILLATION DETECTORS III - NEUTRON-SENSITIVE DETECTORS: 2

Design of a New Cold Neutron Detector for Chromatic Analysis Neutron Diffractometer Or Reflectometer at NCNR

Alon Osovizky[1,2], Nicholas C. Maliszewskyj[1], Kevin Pritchard[1], Jeffrey B. Ziegler[1], Nancy Hadad[1], Yaacov Yehuda-zada[3], Max Gehelman[3], Ed Binkley[1], Richard M. Ibberson[1], Charles F. Majkrzak[1]

[1]NIST Center for Neutron Research, Gaithersburg, Maryland
[2]Rotem Industries Ltd, Rotem Industrial Park, Israel
[3]Nuclear Research Center Negev, Beer-Sheva Israel

Neutrons are an effective tool to probe the structure of materials. Neutron diffraction is the application of neutron scattering to the determination of atomic and magnetic structure of materials. Collimated beams of thermal or cold neutrons diffract from the specimen and the direction, energy, and intensity of the scattered neutrons forms the fingerprint of the structure of that material.The NIST Center for Neutron Research (NCNR) in Gaithersburg MD is home to one of the world's premier neutron sources. A recent project at the NCNR is the development of the Chromatic Analysis Neutron Diffractometer Or Reflectometer (CANDOR). Unlike its predecessors, CANDOR will make use of a polychromatic incident beam and will collect the scattered radiation over a number of energy analyzing channels. This design is aimed to permit this spectrometer to measure a reflectometry curve at least ten times faster than a conventional monochromatic reflectometer. In order to achieve this

enhanced performance a large number of highly efficient ultrathin neutron detectors is required.For many decades 3He gas-filled proportional counters have been widely used as the most reliable and efficient neutron detectors at neutron scattering facilities around the world. However, the global shortage of 3He gas has become one of the most challenging scientific difficulties to overcome in many fundamental and applied research areas. In this paper we will present the concept for the CANDOR detector and discuss constraints on the design. Preliminary results measured by an ultra-thin 6LiF:ZnS(Ag) scintillator based neutron detector, tested as a substitute alternative for the 3He tube, are presented. While the 6LiF:ZnS(Ag) plastic scintillator has been used for many years for neutron detection, principally in area-sensitive detectors using wavelength shifting fibers and traditional photomultipliers with a coded readout scheme, this detector is the first in which the thinness of the detector is a design goal and one in which each neutron sensitive element is to be read out using individually assigned silicon photomultipliers (SiPM) as photosensors.Preliminary results measured with the prototype detector showed high stopping power (about 90% for 3.27 meV neutrons) with relatively low light output that yielded a sensitivity of about 45%, with high gamma rejection achieved by pulse shape analysis.This paper describes the process of optimizing this detector. Due to the mechanical constraints of the CANDOR spectrometer, the neutron sensor thickness should be ~1mm to maximize the number of energy analyzing arrays in the given space. By focusing on the chemistry of the scintillator, the arrangement of the WLS fibers, and the photosensor, we hope to increase the sensitivity of the sensor without sacrificing the geometry. The detector sensitivity is determined by both the neutron capture probability (6Li density) and the detectable light output produced by the ZnS(Ag) ionization, the latter of which is hindered by the fluorescence absorption of the scintillation light by the ZnS. Tradeoffs between neutron stimulated light production, absorption, and transmission will determine the stoichiometry of the 6LiF and ZnS(Ag) as well as the volume ratio of scintillator and fiber. The selection of the silicon photomultiplier (SiPM) as photosensor also deserves attention as this solid state sensor facilitates a compact, low cost, and magnetically insensitive design at the expense of thermal dark current contributing to system noise and complicating neutron signal discrimination by pulse shape analysis.

SCINTILLATION DETECTORS III - NEUTRON-SENSITIVE DETECTORS: 3

Cross-correlation measurements with the EJ-299-33 plastic scintillator

Mark M. Bourne[1], Jeff Whaley[1], Jennifer L. Dolan[1], Marek Flaska[1], Shaun D. Clarke[1], Alice Tomanin[2], Paolo Peerani[2], Sara A. Pozzi[1]

[1]Department of Nuclear Engineering and Radiological Sciences, University of Michigan, Ann Arbor, Michigan 48109, USA
[2]European Commission, Joint Research Centre, Institute for the Protection and Security of the Citizen via Enrico Fermi, 2749, 21027 Ispra (VA), Italy

The EJ-299-33 plastic scintillator is of particular interest in homeland security applications due to its pulse-shape discrimination (PSD) capabilities as a plastic, which historically has not been possible. The goal of this work is to characterize the PSD for 7.62-cm diameter by 7.62-cm length cylindrical scintillators using time-of-flight, and to use this to measure the cross-correlation function of a plutonium oxide sample. The PSD performance will be benchmarked to the EJ-309 liquid scintillator using the same scintillator dimensions and photomultiplier tube model. Each detector recorded ^{252}Cf pulses in time-of-flight using a 12.7-cm EJ-309 liquid as the trigger detector. PSD was optimized using the standard PSD figure-of-merit for each detector, and time-of-flight results were used to compute the gamma-ray misclassification rate. It was found that the PSD performance of EJ-299-33 was quite good but less effective than the EJ-309 liquid. Cross-Correlation measurements were then taken with two EJ-299-33 plastics to ^{252}Cf and plutonium oxide. The results show that the EJ-299-33 plastics are capable of measuring the cross-correlation functions of each sample while showing significant differences in each feature.

SCINTILLATION DETECTORS III - NEUTRON-SENSITIVE DETECTORS: 4

Next Generation of Dual Mode Scintillator Crystals

R. Hawrami, U. Shirwadkar, J. Glodo, J. Vaghini, K.s. Shah

Radiation Monitoring Devices, Watertown, MA 02472

Novel crystal detectors are continuously being discovered and developed in academy and industry. In radiation detection and imaging field inorganic crystals are known for decades for their good energy resolution and detection efficiency for photon and electron measurements. Recently, we have discovered a new material for dual mode gamma-neutron detection from the Li-containing alkaline earth halide crystal family with Eu^{2+} activation, $LiSr_2I_5$:Eu (LSI). The material exhibits high light yield of ~70,000 photons/MeV and excellent proportionality. As a result, its energy resolution is already ~3% FWHM at 662 keV with potential for considerable improvement. Upon exposure to thermal neutrons LSI showed

exceptionally high light of >250,000 photons/neutron, which to the best of our knowledge is the highest recorded value for neutron detection. The Gamma-Equivalent Energy (GEE) for thermal neutron detection with LSI was recorded to be as high as ~4.3, which enables excellent γ-n pulse height discrimination (PHD). Our studies showed that LSI also provided very good γ-n gamma-neutron pulse shape discrimination (PSD) with a PSD Figure-of-Merit of ~2. LSI also provides high thermal neutron detection efficiency (>95% within a 1 cm thickness). These are excellent results and they surpass those for all other dual mode gamma-neutron detectors under investigation (such as CLYC and CLLB) in almost all respects.

Acknowledgments

This work has been supported by the US Defense Threat Reduction Agency, under competitively awarded contract. This support does not constitute an express or implied endorsement on the part of the Government. DISTRIBUTION A: Approved for public release: distribution unlimited.

SCINTILLATION DETECTORS III - NEUTRON-SENSITIVE DETECTORS: 5

A Study on the Radiation Hardness of BSO Crystals

Fan Yang[1], Hui Yuan[2], Liyuan Zhang[1], Renyuan Zhu[1]

[1]California Institute of Technology,1200 E California Blvd, Pasadena, CA 91125, USA
[2]Shanghai Institute of Ceramics Chinese Academy of Sciences, 1295 DingXi Road, Shanghai, 200050, CHINA

Cost-effective heavy scintillators with good UV transmittance are pursued by the high energy physics (HEP) community for a homogeneous hadron calorimeter (HHCAL) detector concept, where both scintillation and Cherenkov light are measured to provide good jet-mass resolution for future HEP experiments. Because of low UV cut-off wavelength (300 nm) and low raw material cost (<50% of BGO), Bi_4_Si_3_O_12 (BSO) crystals are under development at Shanghai Institute of Ceramics (SIC) with a cost-effective modified Bridgman growth technique. Because of its potential low cost and reasonable light output BSO crystals also attract attention of the nuclear physics community.We report in this paper an investigation on radiation hardness of four 20 cm long BSO crystals produced by SICCAS for the HHCAL detector concept. There were four 20 cm long samples investigated: samples 12-2221 and 12-2223 were produced in 2012, and 13-05 and 13-09 in 2013. Their optical and scintillation properties, such as transmittance, light output and light response uniformity, were measured before and after γ-ray irradiations. While no recovery was observed in 12-2223 after irradiated to 10^3 rad, all other three showed certain recovery. Quality improvements are observed in both the optical properties and the radiation hardness. Their use for the HHCAL detector concept and in future physics experiments will be discussed.

SCINTILLATION DETECTORS III - NEUTRON-SENSITIVE DETECTORS: 6

Rugged Detectors for Fast, Epithermal and Thermal Neutrons

Rico Chandra, Giovanna Davatz, Ulisse Gendotti, Hannes Friederich, David Murer

Arktis Radiation Detectors Ltd Räffelstrasse 11 8045, Zurich, Switzerland

This work presents the application of a novel light readout technology to two different types of neutron detectors. One of these neutron detectors is a fast neutron detector sensitive to neutrons above 100 keV and is based on scintillation of natural helium. The second detector extends the sensitivity range by using a Li-6 based conversion layer coated onto the detector walls. The light produced by both of these detectors is read out by using solid state readout devices and sophisticated triggering mechanisms integrated into the active volume. The work will present how the light readout was integrated and will present experimental results achieved. In particular, neutron efficiencies and gamma immunity will be discussed. Also, the impact of neutron detectors consisting only of steel, gas and solid-state circuitry – "rugged by design" – on various enabled applications will be discussed.

Gamma-Ray and Neutron Imaging Systems

1:30 PM - 3:00 PM (Alumni Center)

GAMMA-RAY AND NEUTRON IMAGING SYSTEMS: 1

Applications of Gamma-Ray Imaging

Kai Vetter

Department of Nuclear Engineering, University of California - Berkeley, Berkely, USA

Gamma-ray imaging is a widely used technology that enables the detection, localization, and mapping of gamma-ray emitting sources. Applications can be found in diverse fields such as astrophysics, biology and medicine, nuclear security and safeguards, as well as radiological cleanup and remediation. Several imaging modalities have been developed over six decades reflecting the evolving objectives in these diverse applications and the underlying interaction processes of gamma-rays with matter. Each modality is associated with different trade-offs in achievable sensitivity, resolution, and the field-of-view in which gamma-ray emitting objects can be imaged. In this paper, fundamental imaging concepts and associated applications will be briefly reviewed. The focus will be on recent developments of gamma-ray imaging systems developed in Berkeley that can be deployed on a variety of stationary and moving platforms for near-field and far-field applications.

GAMMA-RAY AND NEUTRON IMAGING SYSTEMS: 2

Performance and field tests of handy Compton camera using 3D position-sensitive scintillators coupled with MPPC-arrays

Aya Kishimoto[1], Jun Kataoka[1], Toru Nishiyama[1], Takuya Fujita[1], Kenshiro Takeuchi[1], Hiroshi Okochi[1], Hiroko Ogata[1], Hiroto Kuroshima[1], Shinji Ohsuka[2], Sigeyuki Nakamura[2], Masato Hirayanagi[2], Shunsuke Adachi[2], Tetsuya Uchiyama[2], Hiroki Suzuki[2]

[1]*Research Institute for Science and Engineering, Waseda University, Tokyo*
[2]*Hamamatsu Photonics, K. K., Hamamatsu*

After the Japanese nuclear disaster in 2011, the release of radioactive isotopes (mainly 137Cs, 134Cs) still remains a serious problem in Fukushima, Japan. To help identify radiation hotspots and ensure effective decontamination operation, we have developed a novel Compton camera weighting only 1.9 kg and measuring just ~14×14×15 cm3 in size. Despite its compactness, the first prototype developed in 2013 realizes a wide (>150 deg) field of vision, angular resolution of ~14 deg (FWHM), and offers such excellent sensitivity that a hotspot producing a 5 micro-Sv/h dose at a distance of 3 m can be imaged every 30 sec., as measured with 662-keV gamma rays from 137Cs (Kataoka et al., NIM-A, 732, (2013), 403). Even though such sensitivity is already a factor several times better than that of other cameras being tested in Fukushima, our next challenge is improving the angular resolution to ~7-8 deg (FWHM) together with doubling the sensitivity, without changing the prototype camera's configuration (weight and size). The 3D position-sensitive scintillation detectors fabricated in both the scatterer and absorber are the key in-house technology developed here. By measuring the pulse-height ratio of MPPC-arrays coupled at both ends of a Ce:GAGG scintillator block, the depth of interaction (DOI) is obtained for incident gamma rays as well as the usual 2D positions, with accuracy better than 2 mm, as measured at 662 keV. In this paper, we first present how to optimize the detector design based on Geant 4 simulation. Next we present the detailed performance and various field tests of the prototype camera as conducted in Namie, Fukushima. Moreover, we demonstrate a new concept for the "stereo" measurement of gamma rays that enables us to measure not only direction but also approximate distance to radioactive hotspots even within a crowded forest near a residential area. Finally, the laboratory tests of the "DOI" Compton camera released in March 2014 will be shown for the first time.

GAMMA-RAY AND NEUTRON IMAGING SYSTEMS: 3

Event Localization in Bulk Scintillator Crystals Using Coded Apertures

Klaus P. Ziock[1,2], Joshua B. Braverman[2], Lorenzo Fabris[1], Mark J. Harrison[1], Robert J. Newby[1], Donald E. Hornback[1]

[1]*Oak Ridge National Laboratory, Oak Ridge TN*
[2]*Dept. of Physics and Astronomy, University of Tennessee, Knoxville TN*

The localization of radiation interactions in bulk scintillators is generally limited by the size of the light distribution at the readout surface of the crystal. By finding the centroid of the light spot, which is typically of order centimeters across, practical single-event localization is limited to ~ 2 mm/cm of crystal thickness. Similar resolution can also be achieved in depth of interaction by measuring the size of the light spot. Through the use of near-field coded-aperture techniques applied to the scintillation light, light transport simulations show that more than a five-fold improvement (millimeter spatial resolution) can be achieved both laterally and in event depth for 3-cm-thick crystals. At the core of the technique is the requirement to resolve the shadow from an optical mask placed in the scintillation light path between the crystal and the readout. In this paper, experimental results are presented that demonstrate that the shadow pattern can be clearly resolved, and that the size of the measured pattern is a function of event depth in the scintillator. Data collected with a 1D shadow mask are used to emulate a 2-cm-thick crystal. Spatial resolutions of less than 1 mm in both depth and transverse to the readout face are obtained over most of the crystal depth.

GAMMA-RAY AND NEUTRON IMAGING SYSTEMS: 4

Investigations into Semiconducting Boron Carbide for Neutron Radiography and Tomography Applications

Thomas G. Wulz, Eric D. Lukosi

Nuclear Engineering, The University of Tennesse, Knoxville TN

P-type boron carbide thin films were grown on the (100) plane of n-type silicon wafers in a low pressure chemical vapor deposition (CVD) system from the thermal decomposition of boron trichloride and methane reactant gases with hydrogen as a carrier gas. The thin films were analyzed using scanning electron microscopy (SEM), transmission electron microscopy (TEM), and Laser Induced Breakdown Spectoscopy (LIBS).Due to the orientation of the growth substrate, boron carbide was grown on both sides of the silicon wafers. It is postulated that because the films had boron carbide on both sides, the device contained a p-n-p heterostructure, rather than a p-n heterojunction. The device exhibits current-voltage characteristics that are Ohmic in behavior, instead of exhibiting Schottky diode behavior where the flow of current is resisted in one bias direction.In order to perform a TEM analysis of the silicon-boron carbide interfacial epitaxy, a very thin (500 micron thick) sample of the interface will be prepared using a Zeiss Auriga SEM with a Focused Ion Beam of energetic gallium ions. In addition, LIBS analysis of the thin films has determined that both boron and carbon are present in the deposited films. For one of the seven wafers, the boron to carbon ratio was estimated to be around 9:1. However, the statistical certainty of this ratio has yet to be analyzed. In order to create the desired p-n heterostructure, we plan to polish one side of the boron carbide-silicon samples.

GAMMA-RAY AND NEUTRON IMAGING SYSTEMS: 5

iPIX: An advanced gamma camera technology for rapid and accurate localization of radioactive hotspots

Vincenzo Paradiso, Joshua A. Handley, Audrey Patoz, Florent Bonnet, Dominique Rothan, Khalil Amgarou, Nabil Menaa

CANBERRA France, 1 rue des Hérons - 78180 - Montigny-le-Bretonneux (France)

Gamma imaging allows operators to determine the position of radioactive sources or hotspots from greater distances than conventional rate meters, better aligning with ALARA principles, which are a common priority for all fields in the nuclear industry.A next generation gamma imager - with improved characteristics in terms of portability, sensitivity and angular resolution - has recently been developed by CANBERRA. This system,

the "iPIX" platform, is based on a Timepix detector, a hybrid semiconductor with a 1 mm thick CdTe substrate. A unique coded mask aperture and a RGB camera are used instead of CANBERRA's previous pinhole collimator design, allowing for background subtraction without the use of heavy shielding.A comparison study between the performance of the iPIX system and other gamma cameras is presented. Highlights of the experimental results obtained with an industrial prototype are discussed along with the ongoing research related to the possibility of merging the measured radioactivity map with the 3D geometrical model of the scene under study.

GAMMA-RAY AND NEUTRON IMAGING SYSTEMS: 6

Backscatter Radiography By Selective Detection As a Non-Destructive Examination Tool

James E. Baciak, Edward T. Dugan

Nuclear Engineering Program, University of Florida, Gainesville, FL, USA

Backscatter radiography by selective detection is a form of Compton backscatter radiography that collimates the dominant near-surface x-ray scatter signal to allow for sub-surface imaging of flaws and features of interest in applications in which traditional transmission radiography is impractical. Backscatter radiography by selective detection can utilize x-ray systems up to 1 MV, although practical limitations of the backscatter signal normally limit use to 100-450 kVp. While most backscatter imaging techniques use a highly collimated pencil beam of x-rays to provide position information, this limits acquisition speeds and reduces application space. The use of x-ray fan beam geometries and high frame-rate linear detector arrays allows one to overcome these challenges and produce images over large areas. Current commercial off-the-shelf linear detector arrays have the potential to acquire images at rates of 5 meters per second or higher. In this paper, the principles or backscatter radiography by selective detection are reviewed. The use of linear detector arrays with x-ray fan beams is discussed. We present preliminary results for a prototype system that shows sub-cm position resolution is possible for a number of backscatter radiography applications, with significantly improved acquisition times of approximately 3.5 m^2/s. We discuss several examples of backscatter radiography by selective detection, including land mine detection, spacecraft components, and applied areas such as the inspection of reactor pressure vessel steel, aircraft components, and railroad infrastructure.

GAMMA-RAY AND NEUTRON IMAGING SYSTEMS: 7

High resolution neutron imaging capabilities with MCP/Timepix detector at BOA beamline at PSI

Anton S. Tremsin[1], Manuel Morgano[2], Tobias Panzner[2], Eberhard Lehmann[2], John V. Vallerga[1], Jason B. Mcphate[1], Oswald H.w. Siegmund[1], W. Bruce Feller[3]

[1]*University of California, Berkeley, California 94720, U.S.A.*
[2]*Paul Scherrer Institute, 5232 Villigen PSI, Switzerland*
[3]*NOVA Scientific, Inc., 10 Picker Rd., Sturbridge, MA 01566, U.S.A*

The cold neutron spectrum of the BOA beamline at Paul Scherrer Institute enables high contrast neutron imaging because neutron cross sections for many materials increase with neutron wavelength. However, for many neutron imaging applications, spatial resolution can be as important as contrast. The key factors defining the ultimate spatial resolution of a neutron imaging experiment are the resolution and efficiency of the detector and the beam divergence. In this paper the neutron transmission imaging capabilities of an MCP/Timepix detector installed at the BOA beamline are presented, demonstrating the possibilities for studying sub-20 μm features in various samples. In addition to conventional neutron radiography and microtomography, the high degree of neutron polarization at the BOA beamline can be very attractive for magnetic field imaging, as demonstrated by our initial experiments. The results of our experiments indicate that the BOA beamline is a valuable addition to neutron imaging facilities, providing improved and sometimes unique capabilities compared to other imaging beamlines.

Posters III – Physics& Security Applications and Signal Processing

3:00 PM - 4:00 PM (Ballroom)

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 1

Digital Pulse Analyzer for ITER Vertical Neutron Camera

Alina Ivanova[1,2], Vladimir Amosov[3], Dmitriy Skopintsev[3], Aleksander Khilchenko[1,2], Andrey Kvashnin[1], Peter Zubarev[1,2], Svetlana Ivanenko[1], Aleksander Kotelnikov[1], Ekaterina Puryga[1,2]

[1]*Budker Institute of Nuclear Physics*
[2]*Novosibirsk State Technical University*
[3]*Troitsk Institute for Innovation and Fusion Research*

The International Thermonuclear Experiment Reactor (ITER) is an experimental nuclear reactor operating with a magnetic toroidal field of 5.3 T, plasma current of 15 MA, pulse duration up to 500 s and producing up to 700 MW fusion power. It is aimed to demonstrate the feasibility of nuclear fusion realization generating DD and DT fusion reactions with characteristic neutrons 14 MeV. The Vertical Neutron Camera (VNC) should provide time- and space-resolved measurements of the neutron emissivity and neutron flux, fusion power density and alpha-particle density profile providing information on ITER operation performance.

ITER VNC requires:
- all electronic equipment from ITER Catalog of I&C products;
- multichannel registration;
- common external synchronizing system for all channel registration;
- 12-bit digitizer with sampling rate from 250 MHz to 1 GHz;
- count rate up to 10^7 events/s;
- on-line digital technique for separation and reconstruction pile-up;
- reconfigurable data processing unit.

Taking into account the above-mentioned specifications Digital Multichannel Analyzer for ITER VNC is based on ADC12500PXIe digitizer. It is developed in our workgroup and included into ITER Catalog of I&C products – Fast Controllers (345X28 v2.3).ADC12500PXIe digitizer is a two-channel waveform recorder with reconfigurable data processing unit, based on FPGA. Each measuring channel built on 12-bit ADC with 500 MHz sampling rate and high frequency bandwidth (0-250 MHz) and has programmable gain and zero line position. Data processing unit was configured for Digital Pulse Analyzer (DPA). DPA performs pulse height analysis using on-line algorithms implemented in the FPGA and waveform registration for debugging and monitoring. Pile-up events are detected and reconstructed using several digital processing algorithms, such as triangular or trapezoidal filter.Developed software includes three system levels: Linux device driver, EPICS driver, Human Machine Interface (HMI). The Linux device driver conforms to the standard Linux device model in that you access and control the ADC12500PXIe device and Digital Pulse Analyzer. The driver support library provides all the functionality through a relatively small set of easy to use functions (API) that hide all driver ioctl functions and implementation details. The main purpose of EPICS driver is to interconnect HMI with Linux device driver. Human machine interface (HMI) was developed using Control System Studio. It is based on Java, which allows users to make the program portable between operating systems (Linux, Windows, Mac OS, etc.). HMI provides a graphics-based visualization of spectral and waveform data and control of operating modes.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 2

256-pixel microcalorimeter array for high-resolution γ-ray spectroscopy of mixed-actinide materials

R. Winkler[1], A. S. Hoover[1], M. W. Rabin[1], D. A. Bennett[2], W. B. Doriese[2], J. W. Fowler[2], J. Hayes-wehle[2], R. D. Horansky[2], C. D. Reintsema[2], D. R. Schmidt[2], L. R. Vale[2], J. N. Ullom[2]

[1]*Los Alamos National Laboratory, Los Alamos, NM*
[2]*National Institute of Standards and Technology, Boulder, CO*

For X- and γ-ray spectroscopy applications, unprecedented spectral energy resolutions are attained with the use of cryogenic microcalorimeter detectors. High-precision measurements that are sensitive to weak radiation signatures are vital to the improved analysis of nuclear materials for material accountability and safeguards applications. Current X- and γ-ray spectroscopy of mixed-actinide materials particularly at energies below 200 keV becomes exceedingly difficult due to the large number of closely spaced photopeaks that are impossible to resolve using state-of-the-art high-purity Germanium detectors. Microcalorimeter detectors offer up to an order of magnitude improvement in energy resolution, as low as 22 eV at 100 keV, making these detectors ideal for the study of the complex emission spectra of mixed-actinide materials. A 256-pixel microcalorimeter array has been fabricated and used to collect data on a variety of Pu isotopic standards to both characterize the instrument and enable a detailed study of the measurement uncertainty associated with the determination of relative Pu mass abundances. These measurements represent the first time the simultaneous multiplexed readout of the entire array for Pu data acquisition has been achieved. For measurements of the emission spectra of Pu isotopic standards, an average FWHM of the 102.98 keV ^{241}Am photopeak was determined to be 72.1 eV. In addition to excellent overall array energy resolution, stable array operation for total event rates beyond 1 kHz has been demonstrated. For array count rates of 1.25 kHz, approximately 5.6 cps/pixel, an average pixel FWHM at 100 keV of 83.2 eV was achieved for a Pu isotopic standard CBNM-PU70 measurement. The performance of the 256-pixel microcalorimeter array during the Pu isotopic measurements and its behavior for high count rate operation will be presented.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 3

Progress in the development of a single-volume neutron scatter camera

Erik Brubaker[1], John Mattingly[2], Aaron Nowack[1], John Steele[1], Melinda Sweany[1], Kyle Weinfurther[2]

[1]*Sandia National Laboratories, Livermore, CA*
[2]*North Carolina State University*

We are developing a single-volume double-scatter neutron imager, targeting nuclear security applications such as weak source detection of special nuclear material, arms control treaty verification, and emergency response. The detection concept is the same as that used for the neutron scatter camera (NSC), an imaging spectrometer for fission-energy neutrons, involving the use of kinematic information from two neutron-hydrogen elastic scattering events in organic scintillator. Relative to competing technologies such as coded aperture imaging, time-encoded imaging, neutron time projection chamber, and various thermal neutron imagers, double-scatter imaging provides excellent event-by-event directional information for signal/background discrimination, reasonable imaging resolution, and good energy resolution. Its primary drawback is very low detection efficiency due to the requirement for neutron elastic scatters in two detector cells. In the single-volume neutron scatter camera under development, however, both neutron scatters can occur in the same large active volume. If successful, the efficiency will be dramatically increased over the current NSC cell-based geometry. If the detection efficiency approaches that of e.g. coded aperture imaging, the other inherent advantages of double-scatter imaging will make it a very attractive fast neutron detector for a wide range of security applications. The key technical hurdle for this concept to be successful is the ability to resolve two proton recoils in a single scintillator volume at spatial and temporal separations of order 1 cm and 1 ns, respectively, via the scintillation light isotropically emitted from the two interaction points. This central task would not be possible using traditional photomultiplier tubes, but recent advances in photodetection technology have made it conceivable. A calculation of the achievable improvement in effective area is at least an order of magnitude. The detector footprint will also be greatly reduced. We will present results of recent simulation studies and laboratory experiments.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 4

High pressure xenon TPC radiation background for NEXT experiment

Abdel Bachri[1], Martin Hawron[2], Perry Grant[3], Clayton Martin[1]

[1]*Southern Arkansas University, Magnolia, AR 71753*
[2]*University of Connecticut, Storrs, CT 06269*
[3]*University of Arkansas, Fayetteville, AR 72701*

Neutrino Experiment with a Xenon TPC (NEXT) promises a novel detection method for the neutrino less double beta decay (0νββ). The planned instrument of detection is a 100 kg gaseous Xenon-136 high pressure Time Projection Chamber (TPC) to be installed in the Canfranc Underground Laboratory (LSC). The TPC will search for the rare 0νββ ionization signal of distinct topological signature with Q_{ββ} = 2.458 MeV. However, more frequent internal (within TPC) and external events are capable of depositing energy in the range of Q_{ββ} inside the chamber, thus mimicking 0νββ, or interfering with its direct observation. In the following paper, assuming a basic cylindrical design for a titanium TPC capable of containing 100 kg of Xenon gas at 20 atm pressure, we estimate the background budget for NEXT – 100, analyze the most prominent problematic events. Gamma rays emitted from nuclei of ^214^Bi and ^208^Tl present in the outer shell titanium housing of the TPC are an example of such events for which we calculate probabilities of occurrences. We also study the effect of alpha-neutron (α-n) induced neutrons and calculate their rate. Alpha particles are created by the decay of naturally occurring uranium and thorium present in most materials, these particles can react with the nucleus of low Z elements, prompting the release neutrons and leading to thermal neutron capture. The calculations suggest that the anticipated PTFE coating of the chamber constitutes the primary material for neutron production, specifically, the fluorine component of Teflon proved to be much more likely to undergo an (α-n) reaction. From known contamination we calculate α-production rate from the highest purity titanium vessel when lined with Teflon to be α/year, and using measurements of neutron flux from alpha bombardment we estimate the expected neutron flux from the materials. By identifying all gamma rays (prompt or delayed, of energies comparable to Q_{ββ} originating from thermal neutron capture with all stable elemental isotopes in NEXT proposed TPC, we show that, in order to limit the most probable reactions to a rate of one event per year or less, the neutron flux would have to be reduced to (3 – 6) × 10^(-10) cm^(-2).s^(-1).

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 5

Characteristics of miniaturized CsI(Tl) scintillator for mobile radiation detector

Hyunjun Yoo[1], Chankyu Kim[1], Yewon Kim[1], Segyeong Joo[2], Gyuseong Cho[1]

[1]*Radiation Detection and Medical Image Sensor Lab., Korea Advanced Institute of Science and Technology, Daejeon, Republic of Korea*
[2]*ASAN MEDICAL CENTER, Seoul, Republic of Korea*

Existing radiation detectors using Geiger Muller tube or photo multiplier tube are not suitable for being integrated into a small or mobile devices like smart phones due to its bulky volume. To build a truly miniaturized radiation detector, characteristics of a scintillator coupled with a silicon detector should be confirmed, especially when a scintillator is miniaturized.There are two issues in designing the geometry of the scintillator to be integrated in a mobile radiation detector. One is the performance in detecting background radiations. The other is shaping the scintillators to minimize the photon loss due to the absorption at outer wall (Teflon taping), which are arose by the tapered structure and small output area of the scintillators. Therefore, in this paper, we suggested various geometries of scintillators and tested the performance of the background detection and the amount of photon loss.First experiment checked the performance in background detection with increasing the volume of CsI(Tl) scintillators. A silicon photo multiplier (SiPM) and photo multiplier with hexahedral CsI(Tl) scintillators were used. Background counts of the SiPMs showed slight differences depending on the area of the SiPM while the PMT showed linear increase of background counts. The background counts of the SiPM of 9.48×9.48mm2 area was distinctly higher than that of the SiPM of 6.32×6.32mm2 area since dark count of a SiPM increases according to the area of the SiPM. Therefore the area of a silicon detector like SiPM should be minimized to decrease the dark noise. Second experiment revealed the reduction of the output signal due to the photon loss from absorption at outer walls of scintillators with various shapes. The results showed that the output signal reduction in type 1 shapes was smaller than that of type 2 shapes, which is similar to the simulation results. Large volume of type1 shapes helped in reducing the amounts of photon loss. In conclusion, to determine the geometry of CsI(Tl) scintillator for mobile radiation detectors, the performances of background detection and the photon loss should be considered.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 6

Integration of X-ray and neutron radiography data for enhanced discrimination of materials with high atomic number

Andrew J. Gilbert[1,2], Ben S. Mcdonald[1], Tim A. White[1], Mark R. Deinert[2]

[1]*Pacific Northwest National Laboratory, Richland, WA*
[2]*The University of Texas at Austin, Austin, TX*

Noninvasive detection of illicit high-atomic-numbered (high-Z) materials continues to be an active area of research due to its importance to a wide range of applications including nuclear weapons dismantlement, nuclear material accountancy, and security inspections. Current methods utilizing dual-energy X-ray radiography are limited in their ability to distinguish high-Z materials in heavily occluded configurations such as cargo. Furthermore, X-ray inspections have difficulty distinguishing materials of similar Z due to the similarity of their attenuation coefficients. These factors will limit the ability to distinguish an illicit material, e.g. plutonium or uranium, from common innocuous materials, e.g. lead. Adding neutron radiography as a complementary source of data can increase the accuracy of material discrimination from such inspections. Here we present an inverse problem framework to combine multi-energy X-ray and neutron radiography data to increase accuracy in discrimination of illicit high-Z materials from innocuous in a layered configuration. Improved performance with the combined data set compared to the X-ray only data set is demonstrated using simulated radiography data.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 7

PERFORMANCE OF A SMALL ANODE GERMANIUM WELL DETECTOR

Aderemi S. Adekola, James F. Colaresi, Jonas Douwen, Wilhelm F. Mueller, Kenneth M. Yocum

CANBERRA Industries, Inc., 800 Research Parkway, Meriden CT 06450 USA

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 8

Radiation Damage Study and Characterization of Hamamatsu Silicon Photo-Multipliers

Massimiliano Fiorini[1], Mirco Andreotti[1], Wander Baldini[1], Roberto Calabrese[1], Angelo Cotta Ramusino[1], Flavio Dalcorso[2], Eleonora Luppi[1], Roberto Malaguti[1], Luca Tomassetti[1], Giulia Tellarini[1]

[1]INFN Sezione di Ferrara and Università degli Studi di Ferrara, Italy
[2]INFN Sezione di Padova, Italy

An irradiation test on 16 Silicon Photo-Multipliers (SiPMs) produced by Hamamatsu has been performed at the Louvain-la-Neuve Cyclotron facility in Belgium. The devices have been irradiated with neutrons in three fluence steps: $5x10^8$, $5x10^9$ and $5x10^{10}$ 1 MeV neutron equivalent (n_{eq}) per cm^2. After each irradiation step, the characteristic current-voltage curves and a high statistics sample of the dark noise waveforms have been recorded for offline analysis. In the proposed contribution we present the results on the variation of the main SiPM parameters as a function of the dose for the devices under study, that include as well special samples with "Radiation Hard" design.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 9

ARES Topic 1 - HeliSORDS

Hylton R. Murphy

Sensors & Phenomenology, Leidos, 10740 Thornmint Road, San Diego, CA 92127

HeliSORDS Abstract for SORMA 2014DNDO's Airborne Radiological Enhanced-sensor System (ARES) program seeks to improve methods to detect and localize radiological sources from an airborne platform. The ARES program is divided into two distinct topic areas: 1) the integration of radiological detectors and additional sensing modalities for deployment on rotary wing aircraft and, 2) algorithms that act on the acquired data to yield enhanced detection, localization, and identification of radiological threats.HeliSORDS is an integrated system built to satisfy the ARES Topic 1 requirements to evolve the ability to locate, localize and identify R/N sources in airborne platforms by improving the functionality of existing systems in the areas of detector design and arrangement; object tracking; situational awareness; and characterization and classification. HeliSORDS deploys two Airborne Imaging Modules (AIMs), seven HD video cameras and various auxiliary sensors on a Bell 412 helicopter. Each AIM contains 46 2.5 cm × 2.5 cm × 42 cm CsI(Na) scintillators arranged in a novel detector arrangement providing both peripheral localization

and Compton imaging giving R/N source localization to within 10 meters. HeliSORDS is required to provide an integrated data stream for consumption by ARES Topic 2 algorithms. Data is collected by the AIMs, auxiliary sensors and HD cameras, processed in real time, stored in an on-board RAID array and later provided for post-processing at the LBNL ARES data processing facility.There are three software components for the HeliSORDS systems: HeliSORDS RAVE, ZoP and AIM Processor. RAVE stands for Real-time Aerial Video Exploitation and is a suite of software modules tailored for use in HeliSORDS to include video acquisition, near real-time video mosaicking, geo-registration, and moving object tracking. In addition to acquiring and processing flight video data HeliSORDS RAVE also ingests and processes the data from the R/N detector system and the HeliSORDS auxiliary sensors, ultimately providing HDF5 formatted data. The AIM Processor software acquires and processes the data from the CAEN electronics for the R/N sensors and passes it on to HeliSORDS RAVE. The third HeliSORDS software component, ZoP, stands for Zones of Protection and provides queryable terrain databases for use by the ARES Topic 2 teams. It allows integration of terrain data with all the other HeliSORDS data including the R/N data. A large ZoP developmental effort for HeliSORDS includes the generation of detailed databases for three regions of interest: Washington DC, Las Vegas and San Francisco. During flight the HeliSORDS system utilizes an NTP Server providing GPS timing to synchronize all HeliSORDS sensors. The on-board inertial navigation sensor (INS) and radar altimeter provide accurate location, altitude, and attitude data used for geo-registering video and R/N data to 3D maps and to track vehicles and/or vessels. In addition, temperature and pressure sensors enable calculation of air density and subsequent gamma-ray air attenuation correction.This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-12-C-00097. This support does not constitute an express or implied endorsement on the part of the Government.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 10

Study on Photon Number Resolution of Silicon Photomultipliers with different sizes of micro cells

Hyoungtaek Kim[1], Kyung Taek Lim[1], Chankyu Kim[1], Hyunjun Yoo[1], Yewon Kim[1], Jongyul Kim[1], Myung Soo Kim[1], Daehee Lee[1], Minsik Cho[1], Dong-uk Kang[1], Eunjoong Lee[1], Kyeongjin Park[1], Gyuseong Cho[1], Woo Suk Sul[2]

[1]*Department of Nuclear and Quantum Engineering, Korea Advanced Institute of Science and Technology, Daejeon, Republic of Korea*
[2]*National Nanofab Center, Daejeon, Republic of Korea*

Silicon Photomultipliers (SiPM) has become one of most highlighted radiation detectors for positron emission tomography with magnetic resonance (PET-MR) application with their high gain, good timing resolution, lower operation voltage, compactness and lower cost as well as non-sensitivity to magnetic fields. However the photon response of SiPMs is one of the major drawbacks compare to other photon diodes. The photon response of SiPMs is degraded by their non-linear characteristic and thus photon number resolution (PNR) was suggested to apply this characteristic to the energy resolution. The PNR consists of several noise factors which are defined as excess noise factors of charge multiplication, charge duplication, dark count and non-linearity. These factors have dependencies on the size of micro-cells which is a main parameter when a SiPM is designed. In this paper, the effect of the size of micro-cells on PNR was studied to build an optimum structure of SiPMs for PET application. The 3 x 3 mm^2 SiPMs with several different sizes of micro cells from 25 um to 125 um was designed. The sensors were fabricated by using customized CMOS processes at National NanoFab Center (NNFC). Each micro cell consists of a shallow n+/p well junction on a p-type epitaxial wafer and passive quenching circuit was applied.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 11

SWORD (SoftWare for the Optimization of Radiation Detectors)

Chul S. Gwon[1], Mark S. Strickman[1], Bernard F. Phlips[1], Lori A. Jackson[2], Donald Polaski[2], Byron Leas[3]

[1]*Naval Research Laboratory, 4555 Overlook Ave SW, Washington, DC 20375*
[2]*Praxis, Inc., 5845 Richmond Highway, Suite 700, Alexandria, VA 22303*
[3]*SRA, International, 4300 Fair Lakes Court, Fairfax, VA 22033*

SWORD is a vertically-integrated software package, developed by the Naval Research Laboratory (NRL) for the Domestic Nuclear Detection Office (DNDO) of the Department of Homeland Security, to streamline the process of setting up and running simulations using multiple high-energy radiation transport codes. Using a set of primitive shapes in a CAD-like environment, users may graphically construct their instruments and surrounding environment, assigning radiation emission and/or detector properties to the created geometries. For more expedient setup of a desired

scenario, SWORD also includes an extensive, and extensible, standard library of objects (COTS detectors, vehicles, buildings, etc) and spectra (threat, naturally occurring radioactive materials, sea and terrestrial backgrounds). User-developed projects may be shared with other SWORD users and combined and modified as desired. SWORD also provides analysis tools for processing the results from the simulation. These include spectrum generation, showing the detector response to a source, as well as imaging capabilities for Compton, Coded Mask, and radiography instruments. These outputs are stored in industry-standard formats that can be used with SWORD-provided tools, as well as other common tools available to the community.This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-13-X-00042. This support does not constitute an express or implied endorsement on the part of the Government.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 12

Straw Detector for Ultra High Rate Neutron Detection in the Presence of Ultra High Gamma Flux

Jeffrey L. Lacy, Athanasios Athanasiades, Liang Sun, Christopher S. Martin, Gerson Vazquez

Proportional Technologies, Inc., Houston, TX 77054

The demand for low-cost, efficient neutron detection technologies has been catapulted by the worldwide shortage of ^{3}He gas. Boron-coated straw (BCS) detectors can not only successfully replace ^{3}He tubes in homeland security applications, but can improve performance in applications that require high count rates, and or high tolerance to intense gamma exposure. Many applications require detector capabilities that currently do not exist in this area. These include assessment of new and spent fuel, active interrogation of cargo in which either neutron or gamma flux level produces lengthy paralysis followed by exceedingly high neutron flux or gamma flux or both, and passive and active coincidence and multiplicity counting of high activity fuel. Proportional Technologies, Inc. has previously developed and deployed BCS-based detectors for a numerous applications in the security field, including portal monitoring, standoff detection, and coincidence counting. These detectors consist of arrays of straws, read out in groups. A BCS-based design has been developed recently to demonstrate capability for the above taxing applications. The detector employs 864 straws, each 60 cm in length, distributed with a pitch of 0.76 cm, as a 17×51 array, within a high-density polyethylene (HDPE) moderator block with outer dimensions of 11 cm × 40 cm × 60 cm. The detector, operated with a custom-designed, low-cost electronic readout, and appropriate segmentation into multiple channels (up to one channel per straw) can accommodate count rates up to GHz levels, with acceptable dead time losses. Monte Carlo simulations, implemented in MCNP5, show that gamma tolerance levels of 10^{-11} – 10^{-15} can be achieved with high neutron threshold efficiency ranging from 0.92 – 0.83.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 13

DYNAMIC TEST RESULTS OF A TIME-CORRELATED RADIATION PORTAL MONITOR

Rico Chandra[1], Giovanna Davatz[1], Ulisse Gendotti[1], David Murer[1], Paolo Peerani[2], Hamid Tagziria[2]

[1] *Arktis Radiation Detectors Ltd Räffelstrasse 11 8045, Zurich, Switzerland*
[2] *JRC, Via Enrico Fermi 2749, 21027 Ispra, Italy*

A Radiation Portal Monitor (RPM) exploiting time-correlation was developed in an international collaboration. This paper presents test results where the RPM was used to detect moving sources. The portal exhibited a number of desired capabilities. A primary operational concern for operators of RPMs is the high nuisance alarm rate caused by Naturally Occurring Radioactive Material (NORM). One of the most important sources of NORM alarms is K-40, which is often hard to distinguish from threat material (especially Co-60) even when using more advanced methods such as PVT energy windowing. Our results demonstrate that precisely this task can be solved by employing time correlation, separation of K-40 and Co-60 was achieved even with weak shielded Co-60 sources. Furthermore, also certain types of Special Nuclear Materials (SNM) exhibits time correlation. This works also demonstrates the benefits of using time correlation for the detection of SNM surrogates.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 14

Embedded search and ID capability for human portable radiation detectors

Kirill N. Shokhirev, Bogdan R. Cosofret, Michael A. Costolo

Physical Sciences Inc., 20 New England Business Center, Andover, MA 01810-1077

The search for radioactive sources using man-portable radiation detectors is an essential part of the missions carried out by first responders, law enforcement and military personnel. Current approaches use ad-hoc techniques based on the experiences of individual users and suffer from low repeatability and long localization times. A systematic approach implementing the best search practices and aided by processing algorithms embedded on ubiquitous mobile computing devices, such as smartphones, can significantly enhance the search capability.Physical Sciences Inc. (PSI) developed a set of algorithms enabling enhanced pedestrian search capability against radioactive sources when using handheld, belt, or backpack mounted detector systems. The approaches demonstrated the capability to accurately localize sources. In addition, we developed an approach to associate the source with visible objects to aid tracking and interdiction.The derived solution represents a low cost augmentation of personal radiation detectors (PRDs) through the use of advanced algorithms running on COTS mobile computing devices (MCDs) such as smartphones and tablets. Our approach achieves initial source localization accuracy of 15° (azimuth) and 1.5 meters (range) in 30 seconds. The methods achieved an accuracy of 1 meter in two dimensions after a 30 second sampling of radiation fields during wide area search missions. This capability was demonstrated against a 1 mCi source at 20 meters using man-portable radiation detectors with a nominal sensitivity of ›2000 cps/(μSv/h).PSI performed a systematic trade study and testing of COTS components, including MCD products, man-portable radiation detectors and open source software libraries. The results of the trade study were used to generate a component-level conceptual design for a prototype system with embedded search algorithms.This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-12-C-00087. This support does not constitute an express of implied endorsement on the part of the Government.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 15

Determination of Penn State Breazeale Reactor Fuel Element Burnup by Nondestructive Assay

Sarah Bender, Chad Durrant, Brenden Heidrich, Kenan Ünlü

Radiation Science and Engineering Center, Pennsylvania State University, University Park, PA 16802-2304

Gamma-ray spectroscopy has been the preferred method for the determination of burnup of spent fuel assemblies for nuclear safeguards inspections because it is non-destructive, inexpensive, and efficient. The alternative approach is destructive chemical measurements carried out in hot cells that requires expensive disposal of fuel samples and longer analysis time. Burnup measurements of spent nuclear fuel are used in safeguards applications to verify the operator declaration prior to reprocessing and in power generation to calculate the safe storage limits in spent fuel storage pools in order to remain at sub-critical levels. The Radiation Science and Engineering Center at The Pennsylvania State University houses the Penn State Breazeale Reactor (PSBR), a 1-MW TRIGA Mark-III research reactor, and an inventory of irradiated research reactor fuel spanning 48 years of operation. Direct gamma-ray measurements of the nuclide composition of five irradiated fuel elements removed from the core were performed. The data was used to calculate the incremental and average burnup using the isotopes ratio method. A HPGe detector was used to collect gamma-ray spectra at several intervals over the vertical length of the fuel elements using a collimated beam port to determine the segmented burnup across the axial length of the fuel rod. Predicted burnup values for the fuel elements were produced by the highly specialized, Monte Carlo-coupled depletion simulation code TRIGSIMS previously developed for fuel management at the PSBR. Comparison between the predicted and measured values resulted in average errors ranging from 5.49% to 32.37%. Sources of error may be due to several contributing factors which include simplifying assumptions in TRIGSIMS calculation, the irregular operating history of the PSBR, and isotope migration within the fuel elements. During the development and validation process of TRIGSIMS, simplifying assumptions were made by combining short-run core loadings, effectively averaging the reactor power over these loading. Also, TRIGSIMS uses a constant temperature value for each fuel element when calculating element reactivity changes. This approximation generates additional error in the calculated burnup values through the calculation of the neutron flux. The PSBR operates very irregularly; there are no typical days as for a commercial reactor. The reactor may be power cycled several times some days and operated at a constant power the next day due to the facility's mission of research, education and service activities. This complex irradiation history made it difficult to determine precise burnup values from the operating logs. Lastly, cesium is a volatile metal and has been shown to migrate to colder regions within fuel elements. The magnitude of this error could be evaluated in the future rotating the fuel element in the measurement apparatus.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 16

Finding Gaps in Data to Guide Development of a Radiation Threat Adjudication System

Nicholas Gisolfi[1], Madalina Fiterau[1], Artur Dubrawski[1], Saswati Ray[1], Simon Labov[2], Karl Nelson[2]

[1]*Auton Lab, Carnegie Mellon University*
[2]*Lawrence Livermore National Laboratory*

We consider an incident classification task in a radiation threat adjudication system. As vehicles travel across international borders, they may be scanned for sources of harmful radiation, such as improperly contained medical or industrial isotopes, or nuclear devices. A substantial number of potential threats flagged by radiation measurement devices that may be used in such applications are actually benign artifacts due to naturally occurring radioactive materials (such as ceramics, marble, cat litter, or potash). We have been using machine learning methodology to dismiss alerts that are confidently explainable by non-threatening natural causes, without increasing the risk of neglecting actual threatA robust alert adjudication system must be trained and validated on data that includes the actual threats. However, such data is hard to come by. Therefore, it is practical and common to place the bulk of the available empirically gathered positive incident examples into a testing data set, and create training data using benign measurements mixed with a carefully chosen selection of simulated threat. Nonetheless, the volumes and complexities of the feature space in data typically encountered in radiation measurement applications makes synthesising a robust, sufficiently large, and (most importantly) comprehensive sets of training data difficult and prone to omissions.We present an engineering framework that facilitates data quality audits by automatically detecting gaps in training data coverage. It highlights areas of discrepancy between training and testing samples. It also pinpoints the areas of feature space where the observed performance of the threat adjudication system appears suboptimal. The findings are presented in the form of human-readable, low-dimensional projections of data, in order to ensure interpretability of the results and to simplify planning of corrective actions. The proposed approach can find data gaps directly, by looking at mismatches between the training and testing data distributions in any and all of 2- or 3-dimensional projections of data, to yield a visually interpretable output. The algorithm can also identify data insufficiencies that may impact threat classification performance. It can achieve this by incorporating diagnostic measures resulting from the original classifier performance evaluation observed on the test set samples. These diagnostic measures allow highlighting areas of feature space where the classifier predictions are either inconsistent or potentially unreliable due to partial anomalousness of the test data points. The resulting iterative data improvement procedure boosts threat adjudication accuracy while reducing the required workload of data engineers and application domain experts, when compared to using uninformed data gathering process. The approach has been successfully used to boost performance of a radiation threat adjudication system.This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract IAA HSHQDC-12-X-00218, and by the National Science Foundation under awards 0911032 and 1320347. This support does not constitute an express or implied endorsement on the part of the Government. Lawrence Livermore National Laboratory is operated by Lawrence Livermore National Security, LLC, for the US Department of Energy, National Nuclear Security Administration under Contract DE-AC52-07NA27344.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 17

Improved Suppression of Background Radiation for Detecting Sources from Large Libraries of Known Threat

Peter Huggins[1], Artur Dubrawski[1], Prateek Tandon[1], Simon Labov[2], Karl Nelson[2]

[1]*Auton Lab, Carnegie Mellon University*
[2]*Lawrence Livermore National Laboratory*

Spectral anomaly detection is popular and effective method of handling variability of background radiation. It is often used in the context of nuclear threat detection, where suppression of the part of the signal due to variability of background boosts attainable SNR. Principal Component Analysis (PCA) is the most popular framework for implementing spectral anomaly detection. In PCA, suppression of background radiation aims to find a low-dimensional projection U such that for typical background measurements x in B, the explained variance is maximized. While conceptually appealing, this approach does not explicitly consider detection of known sources when constructing the background model. If we have a (potentially large) library of sources S, then we can simultaneously try to maximize sum of squares residual produced by variations typical in the source library, while also minimizing residual unexplained by typical background variation. A natural way to encode the trade-off is by augmenting the covariance matrix: A=covar(B)-alpha(SS^T) for a positive constant alpha. In an experiment with a library of 900 simulated fissile material spectra with varying complex shielding material/design configurations, we found that performance of detecting source-injected background measurements could be considerably boosted using SNR score derived from PCA applied to a particular A with alpha=0.08, compared to using the standard covar(B) approach, while on uninjected background measurements the correlation between SNR scores was almost perfect at 0.994. Strong correlation on

background indicates that using the new approach gives similar background suppression, while revealing more source signal when it is present. Using a higher alpha (0.2) source detection performance was almost identical to using 900 individual match filters simultaneously, although the correlation on uninjected background dropped to 0.55. Further experiments showed that the ability to detect unexpected source designs (not in the library) is retained in the proposed approach.For very large source libraries, using a single augmented PCA model is computationally superior to repeatedly applying many individual match filters, and the augmented PCA may offer equivalent or better false positive rates, because applying multiple match filters may significantly increase the risk of spurious false positives detections. Furthermore, when prior source information is vague and match filters cannot be used effectively, even the vague information can still be effectively encoded in the augmented PCA framework. Finally, when the stipulated source spectra differ in prior probabilities of encounter, this information can be encoded in the SS^T matrix as well, by multiplying the individual source template spectra by different scaling constants. This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded 2010-DN-077-ARI040-02, and by the National Science Foundation under awards 0911032 and 1320347. This support does not constitute an express or implied endorsement on the part of the Government. Lawrence Livermore National Laboratory is operated by Lawrence Livermore National Security, LLC, for the US Department of Energy, National Nuclear Security Administration under Contract DE-AC52-07NA27344.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 18

Highly Portable HPGe Detector for Safeguards Applications

Jonathan G. Dreyer[1], Morgan T. Burks[1], Ethan L. Hull[2]

[1]Nuclear Security Physics, Lawrence Livermore National Laboratory, Livermore CA
[2]PHDS Co., Knoxville, TN

Spectroscopic Portable Germanium (SPG) is a portable, mechanically-cooled, high purity germanium spectrometer designed for safeguards applications. The SPG offers comparable performance to existing liquid cryogen HPGe detectors in an ultra compact design, making the system an ideal tool for the next generation of safeguard inspection activities. Here we describe the instrument design and compare the performance to existing systems. Results from measurements made during the IAEA Physical Inventory Verification at the Korea Nuclear Fuel Fabrication Company will be presented.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 19

New proposals for radiation portal monitor applications

Byoung-jik Kim[1], Hyon-sock Chang[2], Young-yong Ji[3], Hee-yeoul Choi[1], Jee-yon Lee[1]

[1]Division of safety research, Korea Institute of Nuclear Safety, Yuseong, Daejeon, 305-338, Republic of Korea
[2]Radiation Monitoring Systems Division, Satrec Initiative, Yuseong, Daejoen, 305-811, Republic of Korea
[3]Environmental Radioactivity Assessment Team, Korea Atomic Energy Research Institute, Yuseong, Daejeon, 305-353, Republic of Korea

New concepts and ideas are suggested for gamma-ray detection by vehicle portal monitors at international borders. Troubles in the monitoring systems are analyzed and the resolutions are debated in practical application. The information of radionuclides needs to be as specific as possible in the device promptly. The effectiveness of inspection is also considered in the study. Ideas for minimizing innocent alarms in operations of plastic scintillator system are proposed. Algorithms to give better performance in identifying radioisotopes are figured out. Threatening sources can be detected and give warning signals in effective ways.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 20

Comparison of waveform digitizers for spectroscopy and homeland security applications

Davide Cester[1], Luca Stevanato[1], Giancarlo Nebbia[2], Giuseppe Viesti[1]

[1]*Università di Padova, Dipartimento di Fisica ed Astronomia, Via Marzolo 8, Padova I-35131, Italy*
[2]*INFN Sezione di Padova, Via Marzolo 8, Padova I-35131, Italy*

During recent years digital data acquisition systems have become increasingly popular in replacing analog systems for a variety of applications, from laboratory experiments to homeland security installations. Waveform digitizers represent the core module for most of newly developed set-ups; their performances heavily depend on the electronics characteristics, mainly sampling rate and resolution.In this work we have used three reference detectors: plastic scintillator EJ-228 for studying timing properties, LaBr(Ce) scintillator for energy resolution and liquid scintillator EJ-301 for evaluating neutron/gamma discrimination capabilities.The setups have been exposed to gamma rays and neutrons in various configurations; the signals have been processed with three models of desktop digitizer (CAEN DT5751, CAEN DT5730, CAEN DT5780) working at different sampling rates (250, 500, 1000 and 2000 MS/s) and with different input resolutions (10, 12 and 14 bits).After providing a theoretical background and commenting the expected outputs, the results will illustrate the influence of the digitizer parameters on timing performances, energy resolutions and Pulse Shape Discrimination capabilities.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 21

A liquid scintillator fast neutron multiplicity counter

Steven A. Sheets, Andrew M. Glenn, Phil L. Kerr, Les F. Nakae, Jason R. Newby, Neal J. Snyderman, Wolfgang Stoeffl, Jerome M. Verbeke, Ron E. Wurtz

Lawrence Livermore National Laboratory

Neutron multiplicity counters are frequently used in nuclear safeguards and arms-control applications to passively assay special nuclear material. Traditionally, thermal 3He counters are used in coincidence or multiplicity mode to assay material. In this work, we describe LLNL's research program on fast neutron multiplicity counting using highly segmented arrays of liquid scintillators. Measurements of multiplying special nuclear material are presented and a discussion of the challenges of assaying material in high gamma fields is given.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 22

Development of a digital pulse processing system for a 2-D THGEM-based microdosimetric detector

Sahar Darvish-molla, Kenrick Chin, William V. Prestwich, Soo Hyun Byun

Department of Medical Physics and Applied Radiation Sciences, McMaster University, Hamilton, ON, Canada, L8S 4K1

Inspired by our prototype THick Gaseous Electron Multiplier detector [1,2], a two dimensional microdosimetric detector is currently under development. This detector aims to measure the spatial distributions of high and low linear energy transfer radiation doses simultaneously in mixed radiation fields, which will enable us to overcome the operational limitation of the classical tissue-equivalent proportional counters (TEPCs), particularly for high dose rate fields. The detector consists of an array of 5×5 gas cavities, equivalent to 25 TEPCs, which requires 25 pulse height analyzers to process each individual signal simultaneously. Taking the overall cost, size and flexibility into account, we developed a digital pulse processing system using a modern microcontroller interfaced with an ADS807 12-bit sampling ADC with a sampling rate of 42 Msps. The prototype system was tested using a NaI(Tl) detector in comparison with a traditional analogue system and a commercial digital system. The preliminary test results for dead time and resolution are promising. Detailed analyses for various count rates will be presented.

