Investigation on the Role of Optical Filters on the Point Spread Function of the NASA MIDEX Solar Mission MUSE

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INTRODUCTION AND OBJECTIVE

The NASA MIDEX mission MUSE (Multi-slit Solar Explorer)[1] aims to study the solar corona with unprecedented spectral and temporal resolution. A key factor for achieving this goal is the performance of optical filters that effectively block unwanted radiation while maximizing signal. Traditional filters, such as those with nickel meshes, may introduce diffraction effects [2], impacting the Point Spread Function (PSF).

This study investigates with numerical simulations the impact of different optical filter designs on the PSF of the MUSE spectrograph. We aim to determine the suitability of these filters in terms of angular resolution, in their impact on the PSF shapes and possibly reducing diffraction effects for improved solar observations.

We compare the following designs:

- Heritage-based filters: Nickel mesh-supported filters similar to those used in previous missions (e.g., SDO/AIA)[3] with polyimide and Al or Zr
- Carbon nanotube(CNT)-based filters, with hexagonal coarse CNT mesh structures: in one case with a conservative robust design (DM), in another with innovative hexagonal mesh designs optimized for minimizing diffraction effects (STM). Also coated either with Al or Zr.

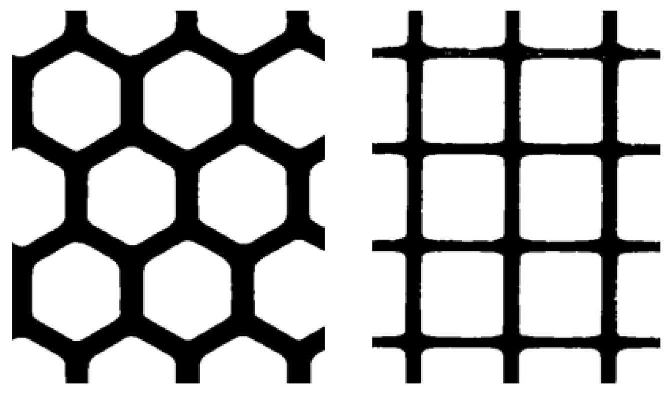

Figure 1. To the right, traditional square mesh (either 5 lines-per-inches (LPI) at 108, 171 Å or 70 LPI at 284 Å), Ni-based; To the left, innovative hexagonal mesh which is also made of CNTs and partially transmissive, about 5 LPI in geometry.

Carbon nanotube-based pellicles offer a scalable, thermally and mechanically resistant material, promising for space applications[4]

SIMULATIONS METHODOLOGY

Selection of filter design (mesh pattern) and simulation parameters: mirror roughness, entrance pupil step, pixel size (")

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Electromagnetic wave simulation (IDL)[5]

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Point Spread Function Analysis (Python)

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Results and Performance Evaluation Across Wavelengths

Figure 2: Flow-chart of the simulation process

PSF REPRESENTATIONS

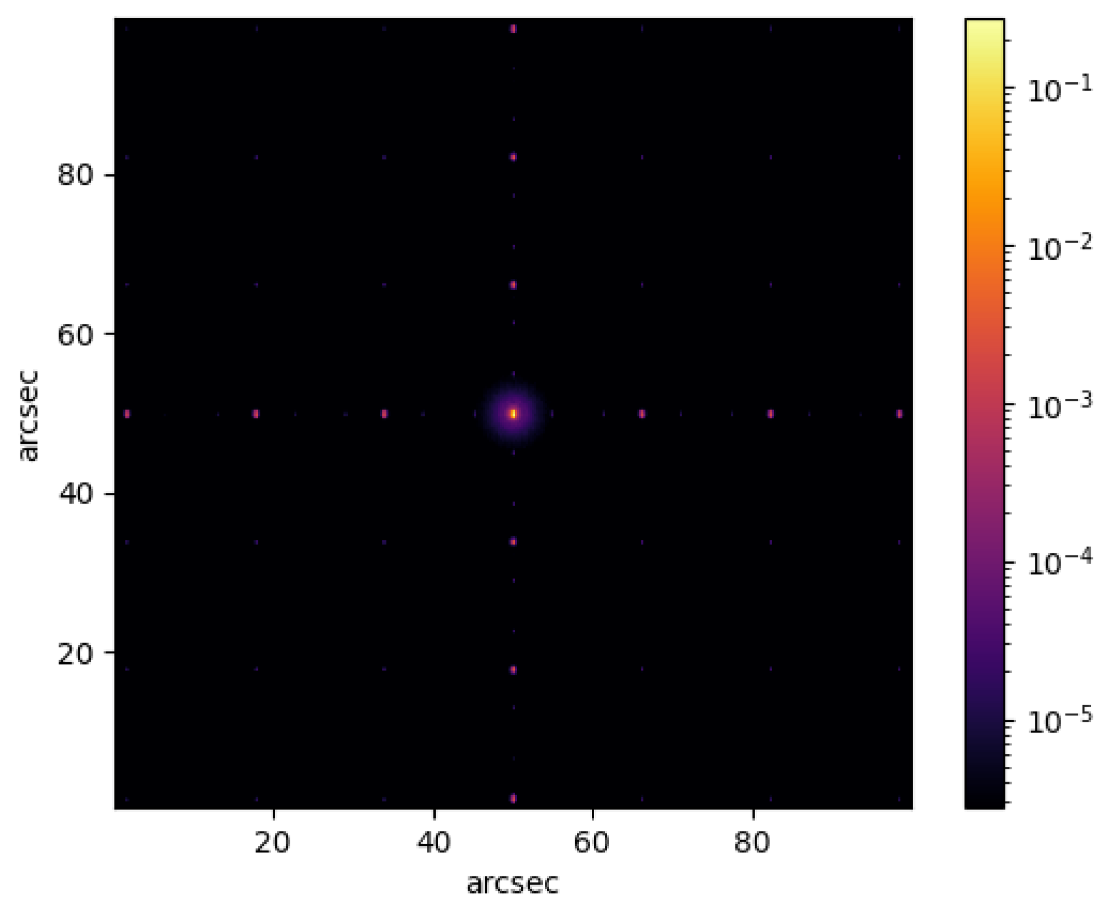

Figure 3: Visual representation of PSF intensity for: heritage Al+ Ni 70 LPI mesh filter (284 Å)

