FY24 Topic Areas Research and Technology Development (TRTD)

# Dual-purpose metasurface focal plane mask for high-contrast imaging and wavefront sensing

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**Strategic Focus Area:** Extra-solar planets and star and planetary formation

## Project Objective:

- Develop a metasurface focal plane mask that will enable contemporaneous wavefront sensing and star-light suppression.
- Enable active stabilization of future flagship missions dedicated to exoplanet imaging.
- Transforming the observatory from being passively stable to being actively controlled
- Relax the requirements on the engineering, but it will also enable new observing scenarios that were not envisioned with a passive system.

## Background:

- Direct detection of exoplanets via coronagraphic imaging is a priority for NASA.
- Passively maintaining wavefront stability at the picometer for long observational periods is difficult.
- Here we combine wavefront sensing and control with high-contrast imaging with no non-common path.
- This combination will relax the requirements on the stability of the observatory system as a whole.

## Significance to JPL and NASA:

- Extend the performance of Zernike wavefront sensor for wider bandpass for greater sensitivity.
- The sensor, along with active control, can relax the telescope observatory stability requirements for future flagship missions.
- Enables risk mitigation and new observing modalities for future flagship missions.

## Approach and Results:

- We have successfully fabricated the dichroic mirror for the wavelength separation.
- We successfully fabricated the visible metasurface devices.
- We have designed and built the wavefront sensing testbed and the white light interferometer.

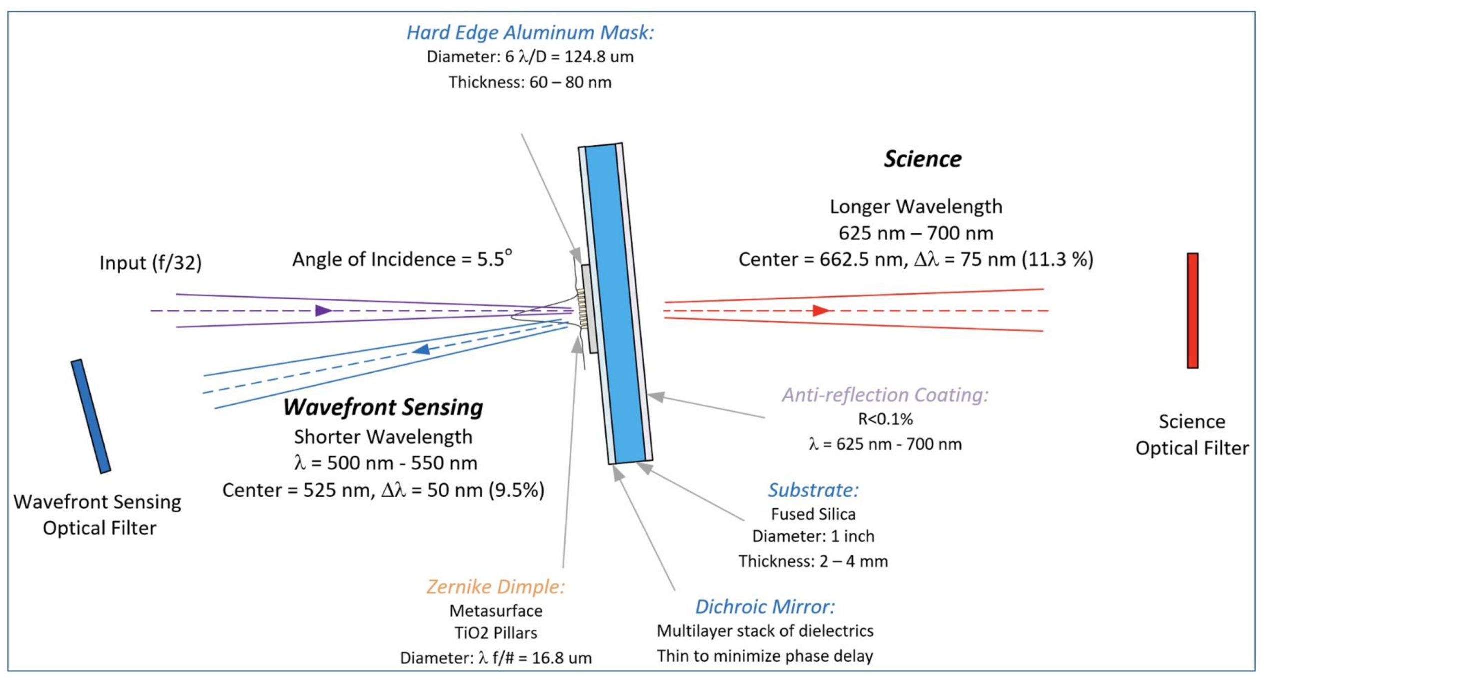


Figure 1. This functional block diagram captures the key functionality of the the dual-purpose device. Long wavelengths that pass through the device are acted upon by the hard-edged coronagraphic stop. Short wavelengths in reflection are acted upon the metasurface Zernike phase dimple for doing wavefront sensing. Because these functions are colocated on the same mask, there is a minimum of non-common path. The wavefront sensing happens exactly where it matters most.