References

[1] S.H. Byun, G.M. Spirou, A. Hanu, W.V. Prestwich, and A.J. Waker, IEEE TNS. 56 (3) (2009) 1108-1113

[2] G.M. Orchard, K. Chin, W.V. Prestwich, S.H. Byun, Nucl. Instrum. Meth. A. 638 (2011) 122–126

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 23

Performance of a new real time digital pulse processing system for X-ray and gamma ray semiconductor detectors

Leonardo Abbene, Gaetano Gerardi, Fabio Principato

University of Palermo, Italy

New generation spectroscopy systems have advanced towards digital pulse processing (DPP) approaches. DPP systems, based on direct digitizing and processing of detector signals, have recently been favoured over analog pulse processing electronics, ensuring better performance. In this work, we present the performance of a new real time DPP system for X-ray and gamma ray semiconductor detectors. The system is based on a commercial digitizer equipped with a custom DPP firmware, developed by our group, for on-line pulse shape and height analysis. X-ray and gamma ray spectra measurements with cadmium telluride (CdTe) and germanium (Ge) detectors, coupled to resistive feedback preamplifiers, will be presented, both at low and high rate environments (up to 1.1 Mcps). The proposed DPP system is a very attractive tool for both laboratory research and for the development of advanced detection systems for high-rate-resolution spectroscopic imaging, recently proposed in diagnostic medicine, industrial imaging and security screening.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 24

Study on Digital Pulse Shape Discrimination in a BF_3 detector

Jinhyeong Kim, J. H. Kim, H. D. Choi

Department of Nuclear Engineering, Seoul National University, Seoul, Korea

For the nuclear non-proliferation and safeguards, an accurate and reliable measurement of nuclear material is essential. As a representative method of non-destructive assay, neutron measurement is difficult due to large background radiation which is secondary radiation, spurious pulse and so on. So neutron should be discriminated from background radiation for the accurate detection. To discriminate neutron signal, pulse shape discrimination system composed of some nuclear instrumentation modules were used in past. However, applications of other discrimination methods require different detection modules and setting parameters and it is time and money consuming procedures. In this study, digital pulse shape discrimination method by using amp bipolar pulse is developed and applied to a neutron detection system by using boron trifluoride (BF_3) gas-filled proportional counter.1-GHz digital oscilloscope of Tektronix DPO7104C model is used for spectrum acquisition. The bipolar pulse of the spectroscopy amplifier is used because it can reduce the amplitude walk. The method of two-dimensional pulse distribution analysis is adopted. Height and width of pulses are used for the peak shape comparison. Background signals are discriminated in 2-D graph of height versus width. Meanwhile, the performance of particle discrimination relies on the method of peak width determination. The optimum condition is obtained by calculation of Figure Of Merit (FOM).

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 25

Development of a 32-Channel Digital Gamma-ray Spectrometer

Hui Tan, Wolfgang Hennig, Mark Walby, Joshua Galecki

XIA LLC, 31057 Genstar Rd, Hayward, CA 94544

A 32-channel digital gamma-ray spectrometer is being developed for nuclear physics or other radiation detection applications requiring digital signal processing with large number of channels at relatively low cost. A single 32-channel spectrometer provides spectrometry and waveform acquisition for 32 input signals per module whereas multiple modules can be combined into larger systems. It is based on the PCI Express standard which allows data transfer rates to the host computer of up to 800MB/s. Each of the 32 channels accepts signals directly from a detector preamplifier or photomultiplier. Digitally controlled offsets can be individually adjusted. Signals are digitized in 12-bit, 65 MHz multi-channel ADCs. Triggering, pile-up inspection and filtering of the data stream are performed in real time, and pulse heights and other event data are calculated on an event-by

event basis. Detailed architecture, signal processing capabilities, gamma-ray spectroscopic performance (energy resolution, linearity, timing resolution), and throughput of this 32-channel gamma-ray spectrometer, will be presented.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 26

Composition Optimization of Polystyrene Based Plastic Scintillator

Yewon Kim, Hyunjun Yoo, Chankyu Kim, Kyungjin Park, Eunjoong Lee, Gyuseong Cho

RDMIS, Department of Nuclear and Quantum Engineering, Korea Advanced Institute of Science and Technology, 291 Daehak-ro,, Yuseong-gu, Daejeon 305-701, South Korea

Plastic scintillator has advantages such as fast decay time, easy fabrication, low production cost and so on. Due to the scintillation property depends on the composition of the scintillator, it is important to find optimum additives ratio that plastic scintillator has maximum light yield. The main substance of the fabricated plastic scintillator was styrene solution and small amount of wavelength shifters (PPO (2,5-Diphenyloxazole) and POPOP (1,4-Bis(5-phnyl- 2oxidazolyl)benzene) were added. The wavelength shifters plays a roll converting ultraviolet (~300nm) emitted from polystyrene to visible light (330~500nm) with relatively longer wavelength by Stoke's shift. Therefore we tried to fabricate polystyrene based plastic scintillator samples including 24 kinds of different wavelength shifter mass ratio. Energy spectrum and emission spectrum at the radiation condition were measured with the samples to compare the emission property of the each scintillator samples. We tried to measure the relative light output of each samples through energy spectrum measurement and to measure the change of the emission wavelength through the emission spectrum measurement.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 27

Modification of the Developed Code for Isotopic Analysis of Uranium

J. H. Kim[1,2], M. Y. Kang[1], Jinhyeong Kim[1], H. D. Choi[1]

[1]*Department of Nuclear Engineering, Seoul National University, Seoul, Korea*
[2]*Nuclear Chemistry Research Division, Korea Atomic Energy Research Institute, Daejeon, Korea*

To strengthen the national nuclear nonproliferation regime by an establishment of nuclear forensic system, the techniques for nuclear material analysis and the categorization of important domestic nuclear materials are being developed. Gamma-spectroscopy is a well-known non-destructive analysis technique for the isotopic analysis of nuclear materials, however, the diversity of detection geometry and some effects – self attenuation, coincidence summing, etc. – suggest an analysis tool under continual improvement and modification especially for high density sources such as nuclear materials. Hence, developing another code for HPGe gamma- and X-ray spectrum analysis is started in this study. In uranium and plutonium spectrum, gamma-ray and X-ray peaks are mixed and different peak fitting functions are required respectively for the accurate determination of peak areas. Peak fitting method by using Gaussian and Lorentzian functions – Voigt profile – is introduced. The user can fix the number of peaks in the spectrum and edit initial fitting parameters like peak center, height, width, etc. on the GUI window. Fitting parameters are searched for the optimum value, and also can be fixed by the user. The analysis of the complex spectrum for 84-100 keV XKα-region is also attempted based on the isotopic responses. The performance of isotopic analysis for 2 to 80% enriched Uranium samples accessed with the spectra obtained by using planar HPGe detectors is discussed.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 28

Gamma-neutron imaging system utilizing pulse shape discrimination with CLYC

Chad M. Whitney, Lakshmi Soundara-pandian, Erik B. Johnson, Bob Vinci, Michael Squillante, Jarek Glodo, James F. Christian

Radiation Monitoring Devices

To determine the presence of special nuclear materials (SNM), one has to detect and identify characteristic signatures. Neutrons and gamma rays are two signatures of these materials, which when detected can confirm the presence of a particular isotope. Gamma ray detection and imaging techniques are useful for locating SNM; however, dense surrounding materials such as lead can significantly attenuate their intensity and obscure gamma images due to scattering. Neutrons, on the other hand, can easily penetrate dense and high atomic number materials. Imaging neutrons, along with gammas, can provide additional verification of the nuclear material's location. Several techniques exist for imaging gammas and neutrons such as telescopic configurations, Compton imaging, and coded-aperture cameras. The main challenge with imaging neutrons using scintillation materials is discriminating background gammas which can reduce the overall neutron contrast. Recently, RMD has investigated the use of CLYC (Cs_2LiYCl_6:Ce), a new and emerging scintillation material, in a gamma-neutron coded aperture imaging system based on RMD's commercial RadCam™ instrument. CLYC is ideal since it offers efficient thermal neutron detection (based on $^{6}Li(n,a)$ reactions), fast neutron detection capabilities (based on $^{35}Cl(n,p)$ reactions), excellent pulse shape discrimination (PSD), and gamma-ray energy resolution as good as 4% at 662 keV. PSD is beneficial to conventional pulse height techniques with CLYC for isolating higher energy gammas from thermal neutron interactions (3.5 MeVee peak). PSD is accomplished in CLYC since neutron interactions result in a slower emission decay tail while gamma interactions result in a faster emission decay tail. By creating a population plot based on the ratio of the decay tail compared to the total amplitude (PSD ratio), discrimination of gammas, thermal neutrons, and potentially fast neutrons is possible.Previously, we have characterized the CLYC-based RadCam system for imaging gammas and neutrons using a layered W-Cd coded aperture mask and employing only pulse height discrimination. In this paper, we present the latest results which investigate gamma-neutron imaging capabilities using pulse-shape discrimination. An FPGA system is used to acquire the CLYC-PSPMT last dynode signals, determine a PSD ratio for each event, and compare it to a calibrated PSD cutoff. Each event is assigned either a gamma (low) or neutron (high) flag signal which is then correlated with the imaging information for each event.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 29

Development of photon-counting X-ray nondestructive testing system using Si Strip detectors and time-over-threshold ASIC

Yang Tian[1], Xiaosong Yan[1], Hiroyuki Takahashi[1], Kenji Shimazoe[1], Takeshi Fujiwara[1], Hideki Tomita[2], Takeshi Ishikura[3], Osamu Ueda[3]

[1]*Dept. of Nuclear Engineering and Management, the Univeristy of Tokyo, Tokyo, Japan*
[2]*Dept. of Quantum Engineering, Nagoya Univeristy, Nagoya, Japan*
[3]*Fuji Electric Co., Ltd., Tokyo, Japan*

Nondestructive testing (NDT) using MeV X-rays provides useful information inside thick material such as concrete structures or steel objects. The drawbacks of the routine radiography method mainly lie in the low efficiency of detection systems. Conventional detection systems are based on integrating method, therefore the contribution of the scattered photons severely limit its application in the NDT of thick structures. We are developing a novel photon-counting imaging system based on a stack of silicon strip detectors (SSDs), which provides a large detection efficiency and energy resolving image. Each SSD is placed with its 5 cm long strips pointing to the source to increase the detection efficiency. A tungsten collimator is placed in front of the SSD stack, some parts of which extend to the intervals between each two adjacent SSD layers. The readout electronics is based on our dynamic time-over-threshold ASIC based front-end electronics, which directly converts an incident photon into digital pulse whose pulse width contains energy information. A prototype detector is fabricated and tested with a 48-channel time-over-threshold (TOT) ASIC to filter the low energy scattered photon events. Some preliminary testing results are included in the paper.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 30

Radiation Sources Driven by Superconducting RF Electron Accelerators

Chase H. Boulware, Terry L. Grimm, Valeriia N. Starovoitova, Jerry L. Hollister

Niowave, Inc., Lansing, Michigan, USA

Superconducting RF linacs can operate continuously with higher average beam intensity (current) than any other type of accelerator (cyclotron, copper linac, etc.). Niowave, Inc. has developed complete turn-key superconducting electron linacs for a broad range of commercial applications. In addition to the niobium accelerating structure, the complete system includes the liquid helium refrigerator, high power microwave source, radiation shielding and licensing. This integrated system enables a company or university research group to quickly and inexpensively use the electron

beam for a number of applications. These applications include radiation sources such as high-power x-ray sources for sterilization or production of medical radioisotopes, high-flux neutron sources, and high-power free-electron lasers. Linacs with beam energy of 0.5 to 40 MeV and average beam power of 1 W to 1 MW are under development, and two integrated helium refrigerator models have been developed with leading experts in the cryogenic industry. This contribution will discuss these integrated accelerator systems and their applications to radiation sources.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 31

Electrical and Plasma Characteristics of a Pulsed Neutron Generator

Syed M. Hassan[1,2], A. Skoulakis[1], Ioannis Fitilis[1], Eugene L. Clark[1], Paul Lee[1,3], John Chatzakis[1], Makis Bakarezos[1], Vasilis Dimitriou[1], Constantinos Petridis[1], Nektarios A. Papadogiannis[1], Michael Tatarakis[1]

[1]*Center for Plasma Physics and Lasers, TEI of Crete 73133 Chania, 74100 Rethymno, Crete, Greece*
[2]*School of Nuclear Engineering, Purdue University, West Lafayette, IN 47907, USA*
[3]*NSSE, NIE, Nanyang Technological University, Singapore 637616, Singapore*

Advanced pulsed power technologies provide an efficient conversion of electrical energy into the pinch plasma for higher neutron production with longer life than existing pulsed neutron sources suitable for materials identification and non-destructive testing. A compact nanosecond pulse neutron generator based on the interactions of fast deuterons beam with the hot dense plasma within the focus pinch column has been designed and examined. The fast deuterons beam is produced by diode action in a thin layer close to the anode with plasma disruptions generating the necessary high voltages. With deuterium gas, the neutron yield of 106 per shot with a temporal pulse width of a few tens of nanoseconds is achieved. Correlation of charged particles and plasma dynamics with neutron emission are obtained by various plasma and nuclear diagnostics. The main electrical characteristics of a device such as the scaling of bank energies with total current and focus pinch current, and the scaling of neutron yields with energies and discharged currents are presented. The Lee's numerical code and magneto-hydrodynamics simulations are used to validate the experimental results.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 32

Neutron Time-of-Flight Measurements; Comparison with Monte Carlo Simulations at the Idaho Accelerator Center

Mayir Mamtimin[1,2], Frank Harmon[1,2], Heather Seipel[1,2]

[1]*Idaho State University, Pocatello, ID, 83209*
[2]*Idaho Accelerator Center, Pocatello, ID, 83201*

In recent years, research and development at the Idaho Accelerator Center has been conducted on intense photon/neutron production facilities and their application in photon activation analysis, isotope production, national security needs and various nuclear fuel cycle investigations. As an example technical feasibility studies of mixed-field photon/neutron transmutation of certain fission products have been carried out (1).In this work it is important to estimate the energy spectrum of radiation fields. Foil activation methods have been used to estimate the flux and energy distributions of photon and neutron field. It is well known that activation foils give only crude estimates of neutron energy distributions. Much better information can be gleaned from properly conducted neutron time-of-flight (nTOF) measurements. In the work reported here a TOF system which was originally developed is used along with the IAC Fast Pulse Linac to measure the neutron energy spectrum emitted from an 40 MeV electron beam driven neutron converter. An evaporation spectrum, similar to a fast fission spectrum, is obtained.In this paper, experimental setup including electron beam parameters, shielding and detector layout will be discussed. Detailed computer simulations of the same setup are compared to experimental results. Experimental limitations on detectable neutron energies and detector efficiency will be addressed.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 33

A Liquid Metal Bremsstrahlung Converter for use with High Power Superconducting Electron Linacs

Dyle D. Henning[1], Terry L. Grimm[1], Jerry L. Hollister[1], Erik S. Maddock[1], Valeriia N. Starovoitova[1], Frank Harmon[2], Jon L. Stoner[2]

[1]*Niowave, Inc. Lansing, MI 48906*
[2]*Idaho Accelerator Center Pocatello, ID 83201*

High x-ray fluxes are required for a variety of applications, including the photonuclear production of isotopes, the sterilization of food and medical equipment, medical and industrial radiography, and the active interrogation of cargo containers. One common way to generate a high x-ray flux is by using an electron beam incident upon a bremsstrahlung converter. Conventional bremsstrahlung converters are made of solid, high-Z materials with high melting temperatures, such as tungsten or tantalum. Such converters perform excellently up to certain power densities, but they can be damaged by higher power loads due to their inability to remove heat effectively without sacrificing bremsstrahlung production efficiency through elaborate cooling methods. We are developing a liquid metal bremsstrahlung converter for a superconducting electron linear accelerator capable of withstanding up to 100 kW of the electric beam power. The electron energy will range from 2 MeV to 40 MeV depending on application. In this work we will present the results of the simulations of the photon and electron fluxes, doses and power depositions, and show the capabilities of a liquid metal converter to manage varying power loads for a range of electron beam energies. We will also present the experimental results from the prototype testing and show a conceptual design of the converter which can be used with the superconducting electron linac for the applications previously mentioned.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 34

Development of a DAQ system for a Plasma-Display-Panel based X-ray detector (PXD)

Hakjae Lee[1], Kisung Lee[1], Young Jun Jung[1], Sangheum Eom[2], Jongseok Kim[2], Jungwon Kang[2]

[1]*Department of Bio-convergence Engineering, Korea University, Seoul, Korea*
[2]*Department of Electronics and Electrical Engineering, Dankook University, Yongin, Gyeonggi, Korea*

The plasma display panel (PDP) is one of the most widely used display components in flat panel displays. It is popular in the TV market owing to its relatively simple cell structure, low cost of materials, and relatively simple manufacturing process. Recently, some research groups showed that the PDP cell structure, which consists of electrodes and a gas mixture, could be utilized in the manufacture of radiation detectors.In this study, we report on the development of a PDP based X-ray detector (PXD). The material and cell structure was designed on the basis of a Monte-Carlo simulation, and a 5 inch prototype detector panel was manufactured. The initial performance of this prototype PXD was quantitatively measured.The prototype detector panel has row and column strips, and it can thus be utilized as an imaging detector. To produce a 2D X-ray image from the PXD, we also developed a dedicated driving and data acquisition (DAQ) circuit. Each module board was individually tested and the integrated system was verified. Additionally, the noise reduction algorithm for the PXD circuit has been implemented in a field-programmable gate array (FPGA).Using this DAQ system, we successfully developed a PXD-based digital X-ray imager.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 35

Investigation of the influence of measurement position on the cosmic-ray induced dose inside a learjet-type aircraft

Adriane C. M. Prado[1,2], Claudio A. Federico[1,2], Mauricio T. Pazianotto[1,2], Odair L. Gonçalez[1,2], Leila R. Dos Santos[1], Alexandre D. Caldeira[2], Heloísa H. C. Pereira[2]

[1]*Instituto Tecnológico de Aeronáutica*
[2]*Instituto de Estudos Avançados*

The cosmic radiation doses received by aircrew are measured or estimated by computational codes which, generally, don't consider the influence of position inside aircraft in the dose rate. Studies on this subject, using computational simulation of commercial aircrafts, were made by some authors but few of them made this analysis with direct measurements, neither on smaller aircrafts. In this paper we report the measurements onboard a Learjet-type aircraft in well controlled flight conditions: at the same altitude (12,192 m) and around the same geographic coordinates 31.25 S; 50.75 W (close to Canoas city, RS, Brazil). The measurement system is the THERMO SCIENTIFIC monitor that consists of an acquisition electronics model FH40G-10 with an internal proportional counter, coupled with an external neutron probe THERMO FHT 762, projected to obtain the response according to Ambient Equivalent Dose for neutrons up to 5 GeV [1]. The measurements of dose rate were performed in several positions inside the aircraft, close and far from pilot locations and discriminating between neutron and non neutronic components. The results show that the neutronic component is attenuated in the back part of the aircraft, close to fuel depots, but the non neutronic component appears to have the opposite behavior. These experimental results are also confronted with results from Monte Carlo simulation, obtained with the MCNPX code, using a simplified model of the Learjet-type aircraft. The Monte Carlo simulation results show the neutron spectra on each of five measurements position where one can see a slight decrease in the total flux near the fuel depots, despite increasing in the thermal flux motivated by the high-energy neutron scattering in the fuel components. The simulation was made using the two main aeronautical fuel used in this type of aircraft and no significant change was observed between their scattering properties.

References

[1] THERMO-SCIENTIFIC, FHT 762- WENDI-2 datasheet, n.42540/85 TD-E, 2009.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 36

Materials Chemistries for Faster Electron Mobilities in Semiconducting Detection Materials

Kim F. Ferris[1], Dumont M. Jones[2]

[1]*Pacific Northwest National Laboratories*
[2]*Proximate Technologies, LLC*

In this paper, we examine the effect of materials chemistries on the estimated electron mobilities of II-VI and III-V semiconducting radiation detection materials. Using a combination of informatic relationships for band gap, effective electron mass, static dielectric constant, the optical polaron mobility is re-examined in terms of the effective bounds for the dielectric and band gap properties of these materials. Properties such as band gap, density, and electron mobility form the fundamental triad of materials properties for a semiconducting radiation detection material, but also impose interacting constraints on the materials chemistries of these compounds. Complicating the problem for semiconducting materials selection, some properties such electron mobility tend to change significantly as synthetic methods and processing conditions improve. After several stages of property estimation and screening, several interesting observations about the candidate materials and their design trends emerge for faster materials: 1) a tendency to smaller differences between static and high frequency polarizabilities, 2) electronegativity differences between the cation and anion sites are balanced against atomic polarizabilities, 3) candidate materials tend to fall into related materials chemistry families, e.g. CZT◊ CMT and HgS types, and 4) ternary variations of the II-VI and III-V compositions need to observe charge and size tendencies of the parent compound.This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-08-X-00872. This support does not constitute an express or implied endorsement on the part of the Government.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 37

Numerical model of electron energy response in CsI:Tl and SrI_2:Eu with diffusion coefficient and rate constants dependent on electron temperature and thus time

Xinfu Lu[1], Qi Li[1], J. Q. Grim[1], A. Burger[2], G. A. Bizarri[3], R. T. Williams[1]

[1]*Department of Physics, Wake Forest University*
[2]*Department of Physics, Fisk University*
[3]*Lawrence Berkeley National Laboratory*

We update the thermalized diffusion-drift & nonlinear quenching model[1,2] to take account of hot electrons by letting the carrier diffusion coefficient, bimolecular exciton formation rate, Auger decay rate, and deep trapping rates depend on electron temperature T_e, which is itself a function of time. $T_e(t)$ is also a function of position via the local conduction electron density[3], but we focus here on time dependence of a position-averaged $T_e(t)$ calculated by Monte Carlo methods using ω_{LO} and m_e^* for each material[4,5]. The time-dependent carrier diffusion coefficient $D(T_e(t))$ is calculated using energy-dependent cooling rate,[4,5] electron group velocity,[6] and effective mass from dispersion of the upper conduction bands. The amplitude of the time-dependent Auger recombination rate $K_3(T_e(t))$ is determined to fit photon density response experiments[7]. The bimolecular exciton formation rate $B(T_e(t))$ and linear deep-trapping rate $K_1(T_e(t))$ are scaled from picosecond absorption, total light yield, and time-resolved luminescence measurements to reproduce the independent experiments consistent with the MC-calculated $T_e(t)$. These time-dependent parameters are then used in solving the current flow and carrier-density rate equations from time zero through the end of radiative emission. It is found that the net direction of the radial diffusion-drift current reverses upon electron thermalization. There is an initial rush of electrons radially outward from the track core driven by the excitation gradient and boosted by the excess kinetic energy of the hot electrons, both of which initially overwhelm the electric attraction to the core of immobile self-trapped holes (STH). Upon thermalization, the collective electric field of the STH core re-asserts itself relative to the now-diminished electron gradient and kinetic energy of the electrons, so the net current becomes directed radially inward in materials with STH, i.e. halides. Quenching by deep traps during this inward flow is determined by competition between the capture time of electrons in the collective field of STH compared to the rate of linear trapping on deep defects integrated over the same time.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 38

The method research of enhancing the spatial resolution of photoneutron radiography

Ping Liu[1,2], Zhi Zhang[1,2], Yigang Yang[1,2], Yuanjing Li[1,2]

[1]*Department of Engineering Physics, Tsinghua University, Beijing, P.R.China*
[2]*Key Laboratory of Particle & Radiation Imaging (Tsinghua University), Ministy of Education, Beijing, P.R.China*

Photoneutron radiography can be simultaneously realized with X-ray radiography because the photoneutrons are the byproducts of the X-rays. To avoid the interference of the intense X-ray pulses, moderation process is necessary to delay the detection time of photoneutrons. But the cost is the spatial resolution of photoneutron radiography deteriorates. In this paper, we present the design of the photoneutron detector that also uses the moderation process but enhances the spatial resolution. The incident angle, θ, of the neutron on the surface of the detector is selected as 78 degree, whose cosine is 0.2, to project the 10 cm "footprints" of the neutron capture positions in the 0.95wt% ^{nat}B loaded liquid scintillator detector to 2 cm on the projection plane of the neutron detector. The spatial resolution could be improved fivefold (from 10cm to 2cm), and hence enhance the performance of PNXR (PhotoNeutron X-ray Radiography), which is the combination of the photoneutron radiography and the X-ray radiography.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 39

Data and software tools for gamma radiation spectral threat detection and nuclide identification algorithm development and evaluation

David Portnoy, Brian Fisher, Daniel Phifer

Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, MD 20723, USA

The detection of radiological and nuclear threats is extremely important to national security. The federal government is spending significant resources developing new detection systems and attempting to increase the performance of existing ones. The detection of illicit radionuclides that may pose a radiological or nuclear threat is a challenging problem complicated by benign radiation sources (e.g., cat litter and medical treatments), shielding, and large variations in background radiation. While there is a growing acceptance within the community that concentrating efforts on algorithm development (independent of the specifics of fully assembled systems) has the potential for significant overall system performance gain, there are two major hindrances to advancements in gamma spectral analysis algorithms under the current paradigm: access to data and common performance metrics with baseline performance measures. Because many of the signatures collected during performance measurement campaigns are classified, dissemination to algorithm developers is extremely limited. This leaves developers no choice but to collect their own data if they are

lucky enough to have access to material and sensors. This is often combined with their own definition of metrics for measuring performance. These two conditions make it all but impossible for developers and external reviewers to make meaningful comparisons between algorithms. Without meaningful comparisons, performance advancements become very hard to achieve and (more importantly) recognize. The objective of this work is to overcome these obstacles by developing and freely distributing real and synthetically generated gamma-spectra datasets as well as software tools for performance evaluation with associated performance baselines to national labs, academic institutions, government agencies, and industry. At present, datasets for two tracks, or application domains, have been developed: one that includes temporal spectral data at a 0.1 second time intervals, which represents data collected by a mobile system operating in a dynamic radiation background environment; and one that represents static measurements with a foreground spectrum (background plus source) and a background spectrum. These data include controlled variations in both Source Related Factors (nuclide, nuclide combinations, activities, distances, collection times, shielding configurations, and background spectra) and Detector Related Factors (gain shifts, resolution changes, and non-linear energy calibration errors). The software tools will allow the developer to evaluate the performance impact of each of these factors.While this first implementation is somewhat limited in scope, considering only NaI-based detection systems and two application domains, it is hoped that (with community feedback) a wider range of detector types and applications will be included in the future.This paper describes the methods used for dataset generation and collection, the software validation/performance measurement tools, the performance metrics used, and examples of baseline performance.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 40

Systematic Measurement of Fast Neutron Background Fluctuations in an Urban Area Using a Mobile Detection System

Anagha S. Iyengar[1], Matthew Beach[1], Robert J. Newby[2], Lorenzo Fabris[2], Lawrence H. Heilbronn[1], Jason P. Hayward[1,2]

[1]*Department of Nuclear and Radiological Engineering, University of Tennessee, Knoxville, TN, USA*
[2]*Oak Ridge National Laboratory, Oak Ridge, TN, USA*

Neutron background measurements using a mobile trailer-based system were conducted in Knoxville, Tennessee, USA. The 0.5 m^2 system, consisting of eight EJ-301 liquid scintillation detectors, was used to collect neutron background measurements in order to better understand the systematic variations in background that depend solely on the street-level measurement position in a downtown area. Data was collected along 5 different streets, and the measurements were found to be repeatable. Using 10-minute measurements, the fractional uncertainty in each measured data point was < 2%. Compared with fast neutron background count rates measured away from downtown Knoxville, a reduction in background count rates ranging from 10-50% was observed in the downtown area, sometimes varying substantially over distances of tens of meters. These reductions are attributed to the net cosmic ray shielding of the cosmic ray neutron flux by adjacent buildings, quantified in part here by a measured angle-of-open-sky metric.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 41

Features of different inorganic scintillators application in neutron-radiation systems for illegal substances detection

Viacheslav F. Batyaev, Romeo R. Bestaev, Sergey G. Belichenko, Aleksander V. Gavryuchenkov

All-Russia Research Institute of Automatics, 22 Sushchevskaya, 127055 Moscow, Russia

The work is devoted to presenting accuracy of the identification of hazardous substances as a function of type and basic parameters of gamma-detectors applyied in neutron-based inspection systems. Monte Carlo simulation of the Tagged Neutron (TN) Method was used to find a dependence of accuracy of inspected object {C, N, O}- relations on the main parameters of inspection system, including the parameters of the gamma-ray detector including the detection efficiency , energy and time resolutions . We considered four types of detectors commonly used in the implementation of the TN method: BGO, LaBr3 (Ce), LYSO, NaI (Tl), their energy and time resolutions were measured. As a result of the analysis we came to the conclusions:

1. Efficiency of a detector is a priority on the accuracy of the inspected object dentification;

2 . Time resolution of a detector has a value only in case the detector is situated quite close to the neutron generator , as well as when a dangerous substance is screened by legal organic materials ;

3 . The energy resolution of the detector can have a serious impact only in problems of identification materials consisting of a sufficiently large number of the chemical elements, as well as when an illicit substance is screened by inorganic compounds , including metals, etc. .

This means that the optimum detector for use in the TN method is those that combines high detection efficiency and time resolution. The LYSO scintillator is the best of those studied here identifying such requirements. However, when the inspected object includes inorganic materials, the inspected system should contain also detectors with good energy resolutions, such as LaBr3(Ce). BGO and NaI would the best in case of inspecting large (~1m) objects

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 42

Fast Neutron Coded Aperture Imager

Richard S. Woolf[1], Bernard F. Phlips[2], Anthony L. Hutcheson[2], Eric A. Wulf[2]

[1]National Research Council Postdoctoral Fellow, Washington, DC, USA
[2]Space Science Division, U.S. Naval Research Laboratory, Washington, DC, USA

The work herein reports on the development of a large-scale, coded aperture imager for fast neutrons, building off a previously presented proof-of-concept instrument [1] developed at the U. S. Naval Research Laboratory (NRL). Work on fast neutron coded aperture imagers done by others can be found elsewhere [2]. The instrument can operate passively or in an active interrogation environment. In the laboratory the instrument was characterized passively. The Space Science Division at the NRL has a demonstrated heritage in developing large-scale (mobile) coded aperture imaging systems for long-range γ-ray detection of hazardous isotopes [3]. The prototype instrument, designed with past work in mind for eventual migration into a mobile unit (ISO container), consists of a 32-element array of 15 cm × 15 cm × 15 cm liquid scintillation detectors (EJ-309) mounted behind a 12 × 12 pseudorandom coded aperture. The elements of the aperture are comprised of 15 cm × 15 cm × 10 cm blocks of high-density polyethylene (HDPE). The aperture has 50% opaque (HDPE block) and 50% transparent (absence of a HDPE block) elements. The arrangement of the aperture elements produce a shadow pattern on the detector array behind the mask. With measurement of the number of neutron counts per masked and unmasked detector, and knowledge of the mask pattern, a source image can be de-convolved to obtain location information. The number of neutrons per detector was obtained by processing the fast signal from each PMT in flash digitizer electronics (Struck, model no. SIS3316). The module performs digital pulse shape discrimination (PSD) to filter out the fast neutron signal from the γ background. The prototype was tested at an indoor facility at the NRL with a 20-μCi ^{252}Cf neutron/γ source at distances up to 26 m (maximum standoff allowed). The imaging and detection capabilities of the instrument were tested by moving the source in one-pixel increments across the image plane. We show the results obtained at three different standoff distances of 9, 15 and 26 m over a 15-minute integration time. Lastly, we investigated imaging a 2-μCi ^{252}Cf source at maximum standoff by reducing the fast neutron background, thus improving the signal-to-noise. Shielding the detector array led to a reduction in the background count rate by a factor of 1.7 and clear source identification over a 15-minute integration time was achieved.

[1] R. S. Woolf, B. F. Phlips, et al., "An Active Interrogation Detection System Detection (ACTINIDES) Based on a Fast Neutron/Gamma-Ray Coded Aperture Imager." IEEE Conference on Technologies for Homeland Security, pp. 30–35, 2012.

[2] P. Hausladen, J. Newby, F. Liang, M. Blackston. "A Deployable Fast-Neutron Coded-Aperture Imager for Quantifying Nuclear Material" Oak Ridge National Laboratory Report No. ONRL/TM-2013/248.

[3] E. A. Wulf, B. F. Phlips, et al., "MISTI Imaging and Source Localization." IEEE Nuclear Science Symposium Conference Record, pp. 2413–2417, 2008.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 43

Multiple Scattering Compton Camera System with Neutron Activation for Material Inspection

Taewoong Lee, Wonho Lee

RDID Lab, Korea University, Seoul, Korea

We designed the multiple scattering Compton camera system (MSCC) based on LaBr3 scintillator to evaluate the realist field application for the 14 MeV neutron-activated prompt γ-ray Compton imaging. When 14 MeV neutrons interacted with target materials such as oxygen, nitrogen, carbon, and chlorine the characteristic prompt γ-rays emitted from specific elements, whose energy spectrum and γ-ray imaging will be obtained by MSCC. If the characteristic prompt γ-ray made serial interaction in the MSCC detectors, the energy and direction of the scattered γ-ray could be reconstructed based on Compton scattering kinematic. The system parameters such as target-detector distance (D0), and inter-detector distance (D1, and D2) were evaluated to achieve high performance in detection efficiency. For the effectiveness of the neutron-activated prompt γ-ray Compton imaging in contrabands or explosives, we performed a receiver operator characteristic (ROC) analysis for the positive images such as trinitrotoluene, methamphetamine, and weapon versus negative images such as starch, soil, and container.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 44

Development of High-Resolution Silicon-Based Particle Sensor with Integrated Amplification

Geehyun Kim[1,3,4], Taehoon Kang[2], Subhashree Ramadoss[3], Mark D. Hammig[1]

[1]*Department of Nuclear Eng. and Rad. Sci., University of Michigan, Ann Arbor, MI, USA*
[2]*Department of Electrical Eng. and Computer Sci., University of Michigan, Ann Arbor, MI, USA*
[3]*Svaati Scientific LLC, Ann Arbor, MI, USA*
[4]*Department of Nuclear Engineering, Sejong University, Seoul, South Korea*

In this research, we demonstrated the feasibility of enhancing the performance of particle-detection sensors, by integrating an amplifying junction as part of the detector topology. We designed the avalanche particle sensor configuration analytically and validated the design with numerical process and device simulations. Both process and device simulation results from the sensors modeled with various geometry, doping profile arrangement, and fabrication conditions are reported. We, then, tested the refined numerical design by fabricating and testing diagnostic sensors. Multiplication junctions were created from sub-micrometer highly-doped layers on silicon wafers, using short-duration, low temperature annealing followed by ion implantation. Expectations from the simulation results matched with our experimental results from testing the prototype sensors.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 45

Design of a Cosmic-ray Muon Radiography System for Dry Storage Cask Imaging

Can Liao, Haori Yang

Oregon State University

The overarching goal of this project is to develop an imaging system to monitor the content of a dry storage cask (DSC) with cosmic ray muons. Because of the growth of the nuclear power industry in the U.S. and the policy decision to ban reprocessing of commercial used nuclear fuel, the used fuel inventory at commercial reactor sites has been increasing. Used nuclear fuel presents extra complexity of security and proliferation issues. A very large amount of plutonium under nuclear safeguards is contained in used fuel assemblies stored in DSCs. These fuel assemblies are practically inaccessible for inspection purposes, as reopening a DSC would require special facilities and would be tremendously expensive. There is currently no practical method to verify the content of a DSC. Thus, expensive, redundant containment and surveillance instrumentation have to be used to avoid loss of knowledge of the content. The cosmic ray muon flux reaching the surface of the Earth is about 10,000 muons per minute per square meter, which makes muons the most abundant cosmic-ray particles at sea level. Cosmic-ray muon radiography has been studied in the past years for various applications. The imaging technique utilizing multiple Coulomb scattering was demonstrated to be a good non-destructive assay method for high-Z materials, such as used nuclear fuel assemblies. In this paper, we report our simulation work on the 2-D and 3-D muon radiography of a DSC. The Point of Closest Approach (POCA) and Maximum-Likelihood Expectation-Maximization (ML-EM) algorithms are used for image reconstruction.We first performed Geant4 Monte Carlo simulation for 2-D muon radiography based on the fact that muons undergoes scattering with larger angles in high-Z materials than in low-Z materials. High-Z materials can be identified in the reconstructed image, but the image quality is poor. For 3-D radiography, we modeled a scaled-down prototype muon tomography system currently under construction. It contains four identical position sensitive muon detectors, forming two muon trackers: one above the imaging cavity and one below it. With the identification of a space point in each detector, the initial and scattered muon trajectories could be reconstructed enabling the determination of the scattering position and scattering angle needed for image reconstruction. Within each position sensitive detector, two orthogonal detection planes, comprising

a single layer of 32 scintillator strips (1 cm by 1cm by 32 cm), created an active area of 32 cm by 32 cm.Using POCA algorithm, the reconstructed image showed good spatial resolution and good material discrimination ability, even though the detector has only 1cm by 1cm resolution.In our current design, EJ-200 is chosen as the scintillator material for muon detection. Each scintillator strip is read out with an embedded Saint-Gobain BCF-92 wavelength shifting (WLS) optical fiber. The optical fibers are coupled to two Hamamatsu H8500C MAPMTs. The PMT signals are then measured with CAEN V792 Multievent QDCs. The prototype is currently under construction. The progress will be presented at the conference and in the full paper.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 46

Study on a pulse analysis algorithm based on template-matching for high throughput spectroscopy

Xianfei Wen[1], Dante Nakazawa[2], Haori Yang[1]

[1]*Oregon State University*
[2]*Canberra Industries*

Innovative systems with increased sensitivity and resolution are in great demand to detect diversion and to prevent misuse in support of nuclear materials management for the U.S. fuel cycle. Nuclear fission is the most important multiplicative process involved in non-destructive active interrogation. This process produces the most easily recognizable signature for nuclear materials. Among others, delayed gammas are emitted seconds or even minutes after fission. Previous research demonstrated that a unique delayed gamma ray energy spectrum exists for each fissionable isotope. Isotopic composition measurement methods based on delayed gamma ray spectroscopy is the primary focus of our work. A linac-based advanced inspection technique utilizing delayed gamma rays after photon-induced fission is being investigated for nuclear safeguards applications.The overarching goal of our effort is to assay plutonium content in spent nuclear fuel. A major challenge in this work is to perform high energy resolution gamma spectroscopy measurements at an ultra-high throughput rate with good accuracy. The HPGe detector is the only practical candidate that can provide excellent energy resolution in a wide energy range as needed in measuring delayed gamma spectra. High throughput spectroscopy systems are being investigated. The effort is two-folded. Firstly, in a pulsed photonuclear environment when the linac is operating, the regular front-end electronics on an HPGe detector quick reaches saturation after a linac pulse and slowly recovers afterword. This prevents any meaningful spectroscopy measurement within tens of milliseconds after a linac pulse. Modification of the front-end electronics is needed to allow the detector to recover from the saturation in a timely manner. Secondly, the spent fuel assembly under assay is expected to be extremely radioactive by itself. Thus, innovative spectroscopy systems using advanced signal processing techniques are needed to improve the throughput rate of an HPGe detector without sacrificing energy resolution. Recent development showed great potential of the template-matching method in high rate applications. Instead of filtering the energy signal, a pre-defined pulse shape template is used in this method to de-convolve the waveform train.In this paper, we report results from our independent study on a pulse analysis algorithm based on template-matching for high throughput gamma spectroscopy. The concept of the algorithm is first demonstrated with simulated data. It is then implemented on digitized waveforms acquired with a 2" by 2" NaI scintillation detector and an HPGe detector. The performance of this algorithm is compared with traditional trapezoidal filtering in both low- and high-rate scenarios. The challenge of implementing such an algorithm on signals with varying shapes (e.g. output from an HPGe detector) is discussed and a compromising solution is proposed to improve throughput rate with some sacrifice in energy resolution.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 47

Parameters of explosives detection via tagged neutron method

Sergey G. Belichenko, Viacheslav F. Batyaev, Romeo R. Bestaev, Aleksander V. Gavryuchenkov

All-Russia Research Institute of Automatics, 22 Sushchevskaya, 127055 Moscow, Russia

Capabilities of the Tagged Neutron (TN) method for detection and identification of explosives materials (EM) are explored using an idealized geometrical model that includes a 14 MeV neutron generator with an integrated alpha detector, a gamma-ray detector based on BGO/LYSO/$LaBr_3$/NaI crystals, and irradiated samples in the form of simulated EM (TNT, tetryl, RDX, etc.) or benign material (BM) such as cotton, paper, etc. Research was carried out under the framework of computational simulations of neutron physics processes by Monte Carlo methods as well as experimental measurements using an ING-27 neutron generator. The work resulted in a comparison between measured and

simulated ROC (receiver operating characteristics) curves obtained via integration of analytically expressed functions of irradiation time, mass, and type of EM and BM. Experimental results indicate that 0.3 kg of tetryl simulant located 45 cm from the neutron generator is detected in 97% of cases after a one minute measurement, with the false-alarm rate being highly dependent on the type of BM present: from ~0% in the case of water to ~5% in the case of silk. Comparison of simulated and experimental data for these results shows they are in agreement in cases where the simulations account for background effects and neutron scattering from the object.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 48

Coded Aperture Approaches to Thermal Neutron Imaging of SNM

Jennifer Littell, Eric Lukosi, Allen Rowan, Robert Milburn

University of Tennessee, Knoxville

A requirement in the detection of special nuclear materials (SNM) is a system which can discriminate characteristic signatures of the SNM from the background. Several methods are currently theorized or in use, including gamma-ray spectroscopy and imaging, fast neutron imaging, thermal neutron detection, x-ray radiography or tomography, and indirect detection of SNM signatures through nuclear or chemical means in the surrounding medium. To enhance our detection ability and confidence a system needs to be develop that will increase both the detection efficiency of SNM from a distance and the gamma-neutron discrimination capabilities. For this reason, we have begun investigations into a detection system which uses directional moderation along with He-3 replacement technology. The detection system proposed consists of an array of ten boron straw detectors within a high density polyethylene (HDPE) block which serves as the moderator. Approaches to optimizing the moderating mask via MCNP simulations, along with post processing techniques will be presented.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 49

Personal Radiation Detector at High Technology Readiness Level for DARPA's SN-13-47 and SIGMA Program Requirements

Dimitry Ginzburg[1], Yakir Knafo[1], Avi Manor[1], Rami Seif[2], Max Ghelman[2], Michael Ellenbogen[1], Vitaly Pushkarsky[1], Yair Ifergan[2], Natan Semyonov[1], Udi Wengrowicz[2], Tzachi Mazor[2], Yagil Kadmon[2], Yossef Cohen[2], Alon Osovizky[1]

[1]*Radiation Detection Department, Rotem Industries Ltd, Israel*
[2]*Electronics & Control Laboratories, Nuclear Research Center - Negev, Israel*

On August 2013 DARPA has released a request for information (RFI) seeking for innovative ideas for radiation detection technology. Further, on December 2013, a broad agency announcement (BAA) for the SIGMA program was released. The RFI focused on a sensor that should meet three main requirements: low cost (~$100 level with large volume orders), highly compact (pager-size) and performances that would enable identifying hidden threats, ranging from special nuclear materials (SNM) to radiological sources. The sensor should also be belt mounted and interface with existing cell phone devices. Consecutively, the BAA presented the specific requirements at an instrument level and compared between the current market status (state-of-the-art) and the SIGMA program objectives.This work presents an optional alternative for both, the detection technology (sensor with communication output and no user interface) and for the Personal Radiation Detector (PRD) required by the SIGMA program. The project objectives are highly challenging, detection technology that can comply with the requirements must maintain the following characteristics: • Scintillation compound based gamma and neutron detector to provide high sensitivity, isotopes identification capabilities and material availability. • The light sensor should be based on a solid state in order to support the compact design and the ability of mass production (~10000) at low cost. • The design should include a computerized process and algorithm that enables automatic calibration and testing that reduces the expense on professional men power during the manufacturing stage. • A very low cost sensor, therefore any part of the PRD that can be replaced by utilizing the connection to the cell phone device should be removed, e.g. adopting the user interface (display, touch panel) and power source that one inherently existed in the mobile device.The PDS-GO (PRD alternative), was first introduced to the market in 2010, consists of the novel solid-state light sensor technology of SiPM. Utilizing the SiPM is the key for achieving the program objectives; it provides the appropriate answer for low cost, mass production and small dimensions however, it maintains the obstacles of dark current (noise) and gain stabilization over a wide temperature range. The PDS-GO performance that was measured by the PHE testing laboratories showed that it meets the scope of specifications defined by various homeland security standards and emphasizes that the device novel detection technology is at high technology readiness level for the SIGMA program requirements. This work discusses the alternatives and the benchmarking of the current status of the PDS-GO compared to the SIGMA program objectives and describes the potential and the required effort to be undertaken for overcoming the apparent gaps (e.g. 6Li based neutron

detector). As an upgrade to the current device the paper presents a new electronic board designed for directional measurement (locate the source origin), improved energy resolution and a flat energy response that can enhance the device performances without major change in the overall cost. Furthermore, a new PC-based software with implementation of algorithm that enables automatic setup of the device parameters (e.g. gain, energy window thresholds) and calibration is presented.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 50

Real time wide area radiation surveillance system (REWARD) based on 3D silicon and (Cd,Zn)Te for neutron and gamma-ray detection

Markus Dambacher

X-Ray Imaging Europe, Stefan-Meier-Str. 21, 79104 Freiburg, Germany

Mobile surveillance systems can be used to find lost radioactive sources and possible nuclear threats in urban areas. The REWARD collaboration aims to develop such a complete radiation monitoring system that can be installed in mobile transport or in buildings across a wide area. The scenarios range from nuclear terrorism threats, to lost radioactive sources, radioactive contamination and nuclear accidents.The main component of the REWARD system is the compact sensor tag based on high efficiency 3D silicon neutron detectors combined with a Coplanar Grid (Cd,Zn)Te gamma detector subsystem with excellent energy resolution, a processing system to control the whole unit and link the data to the communications equipment, a Lithium-ion battery system and GPS for localizing the tag. Two external communication units are under development based on the TETRA technology and GPRS. The REWARD system also incorporates middleware and high-level software to provide web-service interfaces for the exchange of information and an expert system to continuously analyze the information from the sensing tags in real time and correlate it with historical data in order to generate an alarm when an abnormal situation is detected. A security framework is developed to ensure protection against unauthorized access to the network and data, ensuring the privacy of the communications.The paper will show the performance capabilities of the REWARD system in different scenarios. The results include both Monte Carlo simulations and neutron and gamma-ray detection performances in terms of efficiency and nuclide identification. The outcomes of the first background radiation mapping survey with the entire REWARD system in an enclosed area in Naples (Italy) will also be presented.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 51

Gamma-ray and neutron background data collected aboard the MZ-3A airship

Lee Mitchell[1], Bernard Phlips[1], Anthony Hutcheson[1], Chul Gwon[1], Donald Polaski[2]

[1]*Naval Research Laboratory, 4555 Overlook Ave., Washington, D.C. 20375*
[2]*Praxis Inc., 5845 Richmond Highway, Suite 700, Alexandria, VA 22303*

Gamma-ray and neutron background data was collected onboard the MZ-3A airship stationed at the Patuxent Naval Air Station (NAS) as part of a project to improve hyper-spectral data analysis for threat detection. Both static and dynamic measurements were made at various altitudes over both land and water. The gamma-ray spectrum was measured with five high purity germanium (HPGe) detectors, the fast component of the neutron flux was measured with a pulse shape discrimination (PSD) plastic detector, and the thermal neutron component was measured with a He-3 detectojr. The measurement campaign lasted three days for a total of 12hrs of in flight data. As expected, at altitudes below 1500 feet the gamma-ray background shows both atmospheric and ground contributions. Increases in altitude above 1500 ft and up to 3500 ft show little change in the gross gamma count rate and is dominated by the atmospheric contribution. The decrease in count rate with increasing altitude was consistent with attenuation from a planar source for altitudes below 1500 ft. The fast and thermal neutron background showed elevated count rates near the ground and decreased with increasing altitude until approximately 300 ft. At this points the trend reversed and both the thermal and fast component of the neutron background count rate increased with altitude. The results are consistent with simulations and literature. Details of the experimentally measured spectra and Monte Carlo simulations will be presented at the conference.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 52

Gamma-ray and neutron background comparison of US metropolitan areas

Lee Mitchell[1], Bernard Phlips[1], Chul Gwon[1], Donald Polaski[2]

[1]*Naval Research Laboratory, 4555 Overlook Ave., Washington, D.C. 20375*
[2]*Praxis Inc., 5845 Richmond Highway, Suite 700, Alexandria, VA 22303*

