National Aeronautics and Space Administration

FY24 Strategic University Research Partnership (SURP)

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

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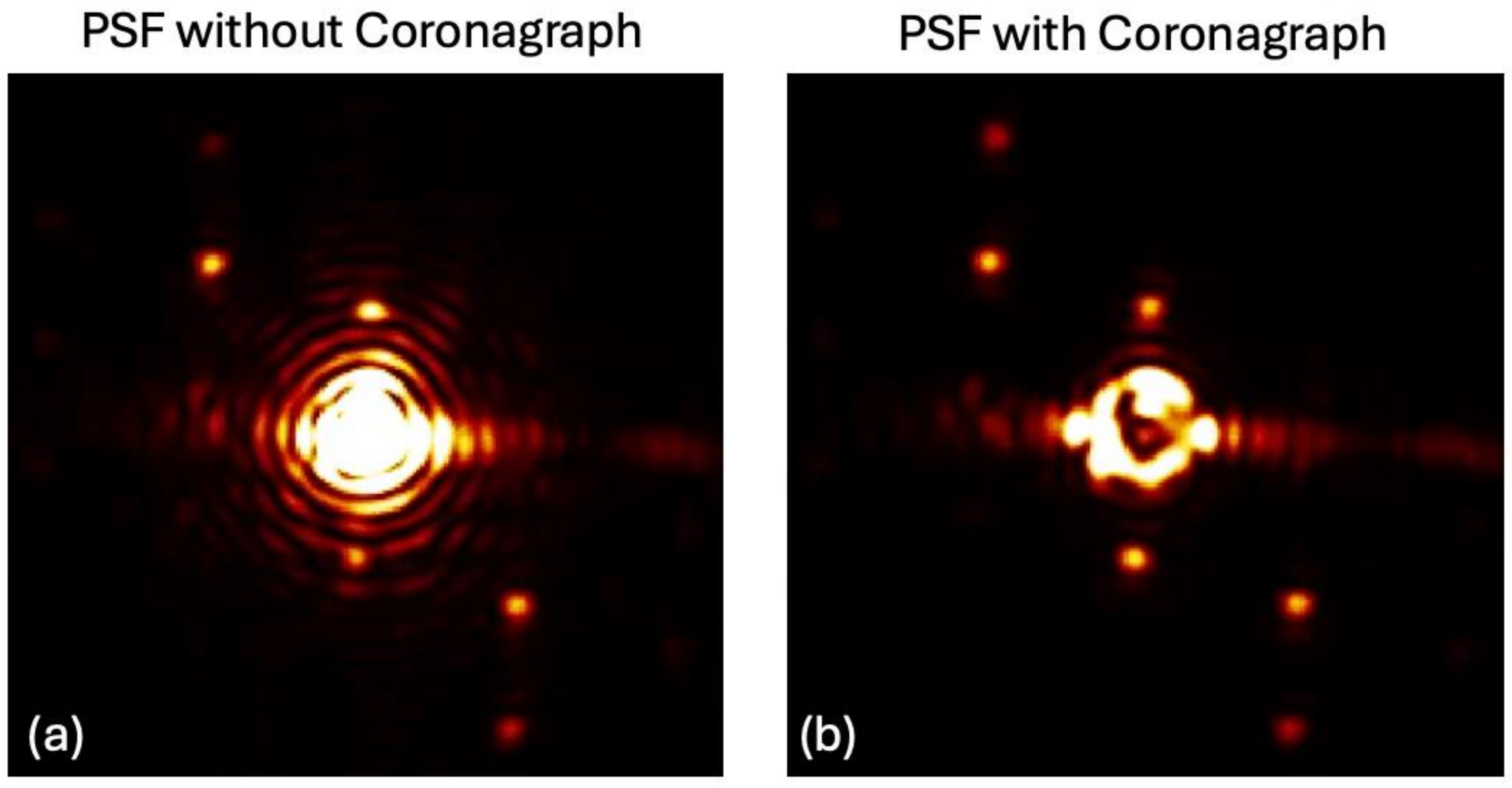
Background:

- To image Earth-like exoplanets with the proposed Habitable Worlds Observatory (HWO), >10,000 wavefront correction modes are desired.
- State-of-the-art deformable mirrors (DMs) used on Roman CGI and ground telescopes have only 2,000-4000 actuators.
- Spatial light modulators (SLMs) are an intriguing alternative with >100,000 correction elements in a compact form factor only a few mm across.
- Graduate student Jennifer Bragg at UofA has built a testbed and has been characterizing an SLM for use in high-contrast imaging.

Objectives:

- Characterize a liquid crystal SLM in three key risk areas for a space mission: 1) **stability**, 2) **chromaticity**, and 3) **polarization**.
- Prove that, if used in a woofer-tweeter setup with a conventional deformable mirror for coarse correction DM, the SLM could provide the second-order correction to reach high contrast.
- Upgrade our optical testbed to include a Lyot coronagraph for higher contrast and then perform higher sensitivity SLM characterization measurements.