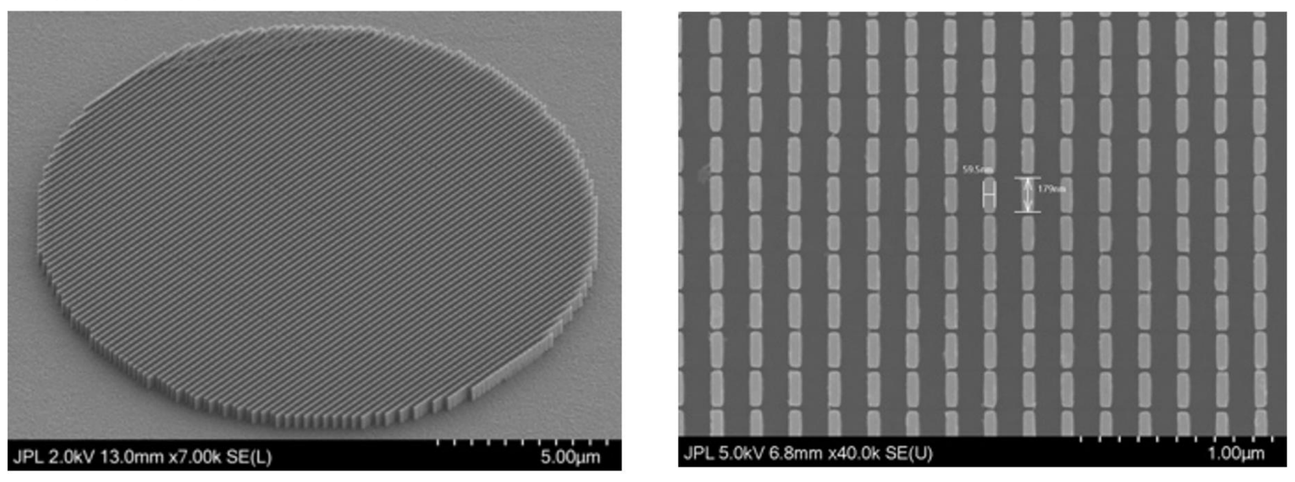


Figure 2. These scanning electron microscope images show the final fabricated metasurface element. This device enables a different phase shift for each of the two linear, orthogonal polarizations. In this way, the dynamic range of the sensor is extended.