Gamma-ray and neutron background surveys were made by the Naval Research Laboratory (NRL) in U.S. cities, including Washington, D.C., Kansas City and St. Louis, Missouri, Chicago, Illinois, Richmond Virginia, Boston, Massachusetts and Baltimore, Maryland. Measurements covered a range of industrial, residential and commercial areas. Germanium grade gamma-ray data over the energy range of 0.05-3.0 MeV, and neutron count rates with unmoderated He-3 sensitivity were recorded as a function of latitude, longitude and elevation in one second intervals. Typical KUT backgrounds were seen along with several anomalies. For example a decrease in thermal neutron flux in large urban canyons was seen and verified via Monte Carlo simulations. The data was collected to provide natural background models for simulation work. Germanium grade spectroscopy is used, since it provides detailed isotopic information of the gamma-ray background. A comparison of the background in these urban areas will be presented at the conference, in particular how the various commercial, residential and industrial areas compare. A discussion of how the background is deconvolved for incorporation into new models and a comparison of Monte Carlo simulations with current models will be presented.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 53

Impact of uncertainties on 3D source localization for gamma ray imaging with scene data fusion

Ross Barnowski[1,2], Andy Haefner[1,2], Lucian Mihailescu[2], Kai Vetter[1,2]

[1]*Department of Nuclear Engineering, University of California, Berkeley*
[2]*Applied Nuclear Physics, Lawrence Berkeley National Lab, Berkeley CA*

The ability to image gamma-ray source distributions in three dimensions for arbitrary imaging domains could have an immediate impact for many applications; such as nuclear decontamination planning and safety, treaty verification, and monitoring nuclear facilities. Furthermore, the ability to localize point sources within unknown environments is a powerful tool for homeland security. In order to achieve full 3D imaging capability for gamma ray sources in unknown and complex environments, a method for tracking the position of a mobile imager as it traverses the environment is required. A mobile radiation imaging system known as the Compact Compton Imager II (CCI-2) has been developed at the Lawrence Livermore and Lawrence Berkeley National Laboratories. The system consists of a pair of planar HPGe detectors with orthogonal strip readouts, yielding position sensitivity and excellent spectroscopic performance. Gamma rays that interact multiple times within the detector are used for Compton imaging, resulting in a system capable of imaging gamma rays in the energy range from hundreds of keV to several MeV with a nearly 4π field of view. Detector tracking and 3D environment modeling is accomplished in real-time using commodity 3D sensing hardware, the Microsoft Kinect. The near real-time capability to localize point sources in 3D has been demonstrated by fusing gamma ray interaction data with the 3D track and model provided by the Kinect sensor.In this work, the impacts of various sources of uncertainty on the ability of imaging algorithms to localize point sources of gamma rays in 3D are investigated. Unlike collimator-based imaging modalities, where the properties of the image (resolution, contrast, SNR) depend predominantly on the collimator properties in conjunction with the incident gamma ray energy, each Compton cone impacts the resolution of the resulting image differently. Furthermore, errors in the tracked position of the detector, and thus the gamma ray interaction positions in the global coordinate system, will affect the accuracy of the volumetric gamma ray image. Experimental data from the CCI-2 system is used to benchmark uncertainty models for the Compton cones and the detector track. The contributions of various sources of uncertainty to the overall image quality are investigated by applying the uncertainty models to simulated gamma ray events with perfectly known interaction positions and deposited energies along idealized detector tracks. The tradeoff between imaging efficiency and 3D image resolution are investigated by applying gamma-ray event selection criteria based on the benchmarked uncertainty models.AcknowledgementsThis work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract 2011-DN-077-ARI049-03. This support does not constitute an expressed or implied endorsement on the part of the US Government.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 54

CLYC-SiPM sensor for handheld detection systems

Jarek Glodo, Mickel Mcclish, Andrey Gueorguiev

Radiation Monitoring Devices, Inc

Non-proliferation efforts rely on identification of special nuclear materials (SNM). SNM include fissile isotopes that emit neutron radiation. Since such materials are rare, detection of any neutrons above the natural background is a strong indication of SNM presence. Most common neutron detectors are He-3 proportional counters but new technologies are being introduced to the market. This includes detectors utilizing Cs_2LiYCl_6 (CLYC) scintillator (e.g. RIIDEye GiN+). CLYC offers (1) more efficient thermal neutron detection on a per-volume basis than He-3; (2) excellent discrimination between gamma rays and neutrons, better than 1e-7; and (3) gamma-ray energy resolution as good as 4% at 662 keV. Recently, we have developed a neutron detector utilizing CLYC and Si-photomultiplier (Si-PM) technologies. The size of the CLYC crystal was 1 cm by 1 cm by 4 cm and the photo-detector was a 6 mm by 6 mm Hamamatsu S10985-025C MPPC. This combination created a compact detector that in terms of size and efficiency outperforms He-3 tubes of comparable size. While intended for thermal neutron counting, the detector is also capable of providing gamma-ray information with ~12% energy resolution at 662 keV. In this presentation, we will provide an update on our developments. Particular focus will be given to new generation detectors constructed using Si-PMs from KETEK, which improve overall performance in terms of pulse shape discrimination figure-of-merit and energy resolution. For example, the energy resolution of new detectors improved to 6% or better at 662 keV. This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract(s) HSHQDC-12-C-00012. This support does not constitute an express or implied endorsement on the part of the Government.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 55

A water-based neutron detector as a well multiplicity counter

Alexandra Asghari[1,2], Steven Dazeley[1], Adam Bernstein[1], Karl Van Bibber[2], Nathaniel Bowden[1], Vladimir Mozin[1]

[1]*Lawrence Livermore National Laboratory, Livermore, CA*
[2]*UC Berkeley, Berkeley, CA*

^{3}He is relied upon heavily for neutron detection, yet current ^{3}He demand exceeds supply by at least 10,000 liters per year. As a result of this shortage, there has been a push to develop alternate neutron detectors. One such detector is being developed at LLNL. It is based on detection of Cherenkov light emitted following neutron captures in purified water, lightly doped with the neutrophage element Gadolinium. Our prototype exhibits high efficiency and gamma ray rejection, and is non-toxic, inexpensive, and non-flammable. We describe the characteristics of our water-based detector, optimized for neutron multiplicity counting. The device may be used for non-destructive assay of fissile sources. The active detector volume is 1.02 m^3 of deionized water, doped with 0.5% $GdCl_3$. The inner walls are coated with a highly reflective material and eight ten-inch PMTs are used to detect Cherenkov light arising from the gamma cascade following neutron capture on Gd. A high solid angle, and thus high detection efficiency, is achieved with a 19 cm wide source cavity that extends 73 cm into the center of the detector volume. The detector performance is evaluated using low intensity ^{252}Cf and ^{60}Co sources, and a pulsed LED to simulate higher intensity backgrounds. The detector exhibits a 28% absolute neutron detection efficiency with a ^{60}Co gamma rejection/suppression factor of ~10^8 to 1 in the presence of background intensities of ~200 kBq or less. For higher gamma background levels up to 4 MBq ^{60}Co equivalent, the neutron detection efficiency is (22 +/- 1)% with the same background suppression. The long-term stability of the detector has been tracked over three months and is found to be consistent within 0.2%. Future tests will take advantage of source gamma-ray shielding, which can and will be added as an insertable sleeve within the well.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 56

Modeling Spent Fuel Gamma-Ray Emissions For Measurement and Detector Development

Douglas C. Rodriguez, Brent A. Vandevender, Luke W. Campbell, T. White, J. E. Fast

Radiation Detection and Nuclear Sciences, Pacific Northwest National Laboratory, Richland, WA

Currently there are over 200,000 irradiated nuclear fuel assemblies in the world, each containing a concerning amount of weapons-usable material. The International Atomic Energy Agency and state agencies monitor the nuclear fuel cycle to verify declarations as a means to deter and detect clandestine diversion of material. Power plant, reprocessing plant, and long-term storage operators would like to know how much they possess for burn-up credits. New technologies are being developed to both allow independence from operator declarations and improve quantification. Some examples of current efforts include the spectroscopy of high-energy delayed gamma rays, bremsstrahlung radiography, and nuclear resonance fluorescence. Studies to date indicate the primary challenge for these photon-based methods is the extraction of the desired signal from the high-intensity radiation emissions after the assembly is removed from the reactor core. There is a severe lack of empirical measurements of spent nuclear fuel to validate the simulation models of the radiation field. This work presents results from measurements of spent fuel material to partially fill this gap. These results include comparisons of the observed spectra to passive gamma-ray Monte Carlo for model validation and models of passive gamma-ray emissions from spent fuel rods and assemblies. Providing this foundation for active and passive interrogation and detector- and imaging-system development, this presentation will further describe how these spent-fuel models advance the Ultra-High Rate Germanium (UHRGe) detector system, the Delayed Gamma Spectroscopy (DGS) and potential emission tomography techniques.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 57

Testing of a Si-PIN Beta-Gamma Radioxenon Detector

Michael Foxe[1], Matthias Auer[2], Ian M. Cameron[1], V. V. Kolomeytsev[3], Justin I. Mcintyre[1], I. Yu Popov[3], Vladimir Yu Popov[3], Amanda M. Prinke[1]

[1]Pacific Northwest National Lab, Richland, WA, USA
[2]Comprehensive Nuclear-Test-Ban Treaty Organization, Vienna, Austria
[3]Lares Ltd., Saint Petersburg, Russia

The International Monitoring System (IMS) includes a system of radioxenon beta-gamma detectors as part of the verification regime for the Comprehensive Nuclear-Test-Ban Treaty (CTBT). An important feature of radioxenon detectors is the ability to distinguish between ^{131m}Xe, ^{133m}Xe, and the ^{133}Xe beta continuum background. Lares Ltd. has developed a beta-gamma detector that utilizes a Si-PIN beta cell instead of a plastic scintillator. With the increased resolution of the Si-PIN detector, it is possible to better distinguish between the ^{131m}Xe, ^{133m}Xe, and ^{133}Xe signals. We present information on the commissioning of the Si-PIN detector and the MDCs for ^{131m}Xe, ^{133}Xe, ^{133m}Xe, and ^{135}Xe measured with the system.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 58

Statistical Predictions of the Performance of a Fast Neutron Multiplicity System for Assaying Plutonium

David L. Chichester[1], Scott J. Thompson[1], Mathew T. Kinlaw[1], James T. Johnson[1], Jennifer L. Dolan[2], Marek Flaska[2], Sara A. Pozzi[2]

[1]Idaho National Laboratory, Idaho Falls, Idaho
[2]Department of Nuclear Engineering & Radiological Sciences, University of Michigan, Ann Arbor, Michigan

Statistical analyses have been performed to develop bounding estimates of the expected performance of a conceptual fast neutron multiplicity system (FNMS) for assaying plutonium. The conceptual FNMS design includes 32 square liquid scintillator detectors, with cubic volumes 7.62 cm in dimension, configured into 4 stacked rings of 8 detectors. Expected response characteristics for the individual FNMS detectors, as well as the response characteristics of the entire FNMS, were determined using Monte Carlo simulations based on prior validation experiments. The results from these simulations were then used to estimate the Pu assay capabilities of the system, in terms of counting time, assay mass, and assay mass variance. This analysis was performed as a parametric study, using assay mass variance as a figure of merit. The results of this analysis are compared against a currently available, thermal neutron multiplicity counter. The advantages of using a fast neutron counting system, versus a thermal, or slow neutron, counting system are significant. Most notably, the time required to perform an assay to an equivalent assay mass variance is greatly reduced with a fast system, by more than an order of magnitude compared with a thermal system, due to the reduced impacts of random summing with the fast system. The improved FNMS performance is especially relevant for assays of masses of 10 g or more. These results provide motivation for the development of a FNMS laboratory prototype.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 59

Delayed gamma-ray spectroscopy of nuclear materials with lanthanum bromide detectors

Andrea Favalli[1], Metodi Iliev[1], Ianakiev Kiril[1], Jonathan Thron[1], Edward Reedy[2], Alan Hunt[2], Vladimir Mozin[3], Bernhard Ludewigt[4]

[1]*Los Alamos National Laboratory (LANL) Los Alamos, NM, 87545, US*
[2]*Idaho Accelerator Center, Idaho State University, Pocatello, Idaho, USA*
[3]*3Lawrence Livermore National Laboratory, Livermore, California USA*
[4]*4Lawrence Berkeley National Laboratory, Berkeley, California, USA*

High-energy delayed gamma-ray (DG) spectroscopy is a potential technique for directly assaying spent fuel assemblies and achieving the safeguards goal of quantifying nuclear material inventories for spent fuel handling, interim storage, reprocessing facilities, repository sites, and final disposal. Other potential applications include determination of MOX fuel composition, hold-up measurements, and characterization of nuclear waste packages. Requirements for the DG gamma detection system, for energies up to ~7 MeV, can be summarized as follows: high efficiency at high gamma-ray energies, high energy resolution for spectroscopy, good linearity between gamma energy and output signal amplitude, ability to operate in very high count-rate gamma fields, and ease of application in industrial environments such as nuclear facilities. High Purity Germanium Detectors (HPGe) are the state of the art, however an important limitation of HPGes, is the inability of a single-crystal based detector to tolerate high count rates. Lanthanum Bromide (LaBr3) scintillation detectors offer: significantly higher count-rate capability due to fast decay time of the emitted light; the highest energy resolution for a scintillator detector (although lower than HPGe detectors); and they do not need a cooling system, and therefore are easy to apply in an industrial environment. Thus LaBr3 detectors may be an effective alternative for nuclear spent-fuel applications. The performance of a high-rate gamma spectrometer based on 2" (length) x 2" (diameter) LaBr3 scintillation detector was evaluated. The spectroscopy characteristics (energy resolutions, linearity, and stability) were measured up to count rates of ~2 Mcps, using a combination of ^{137}Cs and ^{232}Th gamma sources. Further, experimental measurements were conducted at the Idaho Accelerator Center, Idaho State University, where ~3g of ^{235}U and ~3g of ^{239}Pu samples were irradiated with the neutrons from a photon-neutron source. DG spectra were collected and results will be presented. The potentials and limitations of LaBr3 scintillation detector for DG spectroscopy of nuclear material will be discussed.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 60

Evaluation of ^{6}Li metal foil neutron detector for well coincidence counter

Andrea Favalli, Martyn T. Swinhoe, Metodi L. Iliev, Ianakiev D. Kiril

Los Alamos National Laboratory (LANL) Los Alamos, NM, 87545, US

Neutron well coincidence counters are one of the more difficult ^{3}He replacement applications because of the complex and conflicting requirements for high detection efficiency, good gamma to neutrons rejection and low dead time.As part of that effort we report our design and characterization of ^{6}Li-metal-foil-based neutron detector. The detection concept was reported on 2010 SORMA conference, it comprises of 40μm ^{6}Li-metal foils sandwiched between PMMA light-guide strip laminated with 50μm thin scintillator film, to limit the energy deposited by gamma rays. This detector as well as 10B and ZnS/LiF based detectors presents overlapping gamma and neutron distributions. Neutron-gamma discrimination requires to set the detection threshold set above the gamma distribution, and the selection of the threshold is critical for overall performance. Use of ^{252}Cf neutron source together with gamma sources like ^{137}Cs and ^{60}Co for threshold optimization would not provide optimal setting for coincidence counting because of substantially different gamma emission in Plutonium based compounds (e.g.PuO_2, PuF_4) that are need to be assayed for safeguards. Therefore we have used PuO_2 sample with known isotopic composition for characterization and optimization of detection threshold. An estimate of neutrons losses underneath the detection threshold using gamma attenuation technique will be compared with the differences of detector response before and after application of 6Li foil. Another characteristic specific to a neutron detector that uses sandwich scintillators is an axial variation of light transport efficiency. With a light readout that uses the sum of the signals from two PMTs on both sides, this light collection is minimal at the center and is highest close to PMTs. This light collection profile has opposite behavior to the axial neutron capture efficiency. This means that the two effects can partially compensate each other thus benefitting the uniformity of neutron detection along the detector. Measurement results of neutron detection efficiency, axial neutron profile efficiency, as well as neutron coincidence measurements with Plutonium samples will be presented for an assembly of two detector modules. The result will be discussed for the viability of neutron coincidence detector for nuclear safeguard applications.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 61

Optimization of dual sided readout of plastic pixels for neutron block detectors

Mitchell A. Laubach[1], Xiaodong Zhang[1], Jason P. Hayward[1,2]

[1]*Dept. of Nuclear Engineering, University of Tennessee, Knoxville,*
[2]*Oak Ridge National Laboratory, Oak Ridge*

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 62

Development of Calibration Source for XMASS detector

K. Abe[1,3], K. Hieda[1], K. Hiraide[1,3], S. Hirano[1], Y. Kishimoto[1,3], K. Kobayashi[1,3], S. Moriyama[1,3], K. Nakagawa[1], M. Nakahata[1,3], H. Ogawa[1,3], N. Oka[1], H. Sekiya[1,3], A. Shinozaki[1], Y. Suzuki[1,3], A. Takeda[1,3], O. Takachio[1], K. Ueshima[1,4], U. Umemoto[1], M. Yamashita[1,3], B. S. Yang[1], S. Tasaka[2], J. Liu[1], K. Martens[1], K. Hosokawa[5], K. Miuchi[5], A. Murata[5], Y. Onishi[5], K. Otsuka[5], Y. Takeuchi[3,5], Y. H. Kim[6], K. B. Kim[6], M. K. Kim[6], J. S. Lee[6], Y. Fukuda[7], Y. Itow[4,8], K. Masuda[8], Y. Nishitani[8], H. Takiya[8], H. Uchida[8], N. Y. Kim[9], Y. D. Kim[9], F. Kusaba[10], D. Motoki[11], K. Nishijima[10], K. Fujii[12], I. Murayama[12], S. Nakamura[12]

[1]*Kamioka Observatory, Institute for Cosmic Ray Research, the University of Tokyo, Higashi-Mozumi, Kamioka, Hida, Gifu, 506-1205, Japan*
[2]*Information and multimedia center, Gifu University, Gifu 501-1193, Japan*
[3]*Kavli Institute for the Physics and Mathematics of the Universe (WPI), the University of Tokyo, Kashiwa, Chiba, 277-8582, Japan*
[4]*Kobayashi-Maskawa Institute for the Origin of Particles and the Universe, Nagoya University, Furo-cho, Chikusa-ku, Nagoya, Aichi, 464-8602, Japan.*
[5]*Department of Physics, Kobe University, Kobe, Hyogo 657-8501, Japan*
[6]*Korea Research Institute of Standards and Science, Daejeon 305-340, South Korea*
[7]*Department of Physics, Miyagi University of Education, Sendai, Miyagi 980-0845, Japan*
[8]*Solar Terrestrial Environment Laboratory, Nagoya University, Nagoya, Aichi 464-8602, Japan*
[9]*Department of Physics, Sejong University, Seoul 143-747, South Korea*
[0]*Department of Physics, Tokai University, Hiratsuka, Kanagawa 259-1292, Japan*
[1]*School of Science and Technology, Tokai University, Hiratsuka, Kanagawa 259-1292, Japan*
[2]*Department of Physics, Faculty of Engineering, Yokohama National University, Yokohama, Kanagawa 240-8501, Japan*

By using highly purified liquid xenon as a target material, the XMASS has the multipurpose detector system for a dark matter, pp and Be-7 solar neutrinos, and neutrinoless double-beta decay research. We report fabrication and characterization of reference sources used for energy calibration and position reconstruction of the present XMASS detector. Each Am-241 and Co-57 source nuclides were electro-deposited on a tungsten wire. The wire was threaded through a stainless steel tube with 170 μm and 210 μm outer diameter for Am-241 and Co-57, respectively. Its tube-wall thickness is 35 μm for Am-241 and 65 μm for Co-57. The wire was cut at both ends of the tube minimizing the active length. Less than 1 mm of active length was found from a test with a low energy germanium detector. The completed sources can be attached to a source drive system. The calibration of the XMASS detector was made by placing the sources at different locations inside liquid xenon.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 63

Testing the Ultracold Neutron Source at the PULSTAR Reactor

Ekaterina Korobkina[1], Bernard W. Wehring[1], Ayman I. Hawari[1], Graham Medlin[2], Albert R. Young[2], Paul R. Huffman[2]

[1]*North Carolina State University, Department of Nuclear Engineering, Raleigh, NC 27695, USA*
[2]*North Carolina State University, Department of Physics, Raleigh, NC 27695, USA*

Construction is completed and commissioning is in progress for an ultracold neutron (UCN) source at the PULSTAR reactor on the campus of North Carolina State University (NCSU). The source design is based on 3-stage moderation and is optimized for high UCN yield per reactor

power. The neutron moderators are heavy water (operated at temperature of T = 300 K), solid methane (T = 40 K) and solid deuterium (T = 5 K). The source is placed in the thermal column enclosure of the PULSTAR reactor, where neutrons are delivered from the core by streaming through an open port structure. At present, all infrastructure components of the source (heavy water circulation system, gas handling system, liquid He cooling system, the neutron port, and source itself) have been manufactured and tested. Currently, cryogenic characterization of the entire assembly including the source cryostat is underway. Once the commissioning is complete, the research program being considered for the PULSTAR UCN source includes the physics of UCN production, fundamental particle physics (neutron lifetime measurements and support for a search for the neutron electric dipole moment) and material surface studies of nanolayers containing hydrogen.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 64

Characterization of point defect chemistry in scintillator materials by tracer diffusion

Katherine E. Colbaugh[1], Amrita Mishra[2], Scott Broderick[2], Krishna Rajan[2], James Mcguffin-cawley[1]

[1]*Department of Materials Science and Engineering, Case Western Reserve University, Cleveland Ohio*
[2]*Department of Materials Science and Engineering, Iowa State University, Ames Iowa*

The results of tracer diffusion studies, conducted using the isotopes ^{18}O and ^{26}Al, in undoped and doped YAG single crystals will be reported. Experiments were carried out using both commercial and in-house grown Czochralski crystals. Isotope profiling was carried out using time-of-flight secondary ion mass spectrometry (ToF-SIMS) and local electrode atom probe (LEAP) tomography. The effect of doping on mass transport will be discussed in the context of point defect chemistry and observations by others on scintillator performance.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 65

Fast-Neutron and Gamma-Ray Imaging Measurements of Special Nuclear Material

Alexis Poitrasson-riviere, J. Kyle Polack, Michael C. Hamel, Shaun D. Clarke, Marek Flaska, Sara A. Pozzi

University of Michigan, Ann Arbor, Michigan 48109, USA

Dependable techniques to accurately detect and localize special nuclear material (SNM) have become paramount in today's world. SNM has the particularity of emitting fast neutrons and gamma rays; ideally, both of those signatures should be used when trying to detect SNM to minimize false alarms. A detection system capable of simultaneously imaging fast neutrons and gamma rays has been developed at the University of Michigan using organic and inorganic scintillators. The detection principle is based on the scattering physics of neutrons (elastic scattering) and gamma-rays (Compton scattering), which allows for the construction of cones of probable source location using the energies and interaction locations within the detection system. The system is designed as a combination of a two-plane Compton camera and a neutron-scatter camera with the back plane of the camera using two types of detectors: the front, scatter plane consists of EJ-309 liquid scintillators and the back plane consists of interleaved EJ-309 and NaI scintillators.A prototype system has been built and tested at the University of Michigan with a Cf-252 source as a SNM surrogate. A full software suite was developed to acquire and process data in real time. The images and spectra collected reasonably matched expectations and showed potential for the use of this system with an actual SNM. The SNM surrogate has limitations, however, as its gamma-ray emissions do not match the gamma-ray lines emitted from plutonium. A measurement campaign is taking place in the spring of 2014 to test the imaging system with plutonium metal, plutonium oxide, and mixed oxide samples at the Joint Research Centre in Ispra, Italy. In this work, we will present measurement results from the measurement campaign. Multiple source locations and geometries will also be investigated and a performance assessment will be carried out using the data collected.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 66

Improving 3D Compton Image Reconstruction with Visual Volumetric Data

Andrew Haefner[1], Ross Barnowski[1], Lucian Mihailescu[2], Kai Vetter[1,2]

[1]*University of California at Berkeley, Dept. of Nuclear Engineering*
[2]*Lawrence Berkeley National Lab, Applied Nuclear Physics*

Compton imaging is a gamma-ray imaging technique useful for imaging sources in the range of a hundred keV to several MeV. In this energy range applications of gamma-ray imaging include nuclear security, medical imaging, and astrophysics. 3D volumetric image reconstruction is especially of interest in applications of homeland security, treaty verification and contamination remediation. The common challenge with the imaging environments in these applications is that the imaging domains are large, complex and have unknown geometry. This is in contrast to medical 3D imaging where the imaging domain is physically compact. Thus, a solution is desired where a Compton camera could move freely in these environments and map out materials emitting gamma rays in real-time. Compton imaging uses coincidence gamma-ray interactions, which generate scatter cone data. Low count rates are often a challenge for Compton imaging measurements, increasing measurement time or increasing image noise. Additionally when a detector is moving in a 3-D environment it would be very challenging to guarantee that a complete data set is sampled to fully reconstruct the true gamma-ray distribution. Thus there is a need for robust methods that can overcome these challenges.Using measured data we show how visual point cloud data can be used to constrain the reconstruction problem and provide many advantages. This has the effect of taking a problem that is under-determined and making it solvable. It removes image artifacts caused by low count rate and sampling issues and thus improves image quality and source localization. An added benefit of this approach is that computing the image reconstruction is much more efficient because it only needs to be computed in the space constrained by the visual data. To accomplish this we use a constrained list mode ML-EM algorithm. We are also developing and testing other novel methods for this reconstruction approach. Our implementation performs this data fusion in near real-time. We demonstrate this concept with results using measured visual data from our Compact Compton Imaging (CCI-2), which contains a Microsoft Kinect and a two plane DSSD HPGe Compton camera on a cart.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 67

The University of New Mexico spectrometer for high resolution fission fragment yield data, with preliminary results from LANSCE

Adam A. Hecht, Richard E. Blakeley, Lena Heffern, Paul Gilbreath, Corey Vowell, James Cole

University of New Mexico

Fission cross section and fragment yields are important for active interrogation, for understanding secondary reactor heating, and for furthering theory on fission preformation. We have developed a spectrometer at the University of New Mexico (UNM) for particle-by-particle measurements of fragments emitted by fission. We have performed beam measurements with the Los Alamos Neutron Science CEnter (LANSCE) neutron beam on U-235 and calibration tests with Cf-252, and preliminary results will be presented. The spectrometer design is based on the 2E-2v type Cosi Fan Tutte spectrometer with several improvements implemented and planned to improve efficiency and resolution, towards 1 amu heavy fragment resolution. The fission fragment that is emitted in the appropriate direction passes through a time-of-flight (TOF) region and into an ionization chamber (IC), giving both velocity (v) and kinetic energy (E) measurements. With both the velocity and kinetic energy, the fission fragment mass may be extracted. With the IC configured as a time projection chamber, IC timing information yields fragment Z information. The incident neutron kinetic energy on the target is known by timing with the LANSCE pulsed beam. A,Z,N and E measurements for both fragments simultaneously from a binary fission event we will also have a measure of neutron multiplicity and reaction cross section to produce that fragment pair as a function of incident neutron energy. The recent U-235 measurements were performed with a single arm spectrometer. We are currently testing an active cathode design on the IC for improved timing and Z resolution, and will implement detectors on both sides of the fission target for the simultaneous binary fragment measurements for a full 2E-2v spectrometer. This is part of a multi-year detector development and measurement campaign as part of the LANL SPectrometer for Ion Determination in fission Research (SPIDER) collaboration, with UNM prototyping and testing designs to improve resolution and extract more particle information. Measurements will be performed over a range of incident neutron energies and for several actinides of interest.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 68

A Fast Spectrum Neutron Source for Material Irradiation Using a Superconducting Electron Linac

Valeriia N. Starovoitova[1], Terry L. Grimm[1], Frank Harmon[2], Mayir Mamtimin[2]

[1]*Niowave, Inc. Lansing, MI 48906*
[2]*Idaho Accelerator Center, Idaho State University, Pocatello, ID 83201*

Next generation reactor concepts cater to a common goal of providing safer, longer lasting and economically viable nuclear power plants. Developing radiation damage resistant materials for both in-core and out-of core applications is a critical component of these next generation power plants. Testing these novel materials requires an intense neutron environment. A commonly used tool for testing novel materials is a nuclear reactor providing high density neutron flux.We are developing a convenient and low-cost alternative: an intense source of fast fission-spectrum neutrons produced from a superconducting electron linac. The source is based on the photo production of neutrons, including (γ,n) production and photofission, with a high power 10-40 MeV electron beam. The end-station is intended to irradiate small mm-scale samples with a neutron flux of 10^{14} n/cm^2·s. Fluxes greater than 10^{13} n/cm^2·s can be achieved for larger, cm-scale specimens. Beryllium, tungsten, lead and uranium are being investigated as potential neutron target materials. We will present both Monte-Carlo simulations and preliminary experimental results confirming the predicted fluxes.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 69

Weld radiography image process aided by interpolation functions and wavelet transformation function

Rômulo M. Almeida[1], Mariana Burrowes[2], João Marcos Alcoforado Rebello[2], Gabriela R. Pereira[2]

[1]*Program of Metallurgical Engineering and Materials, Department of Metallurgical and Materials Engineering COPPE/UFRJ, Federal University of Rio de Janeiro, Rio de Janeiro/RJ – Brazil*
[2]*Non-destructive Testing, Corrosion and Welding Laboratory(LNDC), Department of Metallurgical and Materials Engineering COPPE/UFRJ, Federal University of Rio de Janeiro, Rio de Janeiro/RJ – Brazil*

In this work a study of processing on digital radiographic images of welding was developed. The aim of this study was to segment the image and get a report automatically and then try to increase the quality of radiographic images. To test the algorithm developed radiographic images of scanned IIW patterns, direct digital radiographic images of the Laboratory of Nuclear Instrumentation UFRJ and radiographic images simulated by Artist Software were used. Once developed the routine which to segment digital imaging and makes the report also scales each defect found in automated discovery the next step was to try to improve the image quality. To this end the use of Wavelet transform that has shown to be a powerful tool for image and signal processing was used. Wavelet tool proved robust and effective in reducing the noise levels of radiographic images, their use allowed the final result came pretty close to ideal. The tool wavelet transform also served to emphasize how influenced a radiographic image can be in terms of reports to the noise level in the image.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 70

Feasibility of screening fast moving highway traffic for illicit nuclear material.

Matthew Dallimore[1], Melissa Schear[1], Chris Frail[1], David Ramsden[2], Mark Foster[2]

[1]*Symetrica, Inc., Maynard, MA USA*
[2]*Symetrica Security, Southampton UK*

An area of critical interest in the Homeland Security Field is the detection and tracking of nuclear material once it has entered a countries transportation system such as highway or rail. An example of this interest can be seen in in the upcoming Radiation Awareness and Interdiction Network (RAIN) ATD from the US government. This Advanced Technology Demonstrator (ATD) is intended to demonstrate the capability of monitoring a highway for nuclear material and assigning a specific alarm to individual vehicles [1]. The aim of this paper is to explore the neutron detector capabilities required to meet the requirements in this ATD. The scenarios simulated in this paper will encompass a range of vehicle speeds, as well as threat source activities, in order to allow an accurate determination of the detection sensitivity required to achieve a particular screening level for neutron emitting threat sources.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 71

High Yield, Gas Target Neutron Source

Evan Sengbusch[1], Greg Piefer[2], Chris Seyfert[1], Arne Kobernick[1], Logan Campbell[1], Casey Lamers[1], Tye Gribb[1], Ross Radel[1]

[1]Phoenix Nuclear Labs, Madison, WI
[2]SHINE Medical Technologies, Madison, WI

Phoenix Nuclear Labs (PNL) has designed and built a high yield deuterium-deuterium (DD) neutron generator with measured yields greater than $3x10^{11}$ n/s. The neutron generator utilizes a proprietary gas target coupled with a custom 300kV accelerator and a microwave ion source (MWS). A pressure differential of approximately 1,000,000X is achieved between the high pressure gas target and the accelerator and ion source region in order to stop the ion beam within a reasonable distance (~70cm in the present configuration). Two prototype neutron generators have been delivered; one to the US Army for neutron radiography and one to SHINE Medical Technologies for medical isotope production. PNL furthermore signed its first commercial order in late 2013 and will deliver a generator to the United Kingdom late in 2014. The ion injector is comprised of a MWS that utilizes 2.45GHz microwaves and solenoid-generated magnetic fields to produce high plasma densities by utilizing electron-cyclotron resonance (ECR) interactions. These sources have proven to have very high power efficiency and a high atomic ion fraction. Subsequent to the MWS and ion beam extraction region is a custom, 300kV electrostatic accelerator that is powered by an in-house produced DC power supply. The 300kV ion beam is focused with either an electrostatic quadrupole triplet (for lower current devices; <35mA) or a magnetic solenoid (for higher current devices; >35mA). After focusing, the beam is transported through a series of differential pumping stages separated by flow restrictions that allow the beam to pass but minimize upstream gas flow. The beam is focused to a choke point at the target entrance (~6mm) that helps hold off the pressure differential between the gas target region and the accelerator region. Experiences operating and optimizing the various subsystems will be described. System performance will be characterized in terms of beam current and voltage, measured neutron yield, and operational reliability. One prototype is currently operated over 100 hours per month and has logged well over 1,000 hours with very high uptime. No lifetime-limiting components have been identified to date. Preliminary results utilizing the neutron generator technology for various federally and commercially funded applications, including thermal neutron radiography, medical isotope production, nuclear instrumentation testing and calibration, and explosives detection will be presented. Multiple next-generation systems are presently being designed and built at PNL with an emphasis on further increasing neutron yield and reliability and on decreasing the physical size and price of the system. Modifications currently underway include further increases in voltage and current, the use of a solid targets (e.g. for fast neutron radiography), and transitioning to a mixed deuterium-tritium beam in the gas target system. The latter modification will result in a neutron yield increase of approximately 50X. Two DD systems will be delivered during the next year, and PNL is targeting delivery of 3 DT generators with neutron yields of $5x10^{13}$ n/s each in early 2016 to SHINE's molybdenum-99 production facility.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 72

Shallow Underground Proportional Counter Characterization and Calibration for Measuring ^{37}Ar

Allen Seifert, Craig E. Aalseth, Ted W. Bowyer, Anthony R. Day, Erin S. Fuller, Derek A. Haas, James C. Hayes, Eric W. Hoppe, Paul H. Humble, Martin E. Keillor, Brian D. Laferriere, Emily K. Mace, Justin I. Mcintyre, Harry S. Miley, Allan W. Myers, John L. Orrell, Cory T. Overman, Mark E. Panisko, Richard M. Williams

Pacific Northwest National Laboratory, Richland, WA, USA

Nuclear reaction products are the ultimate confirmatory signatures that an explosion was nuclear in nature, indicating neutrons have interacted with the environment. Chemically-inert noble gases, such as ^{37}Ar, can be created when neutrons interact with calcium in the soil and are among the most likely radionuclides to escape into the environment. The production of ^{37}Ar via the reaction ^{40}Ca(n,α)^{37}Ar has a relatively high cross-section, especially at neutron energies above 2 MeV, and is expected to provide a measurable signature following a nuclear explosion. With a 35-day half-life, ^{37}Ar is long-lived enough to allow time for soil-gas sampling to occur under the provisions of the Comprehensive Nuclear-Test-Ban Treaty, but is expected to be present at relatively low background levels under normal conditions and has a very low atmospheric background. Detection of ^{37}Ar is challenging as the decay via electron capture emits only low-energy Auger electrons and x-rays. An ultra-low-background gas proportional counting capability has been developed at Pacific Northwest National Laboratory (PNNL) in Richland, Washington, USA. This capability is operated in a shallow underground laboratory (30 meters water-equivalent) at PNNL and is used to assay argon recovered from environmental soil-gas samples for ^{37}Ar activity. This work describes calibration techniques and analysis methods developed to enable quantitative measurements of ^{37}Ar samples. These techniques are applied over a broad range of proportional counter operating pressures and thus sample sizes. Development of an

in-house capability for producing low-level ^{37}Ar sources via calcium irradiation is also described. These efforts, along with parallel work in progress on gas chemistry separation, will enhance existing capabilities for ^{37}Ar soil-gas background studies.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 73

Development of Fast-Neutron THGEM-based Imaging Detector for Fan-Beam Tomography Applications and Spectroscopy.

Marco Cortesi[1], Robert Zboray[2], Volker Dangendorf[4], Horst-michael Prasser[2,3]

[1]*National Superconductive Cyclotron Laboratory (NSCL), Michigan State University, East Lansing MI, 48824-1321, USA*
[2]*Paul Scherrer Institut (PSI), Villigen PSI, CH-5234, Switzerland*
[3]*Swiss Federal Institute of Technology (ETH), Zurich, CH-8092, Switzerland*
[4]*Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, 38116, Germany*

We present our recent results on development of two innovative detector concepts for fast-neutron tomography applications and imaging spectroscopy, with the aims of imaging of physical/chemical processes and of non-destructive analysis (NDA) of samples. • The first concept is a novel high-efficiency, fast-neutron imaging detector intended for future fan-beam tomography applications. It consists of a multi-layer neutron-to-proton converter made of hydrogenous materials (polymer) coupled to a position-sensitive THGEM detector; the latter collects and multiplies the proton-induced electrons released in the gas gap between the converter foils, thereby sensing the impinging-neutron's position. For irradiation with 2.5 MeV neutrons and a total of 300 converter foils, detection efficiencies of ~ 7% and a spatial resolution of around 1 mm are expected.•The second detector, suitable for either energy-selective imaging or for imaging spectroscopy, is comprised of a series of energy-selective stacks of converter foils immersed in a noble-gas based mixture, coupled to a position-sensitive charge readout. The foils in the various stacks are made from two layers of foils of different thickness, fastened together: a hydrogen-rich (plastic) layer for neutron-to-proton conversion and a hydrogen-free coating to selectively stop/absorb the recoil protons below a certain energy cut-off. The neutron-induced recoil protons, that escape the converter foils, release ionization electrons in the gas gaps between consecutive foils. The charge is then drifted towards and localized by the position-sensitive charge readout. The imaging spectrometer consists thus on defined areas with different detection response for different neutron energies which can be accessed by the position sensitive THGEM read out. Neutron spectrometry is realized by the comparison of the responses of a sufficient number of stacks of different energy response and unfolding techniques. We will briefly review the design, operational principles and expected performances of both the new proposed detector concepts and discuss possible applications. Among foreseen applications are neutron tomography in non-destructive testing for the nuclear energy industry, including examination of spent nuclear fuel bundles, non-destructive analysis (NDA) of Special Nuclear Material (SNM), as well as investigations of thermal-hydraulics phenomena.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 74

Stability of Working Reference Standards for Hybrid K-Edge Densitometer Quality Assurance

Tyler Guzzardo[1], Robert Mcelroy[1], Stephen Croft[1], Jon Garrison[1], Ram Venkataraman[2]

[1]*Oak Ridge National Laboratory, Oak Ridge, TN 37831*
[2]*Canberra Industries, Meriden, CT 06450*

The relatively short working life of aqueous solution standards of actinides for the calibration and quality control of Hybrid K-Edge Densitometer (HKED) measurements necessitates the development of a stable matrix material less susceptible to degradation. Degradation in the form of evaporation, radiolysis, settling, sloshing, and sediment formation can all reduce the reliability and working life of an aqueous standard. These factors make aqueous solutions inadequate for long-term quality assurance measurements designed to detect weak or subtle trends in system performance. Epoxy, studied here, is an alternative matrix material that may be less vulnerable to degradation. An additional benefit of epoxy is that standards can easily be characterized as sealed sources which allows for simplified administrative controls during shipping and storage. The stability of working reference standards consisting of U_3O_8 in an epoxy matrix for use in the HKED has been tracked for over 3 years through repeated X-Ray Fluorescence (XRF) and K-Edge (KED) measurements. A set of 6 epoxy standards ranging in concentration from 1 g/L to 76 g/L uranium were determined to be stable, within the expected accuracy of the system, over the period of analysis. During this time, no effort was made to enhance the stability of the epoxy standards; the radial measurement position was not controlled and in the middle of the analysis period the HKED

system and standards were shipped from the vendor's factory to the customer. Epoxy standards afford numerous benefits over those created from aqueous solutions and should be considered when developing HKED standards for quality assurance measurements. The stability of the epoxy allows the development of working standards of a stability and robustness sufficient for use in a proposed international round-robin exercise based on the exchange of such standards.

POSTERS III - PHYSICS & SECURITY APPLICATIONS AND SIGNAL PROCESSING: 75

Cosmic-Ray Scanning of Cargo Conveyances for Nuclear and Conventional Weapons of Mass Destruction

Michael Sossong, Gary Blanpied, Sankaran Kumar, Priscilla Kurnadi, Andre Lehovich, Sean Simon

Decision Sciences International Corporation

Decision Sciences has commercialized technology utilizing cosmic-ray background radiation for the interrogation of maritime cargo containers and other cargo conveyances for nuclear and conventional weapons of mass destruction (WMD). A technical and operational overview will be presented. The Multi-Mode Passive Detection System tracks muons and electrons generated in cosmic-ray interactions with the atmosphere before and after passing through a volume of interest. Measured multiple Coulomb scattering and attenuation interactions in the volume are used to reconstruct the three-dimensional distribution of materials in the volume. This distribution can reveal the presence of WMD, as well as components and precursors, without interfering with the flow of commerce.The MMPDS utilizes large arrays of drift tubes, above and below the volume of interest. A thin wire is strung down the center of a simple aluminum tube. Each tube is filled with a gas to provide controlled ionization and propagation (drift) of these ionized electrons to the wire and permanently sealed. In operation, a voltage is applied to the wire. Charged particles traversing the gas volume ionize the gas. Electrons from this ionization drift at a predictable rate toward the wire and avalanche near the wire to provide a pulse measurable at the end of the wire. The drift tubes provide sub-millimeter position resolution perpendicular to the wire with widths of 5 cm and lengths up to 12 meters, providing geometric acceptance for very large scan volumes at low cost. Tubes are placed in orthogonal layers to track charged particles in three-dimensions.Incoming and outgoing particle trajectories are evaluated for multiple Coulomb scattering and attenuation caused by objects in the volume of interest. These data are processed using imaging techniques based in medical imaging, particularly PET and SPECT imaging, to reconstruct the 3D material distribution in the VOI. This distribution is then automatically evaluated to determine the presence of defined threats. The MMPDS does not apply radiation to the scene being scanned. This means scanning can be performed concurrently with existing operations without endangering workers, operators or drivers. Scan results are delivered in real-time with no human interpretation required, reducing impact on commerce flow and operational costs. Another advantage of this technology is the ability to acquire additional information with extended scanning. Typical scan times are on the order of a minute for clearing of benign cargo. For suspicious configurations, more detail can be obtained by extending the scan time, providing for the clearance of benign cargo or enhanced information for responders in the event of threat detection.Decision Sciences has a pilot tractor-trailer scanning installation in Freeport, Bahamas. This system is being used for vendor development testing as part of DHS-DNDO's Advanced Technology Demonstration (ATD) Nuclear and Radiological Imaging Portal (NRIP) program. Additionally, DSIC is performing testing on the capability to identify conventional WMD and other contraband.This work supported by The US Department of Homeland Security Domestic Nuclear Detection Office, under competitively awarded contract HSHQDC-12-c-00062. This support does not constitute an express or implied endorsement on the part of the Government.

Nonproliferation, Safeguards, and Homeland Security I

4:00 PM - 5:30 PM (Alumni Center)

NONPROLIFERATION, SAFEGUARDS, AND HOMELAND SECURITY I: 1

Can we break the 1% uncertainty barrier for gamma-ray isotopic nondestructive analysis of special nuclear material?

Michael W. Rabin[1], Andrew S. Hoover[1], Ryan Winkler[1], Douglas A. Bennett[2], Carl D. Reintsema[2], Joel N. Ullom[3]

[1]*Los Alamos National Laboratory*
[2]*National Institute of Standards and Technology*
[3]*School of the Art Institute of Chicago*

For about three decades, the core concepts and data analysis techniques for quantitative nondestructive analysis (NDA) of special nuclear material (SNM) using high-purity germanium (HPGe) gamma-ray spectrometers have remained the same. The worldwide expectation of ultimate performance is therefore unchanged, stuck at about 1% total uncertainty for isotopic ratios (or fractions). Gamma-ray isotopic NDA of SNM is in need of a reformation. The core architecture of the current major codes (FRAM, MGA, etc.) was fixed in about 1990. With the exception of some very recent work, gamma isotopic NDA has been by-passed by three technological and conceptual revolutions: digital processing power, Monte-Carlo simulation, and Bayesian data-analysis, especially as applied to understanding uncertainty. Our goal is to develop the scientific foundations for modernized SNM isotopic NDA with 0.1% total measurement uncertainty, a factor-of-ten improvement over current limits. Recent results based on measured plutonium spectra, Monte-Carlo simulations, and our new spectral analysis code are the first real evidence that the ~1% uncertainty limit can be overcome. A sensitivity-coefficient analysis on HPGe spectra (~450 eV FWHM) and microcalorimeter-array spectra (50-80 eV FWHM) has identified the main sources of external systematic error. The biggest difference between sensor types comes from their sensitivity to very small uncertainties in peak central energies (i.e. nuclear energy level differences). For HPGe, this effect is surprisingly large, often the dominant uncertainty contribution at 1-5%. In striking contrast, the corresponding uncertainty contribution for microcalorimeter data is 10-to-60 times smaller. For example, the miniscule, only ~60 ppm uncertainty in the crucial 240Pu peak at 104.230 keV implies up to ~2% systematic uncertainty for conventional (fixed peak energy) HPGe results, but an insignificant ~0.02-0.03% uncertainty for microcalorimeter results.In this talk, we will discuss the significant challenges to reducing total uncertainty for quantitative isotopic analysis of both HPGe and microcalorimeter spectra. A central theme is to use results from microcalorimeter sensor development to improve analysis of HPGe spectra. This includes improved knowledge of key parameters (branching ratios, half lives, peak energies or combinations thereof) and completely new methods of data analysis. Key challenges include decreasing model discrepancy for both spectral shape and the relative efficiency functions; reducing external systematic uncertainty through mathematical reformulation of the measurement model; designing an experimental campaign to self-consistently and simultaneously determine all the necessary key external parameters; and developing a fully Bayesian data analysis methodology. The long-term goal is to propagate new methods and associated data to significantly reduce uncertainty in the worldwide use of HPGe sensors for SNM isotopic NDA.

NONPROLIFERATION, SAFEGUARDS, AND HOMELAND SECURITY I: 2

Application of Fast Liquid Scintillator for SNM Detection using DDA Method

Michael King, Tsahi Gozani, Mashal Elsalim, Matthew Araujo, Krystal Alfonso

Rapiscan Laboratories Inc., Sunnyvale CA

The inspection of hidden nuclear materials utilizing the differential die-away method relies on a large-area, high efficiency, moderated thermal neutron detector to detect induced prompt fission neutrons. In any neutron based active interrogation environment, there is a high flux of both neutrons and gamma-rays generated from induced reactions, such as (n,γ), (n,p) and (n,α). The mixed field usually precludes the use of liquid scintillators with pulse-shape discrimination to detect prompt fission neutrons. In certain scanning scenarios, like a single-sided system where the neutron source and detector are on the same side, a well-shielded liquid scintillator can be used to detect neutrons. In addition, because the detector is located adjacent to the neutron source, time of flight of the thermal neutrons can be used to extrapolate the threat distance. Experimental results with a 5" x 5" cylindrical EJ-301 liquid scintillator will be shown.

NONPROLIFERATION, SAFEGUARDS, AND HOMELAND SECURITY I: 3

Neutron Triples Counting Data for Uranium

Stephen Croft[1], Adrienne Lafleur[2], Robert D. Mcelroy[1], Martyn T. Swinhoe[2]

[1]Oak Ridge National Laboratory, Oak ridge, TN 37831, USA
[2]Los Alamos National Laboratory, Los Alamos, NM 87545, USA

Correlated neutron counting using multiplicity shift register logic extracts the first three factorial moments from the detected neutron pulse train. The descriptive properties of the measurement item (mass, (α,n) to spontaneous fission neutron production, and leakage self-multiplication) are related to the observed singles (S), doubles (D) and triples (T) rate, and this is the basis of the multiplicity counting assay method. The factorial moments required to interpret and invert the measurement data may be calculated from the spontaneous fission prompt neutron multiplicity distribution. In the case of ^{238}U very few measurements of P(ν) are available and the derived values, especially for the higher factorial moments are not known with high accuracy.In this work we report the measurement of the triples rate per gram of ^{238}U based on the analysis of a set of measurements in which a collection of 10 cylinders of UO_2F_2, each containing about 230 g of compound, were measured individually and in groups. Special care was taken to understand and compensate the recorded multiplicity histograms for the effect of random cosmic-ray induced background neutrons, which, because they also come in bursts, mimic fissions but with a different and harder multiplicity distribution. We compare our fully corrected (deadtime, background, efficiency, multiplication) experimental results with first principles expectations based on evaluated nuclear data. Based on our results we suspect the current evaluated nuclear data is biased, which points to a need to undertake new basic measurements of the ^{238}U prompt neutron multiplicity distribution.

NONPROLIFERATION, SAFEGUARDS, AND HOMELAND SECURITY I: 4

Memory effect studies of beta-gamma detectors in the IMS radioxenon stations

Amanda M. Prinke, Ted W. Bowyer, Matthew W. Cooper, Michael Foxe, Derek A. Haas, James C. Hayes, Justin D. Lowrey, Justin I. Mcintyre, Harry S. Miley, Brian T. Schrom, Thomas J. Suckow

Pacific Northwest National Laboratory, Richland, WA

The International Monitoring System radionuclide stations provide daily concentrations for atmospheric radioxenon isotopes. This information is used in the verification regime of the Comprehensive Nuclear-Test-Ban Treaty. Most of the radioxenon detection systems employed by the IMS currently use plastic scintillators to measure electrons from radioxenon decays and also to contain the gaseous xenon samples. Xenon has been shown to diffuse into these plastic scintillators, creating a "memory effect" wherein a fraction of a xenon sample is left behind inside the plastic scintillator after the sample has been evacuated from the detector, thus raising the effective background for subsequent sample measurements. This work examines the impact of this "memory effect" on the International Monitoring System detection capabilities in order to improve the new generation of radioxenon monitoring technology that is being developed on the Xenon International project. Since memory effect raises the backgrounds of radioxenon concentration measurements, it increases the minimum detectable concentrations of xenon radioisotopes, which in turn reduces the sensitivity of the affected radioxenon detection systems. In addition, current calculation methods for quantifying memory effect require a gas background of equal duration to every sample measurement; an improvement in the memory effect calculation could potentially eliminate this frequent background measurement. Eliminating the gas background would allow for longer measurements with roughly twice as many statistics, and this would be a significant improvement in radioxenon system performance. The extensive data set on memory effect generated by the International Monitoring System also allows for a study of the effectiveness of the current calculation methods used to correct for memory effect in backgrounds.

NONPROLIFERATION, SAFEGUARDS, AND HOMELAND SECURITY I: 5

LiF/ZnS Neutron Multiplicity Counter

Sean Stave, Mary Bliss, Richard Kouzes, Azaree Lintereur, Sean Robinson, Edward Siciliano

Pacific Northwest National Laboratory, Richland, WA

Alternatives to the use of ^{3}He for the detection of thermal neutrons are being investigated. One of the most challenging applications for ^{3}He alternatives is in neutron multiplicity counters. Neutron multiplicity counters are used to provide rapid assay of samples which contain an unknown amount of plutonium in a potentially unknown configuration. With appropriate detector design, the neutron single, double, and triple coincidence events can be used to extract information of three unknown parameters such as the ^{240}Pu-effective mass, the sample self-multiplication, and the (α,n) rate. A project at PNNL has investigated replacing ^{3}He-based tubes with LiF/ZnS neutron-scintillator sheets and wavelength shifting plastic for light pipes. A four-panel demonstrator module has been constructed, tested, and compared with detailed modeling results. The findings indicate that a full-scale system can be constructed with the same overall size as the most efficient ^{3}He-based system and with improved performance. Remaining design challenges include compact light sensors and electronics and robust neutron/gamma-ray discrimination based on pulse shape analysis at high rates. A review of the current effort and the most recent findings will be presented.

NONPROLIFERATION, SAFEGUARDS, AND HOMELAND SECURITY I: 6

Material Discrimination Using Scattering and Stopping of Cosmic Ray Muons and Electrons: Differentiating Heavier from Lighter Metals as well as Low-Atomic Weight Materials

Gary Blanpied, Sankaran Kumar, Dustin Dorroh, Craig Morgan, Isabelle Blanpied, Michael Sossong, Shawn Mckenney, Beth Nelson

*Decision Sciences International Corporation,12345 First American Way, Poway CA 92064**

Reported is a new method to apply cosmic-ray tomography in a manner that can detect and characterize not only dense assemblages of heavy nuclei (like Special Nuclear Materials, SNM) but also assemblages of medium- and light-atomic-mass materials (such as metal parts, conventional explosives, and organic materials). Characterization may enable discrimination between permitted contents in commerce and contraband (explosives, illegal drugs, and the like). Our Multi-Mode Passive Detection System (MMPDS), relies primarily on the muon component of cosmic rays to interrogate Volumes of Interest (VOI). Muons, highly energetic and massive, pass essentially un-scattered through materials of light atomic mass and are only weakly scattered by conventional metals used in industry. Substantial scattering and absorption only occur when muons encounter sufficient thicknesses of heavy elements characteristic of lead and SNM. Electrons are appreciably scattered by light elements and stopped by sufficient thicknesses of materials containing medium-atomic-mass elements (mostly metals). Data include simulations based upon GEANT and measurements in the HMT detector in Poway, CA, the TMT in Freeport, The Bahamas, and a package scanner in both Poway and Socorro NM. A key aspect of the present work is development of a useful parameter, designated the "Stopping Power" of a sample. A raw measurement of stopping is affected by sample placement: more un-stopped tracks can exit without passing through the detectors when samples are located near the edges of the detector array. The raw stopping number overestimates stopping since fewer scattered tracks are detected because of the geometry. The Stopping Power, normalizes for undetected scattered tracks adequately to enable characterization of the material of interest. The raw measurement of the number of stopped tracks is simply the number of incident tracks minus the number of scattered tracks. Since not all scattered tracks are detected equally efficiently in all parts of the detector (particularly near the edges of the arrays), dividing by the number of scattered tracks normalizes for variations in detection efficiency. The data show two regimes. The low-density regime, comprising organic materials up to aluminum, is characterized by very little scattering but a strong variation in stopping power. The medium-to-high density regime shows a larger variation in scattering than in stopping power.

