National Aeronautics and Space Administration

FY23 Topic Areas Research and Technology Development (TRTD)

Dual-purpose Metasurface Focal Plane Mask for High-Contrast Imaging and Wavefront Sensing

Principal Investigator: James Wallace (326); **Co-Investigators:** Tobias Wenger (389), Garreth Ruane (383), Jeffrey Jewell (398), A J Eldorado Riggs (383), Nasrat Raouf (383), Mahmood Bagheri (389)

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

Project Objective:

- Develop a metasurface focal plane mask that will enable contemporaneous wavefront 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 successfully completed the design and fabrication of visible metasurface devices using TiO_2.
- We have successfully designed the optical coating for the wavelength separation.
- We will combine and test the two capabilities next year.

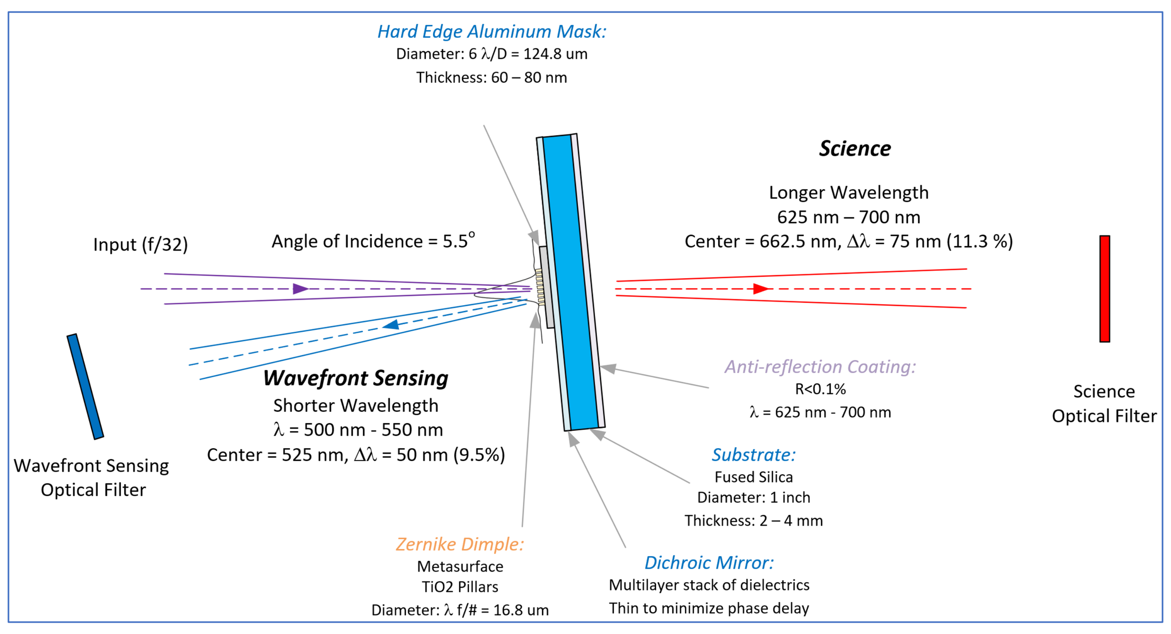

Figure 1. This diagram captures the key capabilities that we seek from the dual-purpose mask. The incoming lights sees the Zernike phase-contrast metasurface that is deposited directly on the coronagraphic mask that is deposited on the dichroic.

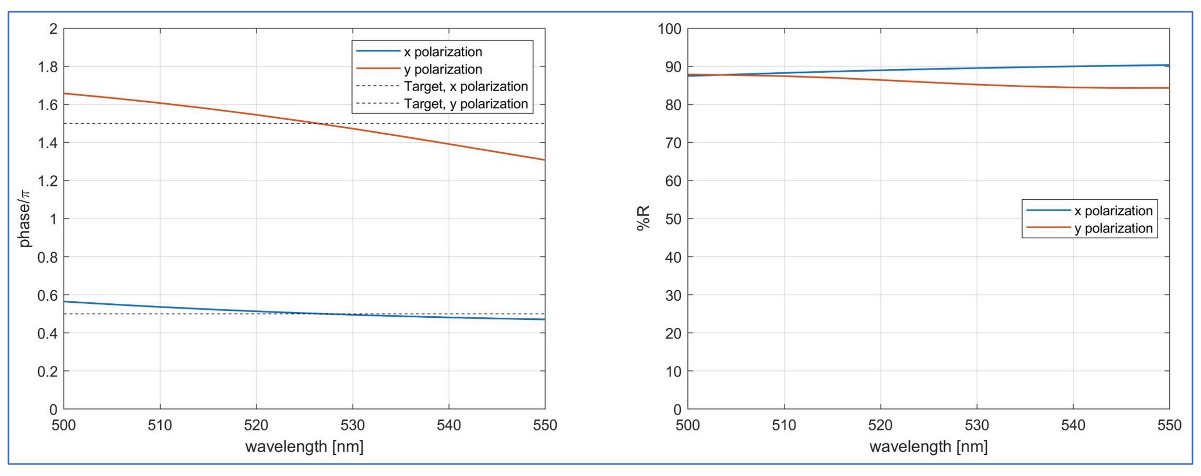

Figure 2. The numerically calculated induced phase for x- and y-polarized light is for a specific TiO2 nanopost design is shown on the left. On the right is shown the reflectivity for the two orthogonal polarization states.