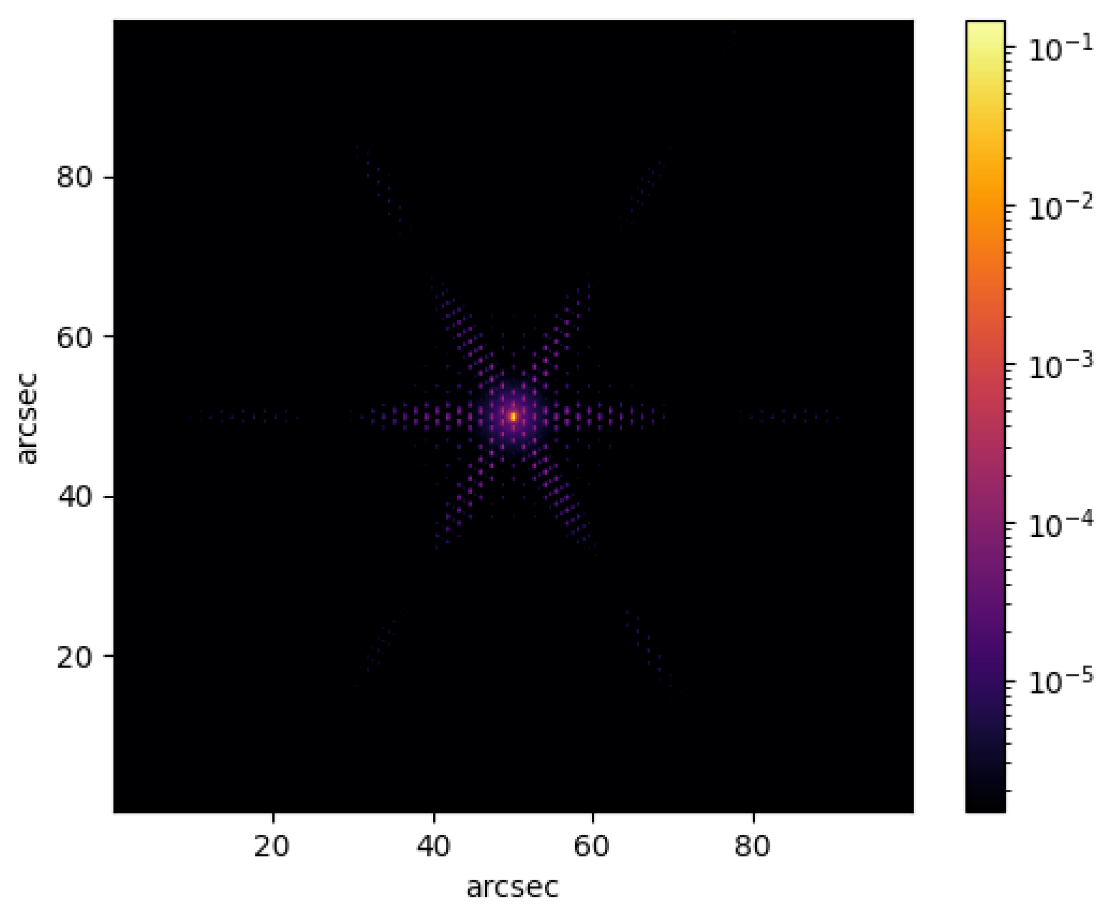

Figure 4: Visual representation of PSF intensity for: CNT/Al + CNT mesh STM filter (284 Å)

RESULTS DISCUSSION

- **In all cases, half energy widths** were less than 0.5'', compliant to MUSE high-resolution requirements
- **DM designs** significantly surclassed by **STM designs**
- **In channels 108 and 171 Å**, CNT-based filters of the STM designs showed significant improvements in the core PSF transmittance and reduced, or comparable, diffraction contents. <u>Diffraction is low</u> anyway for both STM and heritage filters as meshes are very transparent
- **At 284 Å,** heritage filters performed <u>better</u> for the core PSF transmittance than STM filters, but they also were <u>inferior</u> in terms of zero-order diffraction. <u>Moreover,</u> the secondary order peaks remain at high intensity for the heritage filters, while they have a rapidly decaying intensity for STM filters.

These findings suggest that CNT-based filters offer a promising balance of high transmittance, reduced diffraction, and mechanical resilience, making them a promising alternative for space-based EUV coronal spectroscopy.

CONCLUSIONS AND NEXT STEPS

- **Heritage and STM filters** satisfy MUSE restrictive requirements for high-angular resolution
- **CNT-based filters** show improvements in core PSF transmittance (for 108, 171 Å), and significant improvements in the zero-order diffraction efficiency at 284 Å.
- **Future work** will explore the effect of filters on observing high-intensity events (like solar flares) to further evaluate the filter performances and compare.

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