* This work is supported by The US Department of Homeland Security Domestic Nuclear Detection Office, under competitively awarded contract HSHQDC-12-c-00062. This support does not constitute an express or implied endorsement on the part of the Government.

NONPROLIFERATION, SAFEGUARDS, AND HOMELAND SECURITY II: 8

A segmented detector for airborne γ-ray spectroscopy

Paola Garosi[1,2], Marica Baldoncini[3,4], Alessandro Iovene[1], Fabio Mantovani[3,4], Liliana Mou[2,5], Stefano Petrucci[1], Carlos Rossi Alvarez[5], Virginia Strati[3,5], Carlo Tintori[1], Gerti Xhixha[3,5]

[1]*CAEN S.p.A., via Vetraia 11, 55049, Viareggio - Italy*
[2]*University of Siena, via Banchi di Sotto 56, 53100, Siena - Italy*
[3]*University of Ferrara, Department of Physics and Earth Sciences, via Saragat 1, 44122, Ferrara - Italy*
[4]*Istituto Nazionale di Fisica Nucleare (INFN), Ferrara, Via Saragat 1, 44122, Ferrara - Italy*
[5]*Istituto Nazionale di Fisica Nucleare (INFN), Legnaro National Laboratory, viale dell Universita 2, 35020, Legnaro - Italy*

The airborne gamma-ray spectrometry (AGRS) allows to measure the radioactivity level of large areas of interest. Being the survey performed on flight, the risk for the operator is extremely reduced. In the past years many results have been achieved both in geological studies, and for purposes of emergency response.The first Italian prototype for airborne gamma-ray spectrometry has been recently developed. Following the IAEA guidelines for AGRS surveying, four NaI detectors of approximately four liters each has been used for the data acquisition. The system was mounted on an autogyro, and used to map the radioactivity of the Elba Island (Italy). The energy spectrum information was analyzed offline using the Full Spectrum Analysis (FSA) technique with the Non-Negative Least Square (NNLS) constraint to achieve the relative concentration of potassium, uranium, and thorium. Using interpolation techniques the maps of the relative abundance of radioactive nuclides were generated.The promising results achieved encouraged the development of a new segmented device for the airborne radiation monitoring. The great innovation is the new design of the NaI detectors layout, with a structure of sixteen detectors of one liter each.The new detector configuration generates asymmetries in the signal acquisition, that can be used to study the underlying distribution of radioisotopes. The possibility to recognize orphan sources with respect to the natural background has been confirmed by Monte Carlo simulations specifically developed for modeling the expected signals.The new structure makes the system easily portable by a single operator, and rapidly mountable on most common helicopters.Preliminary feasibility studies have been performed to test the mechanics and the hardware of the whole system, which is intended to work without any human attendance. The first flights are planned in 2014, with the aim of detecting artificial point sources having intensities on the order of 108 Bq and natural enriched fields already monitored.

Detector Electronics and Signal Processing

4:00 PM - 5:30 PM (Vandenburg)

DETECTOR ELECTRONICS AND SIGNAL PROCESSING: 1

A data-driven front-end ASIC for charge-interpolating trackers and spectrometry

Gianluigi De Geronimo

Brookhaven National Laboratory, Upton, NY 11973, USA

We present VMM2, an Application-Specific Integrated Circuit (ASIC) for charge-interpolating trackers and spectrometry. The ASIC has been designed for use with micro-pattern sensors such as MICROMEGAS and TGC in the ATLAS muon upgrade. It integrates 64 front-end and processing channels, each providing charge amplification, discrimination, neighbor logic, a variety of amplitude and timing measurement settings, analog-to-digital conversions, and either direct or multiplexed readout. The front-end amplifier is designed to operate with a wide range of input capacitances, and has adjustable polarity, gain and peaking time. The ASIC is designed to measure at 200 pF and 25 ns with resolutions on charge and timing better than 1 fC and 1 ns respectively for input charges up to 2 pC. Designed and fabricated in a commercial 130 nm technology, has a layout size of 13.5×8.4 mm^2 and it is packaged in a custom 400-pin Ball Grid Array (BGA). With a transistor count in excess of 80,000 per channel (> 5 million total) it is the most complex and advanced ASIC developed by our team.

DETECTOR ELECTRONICS AND SIGNAL PROCESSING: 2

Study of the impact of the pixel pitch of the Timepix chip integrated to the GAMPIX gamma camera in terms of spectrometric and imaging performances

Hermine Lemaire[1], Roger Abou Khalil[2], Khalil Amgarou[2], Jean-claude Angélique[3], Florent Bonnet[2], Daniel De Toro[2], Frédérick Carrel[1], Olivier Giarmana[2], Mehdi Gmar[1], Nabil Menaa[2], Yves Menesguen[1], Stéphane Normand[1], Audrey Patoz[2], Vincent Schoepff[1], Philippe Talent[2], Tebug Timi[2]

[1]*French Atomic Energy and Alternatives Energies Commission (CEA), Saclay, France*
[2]*CANBERRA France, France*
[3]*Laboratoire de Physique Corpusculaire (LPC), Caen, France*

Spatial localization and identification of radioactive sources is a main issue interesting nuclear industry as well as homeland security. Gamma imaging is a well-known and widely used technique which allows reaching this need. A new gamma camera, called GAMPIX, has been designed by the French Atomic Energy and Alternative Energies Commission (CEA). GAMPIX enables spatial localization of hot spots on a large energy range (from 10 keV to 1.5 MeV). Sensitivity at low energies, portability (2 kg) and connection aspects were improved in comparison with previous industrial systems. The detection system is based on the 1.4 cm side Timepix pixelated readout chip developed by the CERN and hybridized to a 1 mm thick CdTe substrate. Pixel size of the Timepix chip is usually 55 µm or 110 µm. Ongoing developments concern the addition of a spectrometric capability to the existing system. The challenge lies in the optimization of spectrometric performances while maintaining imaging performances. Pixel size of the Timepix chip is a key parameter for this. Our work intends to assess its impact by means of numerical simulations and innovative experimental calibration of the Timepix chip.Numerical simulations were performed using the MCNPX code and validated experimentally. A large range of pixel pitch (from 55 µm to non pixelated detectors) and energies were tested. Fluorescence impact depending on pixel pitch has been especially demonstrated. It has thus been shown that fluorescence peaks disappeared when the pixel pitch is more than four times the mean free path of fluorescence photons. Pixel pitch impact on imaging performances was also studied. The purpose was to preserve the angular resolution of the GAMPIX gamma camera, i.e. the ability to separate radioactive sources spatially close.Energy calibration of Timepix detectors is a crucial task for energy conversion and optimization of spectrometric performances. In fact, the small pixel size (55 µm or 110 µm) compared to the substrate thickness often induces charge depositions in several pixels, called clusters, and the shift between spectra due to different cluster sizes degrades the energy resolution. The energy calibration of our Timepix detectors has been carried out in the SOLEX compact tunable monochromatic X-ray source (CEA). This was the first time that such a facility was used for energy calibration of Timepix assemblies. SOLEX uses an X-ray tube as an excitation source and a crystal as a monochromator to produce the range of radiation enabled by Bragg's law. In this way, photon beams are produced from 0.6 keV to 28 keV with down to 0.1% energy resolution. After calibration, both energy conversion and energy resolution are found out more efficient for a 110 µm pixel pitch, which is consistent with our simulation results and previous literature results.Our developments show that the replacement of the 55 µm pixelated Timepix chip currently used in the GAMPIX gamma camera by a 110 µm pixel pitch would lead to a significant improvement in terms of spectrometric performances without degrading imaging abilities.

DETECTOR ELECTRONICS AND SIGNAL PROCESSING: 3

Ultra-Low Noise Front End Electronics for Germanium Based Antineutrino Detection

Paul Barton[1], Belkis Cabrera-palmer[2], David Reyna[2], Mark Amman[1], Paul Luke[1], Kai Vetter[1]

[1]*Lawrence Berkeley National Laboratory, Berkeley, CA, United States*
[2]*Sandia National Laboratory, Livermore, CA, United States*

The detection of antineutrinos from nuclear power reactors can yield information on key operating parameters. Existing (anti)neutrino detectors based on inverse beta decay rely on extremely large volumes. By contrast, the predicted but unobserved coherent elastic nucleus scattering (CNNS) process has a cross-section which scales with the number of neutrons squared. High purity germanium (HPGe) is thus an ideal candidate for a CNNS detector, promising a relatively compact and mobile system for reactor safeguards. Because the nuclear recoil energy transferred to electrons is on the order of 100 eV, we are developing kilogram-scale p-type point contact Ge detectors with ultra-low noise readout electronics. Lower noise HPGe detectors are fabricated by reducing point contact size and by minimizing leakage current across the detector surface. The front end is a low mass assembly, fabricated from potentially low background materials. A low input capacitance JFET is held at low temperature and is wire bonded in close proximity to the point contact. Thermal optimization of the JFET operating point minimizes series noise, while the low leakage detector and high value feedback resistor reduce parallel noise. Resistive feedback is accomplished with a cold amorphous Ge thin film resistor which reduces 1/f noise. Series noise contributions are also minimized by employing longer signal integration times appropriate for rare event detection. Results from initial measurements at low temperatures (10-80 K) will also be presented.

DETECTOR ELECTRONICS AND SIGNAL PROCESSING: 4

Electron spectroscopy of ^{68}Ni enabled through digital pulse-shape processing

S. Suchyta[1,2], S. N. Liddick[1,2], Y. Tsunoda[3], T. Otsuka[1,3,4,5], M. B. Bennett[1,4], A. Chemey[1], M. Honma[6], N. Larson[1,2], C. J. Prokop[1,2], S. J. Quinn[1,4], N. Shimizu[5], A. Simon[1], A. Spyrou[1,4], V. Tripathi[7], Y. Utsuno[8], J. M. Vonmoss[7]

[1]*National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, Michigan 48824, USA*
[2]*Department of Chemistry, Michigan State University, East Lansing, Michigan 48824, USA*
[3]*Department of Physics, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan*
[4]*Department of Physics, Michigan State University, East Lansing, Michigan 48824, USA*
[5]*Center for Nuclear Study, University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan*
[6]*Center for Mathematical Science, University of Aizu, Tsuruga, Ikki-machi, Aizu-Wakamatsu, Fukushima 965-8580, Japan*
[7]*Department of Physics, Florida State University, Tallahassee, Florida 32206, USA*
[8]*Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Ibaraki 319-1195, Japan*

A wealth of valuable information can be extracted from experimental signals through digital pulse-shape processing. Notably, pulse-shape analysis aids in the detection of unique decay modes. Thus, pulse-shape processing has been utilized in many fields of research, including but not limited to nuclear-decay spectroscopy, neutrinoless double β decay, and γ-ray tracking. In this study, pulse-shape analysis was applied to analyze signals observed in a 1-cm thick planar Ge double-sided strip detector (GeDSSD) when an arbitrary amount of energy from two independent radiations was deposited in the same voxel of the detector within a time that is short compared to the decay constant of the detector signal. At the National Superconducting Cyclotron Laboratory, the decay of the isomeric first excited state in ^{68}Ni by internal-pair production or internal-conversion-electron emission was investigated following the β decay of ^{68}Co. Although the conversion-electron or electron-positron-pair emission occurred in the same location of the GeDSSD as the ^{68}Co β decay and within just hundreds of nanoseconds of the β decay, by comparing the experimental decay signals to the expected detector response, new, precise information was extracted about the decay of the first excited state in ^{68}Ni. The experimental technique, as well as the results for the first direct observation of the decay of the isomeric first excited state in ^{68}Ni, will be presented.

DETECTOR ELECTRONICS AND SIGNAL PROCESSING: 5

Energy dispersive CdTe and CdZnTe detectors for spectral clinical CT and NDT applications

William C. Barber[1], Jan C. Wessel[2], Einar Nygard[2], Jan S. Iwanczyk[1]

[1]*DxRay Inc., Northridge, CA USA*
[2]*Interon AS, Asker, Norway*

We are developing room temperature compound semiconductor detectors for applications in energy-resolved high-flux single x-ray photon-counting spectral computed tomography (CT), including functional imaging with nanoparticle contrast agents for medical applications and non destructive testing (NDT) for security applications. Energy-resolved photon-counting can provide reduced patient dose through optimal energy weighting for a particular imaging task in CT, functional contrast enhancement through spectroscopic imaging of metal nanoparticles in CT, and compositional analysis through multiple basis function material decomposition in CT and NDT. These applications produce high input count rates from an x-ray generator delivered to the detector. Therefore, in order to achieve energy-resolved single photon counting in these applications, a high output count rate (OCR) for an energy-dispersive detector must be achieved at the required spatial resolution and across the required dynamic range for the application. The required performance in terms of the OCR, spatial resolution, and dynamic range must be obtained with sufficient field of view (FOV) for the application thus requiring the tiling of pixel arrays and scanning techniques. Room temperature cadmium telluride (CdTe) and cadmium zinc telluride (CdZnTe) compound semiconductors, operating as direct conversion x-ray sensors, can provide the required speed when connected to application specific integrated circuits (ASICs) operating at fast peaking times with multiple fixed thresholds per pixel provided the sensors are designed for rapid signal formation across the x-ray energy ranges of the application at the required energy and spatial resolutions, and at a sufficiently high detective quantum efficiency (DQE). We have developed high-flux energy-resolved photon-counting x-ray imaging array sensors using pixellated CdTe and CdZnTe semiconductors optimized for clinical CT and security NDT. We have also fabricated high-flux ASICs with a two dimensional (2D) array of inputs for readout from the sensors. The sensors are guard ring free and have a 2D array of pixels and can be tiled in 2D while preserving pixel pitch. The 2D ASICs have four energy bins with a linear energy response across sufficient dynamic range for CT and NDT. The ASICs can also be tiled in 2D and are designed to fit within the active area of the sensors. We have measured several important performance parameters including; the output count rate (OCR) in excess of 20 million counts per second per square mm, an energy resolution of 7 keV full width at half maximum (FWHM) across the entire dynamic range, and a noise floor about 20keV. This is achieved

by directly interconnecting the ASIC inputs to the pixels of the CdZnTe sensors incurring very little input capacitance to the ASICs. We present measurements of the performance of the CdTe and CdZnTe sensors including the OCR, FWHM energy resolution, noise floor, as well as the temporal stability and uniformity under the rapidly varying high flux expected in CT and NDT applications.

DETECTOR ELECTRONICS AND SIGNAL PROCESSING: 6

Microwave multiplexed readout for large arrays of TES microcalorimeters

Douglas A. Bennett[1], John A. B. Mates[1], Justus Brevik[1], Jiansong Gao[1], James P. Hays-wehle[1], Joseph W. Fowler[1], Johnathon Gard[1], Gene C. Hilton[1], Carl D. Reintsema[1], Dan R. Schmidt[1], Leila R. Vale[1], Joel N. Ullom[1], Ryan Winkler[2], Andrew S. Hoover[2]

[1]*National Institute of Standards and Technology, Boulder, Colorado*
[2]*Los Alamos National Laboratory, Los Alamos, New Mexico*

Microcalorimeters based on transition-edge sensors (TESs) are being successfully deployed in numerous spectroscopic instruments that operate over a large range of incident photon energies. At 256 multiplexed pixels, the LANL-NIST high-resolution gamma spectrometer is the largest operating array of TES microcalorimeters. This instrument is producing high quality spectra (53 eV mean FWHM energy resolution at 100 keV) that are being utilized to evaluate the benefits of microcalorimeter-based spectrometers for non-destructive determination of plutonium isotopics. Larger arrays of microcalorimeters, thousands to tens of thousands of pixels, would dramatically increase the efficiency and count rate of this spectrometer. However, the size of existing arrays is limited by existing readout technologies, primarily time-division, code-division, and frequency-division multiplexing. A readout technology is needed that is able to scale up to much larger arrays, without degrading the performance of the detectors. The most promising candidate for arrays of 10^5 or 10^6 microcalorimeters is the microwave superconducting quantum interference device (SQUID) multiplexer. Using a microwave based readout allows more pixels to be multiplexed by increasing the readout bandwidth from a few MHz to several GHz. A microwave SQUID multiplexer consists of arrays of superconducting microwave resonators, each coupled to an rf SQUID. The current from a TES couples flux into this rf SQUID, which changes the inductance and therefore the microwave properties of the resonator. Microwave resonators with different resonance frequencies are coupled to a common feed line, allowing many resonators to be measured using a single pair of coaxial cables. In order to realize the full potential of this technology, we are developing new microwave SQUID multiplexer designs that promise to be fully detector noise limited. We are also developing room temperature microwave electronics based on a scalable FPGA-based architecture modeled after software defined radio (SDR) systems used to read out microwave kinetic inductance detectors (MKIDs). These electronics are responsible for creating the microwave tones that probe each resonator and then channelizing the output of the microwave SQUIDs. There are a number of additional challenges in adapting the MKID architecture for microcalorimeters, such as implementing flux ramp demodulation to linearize the response of the rf SQUIDs, and achieving the signal-to-noise ratio necessary to preserve the high spectral resolution possible with TES microcalorimeters. We will summarize the performance of the room temperature microwave electronics and present results using the new microwave SQUID multiplexer to read out several high-resolution TES microcalorimeters.

DETECTOR ELECTRONICS AND SIGNAL PROCESSING: 7

Design and fabrication of planar 6 cm x 6 cm microchannel plate photodetector for imaging and fast timing applications

Junqi Xie, Karen Byrum, Marcel Demarteau, John Noonan, Sagar Setru, Mathew Virgo, Robert Wagner, Dean Walters, Xing Wang, Lei Xia, Huyue Zhao

LAPPD Collaboration, Argonne National Laboratory, Argonne, IL

Microchannel plate (MCP)-based photodetectors have shown significant potential for applications in fields such as imaging, time-of-flight system, high energy collider physics and astrophysics. With thin planar geometry and glass-body assembly, the MCP photodetectors are considered as next generation photodetectors to replace conventional photomultiplier tubes. This talk will discuss a new photodetector production facility built at Argonne National Laboratory. Small form-factor, MCP-based photodetectors completely made out of glass were designed and currently under production. Both metal and alkali antimonides photocathodes were proposed to be incorporated in the photodetector. The photodetector design, production sequence and first performance results with metal photocathode will be presented. Possible applications will also be explored.

Abstracts

Thursday

Nonproliferation, Safeguards, and Homeland Security II

8:00 AM - 9:30 AM (Alumni Center)

NONPROLIFERATION, SAFEGUARDS, AND HOMELAND SECURITY II: 1

Cosmic Ray Muon Imaging

Christopher L. Morris

Los Alamos National Laboratory, Los Alamos, NM, 87545 USA

NONPROLIFERATION, SAFEGUARDS, AND HOMELAND SECURITY II: 2

A recently deployed intelligent PVT Portal system

David Ramsden[1], Grant Crossingham[1], Hayden Watkins[1], Matthew Dallimore[2]

[1]*Symetrica Security, Southampton UK*
[2]*Symetrica, Inc., Maynard, MA USA*

Through the combination of a powerful spectral-processing technique and a careful optical design approach, a large-volume PVT gamma-ray spectrometer has been successfully developed. This paper will present the results of a comparative evaluation of such a plastic spectrometer alongside a 2 litre NaI spectrometer, typical of portal applications, in a laboratory environment. A series of tests were conducted by the Joint European Research Centre of a PVT spectrometer and its associated NORM discrimination and threat ID software. Results provided the key information required to optimize our RPM designs for use in ports where wider portal separations and faster scanning speeds are mandated. The first batch of such PVT detectors has recently been deployed in a port environment and results from extended testing there are presented.

NONPROLIFERATION, SAFEGUARDS, AND HOMELAND SECURITY II: 3

Mobile HPGe Detector Array for Remote Gamma Ray Spectroscopy

Benoit Pirard, Milan Zuniv, Antoine Broche, Jean Clauss, Jeremy Flamanc, Marie Odile Lampert, Vlad Marian, Pascal Quirin

Canberra France

This paper presents the configuration and performance of a turnkey and versatile HPGe solution developed by CANBERRA for mobile radionuclide identification and mapping. The high-resolution spectrometer design relies on advanced technologies such as the encapsulation in ultra-high vacuum (UHV), low vibration electrical cooling, digital signal processing with add-back mode, and real-time data analysis and mapping display. Key performances have been assessed and are presented in the case of an airborne application.

NONPROLIFERATION, SAFEGUARDS, AND HOMELAND SECURITY II: 4

Integrated Detection and Localization Algorithms for Aerial Radiation Search Applications

Carolyn Seifert, Kevin Anderson, Bruce Bernacki, Carrie Carlson, Rebecca Detwiler, Kevin Dorow, David Jordan, Warnick Kernan, Jonathan Kulisek, Jon Mccall, Jr. Ronald Mcconn, Erin Miller, Mitchell Myjak, Ryan Ostler, David Pfund, Amanda Prinke, Sean Robinson, John Schweppe, Sean Stave, Timothy Stavenger, Trevor Stewart, Carolyn Wolkenhauer, Jennifer Webster, Richard Wittman

Pacific Northwest National Laboratory, Richland, WA

As a part of the Aerial Radiological Enhanced Sensors (ARES) Advanced Technology Demonstration program, PNNL is developing integrated algorithms that take advantage of orthogonal data sources to improve operational detection and localization of radioactive sources from aerial platforms. These algorithms use gamma-ray spectroscopy data in concert with position and video data—as well as information about the environment—to feed spectral anomaly detection and maximum likelihood localization methods. We present an overview of the methodologies being developed and an initial assessment of detection and localization performance against simulated and measured data of scintillator detector arrays on a helicopter platform. This work has been supported by the US Department of Homeland Security, Domestic Nuclear Detection Office, under competitively awarded contract/IAA HSHQDC-12-X-00376. This support does not constitute an express or implied endorsement on the part of the Government.

NONPROLIFERATION, SAFEGUARDS, AND HOMELAND SECURITY II: 5

Field test results from the Multi-Modal Gamma Imager

Morgan Burks, Jonathan G. Dreyer

Lawrence Livermore National Laboratory

In collaboration with our industrial partner, we have built and tested the Multi-Modal Gamma Imager (MMGI). This is a small, portable, high-resolution gamma-ray imager based on a large planar germanium crystal. MMGI is capable of coded aperture, pinhole, and Compton imaging. Thus it is sensitive to a broad range of gamma-ray energies and source types. MMGI is novel because it is the first portable germanium-based Compton imager. Because the germanium crystals are mechanically-cooled, this entire system is easy to transport (fitting into a carry-on suitcase) and easy to deploy. As a result this instrument has been tested in the field against a broad range of potential applications including: nuclear-weapon mockups for arms control, hold-up and contaminated equipment at uranium processing facilities for safeguards, building-to-building imaging for search applications, and storage containers for waste management. In many of these cases specialized imaging algorithms have been developed, or are being developed, to handle challenges unique to each scenario. For example, automated alarming algorithms have been tested which aid in search or for unattended monitoring applications. In addition, work is being done on the more challenging problem of 2D and 3D shape recognition for warhead identification. Results from field tests and algorithm development will be presented. In addition, the potential strengths and weaknesses of gamma-ray imaging for each of these applications will be discussed.

NONPROLIFERATION, SAFEGUARDS, AND HOMELAND SECURITY II: 6

Radiographic Imaging Components for Dose Reduction in Cargoes

Areg Danagoulian, William Bertozzi, Wilbur A. Franklin, Stephen E. Korbly, Robert J. Ledoux, David Swenson

Passport Systems, Inc.

Cargo security in the US and internationally relies heavily on X-ray radiography to non-intrusively verify the contents of cargo containers and airport baggage. The use of ~MeVbremsstrahlung photon beams is particularly common in cargo security, as it allows for apenetration that's large enough applying various radiographic and active interrogationtechniques. Given the variable loading of many containers a significantly greater dose isdelivered to the cargo than is necessary. Reducing the dose requires the development of newtechnologies which will allow for a reduction of dose to the container without sacrificingpenetration and analyzing power of the active interrogation techniques.Passport Systems is currently working on an Exploratory Research Program (ERP) fundedby Domestic Nuclear Detection Office (DNDO) with the aim of developing radiographiccomponents which will allow for dose reduction in cargo scanning applications. To this end,two components are being developed: feedback functionality for dynamically adjusting thephoton flux, and a 2D imager which can operate in photon counting mode. The feedback willreduce the dose to cargo and the imager itself, preventing radiation damage while enablingphoton counting. The second component of the program is the development of a 2 dimensional(2D) imager which would be capable of counting individual transmitted X-ray photons andprovide fast input to the feedback functionality. The 2D design of the imager allows a moreefficient use of the bremsstrahlung output and reduces the peak counting rates.Photon counting is a key feature of the imager under development. Counting wouldproduce spectral information on the transmitted flux. As pair production cross section dependson Z^2, the higher Z nuclei attenuate 5-9MeV photons significantly more than low Z nuclei.This results in significant differences in transmitted photon energy distributions. Hencespectral information can be used to distinguish between various

cargo types.The final system will use a 9MeV bremsstrahlung scanning, pencil-like beam of a variableintensity. The ERP will culminate in a Proof of Concept demonstration, which will usePassport Systems's scanning infrastructure. This includes a tunnel, a motion system, a CWelectron accelerator, a beam transport and a bremsstrahlung source.This work has been supported by the US Department of Homeland Security, DomesticNuclear Detection Office, under competitively awarded contract/IAA HSHQDC- 13-C-B0035.This support does not constitute an express or implied endorsement on the part of theGovernment.

NONPROLIFERATION, SAFEGUARDS, AND HOMELAND SECURITY II: 7

Impact of gamma-ray spectral resolution and efficiency on detection of nuclear threats

Simon Labov

Lawrence Livermore National Laboratory

The detection of nuclear threats requires both the detection of radiation from the threats and differentiating the threats from the many common benign sources of radioactivity including the highly fluctuating radiation background. Gamma-ray spectroscopy is well suited to this task, but the capabilities of any measurement will depend on its quality. We present here results analyzing the impact of detector spectral resolution, dimensions, and material on its ability to detect and differentiate between nuclear threats and benign radionuclide signatures. We consider a range of different detection scenarios including those related to nuclear search and the analysis of radioactive samples. Our analysis evaluates the statistical difference between threats and non-threats and thus provides an upper bound to the best possible threat detection and classification performance regardless of the radionuclide analysis technique or algorithm used. The different measurement scenarios use a range of detectors with different spectral resolutions, detector thicknesses and materials, source signal strength, background signal strengths and hence signal-to-background ratios. Using a population of possible nuclear threat configurations, we examine the impact of the detection performance for various threat types of interest under a range of different shielding conditions.

Unconventional Radiation Detectors

8:00 AM - 9:30 AM (Vandenburg)

UNCONVENTIONAL RADIATION DETECTORS - SUPERCONDUCTING AND CRYOGENIC MICRO-CALORIMETERS: 1

Transition Edge Sensor Electron Capture Spectroscopy: Towards A Neutrino Mass Measurement

Gerd J. Kunde[1], J. W. Engle[1], F. M. Nortier[1], E. R. Birnbaum[1], W. A. Taylor[1], V. Mocko[1], M. P. Croce[1], A. S. Hoover[1], M. W. Rabin[2], J. Hayes-wehle[2], R. D. Horansky[2], V. Kotsubo[2], D. R. Schmimdt[2], J. N. Ullom[2]

[1]*Los Alamos National Laboratory, P.O.Box 1663, Los Alamos, NM 87506*
[2]*National Institute of Standards and Technology, 325 Broadway, Boulder, CO 80305*

Calorimetric spectroscopy via electron capture (ECS) of isotopes with a Q- value of a few keV, e.g. ^{163}Ho, is a candidate for a direct measurement of the neutrino mass. We will present Transition Edge Sensor based Q-spectra measurements for the ECS isotopes of ^{163}Ho Q(163Ho< 3keV) and ^{55}Fe(Q=231 keV). While we can access the performance of the system with the commercially available ^{55}Fe, it requires a modified absorber. We furthermore discuss methods of accelerator and reactor production and the isolation of ^{163}Ho, which is not commercially available, by high performance liquid chromatography. The ECS isotopes are embedded within microcalorimeter absorbers, which are attached to TES microcalorimeters developed specifically for this application, with variability based on encapsulation method and isotopic purity. Techniques and results on spectral performance of the transition edge sensors as well as measurements for ^{55}Fe and ^{163}Ho will be presented.

UNCONVENTIONAL RADIATION DETECTORS - SUPERCONDUCTING AND CRYOGENIC MICRO-CALORIMETERS: 2

First results with a microcavity plasma panel detector

Claudio Ferretti[1], Daniel S. Levin[1], Peter S. Friedmann[2]

[1]*PPS collaboration, University of Michigan, 450 Church St, Ann Arbor MI*
[2]*Integrated Sensors, LLC, Ottawa Hills, Ohio, 43606, USA*

We report on the first experimental results of a micropattern type gaseous radiation detector based on a closed-cell, microcavity plasma panel sensor (PPS) design with isolated pixels. Initial measurements with 2 cubic millimeter cavities, in parallel with a simulation effort, demonstrate good efficiency and few nanosecond time dispersion for beta particle radiation. The microcavity-PPS cell design and materials provide a physically robust, hermetically-sealed device having a voltage operating window about 100 volts and good isolation between cells.

UNCONVENTIONAL RADIATION DETECTORS - SUPERCONDUCTING AND CRYOGENIC MICRO-CALORIMETERS: 3

LET dependence of bubbles evaporation pulses in superheated emulsion detectors

Angela Di Fulvio, Jean Huang, Lawrence Staib

[1]*Yale University, Dept Diagnostic Radiology, TAC N140, New Haven, CT 06520-8043*
[2]*Scuola di Ingegneria, Universitá of Pisa, Pisa, Italy 56100*

Superheated emulsion detectors are suspensions of metastable liquid droplets in a compliant inert medium. Upon irradiation with ionizing radiation, droplets evaporate generating visible bubbles. Bubble expansion associated with the boiling of the droplets is accompanied by pressure pulses, in both the acoustic and ultrasonic frequency range.At room temperature emulsions based on superheated chloropentafluoroethane (R115) are sensitive to both gamma rays and neutrons. R115-based detectors were irradiated with gamma rays (137Cs and 60Co) and neutrons (241AmBe) check sources. The same type of emulsion was used to detect both photons and neutrons. It was thus possible to analyze the ultrasound emissions of the same edtectors for radiations of different LET (electrons for photon interactions and recoil ions for neutron interactions). The power spectral density of the acoustic signal produced by neutron-induced evaporations show a characteristic frequency pattern in the 1-6 MHz range, which is not observed when bubbles evaporate upon gamma rays irradiation.Acoustic pulses contain valuable information about the nucleation process. The spectral analysis of the pressure pulses may be used to analyze multiple modes of bubble oscillations during nucleation. The detection of ultrasonic pulses can be exploited as a readout method alternative to the previous procedure, based on pulse-shape analysis of lower frequency pulses (~5 kHz). Bubble counting based on this approach would allow both a low dead time and noise free measurement: allowing operation at higher count rates, also suitable for coincidence/multiplicity counting. Superheated emulsions coupled with high-frequency readout electronics could be thus used in both noisy harsh environments (i.e. radiation portal monitors with active interrogation setup), as well as in high neutron fluence facilities (linear accelerators where pulsed radiation is typically produced and low response time is needed).

UNCONVENTIONAL RADIATION DETECTORS - SUPERCONDUCTING AND CRYOGENIC MICRO-CALORIMETERS: 4

Response measurement of single crystal CVD diamond radiation detector for intense X-rays aiming at burn-history measurement on an inertial confinement fusion with fast ignition.

Takehiro Shimaoka[1], Junichi H. Kaneko[1], Yasunobu Arikawa[2], Mitsutaka Isobe[3], Yuki Sato[4], Masakatsu Tsubota[1], Takahiro Nagai[2], Sadaoki Kojima[2], Yuki Abe[2], Toshiki Sakata[2], Shinsuke Fujioka[2], Mitsuo Nakai[2], Hiroyuki Shirakami[2], Hiroshi Azechi[2], Akiyoshi Chayahara[5], Hitoshi Umezawa[5], Shinichi Shikata[5]

[1]*Hokkaido University*
[2]*Osaka University*
[3]*National Institute for Fusion Science*
[4]*RIKEN*
[5]*National Institute of Advanced Science and Technology*

Response measurement of single crystal CVD diamond radiation detectors fabricated by Hokkaido University for extremely intense X-rays caused by additional irradiation by the LFEX laser was conducted aiming burn-history measurement on an inertial confinement fusion with fast ignition. Single diamond crystals were homoepitaxialy grown by a chemical vapor deposition (CVD) method on high-pressure/high-temperature (HP/HT) grown type IIa diamond single crystal substrates. A self-standing single crystal CVD diamond in size of 5×5×0.1 mm was obtained by a lift-off method, and then an oxygen-termination process using dichromic acid was carried out. An aluminum Schottky contact and a Ti/Au ohmic contact in size of φ3 mm were fabricated by evaporation method on the both sides of the diamond crystal. Induced charge distribution measurement using 5.5 MeV alpha particles from an 241Am source was carried out in advance. Charge collection efficiencies of diamond radiation detectors were 100±0.7% for hole and 97%±1.1% for electron. Typical output pulse from a current preamplifier connected with a diamond radiation detector for an alpha particle of 5.5 MeV were measured by a digital oscilloscope with analog bandwidth of 5 GHz. Average pulse width in FWHM of 10 signals was 733±14ps. An experiment at FIREX, diamond radiation detector was settled at 30 cm from a target in a vacuum target chamber. A lead shield in length of 3 cm was attached in front of the detector. All instruments were settled in an electromagnetic shielding box. Furthermore, the detector and a measurement port were completely insulated from the target chamber.Diamond radiation detector succeeded to obtained high intensity bremsstrahlung X-rays with pulse width of c.a. 1 ns, and there was no slow component. DD neutron yield of present FIREX with fast ignition by the LFEX laser is only 10^6 n/shot; detection efficiency of the present detector was not sufficient at all. With increase of DD neutron yield, we intend to improve performance of diamond radiation detectors and the measurement system, i.e, increasing of saturation drift velocity in a diamond crystal, reduction of charge trapping in a diamond crystal, optimization of thickness and capacitance of a detector and improvement in RF shielding and suppression in noise. Moreover development of an unfolding method is indispensable to achieved required time resolution that is faster than 100 ps.

UNCONVENTIONAL RADIATION DETECTORS - SUPERCONDUCTING AND CRYOGENIC MICRO-CALORIMETERS: 5

Gamma-ray Spectrometer based on Superconducting Transition Edge Sensor for Nuclear Materials Analysis

Shuichi Hatakeyama[1], Masashi Ohno[1], Hiroyuki Takahashi[1], Thushara Damayanthi[2], Chiko Otani[2], Koji Takasaki[3], Takashi Yasumune[3], Takashi Ohnishi[3], Shinichi Koyama[3]

[1]The University of Tokyo, Japan
[2]RIKEN, Japan
[3]Japan Atomic Energy Agency, Japan

Since an investigation of a massive nuclear material and an inspection of a contaminant are required in civil nuclear power plant accident, it is necessary to identify the plutonium and minor actinides in a nondestructive inspection. So far X-ray fluorescence and Gamma rays radiated from nuclear material have been measured by using high-purity germanium (HPGe) detectors. However, it is difficult to distinguish the energy peaks of nuclear material due to the limited energy resolution. Superconducting transition edge sensor (TES) microcalorimeters have been developed for high-resolution X-ray spectroscopy. TESs work as a sensitive calorimeter by measuring the temperature rise of incident radiation, and provide at least 10 times better energy resolution than that of HPGe detectors. We are developing a high-resolution hard X-ray and gamma-ray TES spectrometer for nuclear materials analysis. In order to detect high energy photons near 100 keV, the superconducting tin (Sn) absorber is coupled to an Ir/Au TES. To improve the count rate performance and the energy resolution of the detector, we have designed a new detector where the absorber is coupled to the TES by using a gold bump post. The reported energy resolution is 156 eV FWHM at 59.5 keV (Am-241) and 166 eV FWHM at 122 keV (Co-57) gamma-rays. We performed measurement of a plutonium sample and clearly separated the Pu-239 (56.828 keV) and the Am-241 (59.5 keV) peaks by the TES microcalorimeter which cannot be resolved by the HPGe detector. In addition, the energy peaks from the fission product sample were clearly resolved by the TES microcalorimeter.

UNCONVENTIONAL RADIATION DETECTORS - SUPERCONDUCTING AND CRYOGENIC MICRO-CALORIMETERS: 6

Novel use of optical crystals for radiation detection

Adam Hecht, Erin Husher, Ladan Arissian, Jean-claude Diels

University of New Mexico, Albuquerque, NM

While some ionic crystals have been used in radiation detection, for example as a scintillator or for optically stimulated luminescence, we take a new approach to using these materials that opens the door to other materials. Transparent crystals can be monitored for radiation damage to serve as a detector for both immediate dose and integrated dose for signatures of radiation exposure history, and we examine novel approaches to both gamma-ray and neutron dosimetry. Gamma-ray interactions primarily produce electron displacements, which are preserved as color centers in ionic crystals. Optically stimulated luminescence has been used to probe trapped high energy states by pumping the material with the appropriate wavelength. Our approach to dosimetry for this primarily gamma ray effect is to examine the color centers through the changed absorption and transmission spectra. These spectra can be quantified using prior technology, and have been examined here starting with CaF2 crystals. In contrast, neutron interactions in the crystals produce lattice displacements and damage that affect the index of refraction much more than expected from a comparable gamma ray dose. Due to prior limits in phase sensitivity enormous changes in the crystal structure were required to observe a different index of refraction. An example is the index difference between amorphous and crystal quartz. We are using novel techniques based on nested frequency combs to measure the change of index due to irradiation. Initial work on CaF2 irradiated by a PuBe neutron source at the University of New Mexico shows a readable index change. That work will be presented.

UNCONVENTIONAL RADIATION DETECTORS - SUPERCONDUCTING AND CRYOGENIC MICRO-CALORIMETERS: 7

Development of microcalorimeters for Q and electron capture spectroscopy

Mark P. Croce[1], E. M. Bond[1], A. S. Hoover[1], G. J. Kunde[1], V. Mocko[1], M. W. Rabin[1], N. R. Weisse-bernstein[1], D. A. Bennett[2], J. Hayes-wehle[2], V. Kotsubo[2], D. R. Schmidt[2], J. N. Ullom[2], K. E. Koehler[3]

[1]*Los Alamos National Laboratory, Los Alamos, NM, USA*
[2]*National Institute of Standards and Technology, Boulder, CO, USA*
[3]*Western Michigan University, Kalamazoo, MI, USA*

We are developing superconducting transition-edge sensor (TES) microcalorimeters that are optimized for total nuclear reaction energy (Q) spectroscopy (QS) and electron-capture spectroscopy (ECS) applications. With radioactive material encapsulated in the detector, new measurements are possible, and new detector design challenges arise. Detectors for QS measurements of trace actinide samples must measure energies up to 6 MeV, while ECS measurements are typically done in the 0-20 keV energy range. Absorbers with integrated radioactive material are being developed for both applications. Previous TESs relied on a fragile silicon nitride membrane to provide thermal isolation of the sensor. We have developed a TES that uses a much more robust silicon spring instead of a membrane. This design allows for more options in absorber type and attachment. For example, we have demonstrated a configuration with a removable absorber linked to the TES by wire bonds, which allows for re-use of the TES with multiple QS samples. The silicon spring TES is also well suited to ECS measurements from 0-20 keV, where a lower heat capacity is required. We will present recent work on the electrothermal characterization, detector assembly methods, and measurements with this new TES design.

Posters IV – Medical & Environmental Applications

9:30 AM - 10:30 AM (Ballroom)

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 1

Radiation dose evaluation of pediatric voiding cystourethrography–phantom study

Ling-ling Hsieh[1], Chun-wen Chen[2], Cheng-hsun Lin[1], Shann-horng Yeh[3], Kai-yuan Cheng[1], Guo-long Lin[1]

[1]*Department of Medical Imaging and Radiological Sciences, Central Taiwan University of Science and Technology, TaiChung City, Taiwan, R.O.C.*
[2]*Department of Radiology, TaiChung Armed Forces General Hospital, TaiChung City, Taiwan, R.O.C.*
[3]*Department of Medical Imaging and Radiological Sciences, Tzu Chi College of Technology, Hualien, Taiwan, R.O.C.*

Fluoroscopy is a common pediatric radiation examination. Voiding cystourethrography is generally the most used type and has been applied to high-fever-induced urethra infection, hydronephrosis before birth, and vesicoureteric reflux examination. Philips-Super 80 CP with routine X-

ray and fluoroscopy is a clinical diagnostic tool for voiding cystourethrography applied to this study. Doses of 11 organ points were measured in a 10-year-old anthropomorphic phantom (ATOM-706 Dosimetry Phantom, CIRS, Virginia, U.S.A.) with TLD-100 and MOSFET RD-1002 under operating voltages of 60, 70, and 80 kV, with fluoro-times of 0.5, 0.7, 1, 1.3, 1.5, 2, and 3 minutes. The IQFInv score and dynamic range images were assessed with CDRAD and the image phantom of DIGI-13. Results show that the absorbed dose is higher in male gonads than in female gonads. As the fluoro-time increased, the difference between the male and female gonads increased. As for the different parameters of kV, the relatively best image quality was generated under 70 kV. For the overall results, a slightly decrease in the absorbed dose for 80 kV was observed. This study obtained the relationship between VCUG examination time and the absorbed doses for each organ, which could clinically offer a radiation dose reference for doctors and patients.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 2

Preliminary Tests of a Kerma-Area Product (KAP) Meter to be used as a Monitor Chamber in a Conventional Diagnostic X ray system.

Eduardo Correa[1,2], Vitor Vivolo[1], Maria Da Penha Potiens[1], Nathalia Costa[1], Cristina Kikuti[2], Camila Murata[2], Regina Medeiros[2]

[1]*Instituto de Pesquisas Energeticas e Nucleares*
[2]*Universidade Federal de Sao Paulo*

In the calibration laboratories of radiation meters it is common to find a monitor chamber in the calibration setup. This instrument is used to monitor the radiation beam in real time and it is important in standardization dosimetry laboratories, which must always work with reduced uncertainties.The Calibration Laboratory (LCI) of the Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN-SP), has a PTW monitor chamber (reference chamber) installed on its industrial X ray calibration system.The radiation physics and hygiene coordination of the federal university of São Paulo (CFHR-UNIFESP), has a laboratory (LEMADIM) with a clinical X ray system to perform research measurements and to teach image techniques. This study presents the results of the preliminary tests performed using a Kerma –area product (KAP) meter in order to verify its usefulness as a monitor chamber in the presented X ray system. The tests done were tube current linearity, measurement fluctuation with the variation of the distance and field size, surface measurement uniformity and repeatability. The results showed that the KAP meter has a good behavior (a maximum variation of 0.4 % in the repeatability test), its surface has a homogeneous response (a maximum variation of 1.0 % between the different irradiated regions), the response is linear with the tube current and the kerma-area product variation was smaller than 3.43 %. When placed in front of the X-ray beam the KAP meter attenuated the beam from 10.97 % to 17.74 %, depending on the quality.However the KAP meter energy dependence reached values of up to 25 %, which is greater than the 8 % required by IEC 60580. Some previous studies showed that a great variation of the calibration factor is common in this kind of instrument. So, the calibration factors must be well known and used properly, according to the radiation quality used.In general the results show a good performance of the KAP meter confirming that is possible to use this instrument as monitor chamber since the correction factor for energy dependence and attenuation factor for beam quality are considered.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 3

Monte Carlo simulations and benchmark measurements on the response of TE(TE) and Mg(Ar) ionization chambers in photon and electron beams

Yi-chun Lin[1], Yuan-hao Liu[2], Wei-lin Chen[3], Yen-fu Chen[4], Shu-wei Wu[5], Sander Nievaart[6], Shiang-huei Jiang[7], Tseng-te Huang[1]

[1]*Healthy Physics Division, Institute of Nuclear Energy Research, Taiwan*
[2]*Nuclear Science and Technology Development Center, National Tsing Hua University, Taiwan*
[3]*Institute of Nuclear Engineering and Science, National Tsing Hua University, Taiwan*
[4]*Nuclear Engineering Division, Institute of Nuclear Energy Research, Taiwan*
[5]*Department of Biomedical Engineering and Environmental Sciences, National Tsing Hua University, Taiwan*
[6]*Institute for Energy, Joint Research Centre, European Commission, The Netherlands*
[7]*Department of Engineering and System Science, National Tsing Hua University, Taiwan*

The paired ionization chambers technique is commonly employed to determine neutron and photon doses in radiology or radiotherapy neutron beams, where neutron dose shows very strong dependence on the accuracy of accompanying high energy photon dose. These photons and the following electrons can be generated from reactor core, beam filter and moderator, and materials such as phantom or human tissue along the

beam pathway. During the dose derivation, it takes an important role to evaluate the photon and electron response functions of two commercially available ionization chambers, denoted as TE(TE) and Mg(Ar), used in our reactor based epithermal neutron beam. Due to the different particle behaviors and for the sake of accurate dose measurement, dose responses of chambers to incident photons and electrons with energy from 20 keV to 20 MeV were calculated and current responses were measured in the benchmark photon and electron beams. The Monte Carlo code, MCNP5, was used to calculate energy deposition in chamber cavity by using simple spherical and detailed IC models, and was compared with other Monte Carlo codes, EGSnrc, FLUKA and GEANT4 for photon beams. For electrons, the cavity energy depositions were only calculated with MCNP5, EGSnrc and FLUKA codes. The influence of ESTEP parameter in the three electron transport modes of MCNP5 was studied for the purpose of photon optimal calculation. Validations of chamber current were performed in 80, 100, 120, 150 kVp X-ray, ^{60}Co field, 6 MV, and 10 MV LINAC photon beams as well as 6 MeV and 18 MeV LINAC electron beams.In the Mg(Ar) chamber model, MCNP5 showed lower response than other codes for photon energy below 0.1 MeV and presented similar response above 0.2 MeV. For TE(TE) chamber, all codes were almost identical over the whole photon energy range. Regarding the application of photon and electron dosimetry, MCNP5 with ESTEP setting between 100 and 1000 in ITS mode is recognized as the more suitable calculation setting with respect to calculation efficiency and trustiness. Electron energies below 1 MeV did not cause dose contribution to the Mg(Ar) chamber with 3 mm thick wall and to the TE(TE) chamber with 5 mm thick wall, respectively. With the increase of electron energy, the response difference between MCNP5 and other codes became larger. It was because that the electron energy deposition paths of the two codes showed straggle on higher energy beam. This phenomenon depended on the different electron transport algorithm in the two codes. That resulted in the responses by MCNP5 code compared to measurements were lower in below 120 kVp X-ray beams for the Mg(Ar) chamber. This work shows us a better insight into the performance of different Monte Carlo codes in photon-electron transport calculation and it reveals the significant energy dependent response functions of the chambers to incident photons and electrons. However, the MCNP5 code is applicable for paired ionization chamber response within an accuracy of 5%, which is sufficient for dominant 2.2 MeV induced photons in an epithermal neutron beam.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 4

A COMPACT HIGH RESOLUTION SPECTROSCOPY BREAKTHROUGH FOR HARSH ENVIRONEMENTAL CONDITIONS

Jean Clauss, Benoit Pirard, Nabil Menaa, Pascal Quirin, Jeremy Flamanc, Vlad Marian, Marie Odile Lampert

Canberra France

A novel turnkey HPGe-based system has been developed to address outdoor gamma spectroscopy measurement. Able to withstand harsh environmental conditions with industrial reliability and fast deployment, this solution targets any application in which measurements under various weather conditions, contaminated areas, underground or submarine location are required. The detector is encapsulated in a high pressure housing, coupled to a compact electric cryocooler and connected to a state of the art DSP analyser.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 5

Optimal energy window selection of a CZT-based small animal SPECT for quantitative accuracy

Su-jin Park[1], A Ram Yu[1,3], Yun Young Choi[2], Kyeong Min Kim[3], Hee-joung Kim[1]

[1]*Department of Radiological Science, College of Health Science, Yonsei University, Korea*
[2]*Department of Nuclear Medicine, College of Medicine, Hanyang University Hospital, Korea*
[3]*Molecular Imaging Research Center, Korea Institute of Radiological and Medical Science, Korea*

CZT-based small animal single-photon emission computed tomography (SPECT) has desirable characteristics such as superior energy resolution, but data acquisition for SPECT imaging is usually performed with a fixed energy window. The purpose of this study was to select the optimal energy window settings for ^{99m}Tc and ^{201}Tl, the most commonly used in SPECT imaging, using CZT-based small animal SPECT for high quantitative accuracy. We experimentally investigated scatter fraction (SF), primary counts rate, and contrast-to-noise ratio (CNR) within various energy window settings using Triumph X-SPECT. The two ways of the energy window settings were considered: an on-peak window and an off-peak window. In the on-peak window setting, whose centers were set on the photo-peaks. In the off-peak window setting, the ratios of energy differences between lower energy threshold from the photo-peak and higher energy threshold from the photo-peak were varied from 4:6 to 3:7. In

addition, the energy-window width for ^{99m}Tc was varied from 5 % to 20 %, and that for ^{201}Tl was varied from 10 % to 30 %.The results of this study enabled to determine the optimal energy windows for each isotope in terms of SF, primary counts rate and CNR. We selected the optimal energy window that can increase the primary count rate and CNR while decreasing SF. For ^{99m}Tc SPECT imaging, the energy window of 133-147 keV, with a 10 % width and off-peak 3:7, was determined as the optimal energy window. For ^{201}Tl SPECT imaging, the energy window of 67-74 keV, with a 10 % width and on-peak, was considered as the optimal energy window.Our results demonstrated that the proper energy window should be carefully chosen based on quantitative measurements in order to take advantage of desirable characteristics of CZT-based small animal SPECT. These results provided valuable reference information for task-based small animal study and may offer the insights into the potential of multiple isotope imaging using CZT-based small animal SPECT.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 6

Design of a low background thermal neutron detector

Zhaoming Zeng[1], Hui Gong[2], Qian Yue[3], Jianming Li[4]

[1]*Department of physics and engineering, Tsinghua University,Beijing China*
[2]*Department of physics and engineering, Tsinghua University,Beijing China*
[3]*Department of physics and engineering, Tsinghua University,Beijing China*
[4]*Department of physics and engineering, Tsinghua University,Beijing China*

This paper designed a detector system for low background thermal neutron flux measurement. Proportional counter tube made up of oxygen-free copper which has a 6% energy resolution filled with ^{3}He gas was used to detect the thermal neutron flux. The internal background of the detector itself has been thoroughly studied. The counter is position-sensitive which made improper events like occasional spark signals caused by the high-voltage cables can be easily discriminated. The electronics readout system records the entire waveform for further processing on PC which can guarantee a proper processing for each possible event.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 7

DOSIMETRY IN COMPUTED TOMOGRAPHY USING A SHORT IONIZATION CHAMBER AND A SEMICONDUCTOR DETECTOR

Cinthia M. M. Paschoal[1], Fernanda C. L. Ferreira[2], Divanizia N. Souza[3], Luiz A. P. Dos Santos[4]

[1]*Departamento de Engenharia Civil, Universidade Estadual Vale do Acaraú, Sobral-CE-Brasil*
[2]*Departamento de Física, Universidade Federal do Sul e Sudeste do Pará, Marabá-PA-Brasil*
[3]*Departamento de Física, Universidade Federal de Sergipe, São Cristóvão-SE-Brasil*
[4]*Centro Regional de Ciências Nucleares (CRCN-NE), Comissão Nacional de Energia Nuclear, Recife-PE-Brasil*

The effective doses from computed tomography (CT) procedures are typically higher than those associated to other common types of diagnostic radiology procedures. The advance of multislice computed tomography has become inadequate the currently dosimetric protocol used. Instead of dosimetry based on the measurement of CTDI (Computed tomography dosimetry index) using a pencil ion chamber of 100 m of length, some researchers proposed the use of a small ion chamber and the calculating the dose equilibrium at the location of the chamber. Studies have suggested some unusual types of detectors for CT dosimetry: ion chambers (IC) of small volume, diamond detectors, optically stimulated luminescence (OSL) strips and semiconductor detectors. The objective of this work was to compare the performance of a short ionization chamber and a commercial photodiode to measure the accumulated dose at the center of the scan length L, $D_L(0)$ and to obtain the equilibrium dose D_{eq}using these two detectors. The result for L=100 mm was compared with the result of a pencil chamber. The detectors used were a Radcal "Farmer-type" 0.6 cm^3 ionization chamber, a Radcal 100 mm pencil chamber, and a commercial photodiode (BPW34FS from Siemens). The photodiode detection system consists of: the photodiode; a Flip-flop electrometer (EFF) developed at the Nuclear Instrumentation Laboratory of CRCN-NE; and the DoseX software, which controls the EFF. The semiconductor device was soldered in a printed circuit board, and a cylinder cap was used to avoid the environmental light. A Siemens Somaton Spirit Dual-Slice CT Scanner was used for the tests. The data were collected at the center and periphery holes of polymethylmethacrylate (PMMA) head phantom placed on the patient table. The scanning was made in axial mode. The accumulated dose at the center of the scan length were evaluated for different scan lengths (from L= 100 mm up to L = 400 mm) for the photodiode and the small IC. The results indicate that the commercial photodiode is suitable to measure the $D_L(0)$ as compared with the small ion chamber. For L = 100 mm,

the results of the photodiode and the small IC were satisfactory when compared with the pencil chamber results. This methodology allows measurements of the accumulated dose for any desired scan length, allowing measuring the equilibrium dose D_{eq} if the phantom is long enough to allow this.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 8

