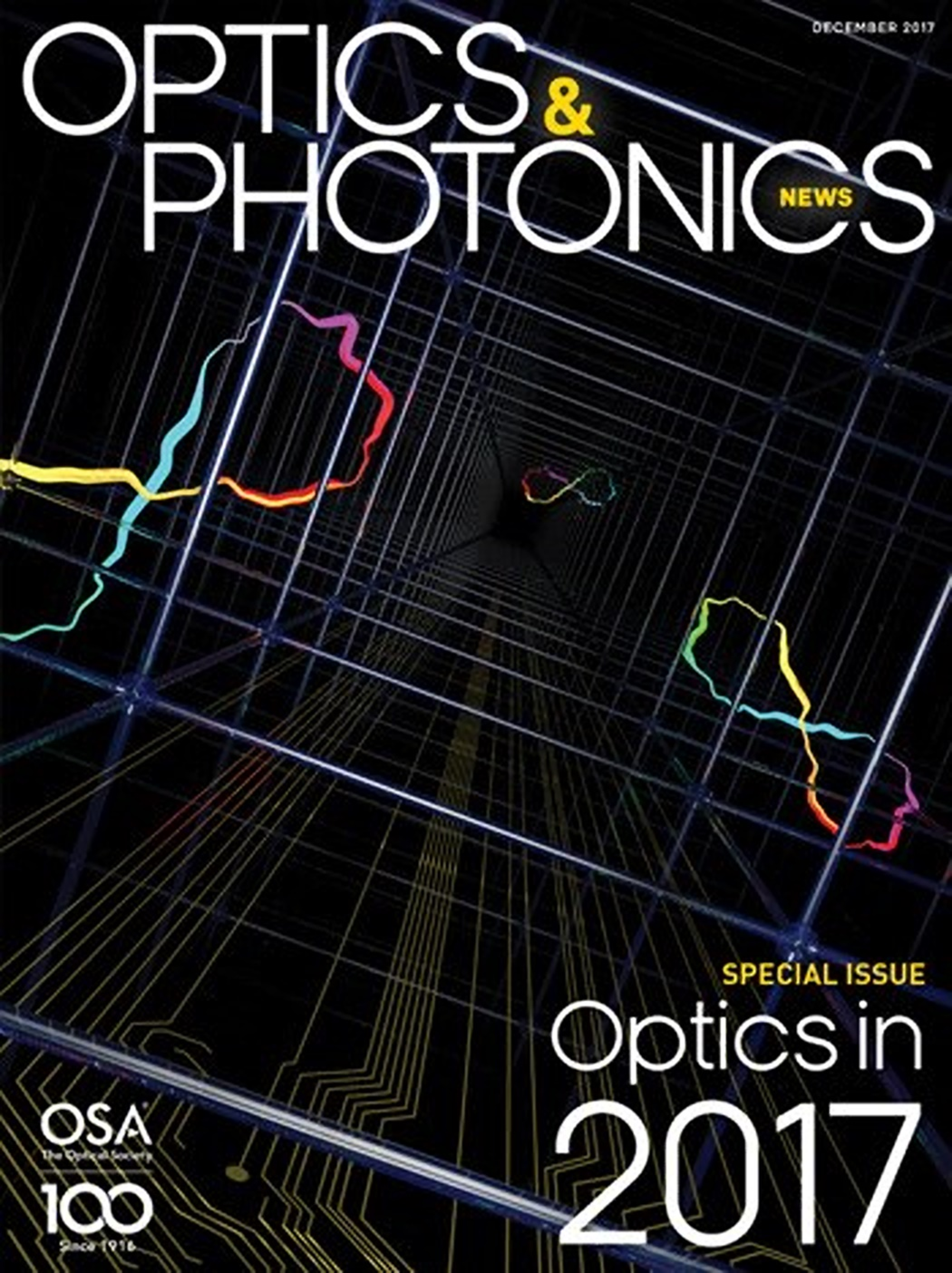
DECEMBER 2017

OPTICS & PHOTONICS NEWS



SPECIAL ISSUE

Optics in 2017

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Optics in 2017

This special issue of *Optics & Photonics News* highlights the most exciting peer-reviewed optics research to have emerged over the past 12 months.

Our panel of editors reviewed 125 research summaries from scientists from around the world. They selected for publication 30 stories that they felt most clearly communicated breakthroughs of interest to the optics community. Some of the summaries have related multimedia that you can access at **www.osa-opn.org/optics-in-2017**. Thanks to all who submitted summaries as well as to our panel of guest editors.