Figure 2: >100x fainter SLM-actuated spots for calibrations are cleanly resolved with the newly installed coronagraph.



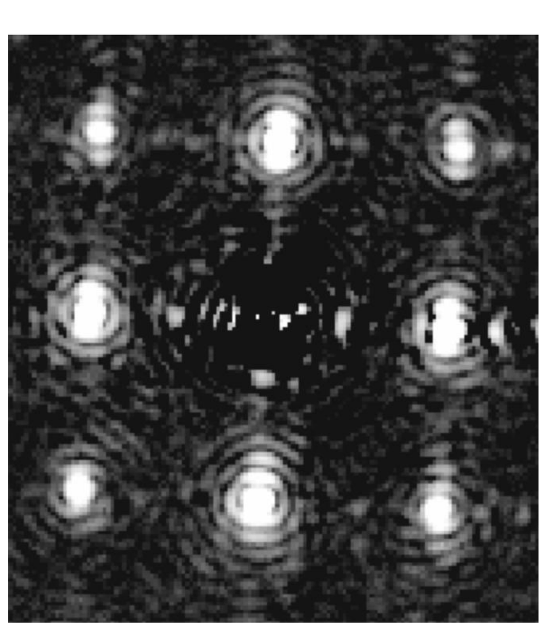
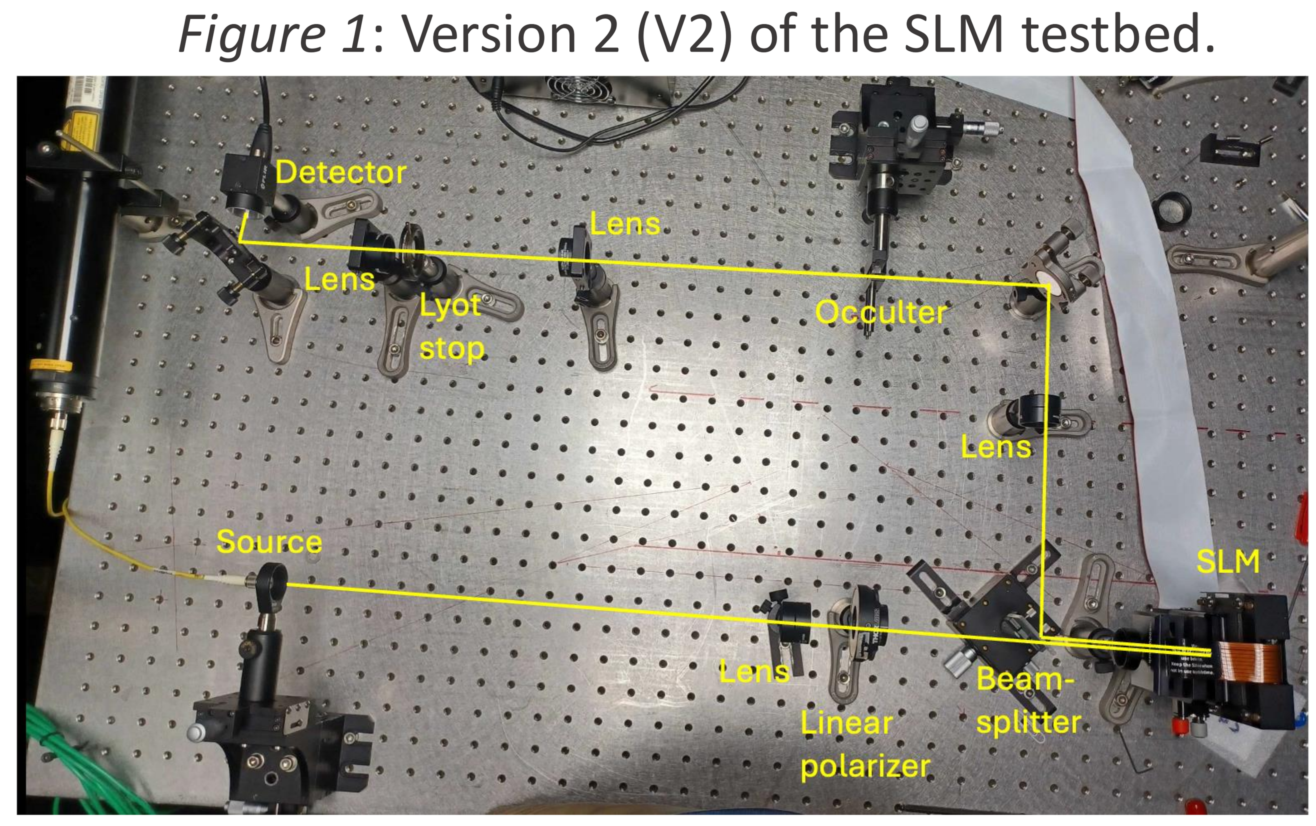


Figure 3: Differenced images with and without spots show a noise floor of 1e-8 contrast and cleanly measured spots from the SLM at the faintest setting of 1e-4 contrast.