Denoising of High Resolution Small Animal 3D PET Data using the Non-Subsampled Haar Wavelet Transform

Humberto De Jesus Ochoa, Leticia Ortega, Boris Mederos, Osslan Osiris Vergara, Jose Manuel Mejia, Vianey Guadalupe Cruz

Universidad Autónoma de Ciudad Juárez

PET allows the imaging of functional properties of the living tissue. However, one of the most serious technical shortcoming affecting the reconstructed data is the noise. This problem is particularly severe in images of small animals because the noise distorts areas of interest within small organs. In this paper, a novel denoising method for high-resolution small animal 3D PET data is proposed with the aim to reduce the noise and preserve small structures. The method is based on the estimation of the noise-free wavelet coefficients using a linear estimator in the non-subsampled Haar wavelet transform domain. The procedure is applied to the volumetric image, after iterative reconstruction, without including correction for scatter and random events. Results show that the method preserves the small structures and drastically reduces the noise that contaminates the image.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 9

Feasibility of CT Imaging with Detection Module of High-Resolution CdTe-Semiconductor PET scanner

Yohei Kikuchi, Seong-yun Kim

Graduate School of Engineering, Tohoku University, Japan

Feasibility of CT Imaging with Detection Module of High-Resolution CdTe-Semiconductor PET scannerMultimodality scanners are highly powerful tools in preclinical medical studies and clinical medicine. PET/CT scanners, which provide functional and anatomical images, are representative examples of such scanners. We propose the concept of a PET/CT scanner that obtains both functional and anatomical images with a unique detection system. We report the results of preliminary CT image acquisition by using a detection module applied to a small-animal PET scanner. The scanner, which we developed in previous studies, can acquire PET images with a spatial resolution of less than 1 mm FWHM. The fine-strip Schottky CdTe detector employed in the detection module enables such high resolution. The module consists of a detector assembly that includes 32 detection elements and front end electronics. Two strip detectors are mounted backward and forward on a glass-epoxy substrate to obtain distinctness of image (DOI) information. The detector thickness is 1 mm, and 16 strips (1.1 mm in width × 5.0 mm in depth) prepared by dicing the Indium electrode are aligned at a pitch of 1.2 mm. Detection modules of PET scanners are commonly based on photon counting of a 511 keV γ-ray. Therefore, X-ray measurements in our new PET/CT scanner are also performed in the photon counting mode. A high energy resolution is guaranteed in our scanner by the use of semiconductor detectors. This characteristic is useful for energy discrimination or subtraction of continuous-energy X-rays, which contributes to fine images on photon counting CT.Our concern in this study is whether sufficient resolution for practical applications could be obtained with the module. We acquired CT images of several objects (a stainless-rod and acrylic phantoms) by using the module. To assess the high-contrast resolution of our detection module for CT imaging, the stainless rod of 0.2 mm in diameter was measured in the setup. Approximately 0.3-mm FWHM including the rod size was achieved. And, precise and fine images of acrylic phantoms were also obtained successfully. From the studies, we confirmed an adequate FWHM resolution of less than 0.5-mm. This indicates the feasibility of remodeling a small animal scanner to acquire both functional and anatomical images with sub-millimeter resolution.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 10

Development of an on-line dose profiler for hadrontherapy treatments

Vincenzo Patera[1,3], Michela Marafini[1,3], Adalberto Sciubba[3], Luca Piersanti[3], Cecilia Voena[3], Riccardo Faccini[2,3], Paola Maria Frallicciardi[1,3], Francesco Collamati[2,3], Fabio Bellini[2,3]

[1]Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi, Roma, Italy
[2]Dipartimento di Fisica, La Sapienza Università di Roma, Roma, Italy
[3]INFN, Sezione di Roma, Roma, Italy

A novel hadrontherapy monitor, able to measure the shape and absolute value of the deposited dose during treatment (in beam), is crucial to assess the agreement between the planned target volume and the actually irradiated one. In order to spot the position of the dose release, one (or more) secondary families coming out from the patient can be used, taking care to reject other secondaries that act as background. In this context, a new detector able to monitor the dose release during a hadron therapy treatment, that uses charged fragments to identify the BP position, has been proposed. Such a device, called "Dose Profiler", is composed of two main parts: a tracker and a calorimeter. A detector made of scintillating fibers has been chosen as tracker. Six squared layers (10~cm), each of them made of two orthogonal planes of squared fibers (0.5~mm), will provide the necessary information about particle direction, while a matrix of 16 pixelized LYSO crystals will act as a calorimeter. A first prototype of the tracker made by one layer was realized at SBAI (Sapienza Università di Roma, Italy) department mechanic

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 11

Effect of contrast agent administration on dosimetry in radiotherapy planning

Ching-jung Lo[1], Pei-ying Yang[2], Tsi-chian Chao[2], Shu-ju Tu[2]

[1]Department of Radiation Oncology, Chang Gung Memorial Hospital, Kwei-Shan, Tao-Yuan 333, Taiwan
[2]Department of Medical Imaging and Radiological Sciences, Chang Gung University, Kwei-Shan, Tao-Yuan 333, Taiwan

In treatment planning of radiation therapy, CT scanning with the administration of contrast agent (CA) to patients may assist physicians to contour the target or organs with better accuracy. However, contrast media are not given to patients in delivering the radiation treatment. In this study, we evaluate the quantitative effect of contrast media on the dosimetry between scenarios that CA is present in CT planning and absence in radiation delivery. Contrast media with various concentrations were prepared for CT imaging to acquire their corresponding Hounsfield units. An analytical phantom based on AAPM TG 119 and clinical cases of cervical cancer are included in the study. We consider the following different factors in the assessment of dosimetric variations: concentrations of CA media, irradiation techniques, and algorithms of dose calculations. In particular, we include a recent clinical technique of volumetric modulated arc therapy (VMAT). For CA media of 20% and 100%, measurements of Hounsfield units are 823 and 3019 in CT scanning of 120 kVp. In the phantom study, percent dose difference is reduced from 9.38 of one-portal AP to 7.50 of VMAT delivery. In the phantom study planned by the recent VMAT technique, we suggested an upper limit of 32% of CA media to be used in CT planning to manage the percent dose difference to be less than 3%. For the clinical cases, an average of upper limit of 1.57% of contrast media in CT planning is suggested. The biological consequence of mucosal complication is identified and discussed in our study.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 12

Comparison of timing resolution of novel scintillators coupled to blue-sensitive silicon photomultipliers and fast photomultiplier tubes

Nuray Yavuzkanat, David Jenkins, Pankaj Joshi

Department of Physics, The University of York, York, UK

Scintillator detectors coupled to photomultiplier tubes are a standard technology used across a broad range of applications from nuclear physics to medical imaging. Silicon photomultipliers offer an attractive replacement for photomultipliers in certain applications, particularly where

it is desirable to operate in regions of high magnetic field. Historically speaking, the performance of such devices is poor in terms of timing resolution which would disbar applications such as time-of-flight PET in medical imaging, or fast-timing measurements in nuclear physics. Recently available silicon photomultipliers from SensL have a fast timing output which would be suitable for such applications. Moreover its blue sensitivity favours coupling to next generation scintillators like $LaBr_3$ and $CeBr_3$ which are known their excellent energy resolution and detection efficiency. The main goal of this study was to compare the coincidence time resolution of 6 X 6 mm^2 SensL B-series MicroFB-60035-SMT blue sensitive silicon photomultiplier and fast Hamamatsu PMTs (R9880U-210-super bialkali R3998-100-02). The best timing resolution obtained in the present work is 155 ps for a $LaBr_3$ crystal optically coupled with a Hamamatsu PMT-R9880U-210. The performance of the blue-sensitive SiPM was found to be much better than traditional silicon photomultiplier and avalanche photodiode in terms of efficiency, temperature stability and timing resolution. A timing resolution of 470 ps was obtained for a 6 X 6 mm^2 SiPM coupled to a 0.5" diameter $LaBr_3$ crystal.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 13

Calibration of mini TEPC using the nitrogen-neutron-capture peak

Meng-tsung Lin[1], Chuan-jong Tung[1,2], Fang-yuh Hsu[1]

[1]*National Tsing Hua University*
[2]*Chang Gung University*

Tissue-equivalent proportional-counter (TEPC) is a common device that is used in microdosimetric lineal energy measurements. This device measures the pulse height spectra of charged particles that pass through its gas cavity. Charged particles can be either directly from ion beams or set in motion in the TEPC wall by uncharged particles. The measured pulse height spectra need to be converted into the lineal energy spectra through appropriate calibrations. Such calibrations are usually performed using an internal alpha source or through the proton edge technique. The alpha source method easily generates errors from the calculation of energy depositions and the knowledge of path lengths across the cavity. The proton edge technique can only be applied to a neutron field that produces recoil protons with the maximum stopping power.In the present work, the calibration of a mini-TEPC is based on the reaction14N(n,p)14C, which develops the pronounced marker point in the lineal energy spectra. The tissue equivalent wall of the mini-TEPC is drilled a hole and is filled with an insert containing the nitrogen-enriched material. This mini-TEPC is operated at a filling gas pressure of propane-based tissue equivalent gas mixture to simulate the biological site. When the mini-TEPC is exposed to the neutron field in the Thing Hua Open-pool Reactor (THOR), a sharp peak corresponding to the monoenergetic protons produced in the reaction can be easily identified. After the calibration, the drilled hole is then filled with an insert of the tissue-equivalent or boron-enriched material to study the radiation quality for ion beam therapy or boron neutron capture therapy.The present study has been carried out for a 1 mm diameter cylindrical mini-TEPC. Measurements of the lineal energy spectra were made in the epithermal neutron field of the THOR. Applications will be discussed.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 14

Isotope Production Using a Superconducting Electron Linac

Valeriia N. Starovoitova[1], Chase H. Boulware[1], Terry L. Grimm[1], Dyle D. Henning[1], Jerry L. Hollister[1], Erik S. Maddock[1], Frank Harmon[2], Jon L. Stoner[2]

[1]*Niowave, Inc. Lansing, MI 48906*
[2]*Idaho Accelerator Center, Idaho State University, Pocatello, ID 83201*

The majority of radioisotopes used in the U.S. today come from foreign suppliers or are generated parasitically in large government accelerators and reactors. Both of these restrictions limit the availability of radioisotopes, especially short-lived ones, and it discourages the development and evaluation of new isotopes and radiopharmaceuticals. Linacs are an excellent alternative to nuclear reactors for production of many isotopes such as ^{67}Cu, ^{99}Mo, and ^{225}Ac. Linacs operate at much lower costs than nuclear reactors and produce far smaller waste streams. Initial capital costs are a fraction of nuclear reactors and time to production is far quicker. Despite these advantages, electron linacs have not been widely used for isotope production as of today, mostly due to the absence of affordable high power accelerators and bremsstrahlung converters.In this talk we will present the design of a production setup based on a superconducting electron accelerator equipped with a liquid metal bremsstrahlung converter. The converter will be capable of dissipating hundreds of kilowatts of electron beam power and providing very high photon flux density, over 10^{17} photos/cm^2 per second for a 40 MeV, 2.5 mA electron beam. We will show the results of the initial testing of a

prototype Pb-Bi eutectic (LBE) converter. We will also present the results of the studies of conversion efficiency, power handling and yields of several isotopes including ^{67}Cu, ^{99}Mo, and ^{225}Ac using a superconducting linac and a liquid metal converter.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 15

A High Intensity 10 MeV X-ray Generator to Eliminate High Activity Sources Used for Sterilization

Erik S. Maddock[1], Chase H. Boulware[1], Terry L. Grimm[1], Jerry L. Hollister[1], Valeriia N. Starovoitova[1], Alan W. Hunt[2]

[1]Niowave, Inc. Lansing, MI 48906
[2]Idaho Accelerator Center, Idaho State University, Pocatello, ID 83201

One of the most common ways to sterilize goods is with gamma producing radioactive sources, typically Co-60 and Cs-137. There are approximately 5000 devices containing 55,000 high activity radioactive sources being used in the United States today [1]. Primarily the gamma producing radioisotopes Co-60 and Cs-137, these sources are used for a wide variety of medical and industrial applications. Eighty-five percent of gamma sources are used for cold sterilization, either of food products or medical equipment [2]. However, there are significant problems with using gamma sources for sterilization [3]:

- Isotropic radiation from high activity sources require either large quantities or long exposure times to reach effective sterilization dosages
- High activity sources must be routinely replaced because of radioactive decay
- High activity sources become radioactive waste when depleted
- Regulations are increasingly burdensome to possess and dispose of high activity sources
- High activity sources require extensive shielding and tight security procedures
- High activity sources could be used as a Radiological Dispersal Device ("Dirty Bomb")

We are developing a radiation sterilization system based on a 10 MeV superconducting linac to displace radionuclide gamma sources in sterilization. In this talk we will present the results of the simulations and corresponding experimental measurements of the dose rate distribution in a water equivalent phantom. Our results show that a superconducting linac can generate up to 120 kGy/h for a 2 MeV 10 kW beam and up to 3,100 kGy/h for a 10 MeV 10 kW beam.

[1] "Radiation Source Use and Replacement: Abbreviated Version", Science Committee on Radiation Source Use and Replacement, National Research Council, 2008.
[2] Gamma Irradiators for Radiation Processing, International Atomic Energy Agency, 2005.
[3] K. da Silva Aquino, "Sterilization by Gamma Irradiation", Gamma Radiation, Edited by: Feriz Adrovic, 2012.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 16

Photon-scattering, electron-loss and shadow-effect correction factors calculation for cylindrical free-air chamber

Tseng-te Huang, Chien-hau Chu, Yi-chun Lin

Health Physics Division, Institute of Nuclear Energy Research, P.O. Box 3-10, Longtan 325, Taiwan, ROC

A cylindrical free-air ionization chamber is used as the medium X-ray air kerma primary standard at the Institute of Nuclear Energy Research (INER, Taiwan). Photon-scattering, electron-loss and shadow-effect correction factors are taken into account for the measurement of air kerma by cylindrical free-air ionization chamber. The photon-scattering correction factor is to deduct ionizations caused by scattered photons. The electron-loss correction factor is to compensate for the loss of electrons striking the electrode shell without fully depositing their energies to the charges in the air. The shadow-effect correction factor is to compensate for the loss of electrons striking the collecting rod at the center of the chamber. The photon scattering and the electron loss correction factors previously used at INER were based on the least-squares fit with the experimental data published in the NBS Handbook 64. The shadow-effect correction factor was not considered. In this study, photon-scattering, electron-loss and shadow-effect correction factors for each mono-energetic photon were calculated by Monte Carlo code EGS5. Then the mono-energetic correction factors were substituted into the ISO 4037 radiation qualities spectrum and calculated for the energy weighted correction factors. Comparing the

calculated correction factors with the previous correction factors, the maximum differences were 0.51 % and 1.22 % for N-250 and N-300 radiation qualities. In the report of comparison of national air kerma standards for ISO 4037 narrow spectrum series (EUROMET.RI(I)-S3) conducted from 2004 to 2005, the ratio of differences and expanded uncertainties (Di/Ui) are 0.9 and 1.8 for INER's N-250 and N-300 radiation qualities. If the correction factors obtained in this study are substituted, the differences can be reduced, and Di/Ui become 0.36 and 0.6.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 17

Feasibility Study on Fiber-optic Cerenkov Radiation Sensor for Radiotherapy Dosimetry: Estimation of Cerenkov Radiation Generated in Optical Glasses Using MCNPX Simulation

Jae Seok Kim, Sang Hun Shin, Kyoung Won Jang, Hyesu Jeon, Wook Jae Yoo, Bongsoo Lee

School of Biomedical Engineering, College of Biomedical & Health Science, Research Institute of Biomedical Engineering, Konkuk University

Scintillating fiber-optic dosimeters (SFODs) consisting of organic scintillators and optical fibers have been developed to measure absorbed doses in radiotherapy dosimetry. This kind of dosimeter has many advantages such as water-equivalence, small sensitive volume, and immunity to electro-magnetic fields. Unfortunately, when we measure absorbed doses using a SFODs, Cerenkov radiation is generated in optical fibers. Cerenkov radiation is produced by a charged particle traveling through a dielectric medium with a velocity greater than that of light in the same medium; here, to generate Cerenkov radiation in a medium, the charged particles should have over a threshold energy varying with refractive index of a media. This kind of radiation is frequently regarded as a noise signal in a radiotherapy dosimetry using a SFODs because its intensity varies according to irradiated lengths of optical fibers. However, since the Cerenkov radiation is induced by interactions between ionizing radiations and dielectric media, it can be a significant signal when the irradiated length of optical fiber is fixed. To apply Cerenkov effect to radiotherapy dosimetry, in this study, we designed the fiber-optic Cerenkov radiation sensors (FOCRSs) using a plastic optical fiber (POF) and optical glasses such as CaF_2 and BaF_2; here, the POF and optical glasses having different refractive indices were used as a transmission fiber and Cerenkov radiators, respectively. Also, to determine the relationship between the intensities of Cerenkov radiation generated from FOCRSs and absorbed doses for therapeutic photon beams, electron fluxes over Cerenkov threshold energies (CTEs) and energy depositions of 6 MV photon beams were calculated by using the Monte Carlo N-particle Extended transport code simulations (MCNPX).

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 18

X-ray large area detector using thermoluminescence properties of commercial ceramics

Kiyomitsu Shinsho[1], Yusuke Koba[2], Genichiro Wakabayashi[3], Yasuyuki Kawaji[4], Masahiro Fukushi[1]

[1]*Tokyo Metropolitan Univ., Tokyo, Japan*
[2]*NIRS, Chiba, Japan*
[3]*Kinki Univ., Osaka, Japan*
[4]*Junshin Gakuen Univ., Fukuoka, Japan*

Recent Radiation therapy can focus radiation in the objective tumor with high precision, leading to high therapeutic gains. Therefore, both the irradiation field and the dose require high precision validation. In particular, the verification in two or three dimensions is indispensable since the irradiation field has complex three-dimensional characteristics. Currently, radiochromic film is typically used for 2-D verification. With this method, high-resolution imaging of around 50μm is possible. However, there are some problems with this technique. i.e. The cost is high, dynamic range is narrow and the interval between irradiation and measurement is significant etc.We are currently developing an x-ray imaging device having TL material arranged in a 2D plane, a wide dynamic range and a high spatial resolution. Remarkably during the development, it was discovered that Alumina, Zircon Cordierite and other commercially available plates have good TL characteristics usable as a 2D storage dosimeter. While OSL and TL characteristics of Al_2O_3 : C, Al_2O_3 : Mg, Y, Al_2O_3 : Cr, Al_2O_3 : Cr, Ni are widely published, results from research into large area imaging with these materials are not yet available. We have found no reports regarding Zircon Cordierite used as a TL dosimeter. Here we present the basic TL characteristics and x-ray imaging from these two types of ceramic plates.Due to what is thought to be the effects of SiO_2 and MgO sintering additives in the commercially available Alumina plates we used, their glow peaks were located at 170 ℃ and 300 ℃, different from data already published on the research-use materials. TL sensitivity per unit area was found to be on par with commercial TL material Matsushita UD-110S. The TL wavelength was located at 693nm, attributed to the ^2E-$^4A_2$ of the embedded Cr^{3+}. Commercial personal radiation dosimeters use TL material

with a TL wavelength in the proximity of the high sensitivity region of photomultipliers. On the other hand the Alumina plate used here has a longer TL wavelength, close to the sensitive region of the CCD and exhibits stable trapping, making it a suitable candidate for TL imaging with a CCD. For this experiment, an 80mm × 80mm × 1mm Alumina plate was used both to x-ray image a "shishamo smelt" fish and a USB memory device, and in a CyberKnife beam alignment test. Even without image calibration, an excellent x-ray imaging spatial resolution of 80μm was achieved and the CyberKnife beam alignment test showed results on par with radiochromic film. The same results were achieved with the Zircon cordierite plate.This research shows that commercially available Alumina and Zircon plates are excellently suited to use as x-ray large area detectors useable for beam alignment testing of precision radiotherapy equipment.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 19

Multi-resolution Voxellation Scheme in Full-FOV Iterative CT Reconstruction for Moderating the Computational Cost

Minsik Lee

Department of Radiological Science and VYSION Research Center, Yonsei University, Wonju 220-710, South Korea

In some clinical CT applications, only a small region-of-interest (ROI), compared to entire field-of-view (FOV), such as heart, teeth, or other particular tissues, is often required to be focused with high image accuracy. However, reconstructing full-FOV with high accuracy via, especially, an iterative reconstruction process is still challenging mainly due to the required computational cost of time and/or memory. In this study, in order to overcome these difficulties, we have proposed an effective multi-resolution voxellation scheme in the full-FOV iterative CT reconstruction, in which a block of N^3 voxels in the outside region of the focused ROI is binned into a single large voxel, keeping the voxel size in the focused ROI unchanged. As an effective iterative reconstruction method, we considered a compressed-sensing (CS) based algorithm that exploited the sparsity of the image with substantially high image accuracy. We implemented the algorithm and investigated the feasibility by performing systematic simulation works. According to our preliminary results, the multi-resolution voxellation scheme seems to work effectively in reducing computational cost, preserving high image quality in the focused ROI. More details on the implementation of the algorithm and the simulation results will be described in the paper.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 20

Simulation and Experimental Studies of 3D Image Reconstruction from Insufficient Sampling Data for Applications of Low-dose Dental CBCT Imaging

Minsik Lee

Department of Radiological Science and VYSION Research Center, Yonsei University, Wonju 220-710, South Korea

In practical applications of 3D tomographic imaging, there are often challenges for image reconstruction from insufficient sampling data. In dental cone-beam CT (CBCT), for example, image reconstruction from few views and/or limited-angle views would enable fast scanning with reduced imaging doses to the patient. In this study, we investigated and implemented an efficient reconstruction algorithm based on the compressed-sensing (CS) theory, which exploits the sparseness of the gradient image with substantially high accuracy, for low-dose dental CBCT reconstruction. We performed systematic simulation works and investigated the image characteristics to demonstrate the algorithm for image reconstruction in insufficient data problems. We also applied the algorithm to a commercially-available dental CBCT system (Expert7^{TM}, Vatech Co., Korea) and performed experimental works. We successfully reconstructed CBCT images from several undersampled data and evaluated the reconstruction quality quantitatively. Both simulation and experimental demonstrations of the CS-based reconstruction algorithm in insufficient sampling problems appear to show that it can be applied to current dental CBCT systems for reducing the imaging doses and improving the image quality. More details of the simulation and the experimental results will be described in the paper.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 21

3D Image Reconstruction for Digital Tomosynthesis with a Circular X-ray Tube Based on Compressed-sensing (CS) Theory

Y. O. Park, H. S. Cho, D. K. Hong, M. S. Lee, U. K. Je, C. K. Park, H. M. Cho, S. I. Choi, Y. S. Koo

Department of Radiological Science and VYSION Research Center, Yonsei University, Wonju 220-710, South Korea

In this paper, we introduce an effective X-ray imaging system for digital tomosynthesis (DTS) with a circular X-ray tube and its image reconstruction algorithm based on a foundational mathematical theory, compressed-sensing (CS), for low-dose, high-accuracy X-ray imaging. Here, the X-ray tube is equipped with a series of cathodes distributed around a rotating anode and the detector remains stationary throughout the image acquisition. We considered a total variation (TV)-based reconstruction algorithm that exploited the sparsity of the image with substantially high image accuracy. We implemented the algorithm for the DTS geometry and successfully reconstructed images of high accuracy from greatly undersampled frequency information. The image characteristics were investigated quantitatively by using some figures of merit, including the universal-quality index (UQI) and the depth resolution. For selected tomographic angles of 20^o, 40^o, and 60^o, the corresponding UQI values in the tomographic view were estimated about 0.94, 0.97, and 0.98, and the depth resolutions were about 4.6, 3.1, and 1.2 voxels in full-width at half-maximum (FWHM), respectively. We expect the proposed method to be applicable to developing the next-generation dental or breast X-ray imaging system.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 22

Feasibility Studies on Volumetric Image Reconstruction by Using a Dental Panoramic Detector with a Limited-angle Zigzag Scan Geometry

D. K. Hong, H. S. Cho, M. S. Lee, Y. O. Park, U. K. Je, C. K. Park, H. M. Cho, S. I. Choi, Y. S. Koo

Department of Radiological Science and VYSION Research Center, Yonsei University, Wonju 220-710, South Korea

In this paper, we proposed a pragmatic method capable of implementing fast, low-dose, volumetric image reconstruction by using a dental panoramic detector for a cost-effective, low-dose, all-in-one dental X-ray imaging system. In the proposed geometry, a linear-typed dental panoramic detector is rotated 90^o from the orientation for dental panoramic imaging and is scanned along a limited-angle zigzag trajectory in the axial direction to cover the whole imaging volume thickness. For image reconstruction, we considered a compressed-sensing (CS)-based algorithm that exploited the sparsity of the image gradient and was capable of reconstructing volumetric images with substantially high image accuracy against the image artifacts from sparse-view data. We implemented the algorithm for the proposed geometry and performed systematic simulation and experimental works to demonstrate its feasibility for dental imaging applications. We have successfully reconstructed the images of substantially high accuracy from the proposed geometry through the reconstruction algorithm. We expect that the proposed method can be applicable to developing a cost-effective, low-dose, all-in-one dental X-ray imaging system.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 23

Development of Portable Gamma Imager with Coded Aperture

Kenji Shimazoe

The University of Tokyo

For the applicaton of in-situ diagnosis in surgery, a compact coded aperture gamma imager was designed and developed. The detector consists of 12 x 12 scintillator matrix (2 x 2 x 10 mm Ce:GAGG) individually coupled with APD array. The front-end electronics is composed of time based ASICs and a FPGA. The M-array coded mask was adopted and fabricated with tangsten (0.5 mm thickness). The image was reconstructed with a ^{57}Co source and a ^{137}Cs source. The measured spatial resolution is around 1.5 mm in the field of view.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 24

Study on Effective Imaging Conditions in Moving Grid Technique for Elimination of Grid Line Artifacts

Chul Kyu Park

Department of Radiological Science and VYSION Center, Yonsei University, Wonju 220-710, South Korea

The use of antiscatter grid in diagnostic X-ray imaging is the most widely applied method for reducing the amount of scatters at the imager. A problem with using grid, however, is that whenever the imager resolution is comparable or higher than the grid spacing, a shadow of grid strips themselves may be seen in X-ray images. Moreover, moiré pattern, a wavy shadow of grid strips having a low frequency, is easily observed in digital X-ray images. In our previous works, we found that a moiré-free image could be produced through frequency synchronization between the grid and the imager, possibly by adjusting the magnification of the grid strips. However, complete matching of the grid frequency to the imager frequency is often impractical. In this paper, in order to find a practical solution against the grid line artifacts, we revisited moving grid technique, originally proposed by Bucky, with effective imaging conditions. We implemented a useful moving-grid simulation code, iTOM, for theoretical analysis and performed systematic simulation and experimental works to find effective imaging conditions in the use of moving grid technique. More details on the moving-grid simulation code and the simulation and experimental results will be described in the paper.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 25

Image Reconstruction of Optical Computed Tomography Using Algebraic Reconstruction Technique for Dose Readout of Polymer Gel Dosimeters

Yuan J. Chang[1], Jui T. Hsu[2], Cheng T. Shih[3], Rou P. Han[1], Shu J. Chang[4], Jay Wu[5]

[1]*Department of Management Information Systems, Central Taiwan University of Science and Technology, Taichung, Taiwan*
[2]*School of Dentistry, China Medical University, Taichung, Taiwan*
[3]*Department of Biomedical Engineering and Environmental Sciences, National Tsing Hua University, Hsinchu, Taiwan*
[4]*Health Physics Division, Institute of Nuclear Energy Research, Atomic Energy Council, Taoyuan, Taiwan*
[5]*Department of Biomedical Imaging and Radiological Science, China Medical University, Taichung, Taiwan*

Optical computed tomography (OCT) has been proved as a gold standard for dose readout of polymer gel dosimeters. Several defects, such as noise, inconsistent detector response, and misalignment, may occur and cause artifacts in the images reconstructed by the filtered-back projection (FBP) algorithm in OCT scan. In this study, we used the algebraic reconstruction technique (ART) for image reconstruction to improve the quality of OCT images. Two cylindrical containers filled with the NIPAM polymer gel were irradiated by a medical linear accelerator to produce circular and square dose distributions. The containers were scanned by OCT to acquire projection data. The OCT images were reconstructed by using FBP and ART, and the image quality were evaluated and compared. For the circular dose distribution, ART successfully reduced the ring artifacts and noise in the reconstructed image. For the square dose distribution, ART reduced the amount of quantum noise and increased the uniformity of the irradiated region. In the ROI analysis, the coefficient of variance (CoV) calculated from the image reconstructed by ART was 43.9% and 41.5% lower than the result of FBP for the circular and square dose distribution cases. We conclude that ART can be used for image reconstruction of OCT to improve image quality and further provide accurate dose conversion of polymer gel dosimeters.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 26

Techniques for leak measurement of the medical diagnostic X-ray machine

Chin-hsien Yeh, Ming-chen Yuan, Kuo-wei Lee

Health Physics Division, Institute of Nuclear Energy Research, Taiwan (R.O.C.)

According to radiation safety examination regulation of the Atomic Energy Council (AEC) in Taiwan, the X-ray machine tube target should be periodically checked for the highest leak rate measured at 1 m distance and the value should be less than 0.87 mSv/h. Also the value for the leak rate measured of the main beam at 30 cm distance outside the wall surface should be less than 0.5 mSv/h. We made a leak measurement comparison using the ionization chamber detector and the scintillator to see the adequacy of the leak rate actually measured by the detectors as well as the

reasonableness of the leak rate required by the regulations. The results showed that the scintillator has a faster response time, but the VAR value of the detector and the verification results of the photon analyzer were closer to the actual dose rate of the X-ray machine.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 27

Simulation Study on Electrode Structure of Plasma Display-like X-ray Detector

Jongseok Kim[1], Sangheum Eom[1], Jungwon Kang[1], Hakjae Lee[2], Kisung Lee[2]

[1]*Department of Electronics and Electrical Engineering, Dankook University, Yongin, Gyeonggi, Korea*
[2]*Department of Bio-convergence Engineering, Korea University, Seoul, Korea*

In this study, the PDP-like X-ray detector was calculated using Garfield code. The multiplication of Double Ridged CAC structure was 6074.68 and it was about six times larger than that of CAC and two times larger than that of Ridged CAC 1 structure. The avalanche drift of charged particles in Double Ridged CAC structure was stronger than those of other strutures. The Double Ridged CAC structure is expected to show the higher performance than those of other CAC structures.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 28

INTERCOMPARISON OF PHYSICAL PARAMETERS PHANTOM USING FOR DENTAL X-RAYS

Fernanda Carla Lima Ferreira[1], Cinthia Marques Magalhães Paschoal[2], Lilian Ferreira Silva[1], Jhonatan Maciel Santos[1]

[1]*Department of Physics, Universidade Federal do Sul e Sudeste do Pará, Marabá-Brazil*
[2]*Universidade Estadual Vale do Acaraú, Sobral-Brazil*

The equipment of dental X-rays are commonly used for image acquisition and verify some sort of anomaly or some sort of the study related to accurate diagnosis, such as molar, adjacent anatomical structures and channel structure dental. On intraoral procedures all radiography are obtained with intra oral film that can be positioned in three ways, periapical, occlusal and interproximal. The objective of this study was intercompare results periapical radiography obtained with dental phantom and evaluate the high and low contrast in dental radiographs service of Maraba-PA, northern Brazil. The phantom possesses cylindrical, metal mesh inside dimensions of 40, 60, 60 and 100 lines per inch for the evaluation of regions of high and low contrast. In the intercomparison of results from periapical radiographs obtained with phantom [4], we evaluated 30 radiography obtained in 15 dental X-ray in the city of Maraba, State of Para, northern Brazil. For each device, we performed two of the image acquisition and observed the presence or artifacts little sharpness in the details of the anatomical structures of the tooth, as well as high and low contrast and visualization of metal mesh inside dimensions of 40, 60, 60 and 100 lines. The important factor in the analysis of the images was the high and low contrast, comparing the images A and B, we observed that exposure of radiation on the metal mesh of the phantom was not possible to identify which mesh sizes, so due to lack of standard image quality performing radiography in a and B. in the image C, the low contrast further damaged the image resolution without definitions of metal mesh is not recommended. The evaluation parameter of the images for the intercomparison of the results, were defined from the preview images of the tooth anomalies, we observed that 48% of dental radiological equipment showed no abnormalities details of the tooth, with a low resolution image in, presence of artifacts and some images do not show the sharpness of wax that was around the tooth. However, 52% of the equipment presents satisfactory results. Through analysis of the images, it was shown that through inter periapical radiography obtained with dental phantom was possible to evaluate the dental X-ray equipment in Maraba. Just as, in regard to the standard of image quality was possible to observe the difference between the X-rays such as assess high and low contrast, anatomical tooth structures and artifacts. Another relevant aspect is that the intercomparison of images obtained in dental radiology Maraba can contribute significantly in the ratings of other equipment of dental X-rays from the cities of the South and Southeast of Pará, northern Brazil. Therefore, the intercomparison of the physical parameter may also be used for continuing education for radiology professionals.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 29

Monte Carlo simulation of a new design of DOI detector with wavelength shifting (WLS) fiber readout

Su Jung An[1,2], Hyun-il Kim[1,2], Chae Young Lee[1,2], Han Kyeol Song[1,2], Yong Hyun Chung[1,2]

[1]*Department of Radiological Science, College of Health Science, Yonsei University, Wonju, 220-710, Korea*
[2]*Institute of Health Science, Yonsei University, Wonju, 220-710, Korea*

We are attempting to develop a new concept of depth-of-interaction (DOI) PET detector using wavelength-shifting (WLS) fibres for small animal PET. The detector utilizes dual-ended readout of new pattern of scintillator arrays with WLS fibres. The design of detector allows not only to provide DOI information, but also to improve overall performance of system to reduce channel of photo-sensor and electronics and prevents optical cross-talk between adjacent fibres. The detector module consists of 23 × 23 array of 2 × 2 × 20 mm^3 LSO crystals readout by 2 × 2 × 46 mm^3 WLS (BCF-91A, Saint Gobain) fibres. On every other line, crystals which have 2 mm shorter height are arranged to x-direction on the top and y-direction on the bottom of array to make grooves for WLS insertion. WLS fibers are inserted into these grooves and one end of each WLS fiber is coupled to the photo-sensor for the detection of scintillating light trapped in the fiber. In order that the detector design has acceptable performance, it is important to maximize light photon collection from the WLS fiber readout. In this study, as a part of the development of a small animal PET, we determine the factors which can affect the light collection including coupling materials between fiber and crystal, reflector materials, and the length of WLS fiber using Monte Carlo simulations. Effect of height of scintillator on light generation and collection were also studied. The optimal coupling materials and surface conditions of the WLS fibres were derived for a small animal PET with a view towards achieving high sensitivity, as well as high and uniform resolution.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 30

Radiation Measurements Onboard Aircraft in the South Atlantic Region

Claudio A. Federico[1,3], Odair L. Gonçalez[1,3], Linda V. E. Caldas[2], Mauricio T. Pazianotto[1,3], Clive Dyer[4], Alexander Hands[4], Marco Caresana[5]

[1]*INSTITUTO DE ESTUDOS AVANÇADOS, BRAZIL*
[2]*INSTITUTO DE PESQUISAS ENERGÉTICAS E NUCLEARES, BRAZIL*
[3]*INSTITUTO TECNOLÓGICO DE AERONÁUTICA, BRAZIL*
[4]*QINETIQ, UNITED KINGDOM*
[5]*POLITECNICO DI MILANO - DIPARTIMENTO DI ENERGIA, ITALY*

Great concerns and efforts are directed to the potential effects of cosmic radiation, mainly neutrons and protons, on the electronic circuits of the aircrafts, as they can be affected by this type of radiation. Also, since 1991 the International Commission on Radiological Protection (ICRP) has considered the potential exposure from cosmic radiation doses, and recommends that the aircrew potentially exposed to more than the dose limit of 1 mSv needs to be considered as occupationally exposed to radiation. Great part of Brazil and part of South America is subjected to one magnetic anomaly, called South Atlantic Magnetic Anomaly (SAMA) and only few measurements of the radiation dose rate in aircrafts exist in this region, compared to other places in the world. This paper describes measurements taken in one aircraft on the SAMA region, comparing the results obtained from different equipments from Brazilian and European partners. The flights were made with one Learjet-type aircraft, supported by Brazilian Air Force and the geographic region of the measurements involves most part of latitudes covered by Brazilian territory and locations close to the estimated minimum of magnetic field due to SAMA. The flight altitudes ranges from 16,000 feet up to 43,000 feet, and were fully accompanied with a GPS system specially set up for this experiment, to inform the correct position and altitude of the flight. The measurements were taken by means of two active detectors: one of them is a THERMO WENDI-II neutron probe plus a proportional type probe, and the other one is a silicon-based LET spectrometer specially designed for in-flight radiation monitoring (RaySureTM). Some flights were also accompanied by one passive neutron detector based on CR39 PADC (Poly-Allyl-Diglycol-Carbonate) track detector, specialty projected to inform the results in the ambient equivalent dose quantity. All active and passive instruments were previously calibrated and verified at CERN, using the CERF field (Cosmic Ray Reference Field), which reproduces fairly well the spectra encountered on flight altitudes. The measurements were taken in two experimental conditions: a Fixed Point condition, where the aircrafts makes a circular orbit around the same geographic coordinates at the same altitude and on Route Missions where the aircraft comes from one aerodrome to another. The results were intercompared and analyzed in comparison with the estimates obtained by several computational codes. All measurements were taken in quiet solar conditions, with no significant magnetic disturbances (Kp index < 3).

ACKNOWLEDGMENTS

The authors would like to thank the directors and the aircrews from Institute for Research and Flight Tests (IPEV), from Brazilian Air Force, to allow the measurements inside aircraft. The authors thank also to Dr. Markus Brugger and Dr. Marco Silari for the support on calibration of part of equipment on CERF field, to the CITAR project and to the Brazilian agencies FINEP and CNPQ for partial financial support.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 31

Characterizing photon propagation and light collection efficiency of extractive scintillating resin in flow-cell detectors

Amy C. Meldrum[1], Ayman Seliman[1], Valery Bliznyuk[2], Timothy A. Devol[1], Scott M. Husson[2]

[1]*Department of Environmental Engineering and Earth Science, Clemson University, Clemson, South Carolina, USA*
[2]*Department of Chemical and Biomolecular Engineering, Clemson University, Clemson, South Carolina, USA*

Light collection is of critical importance to obtain optimum detection efficiency from extractive scintillating resin. Extractive scintillating resins have been synthesized for use in a flow-cell detector for the ultra-low level detection of alpha and beta radioactivity in water. Many parameters, including the number of bead – interstitial medium interfaces, the pore size of the beads, the packing of the beads within the flow cell, and the index of refraction (n) of the media in the pore space will affect the amount of light collected by a photomultiplier tube (PMT). The goal of this research is to develop a fundamental understanding of how these parameters affect the propagation and collection efficiency of the optical photons produced by the scintillating beads. Experiments were conducted using Teflon columns with inner diameters of 1/16", 3/16", 5/16" and 7/16"were packed with commercially available BC-400 scintillating beads (> 180 μm) and the beads synthesized for this project. The synthesized beads (212 – 425 μm in diameter) are composed of polystyrene, 25% cross-linked with divinylbenzene, with 1,4-Bis(4-methyl-5-phenyl-2-oxazolyl)benzene (DM-POPOP) as a fluor. A solution containing 1086 +/- 8.69 Bq L^{-1} of ^{14}C which filled the pore space of the columns were counted in a liquid scintillation counter (LSC) to determine detection efficiencies. Detection efficiencies of the four columns with BC-400 resin were 25 +/- 2%, 27 +/- 4%, 30 +/- 3%, and 29 +/- 4 %, respectively, and detection efficiencies of the same sized columns with the synthesized resin were 11 +/- 0.5%, 15 +/- 3%, 19 +/- 5%, and 26 +/- 10%, respectively. Solutions containing ^{210}Po and $^{90}Sr/^{90}Y$ were also tested. The Monte Carlo code GATE (GEANT4 Application for Tomographic Emission) was benchmarked against experiments of a simplified geometry. The simplified geometry involved sheets of BC-400 plastic scintillator with differing media between each layer and a ^{210}Po source. The GATE model will be used to model the column experiments to investigate the effects of bead size and packing as well as radiation energy deposition on light propagation and collection efficiency for the flow cell system.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 32

Reconstruction of the Spatial Distribution of Radioactive Contamination using an Array of Directional Gamma-Ray Spectrometers

Laurel E. Sinclair[1,2], François A. Marshall[1,2], Richard Fortin[1], Audrey M. L. Macleod[1]

[1]*Geological Survey of Canada, Natural Resources Canada, Ottawa, Ontario, Canada*
[2]*Department of Physics, Carleton University, Ottawa, Ontario, Canada*

Natural Resources Canada has responsibility in Canada for mobile radiometric survey following a deliberate or accidental release of a radioactive substance. The team has assets for both aerial and ground-based survey, including large volume NaI(Tl) directional gamma-ray spectrometers. In these instruments, four 4 l NaI(Tl) crystals are oriented in a square arrangement, such that self-shielding information is used to provide an azimuthal direction to a source in real-time. An interesting situation arises when the radioactive source in question is not localized but distributed about the survey area. In this case, a single pointing azimuth direction is not as useful. Instead, a mobile survey with a single directional spectrometer can be considered as a set of simultaneous measurements by a stationary array of multiple directional spectrometers. The relative number of counts recorded in each crystal of the array is sensitive to the spatial distribution of the radioactivity, (while of course the total number of counts is sensitive to the total amount of radioactivity). We have developed a method to use the counts recorded in a stationary array of self-shielding detectors to reconstruct the spatial distribution of a distributed radioactive source. The method relies on the use of Monte Carlo simulation

to understand the effect of each region of physical space on each crystal of the array. A minimization of the difference between the measured counts distribution and the counts distribution arising from each region of space, returns the relative contributions of each region of space. Here, we present this reconstruction method, and demonstrate its effectiveness using synthetic sets of radioactive contamination data. We go on to discuss the challenges involved in application of the method to a real-world situation involving a single directional spectrometer on a mobile platform. Finally, we apply the reconstruction method to mobile survey data taken with our directional spectrometer over radioactive La-140 which was explosively dispersed during a series of controlled experiments at the Defence Research and Development Canada – Suffield Research Centre in June and September of 2012.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 33

Environmental monitoring using leaves of Nerium oleander through the technique of X-Ray fluorescence

Ramon S. Santos, Francis A. C. R. A. Sanches, Arthur O. P. Neves, Davi F. Oliveira, Marcelino J. Anjos

Physics Institute, State University of Rio de Janeiro, Brazil

The quality of the air is a topic of great importance worldwide by affect the human health, animals and plants. The air pollutants continuously enter in the human body, causing illness as skin problems, asthma, bronchitis, pulmonary diseases and eyes irritation. With the cities fast growth and the industrialization process the air pollution was aggravated due to different types of emissions associated with these process, as urban traffic, industrial activities, burning fuel, civil industries of construction/demolition, fires and also natural phenomena. Many of these emissions move from long distances due to convections currents and finally tend to deposit mainly in the plants leaves and in the soil, so it can influence the function and the structure of the ecosystem, including its ability of self regulate, thus affecting its life quality. Therewith, the plants leaves can behave as a natural sample of the emissions that are deposited in the same. In this study Nerium oleander leaves were used to measure the environmental pollutions levels in different sampling urban regions in the city of Rio de Janeiro/RJ: Andaraí, Benfica, Bonsucesso, Caju, Engenho de Dentro, Engenho Novo, Estácio, Grajaú, Inhaúma, Lins, Maracanã, Maria da Graça, Méier, Praça da Bandeira, Riachuelo, Rio Comprido, São Cristóvão, Tijuca, Vila Isabel and city Center. The control samples were collected in Campo Grande near of Parque Nacional da Pedra Branca/RJ (National Park of Pedra Branca/RJ). The leaves were collected from adult plants and after the collection the samples were cleaned and placed in the greenhouse for drying, then were mashed and pressed into tablets forms. The analyses were performed using the energy dispersion X-ray fluorescence (EDXRF), developed on the own laboratory and based in a SiPIN detector and a mini X ray tube. It was possible to detect 12 elements in the analyzed samples: K, Ca, Cr, Mn, Fe, Cu, Zn, Br, Rb, Sr, Ba and Pb. The results shows that all elements present higher concentrations than that found in the control samples. Indicating that the biggest source of pollution in these areas has anthropogenic origins as fossil fuel burning in internal combustion engines of motor vehicles, industry and activities associated to the civil construction. , the analysis of the Nerium oleander plant shows a low-cost option and with a substantial efficiency in monitoring environmental pollution.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 34

Fast radiometric method for plutonium monitoring in environmental matrices

Elena Sala[1,2], Ezio Previtali[1,2], Massimiliano Clemenza[1,2], Massimiliano Nastasi[1,2]

[1]*University of Milano-Bicocca*
[2]*INFN Milano-Bicocca section*

In the last century the environmental monitoring has became an important aspect of radio-protection; nuclear tests, fall-out, nuclear accidents and wastes can release a large quantity of radionuclides. Since toxicity and radioactivity of these contaminations are dangerous it is mandatory an environmental control at the area of interest.One of the most significant contamination due to nuclear fall-out events is that of Plutonium isotopes, the most important are ^{238}Pu, ^{239}Pu and ^{240}Pu. Monitoring and security agencies for ionizing radiations use a reference protocol to set the radiological clearance levels for the dangerous isotopes in environment, these values consist in the threshold activity under which there is no danger. The Italian Environmental Protection Agency (ISPRA) reports the clearance levels for the considered isotopes of 150 Bq/kg.For environmental protection it is mandatory to quickly monitor large areas contaminated by possible radioactive fallout in order to establish the best way for site recovering especially for fallout emergency. It is important to use a measurement technique capable to analyze many environmental samples in a fast way. Plutonium concentration in environmental samples can be evaluated with different low level counting techniques, the main techniques are

α spectrometry and mass spectrometry with ICP-MS. These techniques are time consuming because require a long and complex radio-chemical sample pre-treatment and/or long time measurements.A feasible method to avoid sample treatments is to detect the X-rays associated to the decays of all the Plutonium isotopes. This method is more sensitive than γ spectroscopy thanks to the higher B.R. of X-rays. For this purpose a Broad Energy Germanium (BEGe) placed in the Radioactivity Laboratory of Milano-Bicocca has been used. This detector main feature is the capability to register an energy spectrum from 3 keV up to 3 MeV with high efficiency and an excellent energy resolution on the whole spectrum. This system has been optimized through ^{238}Pu standard measurements supported with Monte Carlo simulations needed to evaluate the detection efficiency in different source-detector configuration. An environmental sample, IAEA Fangataufa sediment, measurement has been performed to evaluate the method. The results show that the X-rays Plutonium detection with the BEGe can give information about the contaminations of Plutonium in environmental samples in the range of the clearance levels, set by security agency, in few hours.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 35

Anthropomorfic Phantom to Investigation of Bladder Dose in Gynaecological HDR Brachytherapy

Rogério Vidal Silva[1,3], Walmir Belinato[3], Luiz Andrade Macedo[2], Divanízia Nascimento Souza[1]

[1]*Federal University of Segipe, São Cristovão - SE, Brazil*
[2]*CHAMA Hospital, Arapiraca - AL, Brazil*
[3]*Federal Institute of Bahia, Vitória da Conquista - BA, Brazil*

Intracavitary brachytherapy (ICBT) is an essential component in the treatment of cervical cancer. In 1985, the ICRU-38 proposed guidelines to standardize the dose recording and reporting normal tissue doses in ICBT, aiming for this universal bladder and rectum reference points. Considering the bladder, many studies have demonstrated that the actual dose delivered to this organ is significantly different that one estimated by ICRU reference point. In this way, this paper presents a building model of a dynamic phantom appropriate to bladder dosimetry in ICBT procedures using Radiochromic film and OSL dosimeters. This phantom is able to assess the dose delivered in bladder and to investigate points more representative of dose on this organ surface. The phantom was constructed of polymethyl methacrylate PMMA. Two artificial bladders were 3D-printed from CT images from a female patient during an ICBT planning. Radiochromic films and OSL dosimeters were positioned on the wall of the artificial bladder and the applicators were placement according original CT image. The phantom can simulate the behavior of the dose in bladder in ICBT procedures. The bladder printed in real size can be moved in all directions enabling placement clinical tests for dosimetry in gynecological HDR brachytherapy.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 36

Dose evaluation of ANSI/HPS N13.32-2008 for extremity dosimeter

Chun-liang Chen, Chien-hau Chu, Tzeng-te Huang

Health Physics division, Institute of Nuclear Energy Research, Taiwan (R.O.C.)

In Taiwan, when laboratories of the ionizing radiation field apply for accreditation of the local accreditation organization –Taiwan Accreditation Foundation (TAF), they should pass both on-site assessment and proficiency testing to have the accreditation certificate issued by TAF. Personnel External dosimetry Laboratory supplied to evaluate dose of the radiation stuffs in past several years. This year, the old system, Rialto NE Technology and powder TLD-100H, is going to be replaced by Harshaw DXTRAD system. To implement and verify performances of the new extremity dosimeter system, the criteria, ANSI/HPS N13.32 (2008), has been studied to execute proficiency testing for extremity personnel dosimetry performance in the future. In this study, several ISO beam codes have been used, whereas the differences between both systems have also been compared.Harshaw DXTRAD (TLD-100) ring dosimeter covers TLD-100 chip which is made by Kapton film and fixes on ring card. The reading system includes the Harshaw 8800 PLUS and the WinAlgorithms software. The workers' extremity dose can be calculated through the system and dose correction factor of chips. Moreover, algorithm settings can achieve more accuracy results depend on the known and unknown irradiation conditions. There are two difference conditions to evaluate and compare that includes known and unknown irradiation categories, The results show that DXTRAD system is more stable than old one. This implies that we hold pretty mature techniques in dose evaluation of extremity dosimeter, and can plan to perform the ANSI/HPS N13.32 (2008).

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 37

A Consideration of DAP-based Radiation Dose Management System by the Effect of Scatter Dose

Kyo-tae Kim[1], Jeong-eun Park[2], Ju-yeon Hong[2], Ye-ji Heo[2], Ji-koon Park[3], Sang-hee Nam[1,2,4]

[1]*Dept. of Hybrid Medicine and Science, Inje University, Gimhae, Gyeongnam, Republic of Korea*
[2]*Dept. of Biomedical Engineering, Inje University, Gimhae, Gyeongnam, Republic of Korea*
[3]*Dept. of Radiological Science, International University of Korea, JinJu,Gyeongnam, Republic of Korea*
[4]*Medical Image Research Center, Inje University, Gimhae, Gyeongnam, Republic of Korea*

The world is spending lots of time and funds to construct radiation dose management system. Recently, research is being made to construct radiation management system using DAP (Dose Area Product). DAP is a dosimeter to grasp indirectly the patient's radiation dose, which has the limitation of not considering scatter dose. This study ESE(Entrance Surface Exposure) measured in Chest PA Projection, DAP radiation dose management system was reviewed through comparison with area dose in consideration of the diagnostic reference level and scatter dose presented by the US. In case of considering side scatter dose for area dose, it was found to be a higher value than ESD value under 10mAs of tube current while it was comparatively 14% to 41% lower under other irradiations.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 38

Scintillation properties of Nd-doped fluoride scintillators in the red and near infrared region

Shunsuke Kurosawa[1,2], Akihiro Yamaji[1], Jan Pejchal[2,3], Yuui Yokota[2], Kei Kamada[2,4], Akira Yoshikawa[1,2,4]

[1]*Institute for Materials Research, Tohoku University, Miyagi, Sendai, Japan*
[2]*New Industry Creation Hatchery Center, Tohoku University, Miyagi, Sendai, Japan*
[3]*Institute of Physics, ASCR, Prague, Czech*
[4]*C&A Corp., , Miyagi, Sendai, Japan*

Human body has an optical transparent area around near infra-red region (650 to 1200 nm). Using this "window", a novel real-time dosimeter system can be developed with infra-red emission scintillators. Thus, we show the optical and scintillation properties Nd-doped fluoride scintillators such as Nd:BaF_2, Nd:SrF_2. X-ray excited radio-luminescence spectra of Nd:SrF_2 and Nd:BaF_2 in the infra-red regions were obtained, and we found that the infra-red emission peaks around 920 and 1060 nm, originated from 4F3/2 to 4Ii (i=11/2 and 9/2) transition of Nd^{3+}.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 39

A novel experimental method of in-vivo dosimetry without build-up device on the skin for external beam radiotherapy

Hosang Jeon[1], Jiho Nam[1], Jayeong Lee[1], Dahl Park[2], Wontaek Kim[2], Yonggan Ki[2], Juhye Lee[2], Dongwon Kim[2]

[1]*Department of Radiation Oncology, Pusan National University Yangsan Hospital, Yangsan, Republic of Korea*
[2]*Department of Radiation Oncology, Pusan National University Hospital, Busan, Republic of Korea*

Introduction: The accurate dose delivery is crucial to the success of radiotherapy. The purpose of in vivo dosimetry (IVD) in radiotherapy is to evaluate actually delivered dose to patients. It enables the identification of potential errors in dose calculation, data transfer, dose delivery and patient setup. Various types of detectors have been developed and used for IVD. The IVD detectors for external beam radiotherapy are generally placed on the skin. Thus, the build-up device should be placed on the top of detectors for the satisfaction of electron equilibrium condition. However, there are two disadvantages to use the build-up device in IVD. First, the build-up device is commonly made of tissue-equivalent material or metal which has potential to disturb accurate delivery of planned dose to the patient. Second, it is often laborious and time-consuming process to set the build-up device on the skin because of its considerable volume. In this study, an experimental method for IVD was suggested to solve the problems caused by the build-up device. We suggested a look-up table through a number of measurements using the dosimeter and then calculated the expected dose on the skin where there was only the dosimeter without the build-up device. The IVDs of 126 patients were also performed using our suggested method.Material and methods: The solid water phantom (SP34, IBA, Germany) with the dimensions of 30cm x 30cm x 20cm was

placed on the beam central axis of a linear accelerator (Clinac iX, Varian, CA). We measured the surface doses of six mega-voltage energy beams using the glass rod dosimeters (GRDs) with the 6~20 cm field sizes f and 0~30° gantry angles θ. On the same conditions, we calculated doses at the reference depth of 1.5 cm with radiation treatment planning software (RTP).We defined the correction ratio (CR) that was the measured skin dose divided by the calculated depth dose, and a look-up table of CR(f,θ) was lastly acquired. The CR of an arbitrary radiation treatment field having a fixed f and θ can be obtained by simple bilinear interpolation using this look-up table, and the planned dose at the reference depth is calculated in RTP. It means that we can predict the measured skin dose before actual measurement. The IVDs of 126 patients using CR table were also performed and analyzed.