PANEL CHAIR: Robert D. Guenther, *Duke University, USA*

GUEST EDITORS: Svetlana Boriskina, *Massachusetts Institute of Technology, USA;* **Mihaela Dinu**, *LGS Innovations, USA;* **Dmitry Dylov**, *Skolkovo Institute of Science and Technology, Russia;* **Alexandre Fong**, *Gooch & Housego, USA;* **Andrew Forbes**, *University of the Witswatersrand, South Africa;* **G. Groot Gregory**, *Synopsys Inc., USA;* **Arlene Smith**, *Avo Photonics Inc., USA;* **Stephen R. Wilk**, *Xenon Corp., USA*

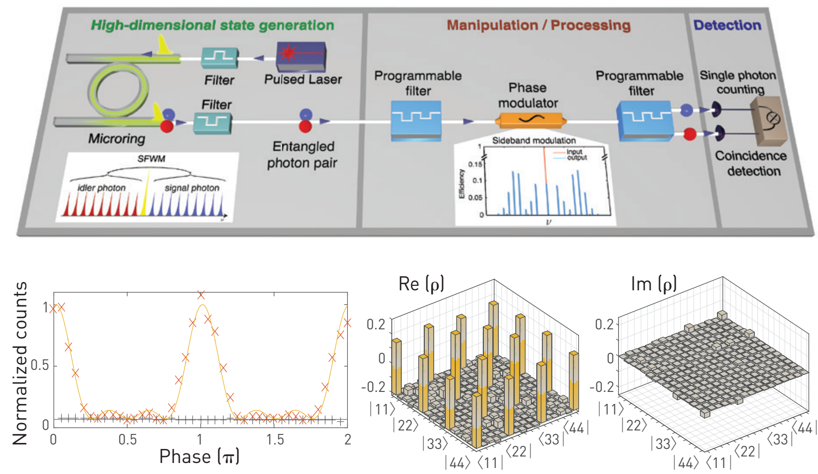
Image: Development of a 3-D all-dielectric topological photonic insulator promises both theoretical and practical benefits, according to the Optics in 2017 summary by Slobozhanyuk et al. (p. 56). [Image courtesy of A. Slobozhanyuk and A. Zubkov, ITMO University, Russia]

ENTANGLED LIGHT

Scaling On-Chip Entangled Photon States to Higher Dimensions

Considerable efforts have recently focused on advancing quantum information processing by increasing the number of qubits (the simplest unit of quantum information) in nonclassical systems such as ultracold atoms and superconducting circuits. A complementary approach to scale up information content is to move from two-level (qubit) to multilevel (quDit) systems.

Realizing solid-state quDits would require a massive increase in both costs and experimental complexity. In recent years, researchers have demonstrated photonic quDits using, for example, orbital angular momentum[1] as well as the temporal or spatial degree of freedom.[2,3] Even these schemes, however, require complex implementations and are not directly compatible with today's scalable and modular optical systems based on fiber and integrated-photonics components.[4] Thus, to date, on-chip entangled quantum sources have been limited to qubits.



Top: An optically excited integrated nonlinear micro-cavity creates high-dimensional entangled photon pairs, processed using a concatenation of spectral programmable filters and an electro-optic modulator. Bottom: Quantum interference and tomographic reconstruction of the density matrix for a 4-D qudit state.

In recent work, we demonstrated—making use of the frequency domain—on-chip generation of entangled quDit states and their coherent control.[5] The photons were created in a coherent superposition of multiple frequency modes using spontaneous four-wave mixing within an integrated microcavity, forming a frequency-bin entangled state. We confirmed the realization of a quantum system with at least 100 dimensions, formed by two entangled quDits with $D = 10$.

Using off-the-shelf telecommunications components, we introduced a coherent control platform to manipulate frequency-bin entangled states, capable of performing deterministic high-dimensional gate operations. We validated this platform by showing violations of high-dimensional Bell inequalities and performing quantum state tomography.

The quantum states were generated and manipulated within a single spatial mode and were transmitted over long propagation distances using standard optical fibers, which underscores their usability for high-dimensional quantum key distribution applications. The approach can also easily support the generation and control of even higher-dimensional states, by considering a larger number of frequency modes. Our results suggest that microcavity-based high-dimensional frequency-bin entangled states and their spectral-domain manipulation can constitute a powerful yet practical platform for reaching the processing capabilities required for meaningful quantum information science. OPN

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REFERENCES

1. A. Mair et al. Nature **412**, 313 (2001).
2. C. Schaeff et al. Opt. Express **20**, 16145 (2012).
3. R. Thew et al. Quantum Inf. Comput. **4**, 93 (2004).
4. S. Tanzilli et al. Laser Photon. Rev. **6**, 115 (2012).
5. M. Kues et al. Nature **546**, 622 (2017).

Visit www.osa-opn.org/optics-in-2017 to view the video that accompanies this article.