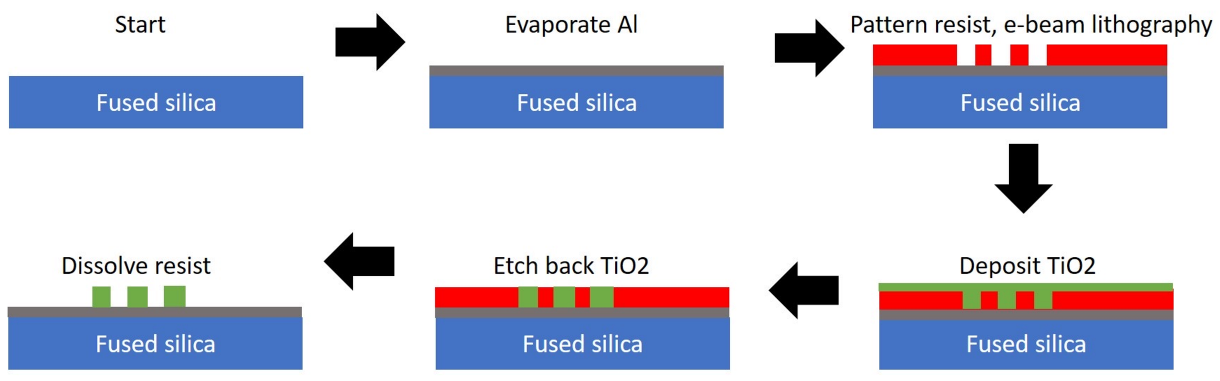

Figure 3. This diagram illustrates the fabrication process for making TiO2 metasurfaces on aluminum. The multistep process has resulted in several useful devices.

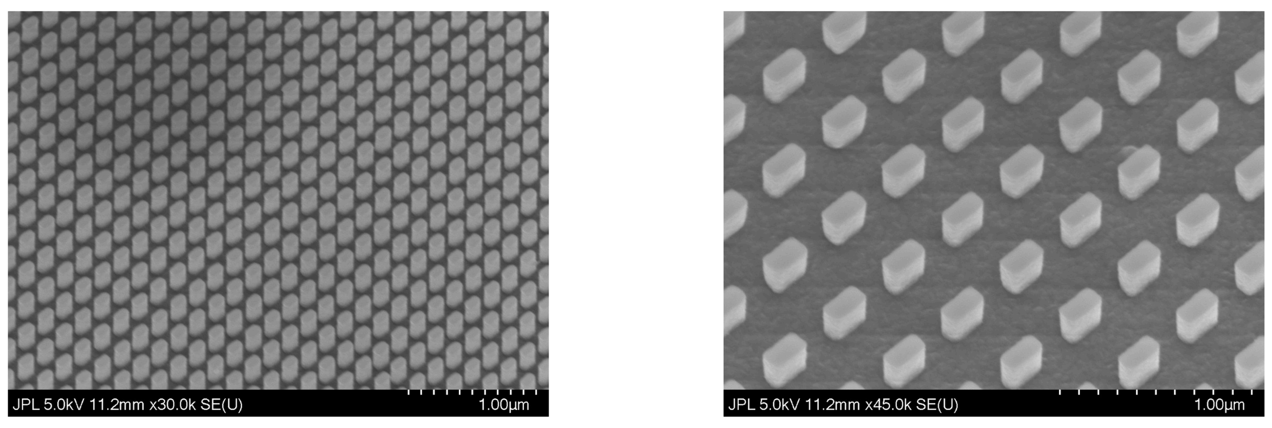

Figure 4. The scanning electron microscope images shown above represent two different fabrication runs. Each of them are a demonstration of TiO2 on aluminum.

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Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

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Publications:

[A] Wenger, T., Wallace, J.K., Ruanne, G., Raouf, N., Jewell, J., Riggs, A.J., Bagherri, M., “Design and Fabrication of Metasurfaces for wavefront sensing and high-contrast imaging in the visible”, Proc. SPIE, (2003)

PI/Task Mgr. Contact Information:

J. Kent Wallace: X3-7066
Email: James.K.Wallace@jpl.nasa.gov