Results and Discussion: The minimum CR value appeared at the smallest field size and gantry angle, and the maximum CR value was at the largest field size and gantry angle. The error histogram between predicted and measured doses for 126 patients was acquired. The mean error was 3.46% (clinically available), and its standard deviation was 2.69%. There were only 3 errors over 10%. The use of build-up devices is laborious and time-consuming work to radiation therapists. Generally, an IVD requires additional several minutes to prepare and install a dosimeter with the corresponding build-up device. On the other hand, the suggested method only requires a few seconds on average that means the time-cost reduction and the improvement of patient convenience. Moreover, the disturbance of dose delivery to patients can be ignored. We expect that our suggestion can provide a practical and effective IVD method for radiation therapists and patients both.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 40

Implementation of a parallel-beam optical-CT apparatus for three-dimensional radiation dosimetry using high-resolution exquisite CCD camera

Wen-tzeng Huang[1], Chao-nan Hung[2], Chin-hsing Chen[3], Chiu-ching Tuan[2], Yuan-jen Chang[3,4]

[1]*Department of Computer Science and Information Engineering, Minghsin University of Science and Technology, Taiwan (R.O.C)*
[2]*Graduate Institute of Computer and Communication Engineering, National Taipei University of Technology, Taiwan (R.O.C)*
[3]*Department of Management Information Systems, Central Taiwan University of Science and Technology, No.666, Buzih Rd., Beitun District, Taichung City 40601, Taiwan (R.O.C.)*
[4]*Institute of Biomedical Engineering and Materials Science, Central Taiwan University of Science and Technology, No.666, Buzih Rd., Beitun District, Taichung City 40601, Taiwan (R.O.C.), ronchang@ctust.edu.tw*

The gel dosimetry has attracted eyeballs for its potential to achieve validation of three-dimensional (3D) dose distribution as compared with the traditional dosimeters. However, accurate, precise and economic readout tool for gel dosimetry is still challenged for application in clinic. Some imaging modalities such as magnetic resonance imaging, optical CT, x-ray CT and ultrasound were adopted as measurement tools for gel dosimeters. However, considering the latest development of gels such as polymer gel and radiochromic gel, optical-CT has great potential and worth more detailed investigation. A number of optical-CT scanning systems have been developed. First-generation laser-based optical-CT OCTOPUS™-scanner developed by MGS (MGS Research, Inc., Madison, CT, USA) was still considered as the 'gold-standard' due to its reliable and precise results compared with treatment plan system (TPS). However, CCD-based optical-CT scanner can acquire a complete plane of data at each step, and obtained a complete 3D dose distribution rapidly with a speed increase of at least an order of magnitude as compared with laser-based optical-CT. In addition, the low-cost and high-resolution CCD-based optical-CT can be achieved if the CCD camera can improve its signal quality and reduce its cost. In this study, a complete parallel-beam optical-CT scanning system was implemented, including the imaging system, optical lens, image sensor, and image-processing system. In addition, we propose a variety of CCD signal-processing algorithm to reduce noise such as pixel response non-uniformity and the use of a bias clamp. The results were evaluated by comparing with that from commercially available CCD and CMOS cameras.The NIPAM gel dosimeter was used in this study. A clinic five-field irradiation treatment plan was generated using the Eclipse planning system. The gel phantom was irradiated using a 6 MV Varian Clinac IX linear accelerator. The gamma analysis was used as a quantitative evaluation tool with gamma criteria of 3% and 3 mm distance-to-agreement.Our results showed that CCD signal-processing algorithm with 8-bit information could guarantee low-noise output, and the coefficient of variation of pixels was reduced from 12.37% to 0.51% using a flat-field correction with an exposure time of 150 ms. Moreover, for a given pixel pitch, CCD can exploit a manufacturing process that leads to CCD pixel sizes that are larger than those of a metal–oxide–semiconductor (CMOS) sensor, so for a given optical signal, each pixel will have more light incident upon it, leading to higher sensitivity. With the same measurement standards, the signal-to-noise ratio of our system was 30.12 dB, which is better than that of commercially available CCD cameras (25.31 dB), or CMOS cameras (29.53 dB). The 50% modulation transfer function (MTF50) of our 1024×1024 pixel camera gave a line width per picture height (LW/PH) of 745, which is 73% of the diffraction-limited resolution. As compared with a commercially available 1024×768 pixel CCD camera with a LW/PH = 358 and 46.6% of the diffraction-limited resolution, and a 3648×2736 pixel CMOS camera with a LW/PH = 1628 and 59.5% of the diffraction-limited resolution, it indicated that our exquisite camera system provides higher spatial resolution and image quality.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 41

Quantitative evaluation of image registration method used for NIPAM gel dosimeter

Yuan-jen Chang[1,2], Chun-hsu Yao[3,4,5], Jay Wu[4], Bor-tsung Hsieh[6], Yuk-wah Tsang[7], Chin-hsing Chen[1]

[1]*Department of Management Information Systems, Central Taiwan University of Science and Technology, No.666, Buzih Rd., Beitun District, Taichung City, Taiwan (R.O.C.)*
[2]*Institute of Biomedical Engineering and Materials Science, Central Taiwan University of Science and Technology, No.666, Buzih Rd., Beitun District, Taichung City, Taiwan (R.O.C.)*
[3]*School of Chinese Medicine, China Medical University, Taichung, Taiwan(R.O.C.)*
[4]*Department of Biomedical Imaging and Radiological Science, China Medical University, Taichung, Taiwan(R.O.C.)*
[5]*Department of Biomedical Informatics, Asia University, Taichung, Taiwan(R.O.C.)*
[6]*Department of Biomedical Imaging and Radiological Sciences, Central Taiwan University of Science and Technology, Taichung, Taiwan (R.O.C.)*
[7]*Department of Radiation Oncology, Ditmanson Medical Foundation Chiayi Christian Hospital, Chiayi, Taiwan (R.O.C.)*

There is a clear need for technology that enables accurate, high-resolution, three-dimensional (3D) measurement of intricate dose distributions associated with modern radiation treatments such as intensity-modulated radiotherapy, tomotherapy, cyber knife, proton therapy, and brachytherapy treatment. The polymer gel dosimetry has become emerging technology due to its great potential to achieve validation of three-dimensional (3D) dose distribution for radiation therapy. Among imaging modalities for gel dosimetry, such as magnetic resonance imaging (MRI), optical CT, x-ray CT and ultrasound, CCD-based optical-CT scanner has advantages of simple structure of mechanism and can obtain a complete 3D dose distribution rapidly. It indicated that the low-cost and high-resolution CCD-based optical-CT can be achieved. In the methodology of gel dosimetry, one important step is the pre- and post-irradiation scan. This process might induce two types of errors. The first one is the positioning error. Xu and Wuu claimed that the maximum uncertainty up to 2.49% is caused by inaccuracies in the positioning process. Generally, the markers were placed on the flask for the purpose of alignment. The second encountered problem is the geometrical distortion of reconstruction image measured by optical-CT. One solution is the adoption of best fit refractive index of matching liquid in measurement of optical density. But it remains a challenge for the dose map image alignment between measured data and treatment plan system (TPS). A registration technique was used for the dose map of TPS and that measured from optical-CT or MRI. In this study, a novel method was proposed to solve these two problems mentioned above. To reduce gel positioning error, a precise positioning gel holder design was used to solve the problem. Passive alignment technique with the pin-holes clamp made it more accurate and easier to re-position the gel phantom in pre- and post- scans. Unlike previous design used in commercial optical-CT, which used four-arms clamp design, new design can improve the image quality because the subtraction from pre-irradiation data can correct many optical artifacts. The new passive-alignment design showed that the artifacts can be reduced in the reconstruction image of gel dosimeter, especially near the wall of phantom. Thus based on the improvement of positioning accuracy, the high level image alignment technique can be used to align dose map of measured data from optical-CT and TPS. A new SIFT-flow algorithm was proposed to solve this problem. It allow to align two images contain objects in a variety of scenes. The SIFT-flow was used for image alignment when the gamma comparison was conducted in this study. Figure 1 is the gamma maps of a six-fields irradiation in NIPAM gel dosimeter. The results showed that the gamma pass rate can increase from 85.6% to 94.9% when SIFT-flow algorithm was applied. The results also showed that the distortion occurred in the dose map image constructed from optical-CT can be correctly aligned with that of TPS using SIFT-flow algorithm. Therefore, the improved gamma comparison results can be achieved.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 42

OFFSET3: a large area, scintillation-fiber tracker for real-time particle imaging

Domenico Lo Presti[1,2], D.l. Bonanno[1], F. Longhitano[2], C. Pugliatti[1,2], S. Aiello[2], G. A. P. Cirrone[3], V. Giordano[2], E. Leonora[2], N. Randazzo[2], S. Reito[2], F. Romano[3], G.v. Russo[1,2], V. Sipala[4,5], C. Stancampiano[2], C. Ventura[2]

[1]*University of Catania, Catania (Italy)*
[2]*INFN - Sezione di Catania, Catania (Italy)*
[3]*LNS, Catania (Italy)*
[4]*University of Sassari, Sassari (Italy)*
[5]*INFN – Sezione di Cagliari, Cagliari (Italy)*

The performances of the OFFSET3 tracker (Optical Fiber Folded Scintillating Extended Tracker) are presented. It exploits a novel system for particle tracking, designed to achieve real-time particle imaging and tracking, large detection areas, and a high spatial resolution especially suitable for applications in medical diagnostics. The tracker is composed by two 29x29 cm^2 FOV position detectors stacked by 10 cm, made by 500 micron squared scintillating fibers ribbon for both directions. The track position information is extracted in real-time in an innovative way, using a reduced

number of read-out channels, thank to which it's possible to obtain the large detection area with moderate costs and complexity. The architecture has been patented by the Istituto Nazionale di Fisica Nucleare (INFN). The performances of the tracker were investigated by beta sources, cosmic rays, 60 MeV- 250 MeV proton and 400 MeV/A carbon clinical beams.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 43

Study on physical parameters of a breast phantom with silicone implant and their influences to mammography

João Vinícius Batista Valença[1], Renan Garcia Passos[1], Fábio Alessandro Rolemberg Silva[2], Divanizia Nascimento Souza[1]

[1]*Departamento de Física, Universidade Federal de Sergipe, 49100-000, São Cristóvão, SE, Brazil.*
[2]*Departamento de Radiologia, Universidade Tiradentes, 49032-490, Aracaju, SE, Brazil*

The discussion about the interference of the silicone implant in screening for breast cancer is not new, and there is a perceived mainstream publications with statistical analyzes comparing the diagnosis and stage of disease in a group of women who developed breast cancer, having some of them implant. The inclusion of these discussions of data from studies with breast phantoms is of great importance, in view of the experimental freedom that these objects provide. Considering the need to continue studying the possibilities of using phantoms with silicone implant to screening for breast cancer, the goals of our work are based on the determination of comparative data related to positioning of the implant in phantom and its effective atomic number (Zeff) and mass attenuation coefficient (μ/ϱ). The study was based on a phantom proposed in literature. In order to evaluate the efficiency of mixing of paraffin gel and acrylic powder employed in phantom proposed we analyzed different proportions of these materials. The CHN elemental analysis was conducted for each of the ratios evaluated. Calculations of the effective atomic number and mass attenuation coefficient were also conducted for each proportion in order to check the one best suited to the simulation of the mammary gland and adipose tissue. Several exposures with different compression characteristics and techniques were performed to evaluate the optical densities of the films. The materials used in the phantom studied were more realistic than from other phantoms usually made with acrylic sheets. It was estimated that the breast tissue with a thickness of 5 mm around the implant presents greater variations in optical density which may preclude an accurate diagnosis for tumors in this region.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 44

RENAL DYNAMIC PHANTOM FOR QUALITY CONTROL IN SPECT

Marcos Alexandre Dullius[1], Mateus Fonseca[2], Marcelo Botelho[2], Clêdison Cunha[2], Divanízia Souza[2]

[1]*Universidade Federal da Fronteira Sul, Campus Cerro Largo-RS, Brazil, 97900-000*
[2]*Universidade Federal de Sergipe, São Cristóvão-SE, Brazil, 49100 000*

To ensure quality assurance in nuclear medicine it is necessary the use of phantoms to perform quality control tests. The phantoms can provide three-dimensional and morphological parameters that are necessary to calibrate equipment individually and comparatively. The accuracy of some diagnostic methods in nuclear medicine can be more easily achieved using dynamic phantoms. Ideally, a specific phantom must be employed for each type of organ. The dynamic renal scintigraphy using DTPA (diethylenetriamine pentaacetic acid) is labeled with technetium-99m. DPTA acts as a renal radiopharmaceutical tracer, almost completely filtered by the glomerulus, allowing an evaluation of the dynamics of renal blood flow and its symmetry, the topography and morphology of the kidneys, and the passage of the radiopharmaceutical through the urinary tract to the bladder. In this work we develop and evaluate the performance of a renal dynamic phantom for use in SPECT. This phantom is composed of anthropomorphic kidneys composed of alginate, and having the same geometry and proportions of an adult human kidney. These artificial kidneys are filled with a thin layer of autopolymerizing acrylic resin. An injection pump connected enables the flow of the radiopharmaceutical into these kidneys. An electrical system controls how long each pump remains in operation. Changes in operating time imply at different flow rates of elimination of the radioisotope, simulating various forms of disposal in scintigraphy with 99mTc-DTPA. Image of the phantom was obtained with dynamic protocol and compared with clinical data. The acquired images are similar to the one obtained in clinical renal scintigraphy. Using the phantom, it was possible to evaluate the response so far from the imaging system to renograms diagnosed as normal. Furthermore, tests performed with this phantom allow intercomparisons between different renograms, scintillation cameras, and nuclear medicine services.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 45

ATTENUATION OF BREMSSTRAHLUNG FROM ^{90}Sr-^{90}Y, ^{147}Pm AND ^{204}Tl IN THICK TARGET COMPOUNDS

Dr Hc Manjunatha[1], Prof L. Seenappa[2]

H.C.Manjunatha Department of Physics, Government College for women, Kolar, Karnataka, India manjunathhc@rediffmail.com

The external bremsstrahlung (EB) produced by beta particles such as from ^{90}Sr-^{90}Y, ^{147}Pm and ^{204}Tl in $PbCl_2$, PbF_2, $Pb(NO_3)_2$and CdO were measured using NaI(Tl) crystal. The beta stopper technique is employed to measure the integral intensities above 100keV energy in different absorber thicknesses. Attenuation of the external bremsstrahlung, excited by 90Sr-90Y, 147Pm and 204Tl beta-emitters in the same compounds has also been studied. The measured attenuation parameter decreases with increasing absorber thickness and it increases with increasing Zmod of the absorber at a particular thickness. Where as, the mass attenuation coefficient of gamma rays of equivalent energy is independent of the absorber thickness. . This confirms that the attenuation of EB in an absorber does not conform to a single exponential law, unlike the absorption of monoenergetic gamma rays. Rather it may be a combination of a large number of exponential terms.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 46

Annual doses for the cave deposits around Çatalhöyük Archaeological Site in Turkey

Enis Sert[1], Ülkü Ulusoy[2], Onur Özbek[3]

[1]Çankiri Karatekin University, Department of Physics, Çankiri, TURKEY
[2]Hacettepe University, Department of Physics Engineering, Ankara, TURKEY
[3]Çanakkale (18th March) University, Department of Archaeology, Çanakkale, TURKEY

Radiation effect dating methods such as Electron Spin Resonance (ESR), Thermoluminescence (TL) and Optically Stimulated Luminescence (OSL) requires the determining of the dose rates or annual doses for the sample sites. In order to evaluate this, the dose rates of the α, β or γ radiation emitted by ^{238}U, ^{232}Th-series and ^{40}K radioactive elements inside crystal lattice or exterior materials within about 30 cm as well as the cosmic rays should be calculated or measured directly in situ.

In this work, the dose rates have been determined for five caves around Çatalhöyük archaeological site in Turkey. For this, two different methods are used: i. directly measuring dose rates in situ by using a portable γ- spectrometer for four caves, ii. calculating dose rates by the contribution of radioactive contents of the crystal lattice and surrounding sediment of the cave as well as the cosmic rays by using the equations in Grün (1989).

At the first way, dose rates were measured by a portable γ- spectrometer for many locations inside and outside of at the caves. At the second way, the dose rates were calculated for maximum, average and minimum concentrations of the radioactive contents for many speleothem samples for each cave. The results were compared with each other. The calculated dose rates seem to be very low than the measured dose rates. Even by using the maximum concentration of the radioactive elements in the sediment, the nearest value to the measured one has been the ¼ of the measured value. The measured and calculated dose rates are listed in the table for five caves.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 47

Improved CCD-based optical computed tomography scanner used in gel dosimetry using a speckle reduction technique

Yuan-jen Chang[1,2]

[1]Department of Management Information Systems, Central Taiwan University of Science and Technology, No.666, Buzih Rd., Beitun District, Taichung City, Taiwan (R.O.C.)
[2]Institute of Biomedical Engineering and Materials Science, Central Taiwan University of Science and Technology, No.666, Buzih Rd., Beitun District, Taichung City, Taiwan (R.O.C.)

The recent development of CCD-based optical computed tomography (optical-CT) scanner enabled the possibility of fast and low-cost three-dimensional (3D) gel dosimetry used in modern radiotherapy applications [1-6]. The CCD-based optical-CT is capable of acquiring complete plane of data at each step, and obtained a complete 3D dose distribution rapidly. A number of previous works proposed various configurations of CCD-based optical-CT [2-6]. Generally, a pin hole combined with diffuser was used to generate uniform light source [6]. However, the ring artefacts appeared in reconstruction image [6]. Some image processing techniques were proposed to remove these artefacts [3,6]. But the results showed it was not sufficient to remove the artefacts. In this study, a speckle reduction technique was adopted to remove ring artefacts in reconstructed image measured from CCD-based optical-CT. An optical-CT scanner (CT-s2) was developed to scan the NIPAM gel dosimeter, as shown in Fig. 1. The laser used in CT-s2 was a diode laser with 120 mW power and 660 nm wavelengths (Power Technology Inc., Little Rock, AR, USA). A rotating diffuser was used in the laser light path in between the laser and the collimating lens. The parallel laser light passed through the cylindrical acrylic gel container and was recorded by a CCD camera. To reduce effect of refraction and reflection, the best-fit refractive index of matching liquid was used in the aquarium [7]. The NIPAM polymer gel was prepared according to the instructions of Senden et al. [8]. The gel phantom was irradiated using a 6 MV Varian Clinac IX linear accelerator (Varian Corporation, Palo Alto, CA, USA). The treatment field was made up of 4 cm X 4 cm square fields with prescribed dose 5 Gy and 300 cGy (535 MU).The reconstructed image of a transverse slice and line profiles of reconstructed image at depth=40 mm. were shown in Fig. 2. Obviously, the fluctuation pattern of reconstructed image shown in Fig. 2 can be reduced using rotating diffuser compared with that using static diffuser. When using the static diffuser, as mentioned in previous research [9], a same speckle pattern is recorded and became localized at infinity of the reconstructed image. If the moving distance is adopted, uncorrelated speckle patterns are superposed in the recorded images. Thus the speckle contrast at infinity reduces and the fluctuation pattern shown in reconstructed image can be minimized.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 48

The application of 90º scattering charged particle irradiation platform in GBM cancer stem cell research

I-chun Cho[1,2], Huan Niu[3], Fang-hsin Chen[1,2], Chuan-jong Tung[1,2]

[1]*Department of Medical imaging and Radiological Sciences, Chang Gung University, Taoyuan, Taiwan*
[2]*Institute for Radiological Research, Chang Gung University and Chang Gung Memorial Hospital, Taoyuan, Taiwan*
[3]*Nuclear Science and Technology Development Center, National Tsing Hua University, Hsinchu, Taiwan*

Glioblastoma multiform (GBM) is the most common and lethal brain tumor in human. The mean survival of GBM patient is about 12-15 months. The particular poor outcome of chemotherapy and conventional radiation therapy in GBM treatment was considered relate with the existence of GBM cancer stem cells (CSCs). GBM CSCs were believed have high resistance to chemotherapy and conventional radiation therapy. Therefore, how to effectively decline the CSCs is the most important issue in GBM treatment development. Charged particle therapy, like proton therapy or boron neutron capture therapy (BNCT) is believed has higher capability in CSCs elimination. In this study, we use the 90º scattering charged particle irradiation platform to study the difference of DNA damage induction and DNA repair capability between non-stem like GBM cell and CSCs. The 90º scattering charged particle irradiation platform is a cell irradiation platform which can provide a uniform 2 MeV alpha beam in vertical direction. The cancer stem cell was isolated from GBM primary culture cell line by using CD-133 microbeads. In this study, the expression of γ-h2ax histone protein was used as a biomarker of radiation induced DNA double strand break. The preliminary results show that the CD-133$^+$ CSCs have higher γ-h2ax expression than CD-133$^-$ GBM cell. Meanwhile, the dissolution of γ-h2ax signal is much fast in stem like GBM cell than non-stem like GBM cell. The results show that a more extensively DNA damage repair mechanism was triggered in cancer stem cell.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 49

Evaluation of radiation doses and image quality for anterior-posterior/posterior-anterior kV portal imaging of lung radiotherapy

Ho-hsing Chen[1], Shen-yein Wang[2], Yen-sheng Tyan[2], Jia-fu Lin[1], Shang-lung Dong[2]

[1]*Department of Radiation Oncology, Taichung Veterans General Hospital, Taichung City, Taiwan*
[2]*School of Medical Imaging and Radiological Sciences, Chung Shan Medical University, Taichung City, Taiwan*

Introduction

The kilovoltage (kV) X-ray portal imaging is widely used in image-guided radiation therapy (IGRT) for the patient setup verification. It is useful for reducing the patient doses by using the posterior-anterior (PA) projection radiography. The purpose of this study is the evaluation of radiation doses and image quality for anterior-posterior (AP)/posterior-anterior kV portal imaging of lung radiotherapy.

Materials and Method

An on-board image system built in a Varian 21ix linear accelerator was used. A RANDO phantom was imaged using clinical chest exposure settings (75 kVp and 5 mAs) and AP and PA kV portal images were acquired. The contrast-to-noise ratio (CNR) was calculated for each image. The PC-based Monte Carlo program (PCXMC) was used for calculating the organ doses and effective dose of each exposure.

Results

The measured values of air KERMA of AP and PA projections at the isocenter were 0.242 and 0.212 mGy, respectively. For the AP projection, the calculated organ dose of breasts, thymus and heart were 0.18, 0.231, 0.1 mGy, respectively. For the PA projection, the calculated organ dose of breasts, thymus and heart were 0.014, 0.014, 0.022 mGy, respectively. The CNR values of AP and PA projections were 17.85 and 16.14, respectively.

Conclusion

Results from this study demonstrated that the radiation doses of PA kV portal imaging of lung radiotherapy were significantly reduced and the image quality was slightly decreased. The PA kV portal imaging may be suitable for lung radiotherapy.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 50

Evaluation of equivalent thickness of BR-12 slab for different age group of Taiwanese women

Shang-lung Dong[1], Yu-hsiu Yeh[2], Yu-ting Chao[1], Yen-sheng Tyan[1]

[1]*School of Medical Imaging and Radiological Sciences, Chung Shan Medical University*
[2]*Department of Radiology, Cheng Hsin General Hospital*

Introduction

The estimations of average glandular dose (AGD) and image quality are important issues in mammography. To provide a simple method for determination of the AGD and image quality, various testing phantoms have been recommended in mammographic protocols from different countries. BR-12 slab is one of important breast-tissue-equivalent materials for the simulation of a patient exposure in mammography. The purpose of this study was to evaluate the equivalence between exposure factors acquired from BR-12 slabs and patient cases of Taiwanese women in mammography.

Materials and Method

This study included 3910 craniocaudal screen/film mammograms on Taiwanese women. The tube loading, compressed breast thickness (CBT), tube voltage, and target/filter combination for each mammogram were collected for all patients. The equivalent thickness of BR-12 was determined for each breast using the exposure factors of the breast in combination with experimental measurements from BR-12 slabs. Equivalent thicknesses of BR-12 to the breasts of Taiwanese women were estimated.

Results

The results from this study show that the range and average equivalent BR-12 thickness were1.8-6.6 cm and 4.2 ± 0.8 cm, respectively. Additionally, 99% of equivalent BR-12 thicknesses was within the range of 2-6 cm. The average thickness of BR-12 slabs producing the same exposure factors as observed in this study is less than that reported for American women (4.9 cm). The equivalences between thickness of BR-12 slabs and CBT of patients were determined for the age groups 30-49 years and 50-69 years. For the same CBT, the equivalent BR-12 thickness calculated from the age group 30-49 years is thicker than that obtained from the age group 50-69 years.

Conclusion

The average thickness of BR-12 slabs producing the same exposure factors as observed in this study is 4.2 cm which is greater than the average thickness of PMMA slabs (4.0 cm) obtained in our previous study. Results from this study may provide useful information for mammographic dose survey.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 51

Dose standardization and spectrum verification in Computed Tomography

Chien-hau Chu, Yi-chun Lin, Tzeng-te Huang

Health Physics Division, Institute of Nuclear Energy Research, Taiwan (R.O.C.)

The "Standards for Medical Exposure Quality Assurance" was enacted by the Atomic Energy Council (AEC) in Taiwan. Thus, the performance assessment of QA instrumentation must be calibrated in computed tomography. The INER measurement standard for the air-kerma length from computed tomography (CT) is described in detail. The beam code for CT chamber calibration recommended by the National Institute of Standards and Technology (NIST) was M120, and its added filter was made of aluminum sheets. CT scans are usually operated in 80-140 kVp X-ray range, other beam codes (M80, M100 and M150) were set up for all energy range applications. The HPGe detector and Compton spectrometer spectrum measurements have also been made for several CT beam qualities. Spectrum differences were compared for measuring by using HPGe system and calculating by using XCOM5R software. According to the IEC 61674, a diaphragm aperture design corresponding to 50% of the chamber rated length was used, whose setup resembles more closely to the clinical situation. And over the rated length, the spatial uniformity of the response varies by less than 3.0 %. The expanded uncertainties (k=2) were within 1.0 %, and the x-ray air kerma length calibration factors were evaluated using the ISO GUM. The comparison with the NIST had a difference less than 0.9 % using transfer ionization chambers (Exradin A101). The results indicated that the CT calibration standard was in reasonable agreement within the standard uncertainty, and it appeared to meet the requirements of the criteria and the needs of the users of clinical practices. The air-kerma length standardization could start with routine calibration services for these beam qualities.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 52

Evaluation of ABS and PLA Thermoplastics For Use As Tissue Substitute in Radiotherapy With Photons Beams

Rogério Vidal Silva[1,2], Walmir Belinato[3], Luiz Andrade Macedo[2], Divanízia Nascimento Souza[1]

[1]*Federal University of Sergipe, São Cristovão-SE, Brazil*
[2]*CHAMA Hospital, Arapiraca-AL, Brazil*
[3]*Federal Institute of Bahia, Vitória da Conquista-BA, Brazil*

Radiotherapy is one of the main modalities in the treatment of cancer. During the planning, the medical radiation team can delineate the GTV, CTV and PTV and risk organs from CT, PET-CT and MR 3D images and estimate the dose values for these structures. However the verification of the real dose distribution delivery on patient tissue is very complicate, because in most cases, is essencialy impossible to place dosimeters inside the body. To evaluate the real dose distribution in organs, most tissue substitutes and phantoms have been developed. Although, actually, most types of commercial solid water are available these products are, in general, sold in plate shape. In a 3D pespective to evaluate the real dose distribution inside the patient remains a challenge due the complexity of the structures inside the body. By other way, 3D printer can reproduce tridimensional volumes with high fidelity and correctly employed can be used for reconstruction of clinical structures such as organs. However, as the physical and dosimetric properties of these materials used for the printing are not well known, in this way, this paper shows the study performed to evaluation of two of the main materials used by 3D printing considering their use as substitute tissue in radiotherapy with megavoltage photons beams. The materials selected to evaluation were polylactide (PLA) and acrylonitrile butadiene styrene (ABS) commercialized by BFB. The analyzes performed were based on document REPORT 44 of the International Commission on Radiation Units and Measurements (ICRU). For assessment of the physical and chemical properties were analyzed: the density; the composition; degradation by repeated irradiations; theoretical mass attenuation coefficient ($\mu t/\varrho$); practical mass attenuation coefficient - ($\mu p/\varrho$). The Monte Carlo code MCNPX version 2.7.0 also was used to confirm the results obtained from ionization chamber. The material showed no change in their behavior after undergoing 10KGy, which corresponds to approximately

5000 radiotherapy sessions. The density founded were 1,23 ±0,13 and 1,02 ±0,05 for PLA and ABS, respectively. The ABS and PLA presented higher concentration of carbon which is excellent for a tissue simulator, decreasing the Z_{eff} (Effective Atomic Number). The ABS e PLA presented good behavior for energy range of radiotherapy.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 53

Fast convergence method for iterative image reconstruction with gradient total variation (GTV) algorithm in cone-beam computed tomography

Chang-woo Seo[1], Bo Kyung Cha[1], Keedong Yang[1], Sungchae Jeon[1], Young Huh[1], Justin C. Park[2], Bongyong Song[2], William Y. Song[2]

[1]*Advanced Medical Device Research Center, Korea Electrotechnology Research Institute, Gyeonggi-do 426910, South Korea*
[2]*Center for Advanced Radiotherapy Technologies and Department of Radiation Medicine and Applied Sciences, University of California San Diego, La Jolla, California 92093, USA*

This paper describes the improvement of convergence speed for reconstruction algorithm with gradient total variation (GTV) in low-dose cone-beam computed tomography (CBCT). We derive a fast algorithm for the constrained total variation (TV)-based a minimum number of noisy projections. To achieve this task we combine the GTV at a TV-norm regularization term to promote an accelerated sparsity inherent in the X-ray attenuation characteristics of the human body. The GTV is derived from a TV and enforces more efficient computationally and faster in convergence until a desired solution is achieved. We apply a gradient projection algorithm that seeks a solution iteratively in the direction of the projected gradient while enforcing a non-negatively of the found solution. To acquisition the projection data from a prototype CBCT system, we applied the X-ray tube (A-132, Varian inc.) having rhenium-tungsten molybdenum target and flat panel amorphous silicon x-ray imaging sensor (PaxScan 4030CB, Varian inc.) having a 397 x 298 mm active area with 388 μm pixel pitch and 1024 x 768 pixels in 2 by 2 binning mode. The 360 (30 fps × 12 s) projection data for the reconstruction were acquired. In comparison with the Feldkamp, Davis and Kress (FDK), the proposed algorithm was available to acquire equivalent image quality comparing with FDK algorithm in reducing the 50% projections. Also, this method showed convergence in ≤14 iterations whereas original TV algorithm needs at least 27 iterations in order to reconstruct the chest phantom image. Future investigation includes improvement in imaging quality, particularly regarding X-ray cone-beam scatter, and motion artifacts of CBCT system.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 54

CT-based Monte Carlo dose calculations for gynecology brachytherapy employing a Henschke applicator

Pei-chieh Yu[1,2], Chuan-jong Tung[3], Hsing-yi Lee[5], Hsin-hua Nien[2], Chung-chi Lee[3,4], Ching-jung Wu[2], Tsi-chian Chao[3]

[1]*Department of Biomedical Engineering and Environmental Sciences, Natioanl Tsing Hua University, 101 Sec. 2, Kung Fu Road, Hsinchu 30013, Taiwan*
[2]*Department of Radiation Oncology, Cathay General Hospital, 280 Renai Rd. Sec.4, Taipei 106, Taiwan*
[3]*Department of Medical Imaging and Radiological Science, Chang Gung University, 259 Wen-Hwa 1st Road, Kwei-Shan, Tao-Yuan 333, Taiwan*
[4]*Department of Radiation Oncology, Chang Gung Memorial Hospital, 5 Fu-Hsin Street, Kwei-Shan, Tao-Yuan 333, Taiwan*
[5]*Department of Radiation Oncology, Sijhih Cathay General Hospital,No.2, Ln. 59, Jiancheng Rd., Xizhi Dist., New Taipei City 221, Taiwan*

In recent years the Henschke applicator has been widely used for gynecologic patients treated by brachytherapy in Taiwan. However, the commercial brachytherapy planning system (BPS) did not properly evaluate the dose perturbation caused by the metal ovoid structures of Henschke applicator. Because of dose perturbation of the Henschke applicator is a major concern for the BPS. We use Monte Carlo N-Particle Transport Code eXtended (MCNPX) to evaluate the Ir-192 source dose distribution of Henschke applicator embedded in heterogeneous patient computed tomography (CT) geometries for intracavitary brachytherapy. This study included two scenarios. First, to investigate dose impact owing to disregard the metal shielding effect, Monte Carlo simulation, and film measurements have been performed for dose assessment in a solid water phantoms. Second, the heterogeneous patient CT geometries are applied to MCNPX for dose calculation of heterogeneous assessments. The comparison between simulation dose calculation and film measurements for solid water phantom CT geometries with Henschke applicator were in good agreement. But, isodose distributions with Henschke applicator by the MC simulation showed significant deviation (-80.55%±7.52%) to those without Henschke applicator. Furthermore, the dose discrepancy of prescription dose in the heterogeneous patient CT geometries with Henschke applicator and solid water phantom CT geometries with Henschke applicator showed no significant deviation (-10.81%±18.7%). This disagreement included that the applicator placement was not exactly the same with simulation condition. But the effect of tissue heterogeneous is still smaller than the metal shielding effect of Henschke applicator. The dose discrepancy for including and excluding Henschke applicator has shown significant

differences, as reported previously in the literature. The overestimation is 80.55% in treatment area. This study demonstrates that the metal ovoid structures of Henschke applicator cannot be disregard from brachytherapy dose calculation. Further, the dose discrepancy derived from the tissue heterogeneities was less than from the metal ovoid shieldings. The MC results demonstrate the inability of Brachytherapy Planning System to account for heterogeneities. Thus, dose distribution of applicator must be evaluated before using new applicator.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 55

Denoising of Small Animal PET Images Using Variational Nonconvex Functional

Jose Mejia[1], Boris Mederos[1], Humberto J. Ochoa[1], Ramon A. Mollineda[2]

[1]*Universidad Autónoma de ciudad Juárez, México*
[2]*University Jaume I, Castelló de la Plana, Spain*

In this paper is introduced a novel nonconvex variational method to denoise reconstructed small animal PET images. The proposed approach carries out a selective smoothing according to the local regularity of each region of the reconstructed noisy image. The method is able to smooth the images while preserving details and borders. Several experimental results have been conducted to show that the proposed technique leads to better results than some of the state of the art post-reconstruction denoising algorithms.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 56

Non-uniformity Correction for Photon-Counting X-Ray Detector Using Multiple Data Points

Yu -na Choi, Seungwan Lee, Hee-joung Kim

Department of Radiological Science and Research Institute of Health Science, Yonsei University, Korea

Photon-counting detectors for hard X-ray imaging have been developed in the last few years. However, current photon-counting detectors based on CdTe and CZT suffer from pixel-to-pixel variation in intrinsic detection efficiency. While most conventional X-ray detectors have a reasonably linear response, photon-counting detectors may have a non-linear relationship between the number of X-ray photons reaching the detector and detected photons depending on the count rate of the detector. Therefore, in this study, we proposed a non-uniformity correction method based on various calibration data points for each pixel of the detector that take the x-ray attenuation of the target object into consideration using a set of homogeneous Al sheets of different thicknesses. We performed a phantom study to demonstrate the effect of the new method on image quality. The results from PID-350 showed that the conventional flat-field (FF) correction method performed best only when the Al thickness for the raw image corresponded to the Al thickness that was used to derive the correction map. On the other hand, our correction method outperforms the raw data and the fixed FF correction method in all cases. In conclusion, we experimentally demonstrated that the FF correction using multiple data points is essential to correct the non-uniformity of photon-counting detector with non-linear count rate characteristics.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 57

Monte Carlo simulations in multi-detector CT (MDCT) for two PET/CT scanner model using adult phantoms MASH and FASH

Walmir Belinato[1,2], William Souza Santos[2], Divanizia Nascimento Souza[2]

[1]*Bahia Federal Institute of Education, Science and Technology – IFBA, Vitória da Conquista, Bahia, Brazil*
[2]*Department of Physics, Federal University of Sergipe – UFS, São Cristóvão,Sergipe, Brazil*

Computed tomography (CT) evolving multi-detector (MDCT) modalities is a radiographic process that produces a photon attenuation map of the patient based on the variable attenuation of a beam of x-rays as it passes through a patient. The positron emission tomography (PET) is well established diagnostic modality based on the detection, in coincidence, of two 511 keV photons emitted, at 180 ± 0.5º from each other, following

the annihilation of a positron and an electron in internal structures to patient. This combination is extensively used in oncology for tumor diagnosis, staging, radiotherapy planning and monitoring, as well as cardiology and neurology. It is possible determine the absorbed dose from each CT scan procedure with tally values in units of MeV/gram/source particle using to absorbed dose in units of mGy/100 mAs by a experimental conversion factor (CF). MCNPX is a general purpose Monte Carlo radiation transport code designed to track many particle types over broad ranges of energies. This study proposes to determine Conversion Factors (CF

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 58

Qualitative analysis of Rhodnius prolixus head using synchrotron radiation phase contrast computed microtomography

Gabriela Sena Souza[1], André Almeida[2], Delson Braz[1], Liebert Nogueira[2], Marcos Colaço[2], José Soares[2], Simone Cardoso[3], Eloi Garcia[4], Patricia Azambuja[4], Marcelo Gonzalez[5], Sara Mohammadi[6,7], Giuliana Tromba[7], Regina Barroso[2]

[1]*COPPE/Federal University of Rio de Janeiro, Brazil*
[2]*Medical Physics Laboratory/Physics Institute/State University of Rio de Janeiro, Brazil*
[3]*Physics Institute/Federal University of Rio de Janeiro, Brazil*
[4]*Laboratory of Biochemistry and Physiology of Insects/Oswaldo Cruz Institute/ FIOCRUZ, Brazil*
[5]*Department of General Biology/Federal University Fluminense, Brazil*
[6]*Department of Physics, University of Trieste, Italy*
[7]*Elettra - Sincrotrone Trieste ScpA, Trieste, Italy*

In recent years advancements in microcomputed tomography (microCT) have increased the achievable resolution and contrast, making this relatively inexpensive and widely available technology potentially useful for studies of insect internal morphology. Phase Contrast X-Ray Synchroton Microtomography (SR-PhC-microCT) is a non-destructive technique that allows the microanatomical investigations of Rhodnius prolixus, one of the most important insect vectors of Trypanosoma cruzi, the etiologic agent of Chagas disease. In Latin America, vector control is the most useful method to prevent Chagas disease, so study Rhodnius prolixus is very important and a detailed knowledge of the interior of structures is crucial for a better understanding of their function and evolution. Traditionally, in both biological morphology and anatomy, the internal structures of whole organisms or parts of them are accessed by dissecting or histological serial sectioning, so studying the internal structures of Rhodnius prolixus head using SR-PhC-microCT is of great importance in researches of vector control. In this work, volume-rendered SR-PhC-microCT images of the heads of selected Rhodnius prolixus samples were obtained using the new set-up available at the SYRMEP beamline of Elettra (Trieste, Italy). In this new set-up, the outcoming beam from the ring is restrained before the monochromator and in a devoted end-station, absorption and phase contrast radiography and tomography set-up are available. Three different groups of Rhodnius prolixus were used. One group was fed with defibrinated rabbit blood and after 10 days was sacrificed, other group was sacrificed 4 days after feeding and the last group remained unfed. The resulting voxel datasets were visualized with Avizo 8.0 software, allowing to see details inside the organs of the insect. This kind of visualization could be very helpful in the study of Rhodnius prolixus and consequently in vector control.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 59

Evaluation of dose equivalent in the labyrinth of a 230 MeV proton therapy facility at CGMH using tissue equivalent proportional counter

Kuan-wei Jin[1], Chuan-jong Tung[1,2], Shien-hsin Chen[1,3], Hui-yu Tsai[1,2]

[1]*Department of Medical Imaging and Radiological Sciences, Chang Gung University, Taoyuan, Taiwan*
[2]*Institute for Radiological Research, Chang Gung University and Chang Gung Memorial Hospital, Taoyuan, Taiwan*
[3]*Department of Radiation Oncology, Chang Gung Memorial Hospital, Taoyuan, Taiwan*

The first proton therapy center in Taiwan is planned to practice clinical treatment at the Chang Gung Memorial Hospital (CGMH) in the late 2014. The facility has four rooms with two wobbling delivery systems and two pencil beam-scanning systems using 70-230 MeV protons for treatment. Radiation fields around the proton therapy facility are highly facility dependent and complex. Secondary radiations include heavy ions, neutrons, photons, and electrons, with a wide range of energy. The dose equivalent in workplace, dominated by neutrons, is one of the most concerned issues. A tissue equivalent proportional counter (TEPC) was used to measure dose equivalent in the mixed radiation field with different

radiation qualities. A homemade TEPC was placed at several positions in the cyclotron room and the treatment room to determine the linear energy distribution of the energy deposition in a mass of gas equivalent to a 2-μm diameter volume of unit density tissue that is similar to the size to the nuclei of biological cells. The TEPC was well calibrated and filled with propane-based TE gas at low pressure. The dead time and time-shift effect were also checked. The dose equivalent was then calculated through the quality factor, which is a function of lineal energy. This study preliminarily evaluated the composition of mixed radiation fields and dose equivalents in workplace of CGMH proton therapy center.Keywords: tissue equivalent proportional counter, linear energy distribution, dose equivalent, proton therapy

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 60

Activation Analysis Study on Li-Ion Batteries for Nuclear Forensic Applications

Erik B. Johnson[1], Chad Whitney[1], Keith E. Holbert[2], Tyler Stannard[2], Taipeng Zhang[2], Anthony Christie[2], Peter Harper[2], Blake Anderson[2], James F. Christian[1]

[1]*Radiation Monitoring Devices, Inc.*
[2]*University of Arizona*

The nuclear materials environment has been increasing significantly in complexity over the past couple decades. The prevention of attacks from nuclear weapons is becoming more difficult, and nuclear forensics is a deterrent by providing detailed information on any type of nuclear event for proper attribution. One component of the nuclear forensic analysis is a measure of the neutron fluence and spectrum. As an example regarding nuclear weapons, the neutron component provides information on the composition of the weapons, whether boosting is involved or the mechanisms used to put the material in a supercritical state. As ^{6}Li has a large cross section for thermal neutrons, the lithium battery is a primary candidate for assessing the neutron spectrum after detonation. The absorption process for ^{6}Li yields tritium, which can be measured at a later point after the nuclear event, as long as the battery can be processed in a manner to successfully extract the tritium content. In addition, measuring the activated constituents after exposure provides a means to reconstruct the incident neutron spectrum. The battery consists of a spiral or folded layers of material that have unique, energy dependent interactions associated with the incident neutron flux. A detailed analysis to the batteries included a pre-irradiated mass spectrometry analysis to correlate test results to simulations developed in MCNP. A set of batteries were exposed to a hard neutron spectrum delivered by the University of Massachusetts, Lowell research reactor Fast Neutron Irradiator (FNI). The gamma spectra was measured from the batteries within a few days and within a week after the exposure to obtain sufficient data on the activated materials in the batteries. The activity was calculated for a number of select isotopes, indicating the number of associated neutron interactions. This final number of neutron interactions is used to determine the incident neutron spectrum. This paper discusses the extraction of data from the batteries and analysis for determining the neutron spectrum.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 61

Tritium Powered Radiation Sensor Network

Marc S. Litz, Dimos C. Katsis, Johnny A. Russo, James C. Brent, James Jeffrey Carroll

Army Research Laboratory, Adelphi, MD

Isotope power supplies offer solutions for long-lived (100 yr), low-power (100uW) energy sources. The energy density of nuclear batteries uniquely serves applications for sensors or communications nodes that are required to last the lifetime of infrastructure. Efficiencies less than 10% are typical for either direct (or indirect)-energy-conversion of radiation to electric current. A tritium beta-source (12.5 year half-life) encapsulated in a phosphor-lined vial is coupled directly to a photovoltaic generating a trickle current into an electrical load. An inexpensive design approach is described consisting of commercially available components that generate 100uW for next-generation compact electronics and sensor applications. 30uW electrical power is measured from 20 Ci tritium packets (200 cc). A compact radiation sensor (1000 cc) has been designed and built to operate during long-lived missions. A low-power (100uW) sensor architecture is described and implemented that makes use of microprocessor controlled sleep modes, judicious choice of low-power electronics and passive interrupt driven environmental wake-up. The low-power early-warning radiation detector network combined with a long-lived isotope power source enables no-maintenance mission lifetimes dependent only on the half-life of an isotope of choice.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 62

X-ray microtomography characterization of carbonate microbialites from a hypersaline coastal lagoon in the Rio de Janeiro State – Brazil

Alessandra Silveira Machado[1,2], Patrick Dal Bó[1], Leonardo Borghi[1], Inayá Lima[2], Ricardo Tadeu Lopes[2]

[1]*Laboratory of Sedimentology, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil*
[2]*Nuclear Engineering Program, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil*

The objective of the present study is to apply the microCT technique to assess recent microbialite samples from a hypersaline coastal lagoon in the Rio de Janeiro State. The study comprises structural assessment, mineralogical characterization and porosity distribution of each sample. MicroCT is increasingly present in geological reservoir analyses, and has advantages over other laboratory techniques since it is non-invasive and allows 2D/3D visualization of inner structures without previous preparation method, such as slabbing, polishing, thinning or impregnation. This technique renders structural analyses which can be spatially resolved to a scale of micrometers. Results show that microCT technique is also adequate for the characterization of carbonate microbialites, providing excellent high resolution 3D images, that enabled to distinguish different mineralogies and porosity distribution beyond it is inner structure.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 63

Study of downscaling sandstone rock porosity by x-ray microtomography

Haimon Alves, Alessandra Silveira Machado, Inayá Lima, Ricardo Tadeu Lopes

Nuclear Engineering Program, Federal University of Rio de Janeiro, Brazil

Dimensional microtomography metrology is a new approach in the petroleum and gas industry. Petrophysical characterization can be achieved by quantitative properties, such as porosity, which is one of the main parameter for the knowledge of reservoir potential. For example, the microporosity is a major factor of control water saturation in oil and gas reservoir. The smaller the pixel size the better the spatial resolution of the system, which leads to the investigation of the micropore network. The goal of this work is to investigate the impact of different pixel sizes on the characterization of internal rock porosity. For that purpose, sandstone rock samples were used in three different dimensions, which were achieved by trimming the edges of the samples. The total porosity results were not equivalent for the used spatial resolutions and the comparison among the microtomography images datasets and pore size distributions showed differences that enhances the importance of the spatial resolution for a complete characterization of the rock sample internal microstructure.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 64

Simulation study of gap supplementation in PET scanner for in-beam PET system

Hyun-il Kim[1,2], Su Jung An[1,2], Chae Young Lee[1,2], Han Kyeol Song[1,2], Yong Hyun Chung[1,2]

[1]*Department of Radiological Science, College of Health Science, Yonsei University, Wonju, Republic of Korea*
[2]*Institute of Health Science, Yonsei University, Wonju, Republic of Korea*

PET scanners can be utilized to verify dose distributions of the therapeutic hadron beams by delivering a large dose in the Bragg peak when placed inside deep-seated tumor. The purpose of this study was to perform simulations to identify the supplement of missing data by gaps between detector modules which designed for an in-beam PET scanner geometry integrated into a carbon beam therapy system. The PET system consists of 14 detector modules and designed the C-shaped to avoid blockage of the carbon beam by the detector modules. Each detector module is composed of a 9 × 9 array of 4.0 mm × 4.0 mm × 20.0 mm LYSO crystals and four 29 mm diameter PMTs using Photomultiplier-quadrant-sharing (PQS) technique. However, the sinogram discontinuity artifact may arise due to the empty space between detector modules. Filling of missing data caused by these gaps is required to prevent artifacts in the reconstructed images. This problem can be solved by rotation of PET scanner. Simulation study using Geant4 Application for Tomographic Emission (GATE) was performed and supplementation of the missing data was verified. Our

results demonstrated that it would be feasible to perform respectably for C-shaped in-beam PET system, and this system can be used in carbon therapy for the dose verification.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 65

GAMMA TRANSMISSION SYSTEM FOR DETECTION OF SCALE IN PIPELINES OF OIL EXPLORATION

Davi Ferreira De Oliveira[1,2], Joseilson Rodrigues Nascimento[1], Carla Alves Marinho[3], Ricardo Tadeu Lopes[1]

[1]*Nuclear Engineering Program, Federal University of Rio de Janeiro, Brazil*
[2]*Physics Institute, State University of Rio de Janeiro, Brazil*
[3]*Centro de Pesquisa Leopoldo A. Miguez de Melo – CENPES/PETROBRAS, Brazil*

The goal of this study is to detect and quantify the thickness of the scale layer on the inside of service pipelines. For this purpose, a system composed by a Cs-137 source and a NaI(Tl) scintillation detector was developed. The source and the detector were positioned according to the geometry of the transmission. A computational routine was developed to generate simulated data, which were later on compared with the experimental ones, in order to calculate the thickness of scale layer. The results of the validation tests show similar values to the real ones. It was therefore possible to conclude that the procedure is efficient for the detection and quantification of materials inside pipelines, and that the system is advantageous for its application in the field, especially with respect to radioprotection.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 66

Fiberglass reinforced by epoxy composites: a 3D look inside the bonded joint

André Rique[1], Alessandra De Castro Machado[1], Davi Ferreira De Oliveira[1,2], Ricardo Tadeu Lopes[1], Inayá Lima[1]

[1]*Nuclear Engineering Program, Federal University of Rio de Janeiro, Brazil*
[2]*Physics Institute, State University of Rio de Janeiro, Brazil*

In oil & gas industry there is a tendency on the use of composite materials, such as fiberglass, epoxy resin and carbon, in sophisticated structures. For example, in Brazil some oil platform uses rises, which is made by fiberglass and carbon materials. Therefore, these kinds of structures are quite common for fluids transport in pipelines. The connections between the several parts of the ducts are made by quick lock bounded joints. At the end of this duct is introduced a subsequent duct with a larger diameter and they are joined by a particular polymeric adhesive material. In this work, samples of plastic reinforced by fiberglass, which is mainly compose by epoxy resin, fiberglass and additive, were used in order to investigate possible defects in the bonded joints. In fact, three glassfiber reinforced epoxy composites were used in this study. Originally, the specimens were bonded joints cut at 60 degrees and had a diameter of 16 inches. However, for this study they were randomly cut (110 x 58 mm) and scanned. One sample contents no defect while the other two content lack of adhesive and lack of compliance, respectively. The lack of compliance was simulated by placing an adhesive tape on the joint surface before applying the adhesive, which generated an area where the stick has not adhered to the surface to be joined. The lack of adhesive was reproduced by placing a smaller amount of adhesive (approximately 30 % less than recommended). This procedure was not homogenized over the entire surface, which, theoretically, produces areas where the adhesive does not fill the space intended for it. In this sense, the study of the occlusions presented in bonded joints will help to minimize failures due to low adhesion of the joints in the industry field. One of the main parameters to be characterized is the porosity of the joint, since these pores are formed by several reasons in the fabrication moment. For such purpose, it was used high-energy X-ray microtomography. The scanned was performed on the entire three samples and the results show its potential effective in recognizing and quantifying directly in 3D all the occlusions regions presented at glass fiber-epoxy adhesive joints.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 67

Efficient Interior CT Reconstruction with Compressed-sensing (CS) Framework for Cost-effective, Low-dose Dental Cone-beam CT (CBCT) Imaging

U.k. Je[1], D.k. Hong[1], S.i. Choi[1], M.s. Lee[1], Y.o. Park[1], C.k. Park[1], H.m. Cho[1], Y.s. Koo[1], T.h. Woo[2]

[1]Department of Radiological Science and VYSION Research Center, Yonsei University, Wonju 220-710, South Korea
[2]Research Group, Systemix Global Co. Ltd., Seoul 121-876, South Korea

In this paper, as a continuation of our dental X-ray imaging R&D, we investigated an efficient interior CT reconstruction with compressed-sensing (CS) framework for cost-effective, low-dose dental cone-beam CT (CBCT) imaging. Here, the interior CT refers to new CT configuration in which X-ray beam from each source position covers only a small region-of-interest (ROI) containing a target of diagnosis from the examined structure. It has been demonstrated that the interior CT leads to various benefits, including reducing imaging doses outside the ROI, reducing detector size and thus X-ray beam width, etc. We proposed an efficient projection data acquisition for interior dental CBCT reconstruction of high image accuracy; it differs from that in ordinary interior CT in that the rotational center moves along a predetermined dental-arch trajectory during the projection acquisition, instead of being stationary. We implemented an efficient CS-based reconstruction algorithm for the proposed configuration and performed systematic simulation works to investigate the imaging characteristics. We have also established an experimental setup to perform experimental reconstruction to demonstrate the potential of practical uses. More details on the algorithm implementation and the simulation and experimental results will be described in the paper.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 68

Angle-weighted Filtered Backprojection (FBP) Reconstruction with Noncircular, Truncated Projections for Low-dose, Cost-effective Dental CBCT Design

U.k. Je, H.s. Cho, D.k. Hong, S.i. Choi, M.s. Lee, Y.o. Park, C.k. Park, H.m. Cho, Y.s. Koo

Department of Radiological Science and VYSION Research Center, Yonsei University, Wonju 220-710, South Korea

A technique for the volume reconstruction of truncated cone-beam computed tomography (CBCT) by using projection data acquired along a noncircular source-detector trajectory is described in this paper. The conditions differ from those in ordinary interior CT in that the rotational center moves along a predetermined dental-arch like trajectory with narrow detector for low dose, cost-effective dental CBCT. We manipulated ordinary FBP reconstruction algorithm into modified reconstruction algorithm which makes angular distribution of ray-based uniformity. Our simulation and experimental results show that the method reduces the strick-shaped artifacts significantly, compared to by the ordinary FBP reconstruction algorithm. The method can be used for the initial image for the iterative compressed-sensing (CS) reconstruction method due to its result of lower stricking artifact than in conventional FBP images in the condition of truncated projection data and non-circular motion. This method can be also used to remove the artifacts occurred after geometrical calibration technique to compensate the imprecise motion of the instrument.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 69

Quantitative analysis of femur head after chemotherapy treatment for breast cancer using Synchrotron X-ray Microfluorescence and Microtomography

Arissa Pickler[1], Rita Alessio[1], Delson Draz[1], Carla Lemos Mota[1], Andrea Mantuano[2], Gabriela Sena[1], Andre Pereira Almeida[2], Liebert Parreiras Nogueira[2], Carlos Eduardo Veloso De Almeida[3], Regina Cely Barroso[2]

[1]COPPE, Federal University of Rio de Janeiro, Brazil
[2]Physics Institute, State University of Rio de Janeiro, Brazil
[3]Radiological Sciences Laboratory, State University of Rio de Janeiro, Brazil

In recent years new techniques have been developed for the analysis of bone matrix. Two of the most widely technologies that make use of X-Rays are X-Ray Microfluorescence (μXRF) and Microtomography (μCT). X-Ray Microfluorescence analysis is a powerful analytical tool for the spectroscopic determination of almost all the elements present in a sample. Microtomography can be used to quantify and qualify the internal

microstructures of the bones creating a cross-section of a 3D object. In this work, both techniques were applied to bones to understand structural and elemental modifications caused by chemotherapy procedure. Ten adult female Wistar rats divided randomly into two groups (control and treated) were used. The treated group received doses of docetaxel and cyclophosphamide drugs while control group was not treated.We analyzed Ca qualitatively and quantitatively with elemental distribution maps by μXRF. Through μCT, significant differences in morphometric parameters were measured and significant bone loss were observed. The measurements of μXRF were carried out at the new X-ray microXRF station at the Brazilian Synchrotron Light Laboratory. Ca distribution maps were analyzed and its concentrations were calculated by the software Pymca®. The tomographic images were obtained at the SYRMEP (SYnchrotron Radiation for MEdical Physics) beamline at the Elettra Synchrotron Laboratory in Trieste, Italy. Our results showed a statistical difference (P value <0.05) for elemental distribution maps and also difference in results of morphometric parameters measured from the images of femur heads of rats between control and treated groups.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 70

Estimation of radiation dose from dental cone beam CT for three different age groups

Ching-ching Yang[1], Chia-chuan Chuang[1], Nien-yun Wu[2], Tung-hsin Wu[2]

[1]*Department of Medical Imaging and Radiological Sciences, Tzu-Chi College of Technology, Taiwan*
[2]*Department of Biomedical Imaging and Radiological Sciences, National Yang-Ming University, Taiwan*

Background:The purpose of this study was to measure the effective dose in dental cone beam CT (CBCT) and investigate the relationship between effective dose and dose-area product (DAP) for three different age groups. Methods:Dose measurements were performed on CS9000 3D CBCT (Carestream, New York, NY) using 3 anthropomorphic phantoms and lithium fluoride thermoluminescent dosimeter (TLD). The imaging protocols involved a 10.8-second partial scan (270 degree rotation) with a field of view (FOV) of 50 x 37 mm. The exposure settings were 68 kVp with 6.3 mA, 70 kVp with 8 mA, 70 kVp with 10 mA for phantoms simulating 5-year-old, 10-year-old and adult patients, respectively. Dose equivalent and effective dose were calculated according to ICRP report 103, while the DAP provided on scanner console was used for comparison.Results:The effective doses to the 5-year-old, 10-year-old and adult phantoms were 28, 35 and 43 μSv, respectively. The salivary gland, the reminder tissues and the thyroid are the major contributors to the effective dose for phantoms simulating 5-year-old, 10-year-old, while the major contributors are the salivary gland and the reminder tissues for the adult phantom. The DAP were 131, 175, 218 mGy-cm^2 for phantoms simulating 5-year-old, 10-year-old and adult patients, respectively.Conclusion:The DAP is widely used in dental radiography which is related to several physical factors of CBCT, such as beam quality, exposure setting and FOV, but does not take into account biological factors, such as body size, tissue composition and radiosensitivity. A conversion between DAP and effective dose presented in this study should be able to provide information to estimate radiation risk of dental CBCT for patients in three age groups.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 71

Evaluation of radiation dose and image quality of CT scan for whole-body pediatric PET/CT: a phantom study

Ching-ching Yang[1], Shu-hsin Liu[2], Nien-yun Wu[3,4], Tung-hsin Wu[4]

[1]*Department of Medical Imaging and Radiological Sciences, Tzu-Chi College of Technology, Taiwan*
[2]*Department of Nuclear Medicine & PET Center, Buddhist Tzu-Chi General Hospital, Taiwan*
[3]*Department of Nuclear Medicine, Taipei Veterans General Hospital, Taiwan*
[4]*Department of Biomedical Imaging and Radiological Sciences, National Yang-Ming University, Taiwan*

Purpose: This study aimed to tailor the CT scan protocols for pediatric patients undergoing whole PET/CT scans with appropriate attention to radiation exposure while maintaining adequate image quality for anatomic delineation of PET findings and attenuation correction of PET emission data.