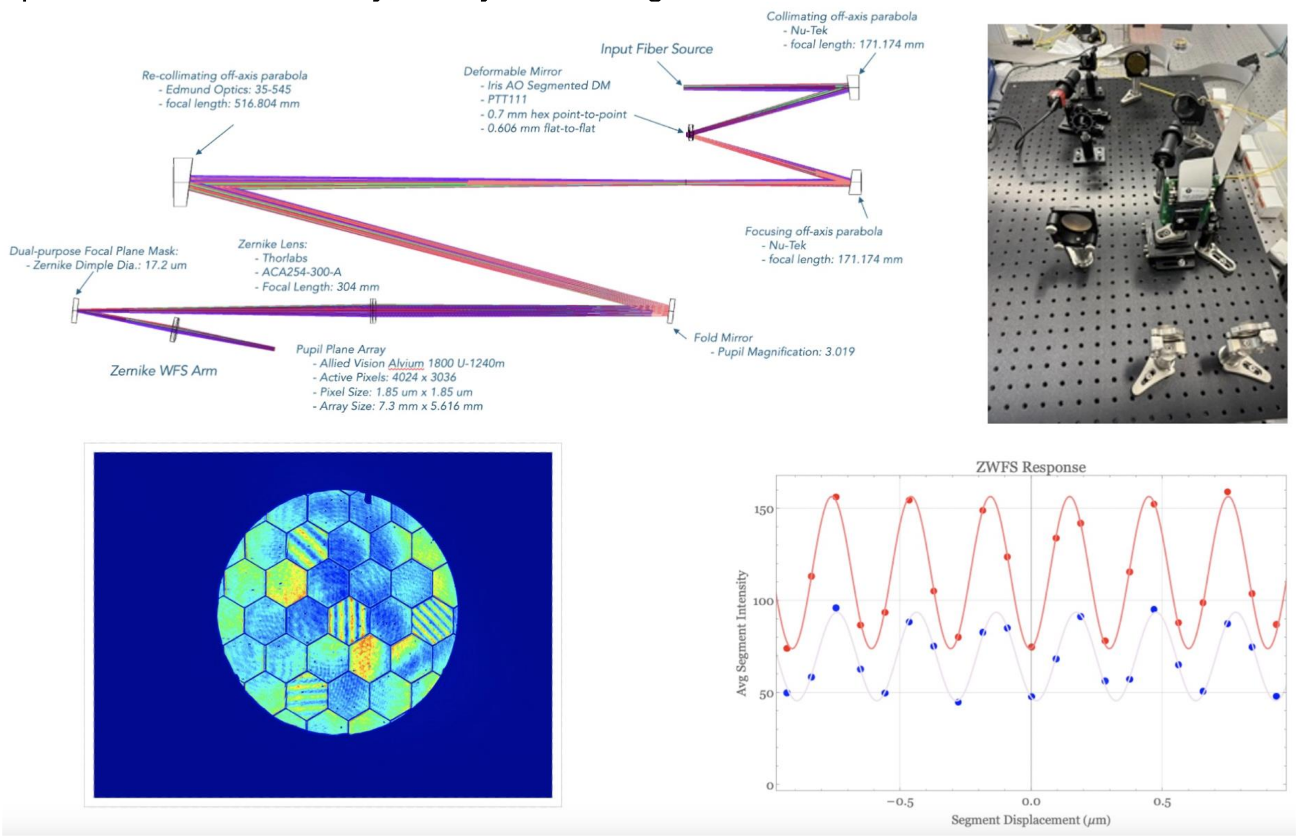


Figure 3. We have assembled a testbed that enables us to test the operation of the dual-purpose mask. There is a segmented deformable mirror that we use to control the light in the system. The sensing camera (image in the lower left) can interpret the intensity pattern and then estimate the shape of the mirror. By scanning a segment of the mirror we can scan the intensity pattern and then estimate the phase of the Zernike dimple for the two polarization states.

Dual-Purpose Mask Metrology

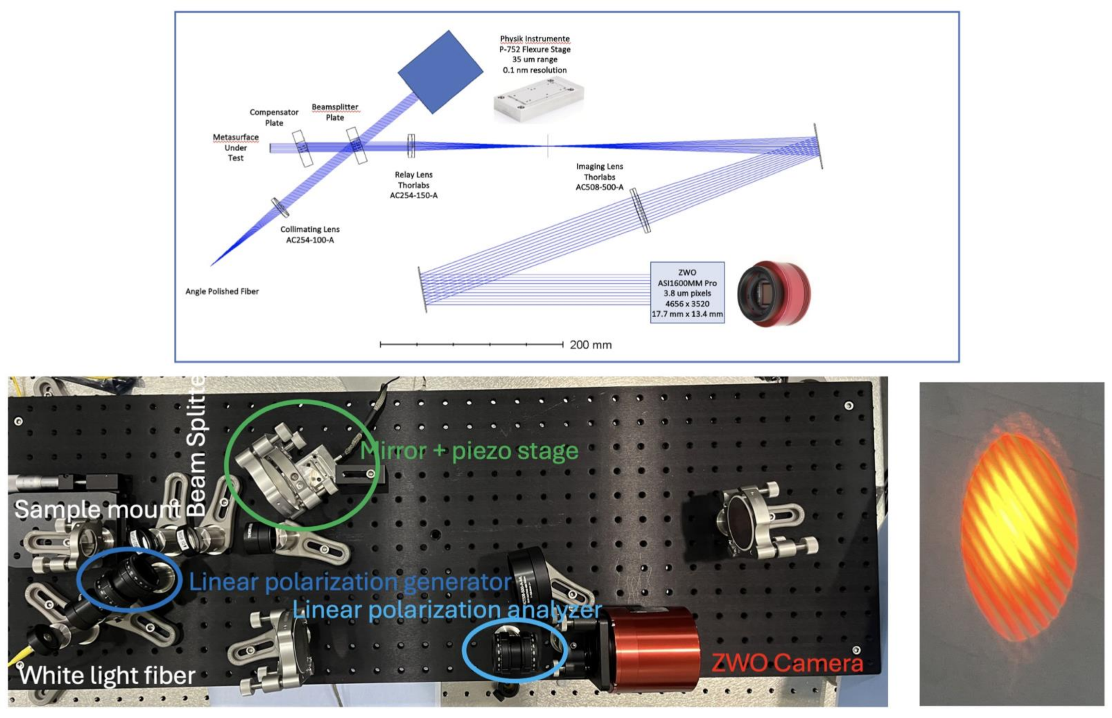


Figure 4. A white light interferometer has been assembled to give us an absolute measurement of the phase of the different elements of the focal plane mask: 1) the dichroic mirror, 2) the coronagraphic mask and 3) the metasurface dimple.

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