National Aeronautics and Space Administration

FY23 Strategic University Research Partnership (SURP)

Evaluation of Spatial Light Modulator (SLM) for High Contrast Imaging

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Project Objective(s)

- High contrast imaging systems for future large space telescopes capable of imaging habitable exoplanets require control of >10,000 actuator, but conventional DMs only provide ~3,000.
- The objective of this project is to show that a spatial light modulator (SLM), a device that contains more actuators than a conventional deformable mirror (DM), can address this challenge by serving as a second order correction after a first order coarse correction using a conventional DM.
- Risk areas for space missions: **Chromaticity**, **Polarization**, **Stability**, Radiation Tolerance

Background

Our work will support the efforts of what is one of the most important astronomy goals beyond the next decade as presented by the decadal survey, which is to investigate Earth-like extrasolar planets. This SLM work will contribute to the large format DM challenge currently experienced in space and ground AO systems, by demonstrating wavefront correction with more than 200,000 actuators in a very compact format. This proposed work also cultivates a relationship between the student and other collaborators which in turn helps the student gain experience and build working relationships with important contributors to the optics and astronomy field.

Approach and Results

- The student has been characterizing the SLM in the lab in a non-coronagraphic setup, with no upstream DM, measuring polarization crosstalk, dynamic stability, and chromaticity, and validating the optical design to control polarization cross-talk
- This stability experiment measured the contrast ration of two speckles. To create the speckles two sine waves were sent to the SLM of two different spatial frequencies of 10 and 13 cycles. Two speckles are shown in Fig. 1 left and the flux ratio as a function of time is shown in Fig. 1 right.

Figure 1

- The data had some high frequency noise, but with only ~.2 percent relative intensity error (1 part in 500) corresponding to 0.1% relative OPD stability. We explored this .2 percent error further by taking a burst of 10,000 at 1 kHz we saw that it was consistent with the 0.1% measurement of noise in the previous plot (Figure 2 left). There is no sign of modulation at f~<100 Hz. By also taking the Fourier transform of the flux data we could also see that the SLM is likely not creating the high frequency noise (Figure 2 right).

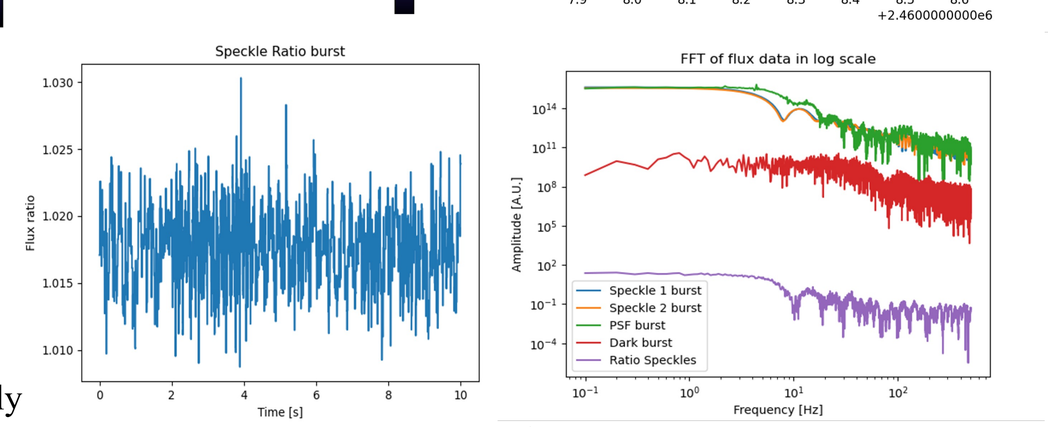

Figure 2

- **Preliminary polarization crosstalk results:** Any light incident to the SLM must be linearly polarized to be actuated, with its polarization axis aligned with the SLM's polarization axis. The student tested the polarization crosstalk by capturing two images through a linear polarizer: one with full actuation and one with no actuation at all. When the linear polarizer was set to an angle that maximizes speckle intensity, the SLM shows the speckles fully actuated. The polarizer was then turned by 90°and the speckles almost completely disappeared showing no actuation. The angle of max speckle intensity is + 90°, a cropped section of one of the speckles was taken and the max pixel value recorded. The polarization axes are orthogonal so it is apparent that when the polarizer is turned 90° that the speckles disappear. We took the ratio of the two maxes and got 0.003. This means that the polarization crosstalk is no more than 0.3%.

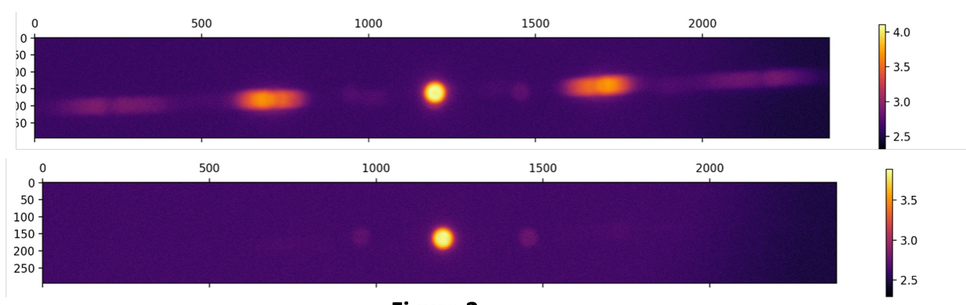

Figure 3

- **Preliminary Chromaticity testing**: A broadband light was then used instead of a monochromatic source and sent to the SLM. Jennifer put speckles onto the SLM and captured an image. In the image taken, the speckles move as a function of wavelength and appear as radially "smeared" speckles. She then performed a polarization test similar to the one performed in monochromatic light in which the polarization crosstalk resulted in a maximum of 0.4%. The measurements show no wavelength-dependent crosstalk at the 0.4% level (Figure 3).

Benefits to NASA and JPL

DM technology is one of the most important elements in an exoplanet imaging mission. Some instruments have shown that the DM needs more maturation to scale them to larger actuator count mirrors, i.e. 128× 128. This effort will help JPL to stay at the forefront of the deformable mirror technology in preparation for future missions.

CONCLUSION: The stability and polarization measurements indicate that speckles added by SLM actuation are stable and free of polarization crosstalk at better than percent level. These preliminary results indicate that SLM actuation could be used to improve contrast from ~1e-8 contrast pre-SLM to ~1e-10 contrast.

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