Methods: The measurements were made by using three anthropomorphic phantoms representative of 1-, 5-, and 10-year-old children with tube voltages of 80, 100, and 120 kVp, tube currents of 10, 40, 80, and 120 mA, and exposure time of 0.5 second. Multiple linear regression methods were used to investigate the effects of patient age, tube voltage, and tube current on CT radiation dose and image noise.

Results: The effective dose ranged from 0.09 mSv for 10-year-old phantom to 4.08 mSv for 1-year-old phantom. For tube current larger than 80 mA, the 80-kVp scans yield the best image contrast, followed by 100- and 120-kVp acquisitions. However, contrast degradation is most severe in

80-kVp scans as the tube current decreased from 80 to 10 mA among the three tube voltages, especially in the 10-year-old phantom. A negative correlation between linear attenuation coefficient at 511 keV and CT image noise was found in bone-simulating materials. The relationship becomes stronger in data acquired by using anthropomorphic phantoms simulating older children. With regard to multivariate analysis, the coefficient of determination was greater than 0.81 for both regression models, indicating a good fit to the data.
Conclusion: The low-dose CT protocols derived from regression models presented sufficient image quality with 75% dose reduction. For imaging tasks requiring high image contrast, an 80-kVp scan can be carried out with tube current of 60, 80, and 100 mA for the 1-, 5-, and 10-year-old children, respectively. Conversely, for imaging tasks requiring accurate PET quantification, a 120-kVp scan can be carried out with tube current of 10, 20, and 30 mA for the 1-, 5-, and 10-year-old children, respectively.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 72

Comparison of reconstruction methods and quantitative accuracy in Siemens Inveon PET scanner

A Ram Yu, Jin Su Kim, Sang Moo Lim, Kyeong Min Kim

Molecular Imaging Research Center, Korea Institute of Radiological and Medical Sciences, Seoul, Korea

Purpose: For the quantification of PET data, PET reconstruction is necessary. Various reconstruction methods was developed and implemented in commercialized PET scanner. To our best knowledge, there was no comparative study of reconstruction methods. In this study, we compared reconstruction methods with various filters in terms of spatial resolution, non-uniformities (NU), recovery coefficients (RCs), and spill over ratios (SORs). In addition, linearity of reconstructed radioactivity for the various reconstruction methods was also assessed, because linearity of measured and true concentration in dynamic range would be important in PET quantification.
Methods: A Siemens Inveon PET scanner was used throughout. Spatial resolution was measured by NEMA standard using 1 mm^3 sized ^{18}F point source. In addition image quality was measured using NU4 image quality phantom by NEMA standard. To assess linearity of measured and true concentration, the amount of 444 MBq of ^{18}F was injected into phantom and emission data was acquired for 20 min with an interval of 1hr until activity was < 0.01 mCi. The list mode data were sorted into a sinogram using FORE and reconstructed using FBP, OSEM and MAP (ß=1.5 & 5E-5).
Results : The highest achievable volumetric resolution was 2.31 mm3 and the highest RC was 0.38, 0.75, 0.95, 1.02, and 1.1when OSEM2D was used. With regards to analytical reconstruction methods, the lowest NU was 4.48 % when FBP with butterworth filter was used. The lowest SOR was 1.01 % for air and -1.14 % for water when FBP with shepp-logan filter was used and those were 4.87 % for air and 3.97 % for water using OSEM2D reconstruction algorithm. RC was > 1.3 even at 3 mm rod when MAP reconstruction algorithm (β: 5E-5 and 5E-3) was used. This erroneous result was possibly due to Gibbs phenomenon of MAP reconstruction. The measured activity of reconstruction image was proportional to injected at the radioactivity < 340 MBq(16MBq/ml) when FBP or OSEM reconstruction method was used. In contrast, in the MAP reconstruction method, activity of reconstruction image was proportionally increased regardless of the amount of injected radioactivity. Although measured radioactivity concentration was reduced by 53% compared with true injected radioactivity at > 340 MBq when OSEM2D or FBP was used, non-linearity at higher activity dose level was serious in actual animal PET imaging. This was because we do not use such a high radioactivity concentration (> 340 MBq (16MBq/ml)) using small animal such as mouse and rat and middle sized animal such as cat and rabbit.
Discussion :OSEM 2D reconstruction method provides highest achievable volumetric resolution and highest RC. In addition OSEM 2D provide the linearity of measured and true concentration within 340 MBq (16MBq/ml) of radioactivity. Our data collectively suggest that OSEM 2D reconstruction method provide quantitatively accurate result on reconstructed PET data.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 73

Determination of energy windows for triple energy windows scatter correction method for I-131 on Siemens SYMBIA gamma camera: GATE simulation study

Young Sub Lee[1,2], Jin Su Kim[1], Kyeong Min Kim[1], Hee-joung Kim[2], Sang Moo Lim[1]

[1]*Molecular Imaging Research Center, Korea Institute Radiological and Medical Sciences, Korea*
[2]*Department of Radiological Science, College of Health Science, Yonsei University, Korea*

Purpose: For the quantification of gamma camera imaging of I-131, the correction for scattered photon of I-131 was important. To correct scattered photons in I-131, triple energy window (TEW) scatter correction method was introduced. However, there was no report on scattered photons fraction of I-131 with various energy windows and optimal main energy window and sub-energy window for the implementation of TEW in I-131 imaging. In this study, we assessed the scattered photons fraction and determined the optimal main- and sub- energy windows for TEW in I-131.
Method: A Siemens SYMBIA T2 SPECT/CT scanner and corresponding Monte Carlo GATE simulation code were used. To validate Monte Carlo simulation code, spatial resolution between experimental result and Monte Carlo simulation result was assessed. Tc-99m and I-123 radioisotope and LEAP and LEHR collimators were used for the measurement of spatial resolution. Figure 1 shows the I-131 point sources positioned at different locations in water equivalent material. To assess the scattered photons fractions, I-131 radioisotope were positioned 7 different locations (0,0,0 cm, ±7,0,0 cm, 0,±7,0 cm, 0,0,±7 cm) of FOV in water equivalent material (diameter: 16 cm, length: 32 cm) and center (0,0,0 cm) of FOV in air equivalent material. HE collimator was used. To implement triple energy window (TEW), 2 different main energy window widths (15, 20%) and 2 different sub energy window widths (3 and 5keV) were implemented. The TEW method estimated the scatter fraction in the photo-peak from the counts acquired in two adjacent narrow windows. Linear interpolation between the two sub-windows could be used to obtain the following trapezoidal approximation of the scatter counts: Cs = (Cleft/Ws + Cright/Ws) x Wm/2.
The scattered photons fractions at default main energy window were calculated using Monte Carlo simulation. To perform TEW, optimal main energy window width and sub energy windows should be determined. Without selecting optimal main and sub energy window width, erroneous scatter correction such as over-correction or under-correction would be induced. In this study, scatter photons fraction in TEW was calculated and then the correlation coefficient between the values of scattered photons fractions (at main energy window vs. at main energy window + sub energy window) was calculated and regression analysis was also performed.
Result and Discussion: The correlation coefficient between scatter photons fractions was highest value (0.92) when 15% of main energy window and 5 keV sub energy window width was selected for TEW. The 15% of main energy window with 5 keV sub-energy windows were suitable for triple energy window scatter correction methods for I-131. The result provides the optimal energy window for I-131 gamma camera acquisition and data quantification.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 74

Quantification of neuroimaging of brain glioma using statistical probabilistic anatomical maps

Jin Su Kim[1], Kyeong Min Kim[1], Chang Hoon Lee[2], Sang Moo Lim[1]

[1]*Molecular Imaging Research Center, Korea Institute of Radiological and Medical Sciences, Seoul, Korea*
[2]*Department of Neurosurgery, Korea Institute of Radiological and Medical Sciences, Seoul, Korea*

Purpose: Multi-tracer neuroimaging for brain glioma was widely used for the diagnosis, radiotherapy, and neurosurgery. For the resection or radiation therapy of brain gliomas in patients, anatomical and functional information was important to avoid neurological deficits. Although ^{15}O water PET or functional MR was the possible solution for the regional mapping, additional scan should be performed. In addition, ^{15}O water PET scan was limited due to short half life (2 min). PET images such as ^{18}F-FLT and ^{18}F-FET lack the anatomical information. The aim of this study was to investigate presurgical anatomical labeling of brain glioma on ^{18}F-FLT and ^{18}F-FET using statistical probabilistic anatomic maps (SPAM), which were images of cerebral cortical, cerebellar, and subcortical VOIs. Methods: ^{18}F-FDG, ^{18}F-FLT, and ^{18}F-FET PET scan were acquired. FLT and FET PET image was coregistered to FDG PET image. For the accurate registration, performance of 4 registration methods including mutual information (MI), normalized mutual information (NMI), normalized cross correlation (NCC), and entropy correlation coefficient (ECC) were performed and compared. FDG PET image was then spatially normalized onto target brain. Inverse spatial normalization parameter was calculated and applied to SPAM. For the anatomical labeling of brain glioma region, volume of brain glioma on FLT and FET images was extracted using segmentation. Probabilistic information of glioma region was then calculated using SPAM and segmented glioma volume. SPM and in-house program was used for image processing.

Results: Coregistration of FDG and FLT, FDG and FET were successfully performed using MI, NMI, and ECC except NCC method. Probability of SPAM labeled brain glioma region could be extracted using inverse normalized SPAM and segmented glioma region. In sample case, probabilistic anatomical region of glioma include 21% of postcentral gyrus, 12% of superior parietal gyrus, and 6% of angular gyrus (Fig 1 and Fig. 2). Conclusion: Anatomical information about brain glioma could be extracted using SPAM. This proposed method would be optional for presurgical mapping to avoid neurological deficits without additional functional mapping study.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 75

Adaptive PET imaging for quantitative improvement of regional variable activity

Sang-keun Woo[1], Yong Jin Lee[1], Jung Woo Yu[2], Kyeong Min Kim[1], Yong Hyun Chung[2], Sang Moo Lim[1]

[1]*Molecular Imaging Research Center, KIRAMS, Seoul, Korea*
[2]*Dept of Radiological Science, Yonsei University, Wonju, Korea*

The positron emission tomography (PET) provides functional image including biological information using radiopharmaceuticals emitting positron. The respiration and cardiac motion induces degradation of image quality and quantity by causing deficiency of count and blurring of lesion during PET acquisition. The aim of this study was improvement of quantitative tumor evaluation depending on target organ region and tumor intensity. Target region was classified into two groups (high and low) based on the amount of activity, which meant artificial tumor intensity. Molecular sieves target imitating tumor were loaded with 18F and inserted into lung and liver region in rats. All models were classified into two groups based on the activity to compare the effect of tumor intensity. PET images in each region were acquired on a dedicated small animal PET scanner (Inveon™, Siemens Preclinical Solutions, Knoxville, TN, USA) after radioactive molecular sieve insertion under anesthesia maintenance. The rats were injected with ^{18}F-FDG (37 MBq in 0.2 ml) via the tail vein. Respiratory gating was carried out by external trigger device. The acquired emission data were reconstructed using Fourier rebinning and ordered subsets expectation maximization 2D (OSEM 2D) algorithm with 4 iterations. We performed analysis of PET images by comparison of count, SNR, contrast and FWHM for determining gating effect regarding to the organ region and tumor intensity. Estimated count (counts/sec) in lung target of high activity group was 9.31±0.36 and 7.72±0.09, and low activity group was 3.49±0.32 and 3.27±0.52 for static and gated images, respectively. Evaluated SNR in lung target of high activity group was 108.07±11.01 and 28.79±0.61, and in low activity group was 32.57±1.44 and 8.96±3.75 for static and gated images, respectively. Evaluated contrast in lung target of high activity group was 10.01 and 6.97, and in low activity group was 3.57 and 6.19, for static, gated images, respectively. Horizontal and vertical FWHM in lung target was 1.91±0.17 and 3.11±0.01 in static image and 1.83±0.12 and 2.54±0.18 in gated image, respectively. The result of liver region exhibited a sharp decline in SNR and improvement of FWHM as the increase in gate number like the preceding result of lung region. Estimated count (counts/sec) in liver target of high activity group was 4.17±0.07 and 4.18±0.18, and in low activity group was 2.18±0.06 and 2.13±0.12 for static and gated images, respectively. Evaluated SNR in liver target of high activity group was 40.89±4.89 and 13.52±0.86, and in low activity group was 23.52±4.40 and 7.96±0.58 for static and gated images, respectively. Horizontal and vertical FWHM was 2.18±0.06 and 3.16±0.13 in static image and 2.18±0.07 and 2.94±0.19 in gated image, respectively. The liver region showed higher slope of fitting line of vertical FWHM graph (0.0553) when compared to the lung region (0.0177). We confirmed the necessity of gating in low intensity tumor quantification by carrying out a comparative analysis between high and low activity groups. Gating in low intensity tumor could assist in research of new radiopharmaceutical. In consequence, we could quantitatively improve the tumor evaluation considering tumor region and tumor intensity.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 76

Internal motion correction of thoracic PET image using marker and MRI image

Sang-keun Woo[1], Jang Geun Cho[2], Eun Kyoung Ryu[2], Byung Byun Hyun[1], Sang Moo Lim[1], Kyeong Min Kim[1], Su Young Jeong[3]

[1]*Molecular Imaging Research Center, KIRAMS, Seoul, Korea*
[2]*Center of Magnetic Resonance Research, Korea Basic Science Institute, Ochang, Korea*
[3]*Department of Nuclear Medicine, Kangbuk Samsung Hospital, Seoul, Korea*

PET image of tumor located in thoracic region was affected by various organ motions such as respiration and heartbeat. Thoracic motion is difficult to estimate and correct accurately using external measurement or anatomical image solely. The aim of this study was to compare the accuracy of motion correction using PET fiducial marker and MRI image. The radioactive bead for PET fiducial marker was realized from molecular sieve contained 0.37 MBq F-18 and placed in thoracic region. A PET imaging study was performed with a dedicated small animal PET scanner (Inveon™, Siemens Preclinical Solutions, Knoxville, Tennessee, USA) using lutetium oxyorthosilicate (LSO). The rats were injected with ^{18}F-FDG (0.2 mL; 37 MBq) via the tail vein. PET images were acquired as list-mode data for 20 min after a 60-min uptake period following the injection. Coronal 3D MR images were acquired using a T1-VIBE sequence with generalized autocalibrating partially parallel acquisitions (GRAPPA). The parameters were as follows: repetition time = 5.67 ms, echo time = 1.42 ms, flip angle = 10°, slice thickness = 2.11 mm, filter = elliptical filter, phase oversampling = 1%, field of view = 200 mm, and slices per slab = 12. Motion corrected PET image was created by mutual information registration with B-Spline interpolation to the mean image after first realignment. The estimated variation of PET image marker was 2.98, 0.71, 1.42 mm and 0.02, 0.05, 0.13, translations and rotation degree, respectively. The estimated variation of MRI image marker was 0.33, 0.17, 1.01 mm and 0.004, 0.005, 0.005, translations and rotation degree, respectively. Measured FWHM of lung region in motion corrected PET image using PET fiducial marker and 3D

VIBE MRI was measured 4.22±0.09 and 4.59±0.06, respectively. In case of liver region, FWHM using fiducial marker and 3D VIBE MRI was measured 4.47±0.16 and 4.65±0.25 respectively. The evaluated horizontal and vertical FWHM(mm) of marker was 2.01±0.42, 3.06±0.57 before correction, and 1.89±0.02, 2.89±0.03 after correction. The improvement of resolution was observed by proper correction method. The improvement of resolution was observed by proper correction method. In this study PET correction was implemented by motion information extracted from various images. These results suggest motion correction would be possible without external device or fiducial mark using MRI motion data. Motion correction using MRI should be considered acquisition method and organ region in accordance with motion characteristics.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 77

PET/MRI image information based registration with linear interpolation algorithm

Sang-keun Woo, Ji Min Kim, Sang Moo Lim, Kyeong Min Kim

Molecular Imaging Research Center, KIRAMS, Seoul, Korea

Multimodal Image registration was necessary to accurately evaluate diagnostic and monitoring of therapeutic response in clinical phases. PET image registration with anatomical image is required for contrast enhancement and region segmentation. Intramodality and intermodlity registration can be considered the image characteristics and quality. The aim of this study was to estimate the information based algorithm in PET/MRI image registration. PET images were performed using a small animal PET scanner (Inveon™, Siemens) during 20 min after tail vein injection of 37 MBq ^{18}F-FDG. Emission event data was obtained under the condition of 3.432 nSec timing window and 350–650 keV energy window. Emission data was reconstructed to PET images by ordered subset expectation maximization 2D (OSEM 2D) algorithm with four iterations. MRI images were obtained from 3-T clinical MRI (Magnetom Tim Trio, Siemens) with T1-weighted 3D-dynamic volumetric interpolated breath-hold examination (VIBE) sequence condition of TR = 11.6 ms, TE = 3.1 ms and FA = 10 degree. Information based registration methods were performed with mutual information (MI), normalized mutual information (NMI) and kullback leibler distance (KLD). MI registration method was measured mutual dependence of two images and KLD registration method was measured relative entropy between discrete probability distributions information. Interpolation methods were performed linear interpolation (LI) and B-spline interpolation (BSI). LI method was fitted using linear polynomials data and BSI coefficient was computed using recursive filtering by multiplying B-spline coefficients. Registration algorithms performance for multimodal image were estimated by the mean square error (MSE) and peak signal-to-noise ratio (PSNR). PET image size was 128×128×159 and voxel size was 0.78×0.78×0.8 mm. MRI image was 640×640×200 and voxel size was 0.3×0.3×1.0 mm. PET/MRI registration was evaluated with three registration algorithms (MI, NMI and KLD) and two interpolation methods (LI and BSI). Original PET/MRI image MSE and PSNR was 38.91 and 32.23, respectively. MI registration with LI/BSI interpolation MSE and PSNR was 32.29/32.65 and 33.04/32.99, respectively. NMI registration with LI/BSI interpolation MSE and PSNR was 44.48/43.85 and 31.65/31.71, respectively. KLD registration with LI/BSI interpolation MSE and PSNR was 32.03/32.07 and 33.08/33.07, respectively. Multimodal image registration was performed between PET and MRI image with three information based registration algorithms. Information based algorithm showed well-suited result for PET/MRI image registration. Multimodal image registration method should be optimized with various interpolation algorithm. PET/MRI would be expected to improve accuracy of diagnosis and treatment monitoring.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 78

Preliminary evaluation of a chest digital tomosynthesis (CDT) imaging

Young-jin Lee, Dae-hong Kim, Sung-hoon Choi, Haeng-hwa Lee, Do-hyeon Kim, Hee-joung Kim

Department of Radiological Science and Research Institute of Health Science, Yonsei University, Wonju, Korea

The development of an innovative system for digital tomosynthesis (DTS) in X-ray imaging has been studied. In chest X-ray imaging, to overcome the limitations of conventional chest radiography for overlap anatomical structures and for high patient dose with cone-beam computed tomography (CBCT), chest digital tomosynthesis (CDT) has recently been introduced. In the present study, we constructed CDT system with amorphous-silicon digital flat-panel detector with filtered backprojection (FBP) reconstruction methods. We performed systematic simulations and evaluated the image performances by means of root-mean-square error (RMSE) and signal difference-to-noise ratio (SDNR) with respect to scan angles such as ±5°, ±10°, ±15°, and ±20°. The dependence of CDT image performance on reconstruction filters was investigated. We also performed experiments using the CDT system. The results demonstrated that the CDT can improve using wide scan angle. Also, it was found that

the apodizing filter with a Hanning window to limit the high-frequency components improved image performance because of noise reduction. Both simulation and experimental results showed the same tendency when image performances were quantitatively compared. We successfully obtained CDT images using a FBP reconstruction method, which are promising to application to field of medical imaging.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 79

X-ray spectra optimization in contrast-enhanced digital mammography through Monte Carlo simulations

D. M. Cunha[1], P. H. B. Ribeiro1[1], L. S. Del Lama[2], M. E. Poletti[2]

[1]*Instituto de Física, Universidade Federal de Uberlândia, Uberlândia, 38400-902, Minas Gerais, Brazil*
[2]*Departamento de Física, Universidade de São Paulo, Ribeirão Preto, 14040-901, São Paulo, Brazil*

Contrast-enhanced digital mammography (CEDM) has been proposed as a technique for improvement of mammography sensitivity. In this technique, iodine is employed as a perfusion contrast media for enhancement of diseased tissue in image, due to the process of angiogenesis in tumour growth. In this work, we evaluated the performance of different x-ray spectra in CEDM.A MC code for simulation of photon transport was developed. The geometric model adopted simulates a mammographic examination in cranio-caudal position. It consists of a focal spot, compression paddle, compressed breast (thickness t), chest wall, breast suport, antiscatter linear grid (grid ratio 5:1) and image receptor (CsI, 70 mg/cm^2). The compression paddle consists of 3 mm of PMMA. A cylindrical contrasting object with mass thickness of 6 mg/cm^2, was placed within the breast, simulating the iodine contrast medium.The polienergetic spectra used in the simulations for the Mo, Rh and W anodes at different tube potentials were obtained with Monte Carlo simulations, using the code PENELOPE. The anode/filter combinations studied were: Mo/Mo (30 μm), Rh/Rh (25 μm), Rh/Cu (300 μm) and W/Rh (300 μm). The Mo/Mo and Rh/Rh are traditionally employed in mammography, while the Rh/Cu and W/Cu has been proposed for CEDM.The performance of a given anode/filter combination at different values of kVp was studied by means of the contrast-to-noise ratio (CNR) in image and average glandular dose D_g. For a given spectrum, the CNR and D_g were combined through a figure of merit (FOM), computed as FOM = CNR^2/D_g.Results show that, for a given breast thickness t, values of FOM for the Rh/Cu and W/Cu increase considerably for tube potentials above 33 kVp, due to the iodine absorption K-edge at 33.17 keV. Values of FOM for these combinations are similar to each other, and maximum values occur at 45-49 kVp. The Mo/Mo and Rh/Rh combinations provide considerably lower values of FOM, compared to the more energetic spectra provided by the Rh/Cu and W/Cu combinations. It was also observed that, when the FOM for different breast thickness are compared, the optimum tube potential range is practically independent on the values of t, although the numerical values of FOM are very dependent on breast thickness. The results obtained in this work are in agreement with those reported by other authors.In conclusion, results show that the Mo/Mo and Rh/Rh spectra, traditionally employed in mammography, are not suited for CEDM, while spectra from Rh/Cu and W/Cu provide higher values of FOM at tube potentials between 45-49 kVp, for different breast thicknesses.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 80

Breast imaging using scattered radiation: A computational study

M. Antoniassi[1,2], M. E. Poletti[1], A. Brunetti[2], A. L C Conceição[3], L. S. Del Lama[1]

[1]*Departamento de Física - Faculdade de Filosofia Ciências e Letras de Ribeirão Preto - Universidade de São Paulo, Ribeirão Preto, Brazil*
[2]*Instituto di Matematica e Fisica, Dipartimento PolComIng, Università di Sassari, Sassari, Italy*
[3]*Departamento Acadêmico de Física - Universidade Tecnológica Federal do Paraná, Curitiba, Brazil*

In this work, we explored computationally the use of a tomographic technique based on the Rayleigh and Compton scattering signals for breast imaging. The test object (breast) included a cylinder filled with a mixture of healthy breast tissues (glandular and adipose) except for a malignant lesion at the centre consisting of carcinoma. A standard reconstruction algorithm (including the self-attenuation correction) was used to reconstruct Rayleigh, Compton and Rayleigh to Compton ratio (R/C) images from the simulated scattering signals. The results showed that the contrast of Rayleigh and R/C images (strongly dependent on atomic number and incident energy) is greater than the contrast of Compton images (mainly dependent on electron density). Comparisons with conventional transmission images showed that the contrast of Compton images is approximately constant for the studied energy range, and it tends to that obtained in transmission technique for higher energies. On the other hand, both contrast Rayleigh and R/C increase with increasing the incident energy, while the conventional contrast (transmission technique) decreases.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 81

Iridium 192 absorbed dose comparison using the Fricke Xylenol Gel and a brachytherapy planning system

M. V N Nakandakari[1], F. Cavalcante[2], F. G A Sampaio[2], G. Menegussi[1], L. S. Del Lama[2], A. Almeida[2]

[1]*Instituto de Radiologia, Universidade de São Paulo (HC/FMUSP), Av. Dr. Enéas de Carvalho Aguiar - CEP 05403-001 - São Paulo, São Paulo, Brazil*
[2]*Departamento de Física, Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Universidade de São Paulo (FFCLRP/USP), Av. Bandeirantes, 3900 - CEP 14040-901 - Bairro Monte Alegre, Ribeirão Preto, São Paulo, Brazil*

In the present work, absorbed dose distributions in 2 dimensions were obtained using the FXG dosimeter with a CCD optical system and compared to the distributions performed by a brachytherapy planning system, leading to the verification of this dosimeter to perform HDR source measurements and treatment planning quality control. Acrylic cuvettes were specially manufactured with entrance guides to insert HDR ^{192}Ir seeds sources in the gel, using an HDR remote afterloading system. The FXG sample cuvettes once irradiated were analyzed with a CCD system that permitted to obtain the absorbed dose percentage distribution maps, which were compared to those distributions planned with a brachytherapy planning system, belonging to the source equipment. The calibration curve obtained for the FXG shows the applicability of this dosimeter in absorbed dose measurements for HDR brachytherapy sources, due to its linear behavior as a function of the absorbed dose. The PDD curves comparison shows that, although the calculation method for absorbed doses is dierent, both systems respond in a similar behavior, with a 4.5 % maximum dierence. The absorbed dose percentage distribution maps also confirm this result and the FXG provides PDD curves that can be comparable to the ones simulated by the planning system. From the comparison results obtained with the FXG and those from the planning system, it was shown the capacity of the gel dosimeter to take part of a quality control method for a prostate HDR treatment planning.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 82

Effective atomic numbers for materials of medical interest at low photon energy using the Rayleigh to Compton scattering ratio

L. S. Del Lama[1], L. D H Soares[1], M. Antoniassi[1,2], M. E. Poletti[1]

[1]*Departamento de Física, Universidade de São Paulo, Ribeirão Preto, 14040-901, São Paulo, Brazil*
[2]*Instituto di Matematica e Fisica, Dipartimento PolComIng, Università di Sassari, Sassari, Italy*

Although the scattered radiation is not a desirable feature for diagnostic purposes, it has been reported as an important tool for materials characterization when both the elastic (Rayleigh) and inelastic (Compton) contributions are considered. The coherent-to-Compton scatter ratio (R/C) has been used as a reliable quantitative method for analysis of materials, especially biological ones. Unlikely the conventional transmission techniques which are sensitive to linear attenuation coefficients, the R/C ratio is more useful for situations where the μ variations are small and the atomic number variations become more significant. In this sense, this work aimed to investigate experimentally the effective atomic numbers when attenuation (Z_{eff}^{ATTEN}) and scattering ($Z_{eff}^{R/C}$) processes are concerned for materials currently used as tissue substitutes (phantom objects). Gamma rays from a ^{241}Am source with energy of 59.54 keV were considered in order to determine each quantity (Z_{eff}^{ATTEN} and $Z_{eff}^{R/C}$) for several liquid and solid compounds. The effective atomic number (Z_{eff}^{ATTEN}) was conventionally determined based on the total cross-section of each compound, while The effective atomic number ($Z_{eff}^{R/C}$) was also calculated considering the ratio between elastic (Rayleigh) and inelastic (Compton) scattered photons. Several liquid and solid compounds have been used as phantoms for investigation of radiation interaction effects on biological tissues. This work aimed to better choose the most suitable tissue substitutes to simulate biological compound for two different experimental conditions: attenuation or scattering. The Rayleigh-to-Compton scattering ratio showed to be an alternative approach to assist in the selection of appropriate phantom materials.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 83

A modified Fricke gel dosimeter for fast electron blood dosimetry

L. S. Del Lama[1], E. G. De Góes[2], F. G A Sampaio[1], P. C D Petchevist[1], A. Almeida[1]

[1]*Departamento de Física, Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Universidade de São Paulo (FFCLRP/USP), Av. Bandeirantes, 3900 - CEP 14040-901 - Bairro Monte Alegre, Ribeirão Preto, São Paulo, Brazil*
[2]*Instituto de Matemática, Estatística e Física, Universidade Federal de Rio Grande (IMEF/FURG), Av. Itália, km 8 - CEP 96201-900 - Bairro Carreiros, Rio Grande, Rio Grande do Sul, Brazil*

It has been suggested for more than forty years that blood and blood components be irradiated before allogeneic transfusions for immunosuppressed patients in order to avoid the Transfusion-Associated Graft-Versus-Host Disease (TA-GVHD). Whole blood, red blood cells, platelets and granulocytes may have viable T cells and should be irradiated before transfusion for different patient clinical conditions. According to international guides, absorbed doses from 25 up to 50 Gy should be delivered to the central middle plane of each blood bag. Although gamma and X-rays from radiotherapy equipments and dedicated cell irradiators are commonly used for this purpose, electron beams from Linear Accelerators (LINACs) could be used as well. In this work, we developed a methodology able to acquire dosimetric data from blood irradiations, especially after fast electrons exposures. This was achieved using a proposed Fricke Xylenol Gel (FXG_P) dosimeter, which presents closer radiological characteristics (attenuation coefficients and stopping-powers) to the whole blood, as well as complete absorbed dose range linearity. The developed methodology and the FXG_P dosimeter were also able to provide isodose curves and field profiles for the irradiated samples.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 84

Preliminary performance of Cone-Beam CT (CBCT) system with flat panel detector: Evaluation of radiation dose and image quality

Bo Kyung Cha, Chang-woo Seo, Sungchae Jeon, Keedong Yang, Young Huh

KERI

The emergence of flat panel imager (FPI)-based cone-beam CT (computed tomography) shows to offer an attractive technology for volumetric imaging in 3D visualization of soft tissue and bone structure with sub-mm spatial resolution. Modern CBCT system with a mobile C-arm and O-arm incorporating a large area flat-panel detector is widely used as a modality for image-guidance in spine surgery, orthopedic and interventions applications as well as image guide radiation therapy. However, significant effort and more challenging technique such as detector performance, image geometry, X-ray scatter and cone-beam reconstruction algorithm as well as X-ray scanning protocols are still required for high clinical imaging quality at low radiation dose.In this work, a prototype CBCT imaging platform with a single rotating gantry was developed by using a large area flat panel detector with a-Si based TFT device (PaxScan 4030CB). The 361 projection images in binning mode was usually acquired during 12 second scan time with constant 1° gantry interval for reconstructed 2D slice images at tube voltage of 80-120kVp, different current(10-50mA) conditions. Various scan protocols were applied for different human body site such as head, chest and pelvis by using changing in kVp, mA, number of projection images and scan time. The different anti-scatter grids were used for quantitative and qualitative evaluation of X-ray dose and image quality. The anti-scatter grids have different grid ratios (GRs) of 80:1, 10:1, 12:1 with 80 lines/cm and Al interspacing.The preliminary quantitative X-ray performance of our CBCT system was investigated by using AAPM (American Association of Physicists in Medicine) CT phantom in terms of spatial resolution, CNR (contrast noise ratio), CT number linearity and contrast resolution etc. The experimental results of projection data with different anti-scatter grids were measured. And also, the patient radiation dose was measured using 30cm long CT head and body PMMA (Polymethylmethacrylate) phantoms. 0.6cc farmer ion chamber with electrometer which is measured at the iso center and at the periphery position by inserting through holes (10mm diameter) was used for CTDI (computed tomography dose index) measurement at various scan protocol experiment conditions.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 85

Perfusion CT dose assessment for acute stroke and tumor: comparison of bismuth shield and organ-based tube current modulation

Nan-ku Lai[1], Ying-lan Liao[2], Yu-shen Tyan[1], Hui-yu Tsai[3,4]

[1]*Department of Medical Imaging, Chung Shan Medical University Hospital, Taiwan*
[2]*Biomedical Engineering and Environmental Sciences, National Tsing Hua University, Taiwan*
[3]*Department of Medical Imaging and Radiological Sciences, College of Medicine, Chang Gung University, Taiwan*
[4]*Institute for Radiological Research, Chang Gung University and Chang Gung Memorial Hospital, Taoyuan, Taiwan*

Purpose: The goal of this study was to assess the organ doses and effective doses to patients of two novel multi-slice CT scanners for acute stroke examinations. Materials and methods: The radiation doses were measured at Aquilion ONE (Toshiba Medical Systems, Otawara, Japan) and Definition Flash (Siemens Medical Solutions, Forchheim, Germany) CT scanners. The organ doses were measured using GR200A thermoluminscent

dosimeters (TLD) chips inserted into RAN100 anthropomorphic phantom for the ischemia stoke CT scan protocol. The protocol included non-enhanced, perfusion, and neck enhanced (or neck CT angiography procedures) scans. The measured organ doses were used to calculate the effective doses according to ICRP tissue weighting factors. The bismuth shield and organ-based tube current modulation (OB-TCM) technique was used to reduce absorbed doses to radiosensitive surface organs.

Results : The absorbed doses to eye lens within scan range during non-enhanced, perfusion , and neck enhanced (or neck CTA) were 46.7, 151.5, 12.4 mGy for Aquilion ONE CT scanner and 38.48, 287.71, 9.91 mGy for Definition Flash CT scanner. The skin dose within scan range within three scans were 36.11, 114.37, 216 mGy for Aquilion ONE CT scanner and 37.28, 218.45, 11.27 mGy for Definition Flash scanner. The effective doses according to ICRP 103 report were 2.02, 5.18, 6.43 mSv for Aquilion ONE scanner and 2.39, 8.64, 4.0 mSv for Definition Flash scanner. The radiation dose reduction using the bismuth shield were 19.7% to 46.9%. The radiation dose reduction using OB-TCM was 32.2%. Conclusion: The effective doses of ischemia stoke CT protocol include non-enhanced, perfusion, and neck enhanced (or neck CTA) scans were 13.6 mSv for Aquilion ONE CT scanner and 15.0 mSv for Definition Flash CT scanner. The bismuth shield and OB-TCM technique can effectively reduce the absorbed doses to radiosensitive surface organs. We proposed these two methods for radiation dose reduction to superficial organs especially in acute stoke CT examination.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 86

Off-center Effects on Radiation Dose Reduction to Superficial Organs in Chest CT Examination: Comparison of Organ-based Tube Current Modulation (OBTCM), Copper Foil Beam Filtration, and In-plane Bismuth Shield

Ying-lan Liao[1], Sheng-min Su[2], Nan-ku Lia[3], Yu-shen Tyan[3], Hui-yu Tsai[2,4]

[1]*Department of Biomedical Engineering and Enviromental Sciences, National Tsing Hua University, Taiwan*
[2]*Department of Medical Imaging and Radiological Sciences, College of Medicine, Chang Gung University, Taiwan*
[3]*Department of Medical Imaging, Chung Shan Medical University Hospital, Taiwan*
[4]*Institute for Radiological Research, Chang Gung University and Chang Gung Memorial Hospital, Taoyuan, Taiwa*

Purpose: The aim of this study was to compare the off-center effects on radiation dose reduction to superficial organs in CT examinations using three methods of organ-based tube current modulation (OBTCM) technique, copper foil beam filtration, and in-plane bismuth shield.

Materials and methods: An oval PMMA phantom was scanned using routine chest protocol with a dual-source and dual energy CT scanner (SOMATOM Definition Flash, Siemens, Germany). A solid-state diode (CT SD-16, RTI, Electronic AB, Sweden) inserted into the phantom was used to measure the radiation dose profiles under three scanning conditions. Radiation dose profiles at three holes (top, central, and bottom) of the phantom under (1) OBTCM technique, (2) copper foil beam filtration, and (3) in-plane bismuth shield scans were measured. The dose distributions of three methods were compared with that of the reference scan. Furthermore, the off-center effects of radiation dose distribution were also compared with those at iso-center.

Results:The measured dose at the top position of the phantom for the reference scan was 9.45 mGy. The radiation dose reduction at top position was 33% of the OBTCM scan, and 36% of the copper foil beam filtration, and bismuth shield scans. The radiation dose at bottom position of OBTCM scan was 51% higher compared with the reference scan. The superficial doses of the four methods (included reference scan) were reduced when the phantom position was higher than iso-center. The dose reduction was 5%-8% and 14%-23% at 10 mm, and 20 mm above the iso-cneter. When the phantom position was bellowed iso-center, the superficial doses were increased of three scans. The increased radiation dose was 6%-10%, 3%-18%, and 8%-24% at 10 mm, 20 mm, and 30 mm bellowed the iso-center. The bottom dose of the OBTCM scan was the highest of the three scans because the phantom closed to the increased tube current region and higher radiation dose.

Conclusion: We assessed three strategies of radiation dose reduction to superficial organs of the chest CT examination. The organ-based tube current modulation is recommended for protect patient's breast in the chest CT scan. For other CT brands without OBTCM application, copper foil beam filtration or in-plane bismuth shield can be alternative methods. Copper foil beam filtration can be used to reduce radian dose without streak artifact.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 87

Sinogram-based material decomposition in computed tomography with an energy-resolved photon-counting detector

Seungwan Lee, Yu-na Choi, Byung-du Jo, Sung-hoon Choi, Hee-joung Kim

Department of Radiological Science and Research Institute of Health Science, Yonsei University, Korea

Energy-resolved photon-counting detectors provide spectral information produced by energy thresholds. Multi-energy computed tomography (CT) imaging is possible using the photon-counting detectors without the additional exposures and spectral overlap which are regarded as limitations in commercial dual-energy CT scanners. In dual-energy CT, the sinogram-based (pre-reconstruction) technique for material decomposition is able to reduce beam hardening artifacts and improve the quality of decomposed images compared to the image-based (post-reconstruction) material decomposition technique. In this study, we proposed the sinogram-based technique combined with the iterative reconstruction algorithm for material decomposition in spectral CT. The spectral CT system consisted of a micro-focus x-ray tube and a cadmium zinc telluride (CZT)-based photon-counting detector that provides the energy resolving capability with five user-definable energy thresholds. The quantitative accuracy of decomposed images was evaluated by the normalized root-mean-square error (NRMSE). The results showed that the sinogram-based material decomposition technique developed in this study improved the image quality and the quantitative accuracy of decomposed image. This study can potentially be used for the quantification of material composition in spectral CT based on the energy-resolved photon-counting detector.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 88

Applications of ionization chambers in QA of proton therapy

C.h. Lin[1], F.x. Chang[1], M.l. Chu[1], P.k. Teng[1], T.c. Chao[2], C.c. Lee[2,3], C.j. Tung[2], S.y. Cai[2], C.y. Yeh[3], A.e. Chen[4], P.r. Tsai[4], Y.w. Tsai[4], C.h. Wang[5], C.w. Hsieh[6], T.s. Duh[7], Y.c. Lin[7], M.c. Chen[7]

[1]*Institute of Physics, Academia Sinica, Taipei, Taiwan*
[2]*Department of Medical Imaging and Radiological Sciences, Chang Gung University, Lin-kou, Tao-Yuan, Taiwan*
[3]*Proton Therapy Center, Chang Gung Memorial Hospital, Lin-Kou, Tao-Yuan, Taiwan*
[4]*Department of Physics, National Central University, Jhong-li , Taiwan*
[5]*Department of Electro-Optical Engineering, National United University, Miao-li, Taiwan*
[6]*Department of Electrical Engineering, National Chiayi University, Chia-yi , Taiwan*
[7]*Institute of Nuclear Energy Research, Lung-tan, Taiwan*

We report our experience in developing detectors for proton therapy QA. Precision of dose detonation relies on routine QA procedures in proton therapy. Depending on beam deliver and dose detonation methods, check list of routine QA may vary at each proton center. In order to meet various requirements, designs of ionization chamber and electronics are developed separately and the whole detector system combines these two key elements with proper adjustment. Parallel-plate ionization chamber (PPIC) with strip or pad patterns is suitable for lateral beam profile measurement; stack of layers of PPIC's measures distal distribution of proton beam. 256-channel electronics could be current integrators or transient amplifiers with interchangeable resistors to expend its dynamical range. Proton Therapy Center at Chang Gung Memorial Hospital (Lin-kou, Taiwan) will have four treatment rooms which consist of two rooms deploy broad field from wobbly beams and pencil beam scan method will be applied in the other two rooms. Preliminary results and experiences of our collaboration on detector development will be presented.

POSTERS IV - MEDICAL & ENVIRONMENTAL APPLICATIONS: 89

Application of Compressed-sensing (CS) Based Reconstruction Algorithm to Breast Tomosynthesis for Accurate, Low-dose X-ray Imaging

Y. O. Park, H. S. Cho, D. K. Hong, M. S. Lee, U. K. Je, C. K. Park, H. M. Cho, S. I. Choi, Y. S. Koo

Department of Radiological Science and VYSION Research Center, Yonsei University, Wonju 220-710, South Korea

Digital tomosynthesis (DTS) is most commonly used in three-dimensional (3D) mammography because it provides a 3D view, so suspected tumors and masses in the breast can be detected with a higher degree of accuracy. Conventional DTS reconstruction methods are based on the filtered-backprojection (FBP) with an additional deblurring filter. However, this approach usually requires dense projection data with low noise levels for acceptable reconstruction quality, which imposes practical restrictions on the imaging doses and time. Recently reducing doses has become an issue of critical importance in the broader radiological community. In this work, instead, we investigated potential applications to accurate, low-dose breast tomosynthesis with a state-of-the-art image reconstruction based on the compressed-sensing (CS) theory. We implemented an efficient CS-based reconstruction algorithm for breast tomosynthesis and performed systematic simulation works to verify the usefulness of the algorithm. We also performed experimental works in which DTS images of enhanced anatomical resolution were successfully reconstructed through the algorithm. More details of the simulation and the experimental results will be described in the paper.

Neutron Detectors I

10:30 AM - 12:00 PM (Alumni Center)

NEUTRON DETECTORS I - GAS AND SEMICONDUCTOR DETECTORS: 1

Progress in Alternative Neutron Detection

Richard T. Kouzes, Azaree T. Lintereur, Edward R. Siciliano

Pacific Northwest National Laboratory

Within the last decade, the production of 3He from tritium decay has declined as the nuclear weapons stockpile has been reduced. Meanwhile, the demand for 3He has significantly increased, especially for science and national security applications. The largest demand for 3He is in gas proportional counters for neutron detection, where no other currently available detection technology offers the stability, sensitivity, and gamma/neutron discrimination of 3He neutron tubes. Such 3He-based neutron detectors are used in many applications including neutron scattering research, international and homeland security, defense applications, and well logging. The limited supply has curtailed use of 3He, and driven the search for alternate neutron detection technologies to replace it. One of the two largest uses for 3He has been in radiation portal monitors deployed for homeland security, both domestically and internationally, and an alternative had to be found and deployed over a short period of time. The nuclear physics community successfully met this challenge, and recent work has turned to applications for safeguards. One of instruments used most widely by the International Atomic Energy Agency (IAEA) for safeguards measurements of fresh nuclear fuel is the Uranium Neutron Coincidence Collar (UNCL). For this specific application, an Alternative Boron-based Uranium Neutron Coincidence Collar (ABUNCL) has been developed and tested. Results indicate that such an alternative may be a viable replacement for safeguards measurements with the UNCL. This talk will provide an overview of the 3He supply problem and a discussion of various alternative-based systems currently being studied for safeguards applications.

Acknowledgement

This work was supported by the U.S. Department of Energy National Nuclear Security Agency Office of Nuclear Safeguards and Security. PNNL is operated for the US Department of Energy by Battelle under contract DE-AC05-76RLO 1830.

NEUTRON DETECTORS I - GAS AND SEMICONDUCTOR DETECTORS: 2

Advancements in the development of a directional-position sensing neutron detector using acoustically tensioned metastable fluids

Brian C. Archambault[1], Tom F. Grimes[2], Jeff A. Webster[2], Kevin F. Fischer[2], Alex Hagen[2], Rusi P. Taleyarkhan[1,2]

[1]*Sagamore Adams Laboratories, LLC, Chicago, IL, USA*
[2]*School of Nuclear Engineering, Purdue University, West Lafayette, IN, USA*

Advancements in the development of a directional-position sensing fast neutron sensor utilizing the directional acoustic tensioned metastable fluid detector (D-ATMFD) are described. The resulting D-ATMFD system is capable of determining directionality of incoming neutron radiation with a single detector versus use of arrays of detectors in conventional systems. Directional neutron detection and source positioning offers improved detection speeds when compared to traditional proximity searching and the ability to image the neutron source shape, size, and strength in near real time. This work presents major field advancements related to accuracy and precision of ascertaining directionality and source imaging information utilizing enhanced signal processing-cum-signal analysis, refined computational algorithms, and on-demand enlargement capability of the detector sensitive volume. Advancements in the development of the D-ATMFD were accomplished utilizing a combination of experimentation and theoretical modeling. Benchmarking and qualifications studies were successfully conducted with random and fission based SNM neutron sources (^239Pu-Be and ^252Cf).The results of assessments have indicated that the D-ATMFD is not only comparable in technical performance with competing directional fast neutron detector-bank technologies under development worldwide, but it does so with: a single portable (~600cc, <10lb) detector; an unlimited field of view; and at a significant reduction in both cost and size while remaining completely blind to non-neutron background (e.g., beta-gamma) radiation. Rapid and direct SNM neutron source imaging with two D-ATMFD sensors was experimentally demonstrated, and validated against multidimensional nuclear particle transport simulations utilizing MCNPX-PoliMi. Characterization of a scaled, field-ready D-AMTFD based radiation portal monitor (as a cost-effective and efficient ^{3}He sensor replacement) was performed utilizing MCNPX-PoliMi code based 3D model simulations, the results of which are discussed and presented.

