Linear polarizer design for application in the far-ultraviolet spectral range

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I. Introduction & Goals

- NASA requires the development of new FUV coating processes
- Current instrument limitations make examining the polarization properties of these coatings impossible in the FUV (100-200nm)
- Our team developed a polarizer utilizing reflections near Brewster's angle that delivers high extinction ratios in FUV
- This polarizer will enable direct measurements of a variety of coatings and materials for research and development

II. Polarizer Design

Optical Design:

- Reflected light from LiF crystals near Brewster's angle is highly polarized
- SiC crystals are highly reflective in the FUV spectrum
- LiF achieves polarization, SiC maintains adequate throughput

Mechanical Design:

- By pairing 2x SiC and 2x LiF in a 4-mirror reflection system light can exit along its initial optical path
- A 1:3 gear ration between the manipulator and the polarizer assembly allows for a precision of 0.333°
- The polarizer is designed to fit the commercial McPherson 225 VUV Spectrometer



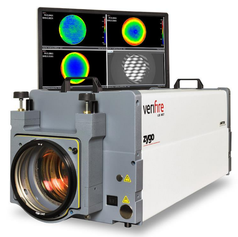
Fig. 1: In air alignment of polarizer assembly (top) & side profile cutout beam path through the polarizer assembly (bottom)

III. Materials Characterization process (I)

- From a pool of multiple SiC and LiF crystals, 2 of each were selected based on their characterized properties
- These characterized properties include:
  - Flatness: PV, Power, RMS (using Zygo VeriFire MST+ (Fig. 2))
  - Roughness: Sq (using Park Systems NX20 AFM (Fig. 3))
  - Spectral Reflectance
- The best two candidate SiC and LiF crystals were chosen based on results obtained during the characterization process

III. Materials Characterization process (II)

SiC Zygo Verifire HD MST+ Sample 1



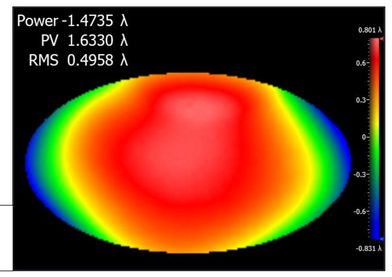
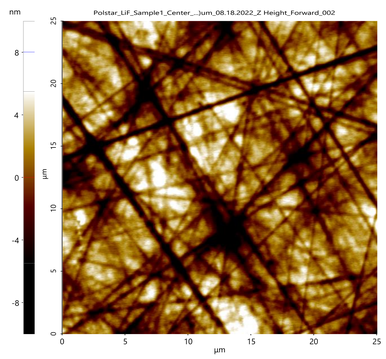
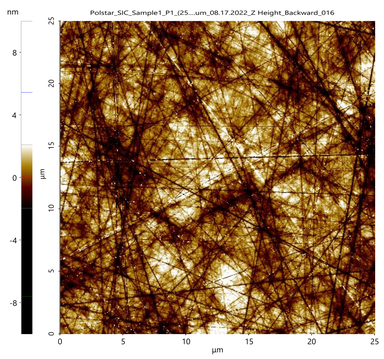


Fig. 2: Fizeau interferometer measurement conducted to determine form of sample

LiF Sample 1 & SiC AFM Sample 1



Region size: 25x25µm
Image Resolution: 556 x 556 pixel
Lateral Resolution: ~45nm/pixel



LiF (left) Roughness: RQ=2.8 nm
SiC (right) Roughness: RQ=1.3 nm



Fig. 3: Atomic force microscope measurement conducted to determine surface roughness of LiF (left) and SiC (right) crystals, and NX-20 AFM (bottom)

IV. Polarizer Experiment & Results (I)

Experimental Set-up:

- Each dataset was taken at Ly-α (121.6nm)
- An MgF_2 flat plate was used as an analyzer
- At Brewster's angle, MgF_2 plate reflects s-polarized radiation only
- Data was collected at six angles of incident for the MgF_2 plate
- AOI ranged from 58° to 64° in 1° increments
- For each AOI the MgF_2 reflected at, a full rotation of the polarizer was collected

Results:

- We used two metrics to assess the effectiveness of our polarizer
  - Extinction ratio (r_e): $r_e = \frac{s_i}{p_j}$
  - Degree of lineal polarization (P): $P = \frac{s_i - p_j}{s_i + p_j}$
- Seen in Fig. 4 are three valleys and two peaks
- The values for r_e, and P can be computed using the recorded peaks and valleys (s_1, s_2 & p_1, p_2, p_3)
- By computing every combination and averaging we can generate the graphs in Fig. 5

IV. Polarizer Experiment & Results (II)

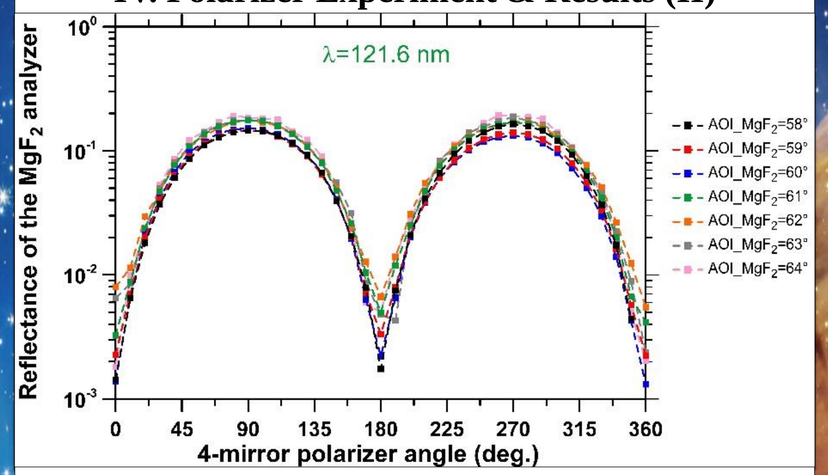


Fig. 4: Normalized reflectance of the MgF2 analyzer as a function of the 4-mirror polarizer rotation angle, at 121.6 nm wavelength.

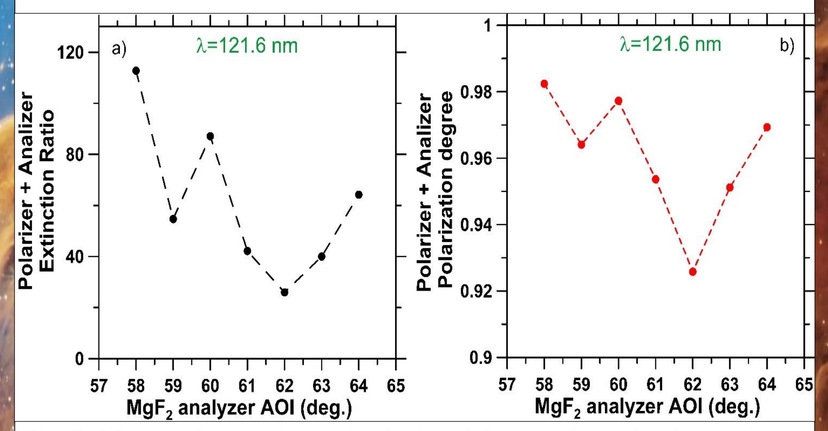


Fig. 5: Measured extinction ratio (left) and degree of lineal polarization (right) of the 4-mirror polarizer and MgF_2 analyzer in crossed configuration at 121.6 nm wavelength as a function of the angle of incidence of the MgF_2 analyzer

V. Conclusion

- Our 4-mirror design uses only bare substrates leading to greater simplicity than that seen in other coated designs
- When paired with a MgF_2 analyzer our polarizer can produce highly polarized light in the FUV spectrum

- At λ=121.6 nm:
  - Extinction Ratio with MgF_2 analyzer at 58° → 114.57
  - Degree of Linear Polarization with MgF_2 analyzer at 58° → 98.19

- Our team believes both metrics could be improved with finer alignment to our test instrument
- Our results are comparable to a prior 4-mirror design carried out by Hass and Hunter [1], but well exceeds that of other contemporary counterparts like that of Larruquert et al. [2]

References

1. G. Hass, W. R. Hunter, Reflection polarizers for the vacuum ultraviolet using Al + MgF2 mirrors and an MgF2 plate, Applied Optics Vol. 17, No.1, 76-82, 1978
2. J. Larruquert et al., Polarizers tuned at key far-UV spectral lines for space instrumentation, SPIE Vol. 10235 102350K-1, 2017

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