Figure 1: Version 2 (V2) of the SLM testbed.



Approach and Results:

- In years 1 and 2 (FY23-FY24), the project goals have been to characterize the SLM's stability, chromaticity, and polarization. The plan for next year (FY25) is to run various wavefront control experiments to demonstrate the unique capabilities of an SLM compared to a DM.
- In this past year, we have been addressing the shortcomings of the 1st testbed and built V2 (see **Figure 1**) to achieve the SLM characterization milestone at higher sensitivity. This setup now contains a Lyot coronagraph (LC). The LC blocks the bright core of the pseudo-star and suppresses the rest of the stellar Airy pattern by >100x.
- For our stability and polarization tests, the LC helps us increase our sensitivity by orders of magnitude because we can now reduce the satellite spot intensities without risk of coherent interference from the underlying stellar PSF (see **Figure 2**) while also increasing the laser power to get the same spot flux as before.
- By differencing summed frames with and without SLM-actuated spots, we observe that our noise floor now is at 1e-8 contrast (see **Figure 3**). Due to our 8-bit SLM electronics, however, the faintest speckle we can directly actuate is at 1e-4 contrast.
- Using the new V2 testbed, we can clearly see that the white noise component of the speckle energy ratio has significantly decreased (see **Figure 4**). The dominant noise term is now a ~half-hour oscillation that we are still tracking down.
- Before moving on to wavefront control experiments with the SLM in FY25, we will finish identifying the noise sources in our higher sensitivity speckle measurements, re-run the polarization crosstalk measurement with the coronagraph installed, and insert a grism with the coronagraph removed to calibrate the SLM chromaticity.

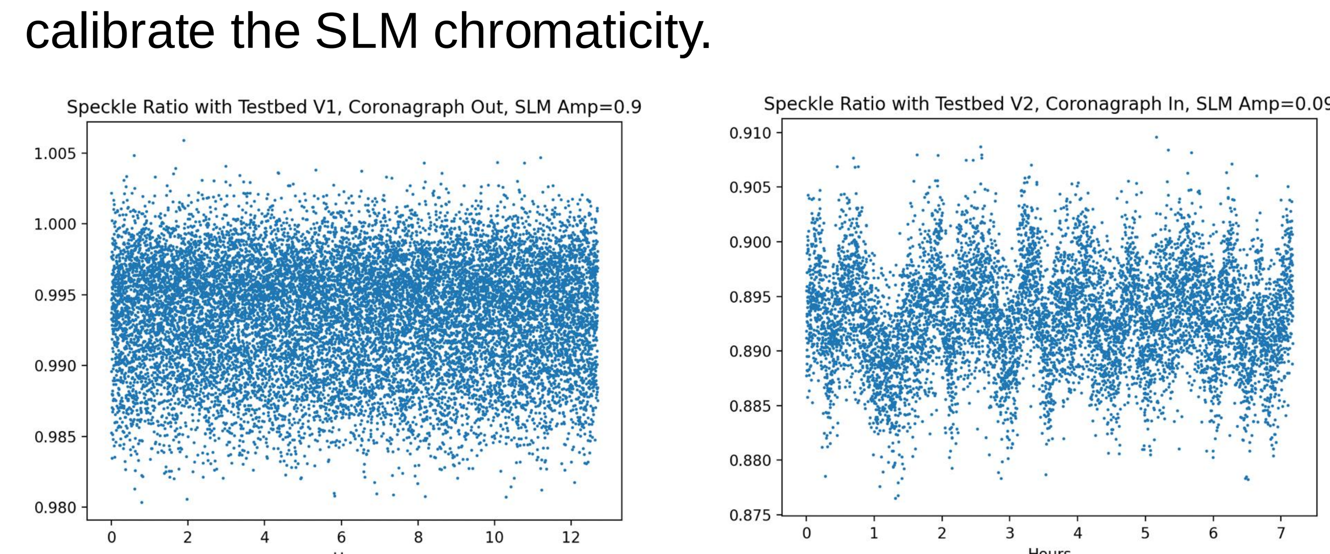


Figure 4: Spot flux stability data from V1 (left) and V2 (right) testbeds.

Benefits to NASA and JPL:

JPL has been a leader in developing coronagraphic technologies for over two decades. To continue leadership in coronagraphy for NASA's proposed HWO flagship mission, JPL should continue to advance technologies to address the NASA APD Tier 1 Gap List items of coronagraph stability and coronagraph contrast and efficiency. This project's SLM research effort keeps JPL at the forefront of wavefront correction technology development.

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