NEUTRON DETECTORS I - GAS AND SEMICONDUCTOR DETECTORS: 3

Fast Differential Die-Away Detector Based on Neutron Moderation

Michael J. King[1], Krystal Alfonso[1], Jeffrey Lacy[2], Athanasios Athanasiades[2]

[1]*Rapiscan Laboratories Inc., Sunnyvale CA*
[2]*Proportional Technologies Inc., Houston TX*

The differential die-away technique is a very efficient, pulsed neutron-based method that detects the thermal neutron induced prompt fission neutron signature. In cargo inspection scenarios, hidden nuclear material is identified by detecting thermal neutron induced prompt fission neutrons above the interrogating source fast neutron decay within the detector. A fast die-away detector, <50 μs, allows the source neutrons to die-away earlier, increasing the signal to background ratio near the end of the source neutron pulse. An even faster die-away detector, <20 μs, can be useful in identifying epi-thermal from thermal neutron induced fission. A fast die-away based on a neutron moderation / thermal neutron detector combination is very difficult to design without sacrificing either detection efficiency for die-away time or visa versa. A 0.25 m2 detector was designed in conjunction with Proportional Technologies. The detector utilizes an array of 4.43 mm diameter straw detectors imbedded within a high density polyethylene moderator. To achieve a fast die-away, detection efficiency was sacrificed by increasing the boron coating 2.0 μm. Experimental results showing both epi-thermal and thermal neutron induced fission will be shown.

NEUTRON DETECTORS I - GAS AND SEMICONDUCTOR DETECTORS: 4

Advancements in the Development of Microstructured Semiconductor Neutron Detector-Based Instruments

Ryan G. Fronk[1], Steven L. Bellinger[1], Luke C. Henson[1], Dave E. Huddleston[2], Taylor R. Ochs[1], Cody J. Rietcheck[1], J. Kenneth Shultis[1], Timothy J. Sobering[2], Douglas S. Mcgregor[1]

[1]*Semiconductor Materials and Radiological Technologies Laboratory, Kansas State University, Manhattan, KS, USA*
[2]*Electronics Design Laboratory, Kansas State University, Manhattan, KS, USA*

Thin-film-coated solid-state thermal neutron detectors have long been used as a compact and reliable means of neutron detection but issues with low efficiency have limited their use in industry. The Microstructured Semiconductor Neutron Detector (MSND) improves on the strengths of the thin-film-coated devices while improving thermal neutron detection efficiency. Intrinsic thermal neutron detection efficiencies of over 45% can be accomplished by etching perforations deep into the semiconductor substrate and backfilling the perforations with a neutron-reactive material. To date, single-layer MSNDs have been developed that have achieved 30.1±0.5% intrinsic detection efficiency as tested with a mono-energetic thermal neutron beam, collimated to a diameter smaller than the MSND itself, normally incident on the center of the detector face. In previous work, two 21% single devices were stacked in an offset configuration to achieve 42% intrinsic detection efficiency. The small size and high thermal neutron detection efficiency of the MSND enables many of them to be arranged into larger and more sophisticated instruments. A small, inexpensive electronics package named the "Domino" has been developed as a means to facilitate the deployment of the MSND technology. The Domino is a complete electronics package that allows for the use of an MSND without supporting NIM equipment.

NEUTRON DETECTORS I - GAS AND SEMICONDUCTOR DETECTORS: 5

Limits of 3-Dimentional Associated Particle Neutron Elemental Imaging

David Koltick, Haoyu Wang

Department of Physics and Astronomy, Purdue University, West Lafayette, IN 47907

Associated particle neutron elemental imaging (APNEI) can produce 3-dimensional images. In most applications APNEI is used only to produce projective images. The limits of projective spatial resolution is discussed and presented. APNEI is also capable of 3-dimensional imaging using two techniques, neutron time-of-flight and tomography. The 3-dimenional voxel dimension limits are discussed using these two techniques. Voxel dimensional limits are affected by: (1) the D-T beam spot size, (2) effects of the associated α-particle transducer fluor, (3) geometry of the α-particle transducer, (4) electronics effects of the α-particle transducer and gamma ray detector, (5) gamma ray detector geometry and other effects. Achievable spatial resolution and elemental sensitivity is discussed. The parameters affecting the image resolution are discussed and measured data supporting performance limits are presented.

NEUTRON DETECTORS I - GAS AND SEMICONDUCTOR DETECTORS: 6

Non-destructive studies of gamma-ray detectors with neutron energy resolved imaging

Anton S. Tremsin[1], Edith D. Bourret-courchesne[2], Gregory A. Bizarri[2], Eric C. Samulon[2], Sven V. Vogel[3], Adrian Losko[3], Michael Mocko[3], Ronald O. Nelson[3], W. Bruce Feller[4]

[1]*University of California, Berkeley, California 94720, U.S.A.*
[2]*Lawrence Berkeley National Laboratory, Berkeley, California U.S.A.*
[3]*Los Alamos National Laboratory, Los Alamos, NM 87545, U.S.A.*
[4]*NOVA Scientific, Inc., 10 Picker Rd., Sturbridge, MA 01566, U.S.A*

Maintaining crystalline quality and uniformity during crystal growth is one of the main roadblocks in the development of new detector crystals. Assessing crystalline quality, both in situ during crystal growth and ex situ after crystal growth, provides important feedback on how to improve the crystal growth reproducibility and yield. While X-ray diffraction techniques are typically used to assess crystal quality of bulk materials, these techniques cannot be used with highly photon-absorbent detector materials. Neutron imaging offers an alternative route to study the crystalline properties of gamma ray detectors that are transparent to neutrons. The measurement, which can be done in situ during crystal growth or afterwards on bulk crystals, allows acquiring information in 3D. The diffraction of thermal and cold neutrons can reveal many important crystalline properties of bulk materials: uniformity of crystallographic orientations within the crystal, distribution of stress values and liquid/solid interface during the crystal growth procedure. The elemental and/or isotopic composition can be studied with neutron resonances. Further the temperature distribution of the material, and thus the gradient, can be studied in situ during crystal growth with neutron resonance transmission analysis. Recent development of high resolution neutron counting detectors with sub-100 μm spatial and ~20 ns timing resolution enables unique non-destructive studies of detector crystals. Measurement of transmission spectra in a wide range of neutron energies for each pixel of the image can be performed at a pulsed neutron source. In this paper we report the proof-of-principle studies of single crystal gamma-ray detectors demonstrating the future capabilities of this technique. The studies of several detector compounds reveal the presence of inclusions and strong gradients of some elements, with

unambiguous and independent mapping of multiple elements present in the samples. The misalignment of crystal domains and existence of multiple small grains within certain crystals are observed through the combined neutron imaging/diffraction experiments. The extension of this technique to in situ studies during crystal growth should enable optimization of the crystal growth parameters and thus improve the quality and yield of gamma-ray detectors.

Space Applications

10:30 AM - 12:00 PM (Vandenburg)

SPACE APPLICATIONS: 1

Thin silicon detectors for measuring dE/dx in energetic particle telescopes: development and test results

Mark E. Wiedenbeck[1], Craig S. Tindall[2], John Klemic[3], Jill A. Burnham[3], Alan C. Cummings[3], Allan W. Labrador[3], Richard A. Leske[3], Richard A. Mewaldt[3], Jamie S. Rankin[3], Edward C. Stone[3], Eric R. Christian[4], Sandy Shuman[4], Tycho T. Von Rosenvinge[4]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109
[2]Lawrence Berkeley National Laboratory, Berkeley, CA 94720
[3]California Institute of Technology, Pasadena, CA 91125
[4]NASA/Goddard Space Flight Center, Greenbelt, MD 20771

Solid-state detector telescopes employing the dE/dx versus total energy technique have been widely applied in ground-based laboratories and aboard spacecraft for analyzing the composition and the energy and momentum distributions in populations of energetic particles. The lower limit of applicability of this technique is set by the requirement that the particles have a range longer than the thickness of the dE/dx detector so that they can penetrate it, thereby allowing a 2-parameter measurement. The availability of very thin silicon detectors has been limited both by the difficulties of fabricating and handling these fragile devices and by the problem of achieving a thickness uniformity sufficient for providing the needed resolution in the dE/dx measurement.

In a recent development, commercial silicon-on-insulator (SOI) wafers have been used as the basis for fabricating position-sensitive, ion-implanted silicon dE/dx detectors that have thicknesses down to 10 microns and are thus suitable for studying heavy ions with energies as low as ~1 MeV/nucleon. Detectors of this type in thicknesses of 12 and 25 microns are included in the instrument being developed to measure energetic ions above ~1 MeV/nucleon on NASA

SPACE APPLICATIONS: 2

Probing in-situ with neutron and gamma rays (PING) prototype instrument results

Ann M. Parsons[1], Julia G. Bodnarik[2], Larry Evans[1,3], Timothy Mcclanahan[1], Suzanne F. Nowicki[1,4], Jeffrey Schweitzer[5], Richard D. Starr[1,6]

[1]NASA/ Goddard Space Flight Center, Greenbelt, MD
[2]University of Arizona, Tuscon, AZ
[3]Computer Sciences Corporation, Lanham, MD
[4]Universities Space Research Association, Columbia, MD
[5]University of Connecticut, Storrs, CT
[6]Catholic University of America, Washington, DC

The Probing In situ with Neutrons and Gamma rays (PING) instrument is an innovative planetary science application of the active neutron-gamma ray technology successfully used in oil well logging and mineral exploration on Earth over many decades. PING combines a 14 MeV deuterium-tritium pulsed neutron generator, gamma ray spectrometer and neutron detectors in a landed instrument to determine a planet

SPACE APPLICATIONS: 3

The Upcoming Balloon Campaign of the Compton Spectrometer and Imager (COSI)

Jeng-lun Chiu[1], Steven E. Boggs[2], Hsiang-kuang Chang[1], John A. Tomsick[2], Andreas Zoglauer[2], Mark Amman[3], Yuan-hann Chang[4], Yi Chou[5], Pierre Jean[6], Carolyn Kierans[2], Chih-hsun Lin[7], Alex Lowell[2], Jie-rou Shang[1], Chao-hsiung Tseng[1], Peter Von Ballmoos[6], Chien-ying Yang[1]

[1]*Institute of Astronomy, National Tsing Hua University, Hsinchu 30013, Taiwan*
[2]*Space Sciences Laboratory, UC Berkeley, 7 Gauss Way, Berkeley, CA, USA*
[3]*Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA, USA*
[4]*Department of Physics, National Central University, Jhongli 32001, Taiwan*
[5]*Graduate Institute of Astronomy, National Central University, Jhongli 32001, Taiwan*
[6]*IRAP Toulouse, 9 avenue du Colonel Roche, Toulouse, France*
[7]*Institute of Physics, Academia Sinica, Taipei 11529, Taiwan*

The Compton Spectrometer and Imager (COSI), which was formerly known as the Nuclear Compton Telescope (NCT), is a balloon-borne soft gamma-ray telescope (0.2-5 MeV) designed to study astrophysical sources of nuclear line emission and gamma-ray polarization. The heart of COSI is a compact array of cross-strip germanium detectors (GeDs), providing excellent spectral resolution (~2.5 keV) and capability of tracking individual photon interactions with full 3D position resolution to 1.6 mm^3. COSI is built upon considerable heritage from the previous NCT balloon instrument, which has flown successfully on two conventional balloon flights to date. The Crab Nebula was detected at a significance of 6-σ in the second flight, which is the first reported detection of an astrophysical source by a compact Compton telescope. COSI has been upgraded from the previous NCT instrument to be an Ultra Long Duration Balloon (ULDB) payload, utilizing a new detector configuration optimized for polarization sensitivity and employing a cryocooler to remove consumables (LN2) for ULDB flights. The instrument is being integrated for an LDB flight in December 2014 from Antarctica on a superpressure balloon. Here we will present the redesign of the instrument and our current progress in preparing for the flight.

SPACE APPLICATIONS: 4

Quantum efficiency measurements at multiple X-ray energies in Si Hybrid CMOS detectors

Zachary Prieskorn[1], Stephen D. Bongiorno[2], David N. Burrows[1], Abraham D. Falcone[1], Christopher V. Griffith[1], Jonathan Nikoleyczik[1]

[1]*Pennsylvania State University, Dept. of Astronomy & Astrophysics, University Park, PA 16802 USA*
[2]*The Johns Hopkins University, Dept. of Physics & Astronomy, 3400 N. Charles St., Baltimore, MD 21218 USA*

Si Hybrid CMOS detectors (HCDs) are sensitive to X-rays between approximately 0.2 – 20 keV. HCDs detect photons in the same way as CCDs, via the photoelectric effect, but pixel read out is performed with a fundamentally different technology. The HCD has a Si PIN absorber array with an Al optical blocking filter. Photoelectron absorption occurs in the Si absorption layer. The CMOS readout multiplexer is separate from the absorber and the two are connected with In bump bonds. The separation of the two functions, photon absorption and readout, allows each to be optimized separately. The design of the Si absorber focuses on high quantum efficiency across the desired spectral band, low dark current, and a large format. The CMOS multiplexers are optimized for low noise, large dynamic range, high speed, and low inter-pixel capacitance (IPC). HCDs can provide superior performance to traditional CCDs in multiple areas: faster read out time, windowed read out mode, less susceptible to radiation & micrometeoroid damage, and lower power consumption. X-ray detectors designed for use in astronomical observatories must have an optical blocking filter to prevent the detectors from being saturated by optical light. We have previously reported on the successful deposition of an Al optical blocking layer directly onto the surface of HCDs. These blocking filters were deposited with multiple thicknesses from 180 – 1000 angstroms and successfully block optical light at all thicknesses, with minimal impact expected on quantum efficiency at the energies of interest for these detectors. We report energy dependent soft X-ray quantum efficiency measurements for multiple HCDs with different optical blocking filter thicknesses for energies from ~1 – 8 keV.

SPACE APPLICATIONS: 5

Characterization of the ProtoEXIST2 CZT Detector Plane

Branden Allen[1], Jaesub Hong[1], Jonathan Grindlay[1], Scott Barthelmy[2], Robert Baker[2], Barbara Rodrigues[1], Peter Mao[3], Fiona Harrison[3]

[1]*Harvard College Observatory, 60 Garden Street, Cambridge, MS 02138*
[2]*NASA Goddard Space Flight Center, Code 661, Astrophysics, Greenbelt, MD 20771*
[3]*California Institute of Technology, Pasedena, CA 91125*

The ProtoEXIST program was initiated for the creation of a modular, highly scalable CdZnTe (CZT)detector plane architecture for deployment as a a large detector plane (1-5 m^2) in acoded-aperture telescope for application as a wide field monitor of the X-ray sky sensitive atenergies between approximately 2 and 600 keV. The successful construction of two separate prototype modules each consisting of an 8 × 8 array of pixelated 2 cm × 2 cm, 5 mm thick CZT detectors with anode pixel pitches of 2.5 mm and 0.6048 mm have been successfully integrated andflown on high-altitude (39 km) balloon flights demonstrating operation in space-like conditionswhile conducting observations of individual sources.Subsequent to these flight additional characterization of the ProtoEXIST2 detector plane has beencarried out in an effort to refine the calibration of the flight data, demonstrate the long term stability of the individual detectors, and to characterize the small-scale distortions in the pixelpattern across the entire detector plane in order to set selection criteria for individualdetectors. The small-scale distortions on the detector plane have been measured using twoindependent scans of a single fan beam in order to determine the extent of the active area of theindividual pixels along the X and Y axis of the detector plane. Individual detectors within the detector plane have been observed to exhibit very different levels and patterns of distortion whichhas been show to correlate well with the variation of the relative efficiencies of individual pixelsin the detector plane.The results of these characterization efforts will be presented in detail.

Low Energy Exotic Beam Facilities

1:30 PM - 3:00 PM (Vandenburg)

LOW ENERGY EXOTIC BEAM FACILITIES: 1

The ISAC program at TRIUMF: status and outlook

Anna A. Kwiatkowski

TITAN at ISAC, TRIUMF, Vancouver, Canada

LOW ENERGY EXOTIC BEAM FACILITIES: 2

The ATLAS/CARIBU facility

Guy Savard[1,2]

[1]*Physics Division, Argonne National Laboratory, Argonne, Illinois*
[2]*Department of Physics, University of Chicago, Chicago, Illinois*

The ATLAS facility and its CARIBU upgrade provide users with high-intensity beams of essentially all stable ion species at Coulomb barrier energy and an array of radioactive ion beams. Radioactive beams of light ions are produced by an in-flight technique from reactions using the intense stable beams while the unique neutron-rich beams are produced by the CARIBU front-end which turns Californium fission fragments into beams at low-energy that can be reaccelerated to Coulomb energy by ATLAS. The facility with its technical capabilities, its complement of experimental instruments, and its physics program, will be presented. This work is supported by the US DOE under contract DE-AC02-06CH11357.

LOW ENERGY EXOTIC BEAM FACILITIES: 3

The Facility for Rare Isotope Beams Project* and the ReA Reaccelerator**

Thomas Glasmacher

Facility for Rare Isotope Beams, 640 South Shaw Lane, Michigan State University, East Lansing, MI 48824

The Facility for Rare Isotope Beams (FRIB) will be a U.S. Department of Energy Office of Science (DOE-SC) national user facility supporting the mission of the DOE-SC Office of Nuclear Physics. Centered on a 400kW superconducting linear accelerator providing heavy-ion beams with energies of 200MeV/nucleon for all ions, FRIB will enable scientists to make discoveries with fast, stopped, and reaccelerated rare isotopes. The FRIB project was baselined at a total project cost of $730M with scheduled completion in June 2022. The project is being managed to early completion in 2020 and civil construction has begun on the campus of Michigan State University (MSU). This talk will give an overview of the FRIB project, its current status and prospects for discovery as well as the ReA reaccelerator at the National Superconducting Cyclotron Laboratory at MSU.

* The design and establishment of FRIB is supported by the U.S. Department of Energy Office of Science under cooperative agreement DE-SC0000661, the State of Michigan and Michigan State University.

**Operation of NSCL as a national user facility is supported by the Experimental Nuclear Physics Program of the U.S. National Science Foundation under cooperative agreement PHY-0110253 and Michigan State University.

Active Interrogation Techniques

1:30 PM - 3:00 PM (Alumni Center)

ACTIVE INTERROGATION TECHNIQUES: 1

Review of active interrogation systems

Tsahi Gozani

DNDO Consultant, Palo Alto, CA 94301

One of the most critical security issues facing the United States and the rest of the civilized world is the detection and interdiction of nuclear materials smuggled into the country through any possible pathway (sea, land or air).Detecting the naturally emitted gamma rays (or neutrons, in some cases) by these materials, is helpful and is commonly done these days, and referred to as “Passive Interrogation”. However when embedded in cargo their detection precipitously declines because of the gamma ray low energy. The Active Interrogation (AI), where neutrons or photons (usually high energy x-rays) are employed to penetrate deep into the cargo to reach the nuclear material and stimulate fissions (or other isotopic characteristics), overcame the inherent limitations of passive interrogation. The fission process is very rich in penetrating nuclear signatures endowed with different (including high) energies and temporal behavior, making it, more readily detectable. Currently prompt neutrons, delayed gamma rays and delayed neutrons are employed in advanced demonstration systems. Some laboratory systems use also prompt fission gamma rays signature. Other very useful, non-fission signatures, such as the approximate atomic number (Z) of elements or nuclear states of isotopes in the inspected cargo are being implemented in advanced AI systems. These are afforded by the use of high energy (≈9MeV) x-rays interrogation which are the basis for the requisite high (spatial) resolution x-ray radiography as well as photofission stimulation of the fissionable isotopes.A variety of interrogation neutron sources such as: (d,D), (d,T), (x-ray,n) are being used to stimulate and detect fission signatures depending on the AI system’s mission. Elaborate shielding and spectral tailoring systems are often employed around these sources Different detectors are being used in AI demonstration systems, for example: liquid scintillators (with PSD), threshold activation (TAD) and moderated thermal neutron for prompt neutrons (the last one is also used for delayed neutrons); plastic scintillators for delayed gamma rays; NaI and plastic scintillators for Z determinations. New detectors have been developed which could enhance or replace existing ones.The multiplicity of signatures, often employed in the same AI system platform, reduces vulnerabilities, increases reliability, robustness and performance and could even lower the overall security cost.The principles and status of active interrogation systems will be reviewed.

Email address: tgmaven@gmail.com

ACTIVE INTERROGATION TECHNIQUES: 2

Prompt Gamma-Ray Production Cross Sections Measurement Using a 14.1 MeV Associated Particle Neutron Generator

David Koltick, Haoyu Wang

Department of Physics and Astronomy, Purdue University, 525 Northwestern Ave., West Lafayette, IN 47907, USA

Knowledge of gamma-ray production rates is important in many elemental analysis applications using active neutron interrogation techniques. However, past measurements are limited to a single fixed angle having small solid angle coverage. The production is then extrapolated to the full solid angle assuming a uniform angular distribution. Even so past measurements are dominated by high backgrounds and overlapping gamma-ray signals having nearby energy. Reported cross sections can vary by a factor of ~4. In order to improve our knowledge of elemental cross sections, we have constructed a spectrometer using an associated particle neutron generator and an array of 12 NaI detectors each 14 cm square by 16.5 cm deep. The array covers ~30% of the solid angle, extending to within ~35 degrees of the entering and exiting electronically collimated neutron beam, on a circular shell ~21 cm in radius from the target. The major improvements in these measurements come from the 3.0 nanosecond coincident timing required between the prompt gamma-ray detection and the associated alpha particle produced simultaneously with the neutron, and the electronically restricted neutron aperture generated by the required alpha particle detection. The timing requirement greatly reduces the detectors exposure to background. To illustrate the improvements using this technique we present first measurements of the 846.8 keV and the 1238.3 keV prompt gamma-ray cross sections from Fe-56.

ACTIVE INTERROGATION TECHNIQUES: 3

Portable High Power X-ray Source Based on a 10 MeV Superconducting Linac

Terry L. Grimm[1], Chase H. Boulware[1], Jerry L. Hollister[1], Erik S. Maddock[1], Valeriia N. Starovoitova[1], Alan W. Hunt[2]

[1]*Niowave, Inc. Lansing, MI 48906*
[2]*Idaho Accelerator Center, Idaho State University, Pocatello, ID 83201*

Cargo scanning using either radiographic imaging or active interrogation for Special Nuclear Material (SNM) requires high energy and high intensity x-rays. The most common source of such x-rays is an electron accelerator. Existing pulsed copper accelerators have low duty cycle beams and correspondingly low average current, which limit the quality of x-ray images and SNM detection sensitivity. Furthermore, inspection systems based on copper accelerators typically weigh several tons, have a large footprint, and consume hundreds of kilowatts of electric power. As a result, these machines require a large, fixed site to operate. To overcome these limitations we are developing a compact, portable, high-efficiency 10 MeV superconducting electron linac. Equipped with a thin liquid metal bremsstrahlung converter, it generates a continuous, high-energy, high-intensity x-ray beam ideal for x-ray radiography or for initiating photonuclear reactions required for active interrogation. Using a superconducting linac as an x-ray source results in a compact and portable scanning system. Despite the high beam intensity, superconducting linacs produce very little electron scatter within the accelerating module, requiring only light shielding and resulting in low radiation doses in the area adjacent to the machine. High efficiency, solid-state radio frequency amplifiers and superconducting accelerating modules allow our linacs to be powered by a portable generator of less than 20 kW. By supplying cryogenic coolant (liquid nitrogen and helium) from insulated dewars, a fully functional, self-contained superconducting linac can be mounted on a small truck for rapid deployment.In this talk we will present the results of the simulations of the photon fluxes and doses, conceptual design of the system, and the experimental results of the prototype testing.

ACTIVE INTERROGATION TECHNIQUES: 4

X-ray and neutron interrogation of air cargo for mobile applications

Seth Van Liew[1], Vernon T. Koslowsky[2]

[1]*American Science and Engineering, Billerica, MA*
[2]*Bubble Technology Industries, Chalk River, Ontario, Canada*

The positive identification of explosives in air cargo requires methods beyond current dual energy x-ray technology, which only classifies materials as organic, inorganic, or metal. Neutron radiography is an excellent complement to x-ray radiography due to its different attenuation properties. Deploying neutron systems, however, has been problematic due to their complexity and total size. In this work we present an x-ray/neutron radiography system using a 140 kV x-ray beam and 2.5 MeV neutrons intended for deployment in mobile applications. We used multiple fan beams of x-rays that matched the geometry of the neutron source, with standard commercial detectors. The neutron detectors were stackable microstructure arrays utilizing a high electric field between miniature elements. The spatial resolution of both the x-ray and neutron system was approximately 1.5 mm. New algorithms developed for the x-ray effective atomic number determination showed an improvement over current commercial systems by a factor of 5. We also demonstrate the clear identification of threat materials, even when they have identical effective atomic numbers to benign materials.

ACTIVE INTERROGATION TECHNIQUES: 5

Observation of Material and Thickness Dependent Effects in Moderate and High Z Targets in a Gamma Ray LIDAR Experiment

Xiaodong Zhang[1], Mitchell A. Laubach[1], Jason P. Hayward[1,2]

[1]*Nuclear Engineering Department, University of Tennessee-Knoxville, TN, USA, 37996*
[2]*Oak Ridge National Laboratory, Oak Ridge, TN, USA, 37831*

We present observations from our measurements which suggest that a new remote-sensing method based on a high-energy, fast-pulse (~50 ps) LINAC and a glass Cherenkov detection system may be feasible. The accelerator-detector system coincidence resolving time was measured to be 93 ps FWHM, which yields a better than 3-cm depth resolving ability for sensing multi-layered moderate and high atomic number (Z) targets. Targets consisted of different configurations and varied thicknesses of iron, lead, and depleted uranium. The analysis of integrated charge from the Cherenkov detectors shows that the long position annihilation lifetime degrades the time/depth resolving ability if all the data collected from a particular target layer is considered. However, this can be corrected through using a higher threshold to discriminate out the influence of 511 keV gammas produced by the position annihilation process; this yields improved depth determination. As expected, the experimental results also show that the iron target tends to produce less charge per pulse and has a smaller shielding effect compared with the same thicknesses of lead and depleted uranium. Considering the lead and depleted uranium targets, the photon responses don't show obvious differences. A detailed data analysis regarding the observed the depth profiles from different targets, as well as new algorithms for improved depth determination, will be discussed in the full paper. We will also discuss potential methods for determining target atomic number and depth.

This work was supported by grant HDTRA 1-09-1-0052.

Neutron Detectors II

3:30 PM - 5:30 PM (Vandenburg)

NEUTRON DETECTORS II - NEUTRON SPECTROSCOPY WITHOUT TIME-OF-FLIGHT: 1

Deuterated Scintillators and Their Application in Neutron Spectroscopy

Michael Febbraro[1], Chris C. Lawrence[2], Frederick D. Becchetti[1], Ramon O. Torres-isea[1], Bruce Pierson[2], James J. Kolata[3]

[1]*University of Michigan, Dept. of Physics, Ann Arbor, MI, 48109, USA*
[2]*University of Michigan, Dept. of Nuclear Engineering, Ann Arbor, MI, 48109, USA*
[3]*University of Notre Dame, Dept. of Physics, Notre Dame, IN, 46556, USA*

Deuterated scintillators have been used for more than 30 years as a tool for neutron spectroscopy without need for neutron time-of-flight (n-ToF). This presentation will provide historical applications such as the Deuterated Anthracene Spectrometer (DAS) and modern systems such as UM-DSA and DESCANT deuterated scintillator arrays. Gamma-neutron pulse-shape discrimination and spectrum unfolding methods such as MLEM, Conjugate Gradient, and Artificial Neural Networks will be discussed. In addition, recent experimental results from measurements of discrete and continuous neutron spectra in nuclear physics research and homeland security applications will be shown.

*This work supported by NSF grant PHY 0969456 and ARI GRANT XXXXXXX.

NEUTRON DETECTORS II - NEUTRON SPECTROSCOPY WITHOUT TIME-OF-FLIGHT: 2

Performance of a New ^{6}Li-depleted Cs_2LiYCl_6 Array for Fast Neutron Spectroscopy

N. D'Olympia, P. Chowdhury, C.J. Lister

Department of Physics and Applied Physics, University of Massachusetts Lowell, Lowell, MA 01854

The Small CLYC Array for Neutron Spectroscopy (SCANS) is a newly developed detector array consisting of 16 ^{6}Li-depleted Cs_2LiYCl_6 (CLYC) scintillators. SCANS has been designed as a next-generation tool for low-energy neutron spectroscopy that does not require neutron time-of-flight or, within a certain energy range, spectral unfolding to infer the energy of incident neutrons. The primary mode of detection is based on the ^{35}Cl(n,p) reaction. Because the energy of the emitted proton is directly proportional to the reaction Q-value and neutron energy, discrete peaks are observed in the neutron spectrum, which can be calibrated to energy. CLYC has been popular as a thermal neutron detector due to its excellent pulse-shape discrimination and favorable gamma-ray detection properties; however, it has only recently been explored for fast neutron detection. SCANS is comprised of 16 1"x1" CLYC crystals that have been depleted of ^{6}Li to suppress the otherwise dominant thermal neutron response from the ^{6}Li(n,α) reaction. The 16 detectors are arranged in a 4x4 square array to function as a larger composite detector. The modularity of using individual detectors also allows for different geometrical configurations. The data acquisition system uses a 16 channel, 250 MS/s, 14-bit digitizer by Struck. Characterization of the response of ^{6}Li-depleted CLYC crystals have been carried at energies from 100 keV, up to 50 MeV and a number of facilities employing mono-energetic and continuous fast neutron beams. Monte Carlo simulations were used to gain further understanding of the response and to provide estimates of efficiency. An evaluation of all 16 detectors for properties such as energy resolution, and pulse-shape discrimination was carried out to assess the crystal growth consistency and demonstrate the feasibility for commercial-scale growth of CLYC . The performance of individual detectors and the entire array has been characterized for both fast neutrons and gamma-rays at the University of Massachusetts Lowell in preparation for the application of SCANS to β-delayed neutron measurements.

NEUTRON DETECTORS II - NEUTRON SPECTROSCOPY WITHOUT TIME-OF-FLIGHT: 3

DESCANT

James Wong[1], P.e. Garrett[1], D. Bandyopadhyay[1], J. Bangay[1], L. Bianco[1], V. Bildstein[1], B. Hadinia[1], K.g. Leach[1], C. Sumithrarachchi[1], S.f. Ashley[2], B. Crider[2], M.t. Mcellistrem[2], E.e. Peters[2], F.m. Prados-estevez[2], S.w. Yates[2], J.r. Vanhoy[3]

[1]University of Guelph, Guelph, ON, Canada
[2]University of Kentucky, Lexington, KY, USA
[3]United States Naval Academy, Annapolis, MD, USA

The DESCANT array at TRIUMF is designed to track neutrons from RIB experiments. DESCANT is comprised of 70 close-packed deuterated liquid organic scintillators coupled to digital fast read-out ADC modules. This configuration will permit online pulse-shape discrimination between neutron and γ-ray events.The anisotropy of the n-d scattering will allow to distinguish higher neutron multiplicities from scattering within the array and to determine the neutron energy spectrum directly from the pulse-height spectrum without using TOF.DESCANT detectors have been used in a ^{24}Mg(^{3}He, n)^{26}Si experiment at the accelerator lab of the University of Kentucky.DESCANT and the first result of the (^{3}He, n) experiment will be presented.

NEUTRON DETECTORS II - NEUTRON SPECTROSCOPY WITHOUT TIME-OF-FLIGHT: 4

Neutron Detector based on particles of 6Li Glass Scintillator Dispersed in Organic Lightguide Matrix

Kiril D. Ianakiev, Markus P. Hehlen, Martyn T. Swinhoe, Andrea Favalli, Metodi L. Iliev, Terri C. Lin

Los Alamos National Laboratory

Most 3He replacement neutron detector technologies today have overlapping neutron-gamma pulse-height distributions, which limits their usefulness and performance. Pulse Shape Discrimination (PSD) or threshold settings can be used that suppress all gammas as well as much of the neutrons. Count rates are limited and dead times are high when PSD is used, and the detection efficiency for neutron events is reduced due to the high threshold. This is a problem in most applications where the neutron-gamma separation of 3He detectors had been essential. This challenge is especially severe for neutron coincidence and multiplicity measurements that have numerous conflicting requirements such as high detection efficiency, short die-away time, short dead time, and high stability. 6Li-glass has excellent light output and a single peak distribution, but is difficult to implement because of gamma sensitivity. The idea of reducing the gamma sensitivity of 6Li-glass by embedding small glass particles in an organic light-guide medium was first presented by L.M. Bollinger in the early 60s but, to the best of our knowledge, has never been reduced to practice. We present a detector design and experimental data for application to a large-area neutron detector, by uniformly distributing the 6Li-glass particles in a non-scintillating organic light-guide and everything in a medium with matched refractive index. Initial results were obtained with a 2”×2”×2” assembly consisting of 1-mm3 particles of 6Li-glass scintillator dispersed 5 mm apart within a PMMA matrix. The proof-of-principle detector was tested with a neutron source and gamma sources and showed a neutron peak at about 1600 keV gamma equivalent with <15 % FWHM well separated from a gamma distribution limited to below 1100 keV regardless of gamma energy. A larger prototype that will be scalable to a detector for coincidence and multiplicity measurements is currently under construction and will be presented at the conference.

NEUTRON DETECTORS II - NEUTRON SPECTROSCOPY WITHOUT TIME-OF-FLIGHT: 5

Spatial Resolution and Efficiency of Neutron Sensitive Micro-channel Plate Detectors

Edward Cazalas[1], Cory Trivelpiece[2], Igor Jovanovic[1]

[1]*Department of Mechanical and Nuclear Engineering, Pennsylvania State University, University Park, PA 16802*
[2]*Materials Research Institute, Pennsylvania State University, University Park, PA 16802*

Neutron detection has generally relied on the use of ^{3}He as the primary detection medium for cold and thermal neutrons and serves as a benchmark for the efficacy of other neutron detection architectures. Due to the decreasing supply of ^{3}He, the neutron scattering community must begin to rely on novel detectors that replace ^{3}He. Many detectors have recently been proposed to replace the existing and aging ^{3}He-detector inventory; however, few of these detectors offer position-sensitivity coupled with spatial and temporal resolution appropriate for high-resolution neutron scattering applications.A detector has been developed that consists of a neutron-sensitive micro-channel plate (MCP) coupled to readout devices that can achieve position-sensitivity with high spatial and temporal resolution. The MCPs used in these detectors are doped with a neutron sensitive nuclide, such as ^{10}B, ^{6}Li, or ^{157}Gd, which, upon the absorption of a neutron, undergo a nuclear reaction in which charged particles are emitted with energies determined from the reaction Q-value and kinematics. These charged particles enter the channels of the MCP and produce electron avalanches that are detected on the backside of the MCP.The goal of this work is to investigate potential detection efficiency gains that could be made by coupling a thin-film neutron converter to the upstream-side of the MCP without sacrificing the spatial resolution of the system. Neutrons would be absorbed before entering the MCP walls, and the charged particles would be emitted directly into the MCP pores, inducing the electron avalanches. Several thin film compositions are modeled to determine: (1) the range of emitted charged particles in the material, and (2) the amount of radial straggling the charged particles will undergo as they are transmitted through the thin film neutron converters. The thin film compositions were chosen based on the absorption cross-section of the neutron-sensitive nuclide and the maximum range of the emitted charged particles from the neutron-induced nuclear reaction. These ranges were calculated using the Monte Carlo code SRIM. As the film thickness increases, neutron absorption efficiency increases and charged particle radial straggling also increases, which worsens the spatial resolution. Thus, a tradeoff exists between efficiency and spatial resolution that may be optimized based on the desired specifications of the MCP system. The effect of straggling on the achievable resolution of the MCP system as a function of film thickness is simulated in GEANT4, which is also used in film optimization.

Contemporary Topics

3:30 PM - 5:30 PM (Alumni Center)

CONTEMPORARY TOPICS: 1

Development of a Neutron Detector Based on a Lithium Glass-Scintillating Plastic Composite

Michael Mayer[1], Igor Jovanovic[1], Jason Nattress[1], Zoubeida Ounaies[1], Amira Barhoumi Meddeb[1], Cory Trvelpiece[1], Kareem Kazkaz[2], Grayson Rich[3]

[1]*Pennsylvania State University, University Park, PA 16802*
[2]*Lawrence Livermore National Laboratory, Livermore, CA 94550*
[3]*University of North Carolina at Chapel Hill, Chapel Hill, NC 27599*

We report on the development of a composite neutron detector with high gamma rejection using a glass-plastic composite. GS20 glass is embedded in a polyvinyltoluene (PVT) matrix with an optimized mass fraction of GS20. The optimal shape and configuration of the GS20 glass have been studied by Geant4 simulations. The preliminary design for the detector geometry is cylindrical, with a radius of 25 mm and a height of 50 mm. GS20 glass in the form of cubes, beads, and square rods of approximately 1 mm × 1 mm are modeled. Optimized placements of the square rods in the PVT matrix have been studied in detail to maintain high neutron detection and gamma rejection. Experimental data are collected from multiple pulse-shape discriminating scintillators with comparable dimensions, including the Eljen

CONTEMPORARY TOPICS: 2

Effects of Detector Efficiency and Energy Resolution on Gamma-Ray Background Rejection in Mobile Spectroscopy and Imaging Systems

Timothy J. Aucott[1], Mark S. Bandstra[2], Victor Negut[2], Joseph C. Curtis[1], Daniel H. Chivers[2], Kai Vetter[1,2]

[1]*University of California, Berkeley*
[2]*Lawrence Berkeley National Laboratory*

The presence of gamma-ray background significantly reduces detection sensitivity when searching for radioactive sources in the field, and this background limits the size and energy resolution of systems that can be used effectively. An extensive survey of the background was performed using both sodium iodide and high-purity germanium, and these measurements were resampled to simulate the performance of a detector array of arbitrary size and resolution. The response of the system as it moved past a stationary source was modeled for spectroscopic and coded aperture imaging algorithms and used for source injection into the measured background. The performance of both techniques is shown for various sizes and resolutions, as well as the relative detection efficiencies for sodium iodide and germanium.

CONTEMPORARY TOPICS: 3

Micro-layered thermal neutron scintillator for increased detection efficiency

Peter R. Menge[1], Michael R. Mayhugh[1], Joao M. Maia[2], Creusa Ferreira[2], Xin Guo[2], James D. Mcguffin-cawley[2]

[1]*Saint-Gobain Crystals, Hiram, Ohio*
[2]*Case Western Reserve University, Cleveland, Ohio*

Mixtures of ^{6}LiF and ZnS(Ag) powders in a polymer binder have been used for several decades as thermal neutron detectors. The ^{6}Li(n,T)α reaction creates ionizing alpha and triton particles which enter neighboring ZnS(Ag) particles. The ZnS(Ag) scintillates, which indicates the presence of neutrons. A problem that inhibits performance of such powder mixtures is that the powder particles do not have uniform sizes, and the mixtures are non-uniform. This leads to a distribution in energy straggling that blurs the energy resolution and lowers detection efficiency. One way to overcome this deficiency is to engineer the particles into a repeating geometry which will make the energy deposition into the ZnS more uniform from one reaction to another. The use of alternating micro-layers (1-50 μm) of LiF and ZnS in a PMMA binder is being explored to achieve a regularly repeating geometry. Such films are manufactured using forced assembly multilayer co-extrusion processing. The main goal of this program is to manufacture films that eliminate low energy depositions. The poor signal-to-noise associated with low energy depositions cause neutron interactions to go undetected due to either falling below the detection threshold or be mistaken for gamma ray interactions. The initial experimental results are presented. Simulations which explore optimum layer thicknesses, particle sizes, and filling factor are also presented.

CONTEMPORARY TOPICS: 4

Day to Day Variations in Neutron and Gamma Ray Background Radiation

Andrew Nicholson[1], Donald Hornback[1], Jason P. Hayward[1,2]

[1]*Oak Ridge National Laboratory*
[2]*University of Tennessee*

To assess the effect of weather variables (pressure, temperature, humidity, rain, etc) on local background radiation, a trailer-based measurement system was designed and built to measure fast neutron and gamma background rates in static or dynamic measurements. An eight detector array mounted inside the trailer provides a total detector area of 0.5 m^2 containing EJ-301 liquid scintillators. In addition, a weather station was installed to record external and internal weather data and a GPS receiver was used to store position, velocity and altitude information. In this work the results from three long-term stationary measurements performed to determine the extent of non-statisticial variations in the local background rates and their correlation with weather variables. The data were collected from late 2011 through early 2012 outside of building 3500 at Oak Ridge National Laboratory. Both the gamma and neutron backgrounds were found to vary significantly due to changes in local weather conditions. Understanding, and accounting for, these effects is important in the operation of systems performing dual gamma and neutron detection.

CONTEMPORARY TOPICS: 5

Comparing the Response of PSD-capable Plastic Scintillator to Standard Liquid Scintillator

Richard S. Woolf[1], Anthony L. Hutcheson[2], Chul Gwon[2], Bernard F. Phlips[2], Eric A. Wulf[2]

[1]*National Research Council Postdoctoral Fellow, Washington, DC, USA*
[2]*Space Science Division, U.S. Naval Research Laboratory, Washington, DC, USA*

We report on a test campaign carried out in December of 2013 to characterize the response of recently developed plastic scintillator with pulse shape discrimination (PSD) capabilities. PSD is a property exhibited by certain types of scintillating material in which incident stimuli (fast neutrons or γ rays) can be separated by exploiting differences in the tail of their scintillation light pulses. The PSD plastic scintillator, initially developed by [1], is commercially available through Eljen Technologies (EJ-299-33). Detector geometries used were: 10 cm × 10 cm × 10 cm cube and 10 cm diameter × 10 cm long cylinder. EJ-301 and EJ-309 liquid scintillators with well-known responses were also tested. The work was conducted at the University of Massachusetts Lowell Van De Graaff generator. Accelerated protons impinging on a thin Li target yield mono-energetic neutrons from the ^{7}Li(p,n)^{7}Be reaction (Q-value: –1.644 MeV). The proton beam nominally operated at energies of 3.0 and 4.0 MeV; additional calibration points were obtained at proton beam energies of 4.2, 4.5, 4.7 and 4.9 MeV. At a fixed proton beam energy, different neutron energies could be obtained by rotating a neutron spectrometer between 0° (on axis) and points off axis up to 135°. Varying the proton beam energy and the angle of the spectrometer allowed for neutron energies between 0.5 – 3.2 MeV in 200 – 300 keV steps. Data were acquired through two sets of electronics capable of performing digital PSD measurements: a 16-channel Struck VME flash digitizing ADC (SIS3316) and a 120-MHz Bridgeport USB base. By using the method of PSD to select out the neutron events from unwanted γ background, we construct a pulse height spectrum for each neutron energy. Obtaining a relationship of the relative light output, as determined by the half-height of the abrupt edge of the pulse height spectrum, versus energy allowed us to construct the response function for the EJ-299-33 detectors. We present the EJ-299-33 response and how it compares with the widely accepted non-linear curves observed in standard xylene-based liquid scintillator, such as EJ-301 (NE-213 equivalent) [2], our results for the EJ-301 and EJ-309 liquid scintillators and how they compare with this previous work, a comparison between the two data acquisition systems, and Monte Carlo modeling results regarding how the beam environment affected the detector response.

[1] N. Zaitseva, B. L. Rupert, et al., "Plastic scintillators with efficient neutron/gamma pulse shape discrimination." Nucl. Instr. Meth. A, vol. 668, pp. 88–93, 2012.
[2] V. V. Verbinski, W. R. Burrus, et al., "Calibration of an Organic Scintillator for Neutron Spectrometry." Nucl. Instr. Meth, vol. 65, pp. 8–25, 1968.

CONTEMPORARY TOPICS: 6

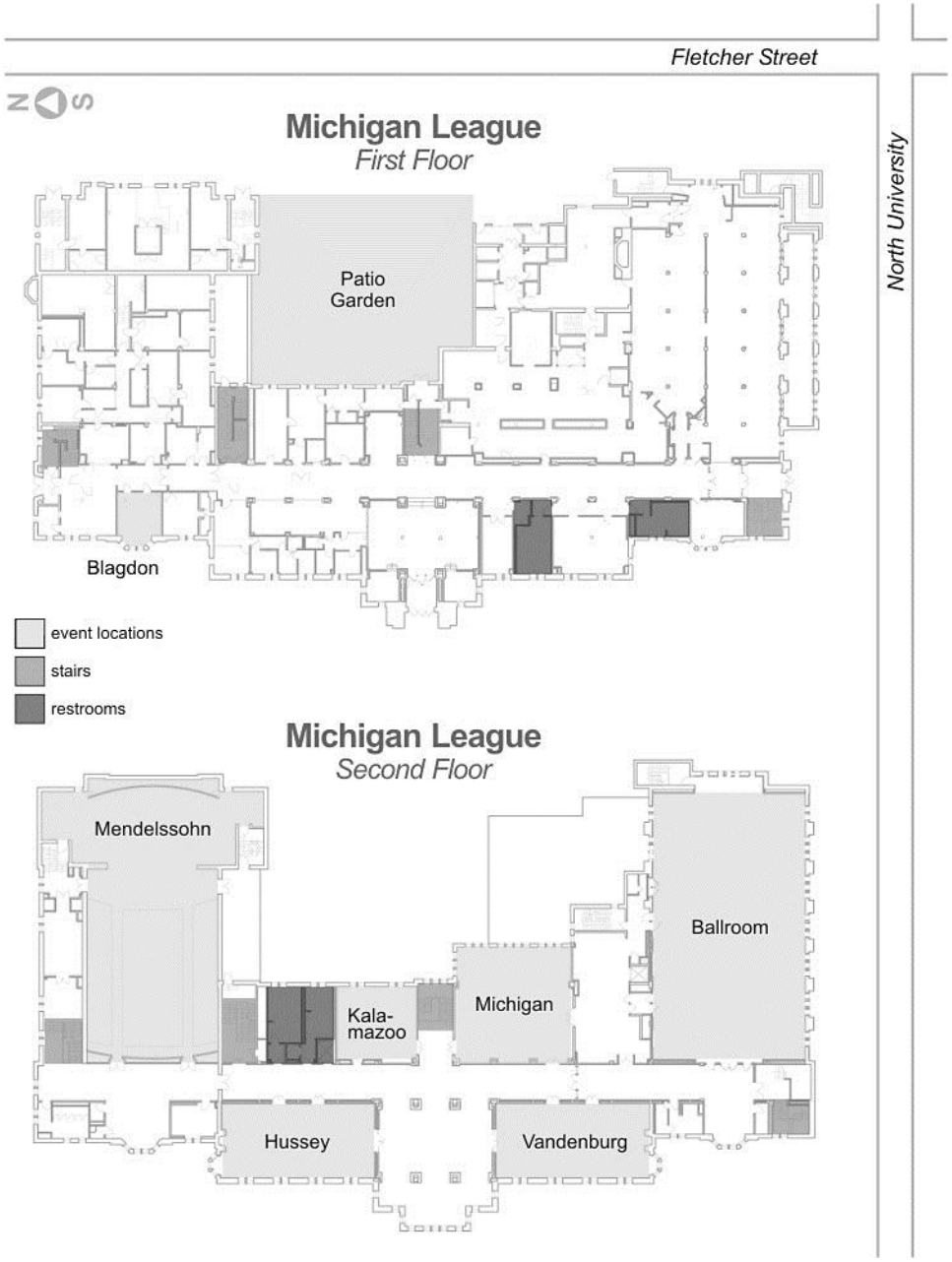
Flexible composite scintillator based on Eu:LiCAF crystal grains

Joanna Iwanowska - Hanke[1], Marek Moszynski[1], Pawel Sibczynski[1], Hiroaki Saito[2], Kentaro Fukuda[2]

[1]*National Centre for Nuclear Research, Otwock, Poland*
[2]*Tokuyama corporation, Japan*

Recently developed by Tokuyama Corp. ^{6}Li based scintillation crystals such as Ce:LiCAF shows comparable gamma-ray discrimination and thermal neutron detection efficiency to GS20 ^{6}Li glass scintillator. However, low light output limits a wider application of this crystal. On the other hand Eu:LiCAF presents significantly higher light output, but worse gamma-ray rejection. The newest solution for neutron detection is a flexible sheet consisting of Eu:LiCAF crystals. Unique configuration of the detector, in which wavelength shifting fibers are incorporated in the scintillation crystal grains, makes efficient light collection from large to small area photodetector.Gamma-ray response as well as slow neutron detection (^{238}PuBe source slowed down by a 10 cm thick wall of a polyethylene) with a sample of rubber Eu:LiCAF scintillator (15×15×5mm^{3} dimension) have been investigated.Pulse height spectra measured for ^{137}Cs and ^{60}Co gamma-ray sources show that energy of scattered electrons decreases rapidly, and we don't observe typical Compton edges. The composition of the scintillator allows to improve gamma-ray rejection in comparison to standard Eu:LiCAF, remaining light yield from neutrons at the same level. Good gamma-ray rejection in the LiCAF rubber is due to a small size of crystal grains, much lower than a range of secondary electrons produced by gamma rays. Thus, only a small fraction of electrons loses a full energy in the grain of crystals.

Michigan League Floor Plan



Registration – 2nd Floor Concourse

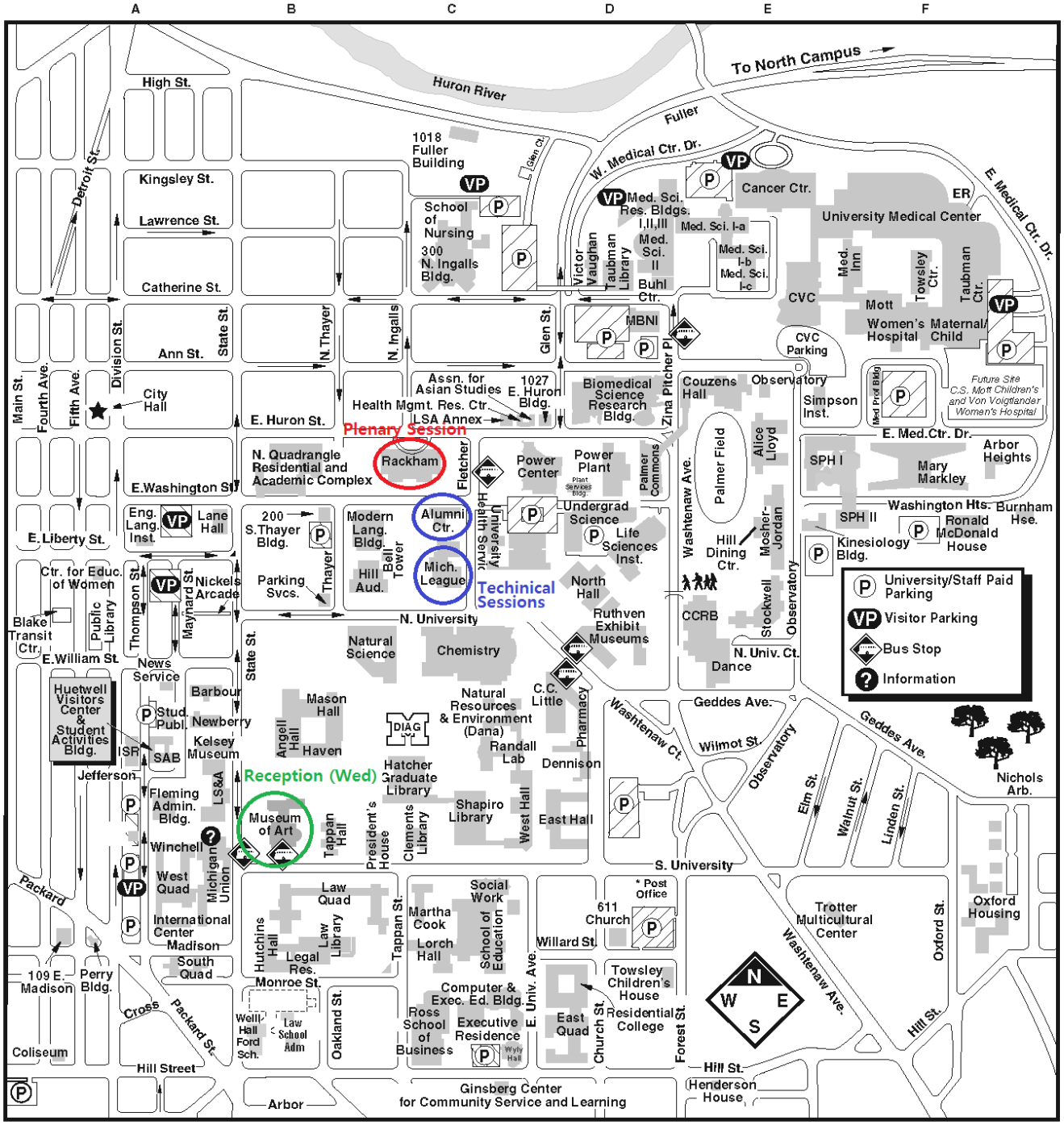
Technical Sessions – Hussey / Vandenburg and Alumni Center

Email Stations and Speaker Practice– Kalamazoo

Rest Area – Michigan

Exhibitors– Ballroom

University of Michigan
Central Campus



To Michigan Stadium
Reception (Tues)

Campus Information Centers, (First floor, Michigan Union, 764-INFO)

Thank you for participating in SORMA XV !

2014 SORMA XV Committee Members

David Wehe
Frederick Becchetti
Neal Clinthorne
Geehyun Kim
Kathy Owens
Zhong He
Sara Pozzi
Mark Hammig
Eileen Shields