National Aeronautics and Space Administration

Metasurface Optics for Zernike Wavefront Sensing

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Program: FY22 R&TD Topics
Strategic Focus Area: Advanced Optics Systems and Telescopes

Project Objective:

Our objective is to engineer metasurface optical elements specifically for performing wavefront sensing on the Keck Telescope. Metasurface optics are sub-wavelength features that are fabricated on optical surfaces and can modify the phase, amplitude and polarization of the electric field at very fine spatial scales. The work here involved designing and fabricating these surfaces to work in the short-wavelength infrared (SWIR) to be used for measuring the optical quality and stability of a segmented aperture telescope.

We successfully designed and fabricated two types of metasurfaces: propagation phase and geometric phase. The first being easier to design and fabricate, the second being more achromatic and thus wavelength insensitive. We also designed and redesigned the pupil-viewing mode of the tracking camera system to separate the polarization states for vector Zernike wavefront sensing. The system is now operating on the Keck telescope.

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.

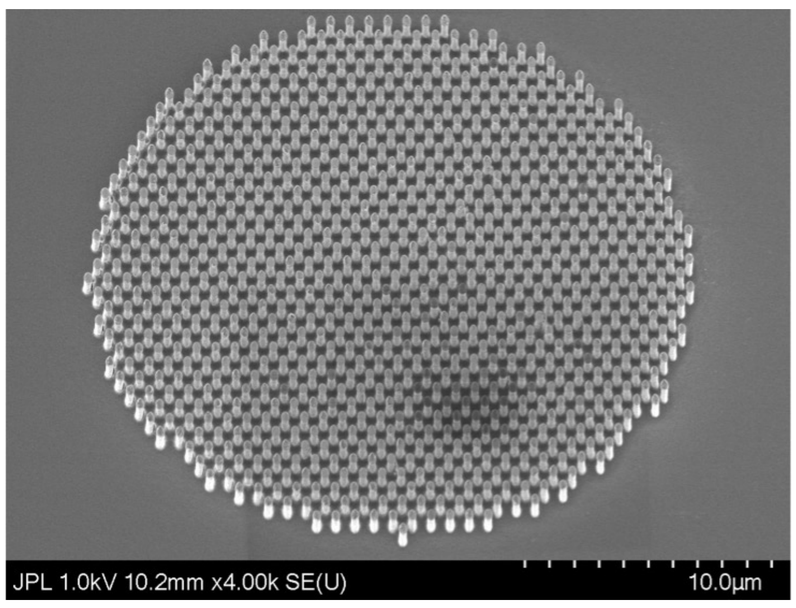

Figure 1. This magnified image of the propagation phase metasurface shows the height, asymmetric aspect ratio and packing of the nanopillars.

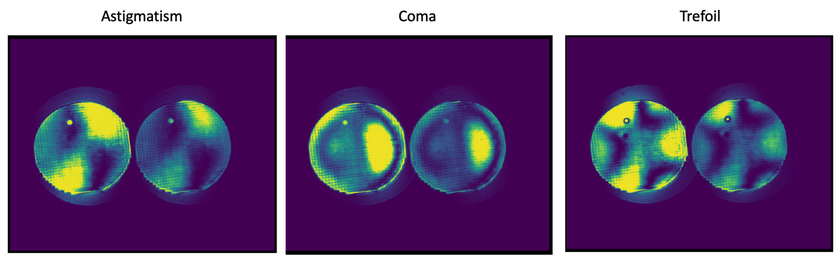

Figure 2. Classic optical aberrations were added to the system and measured by the geometric phase metasurface focal- plane mask.

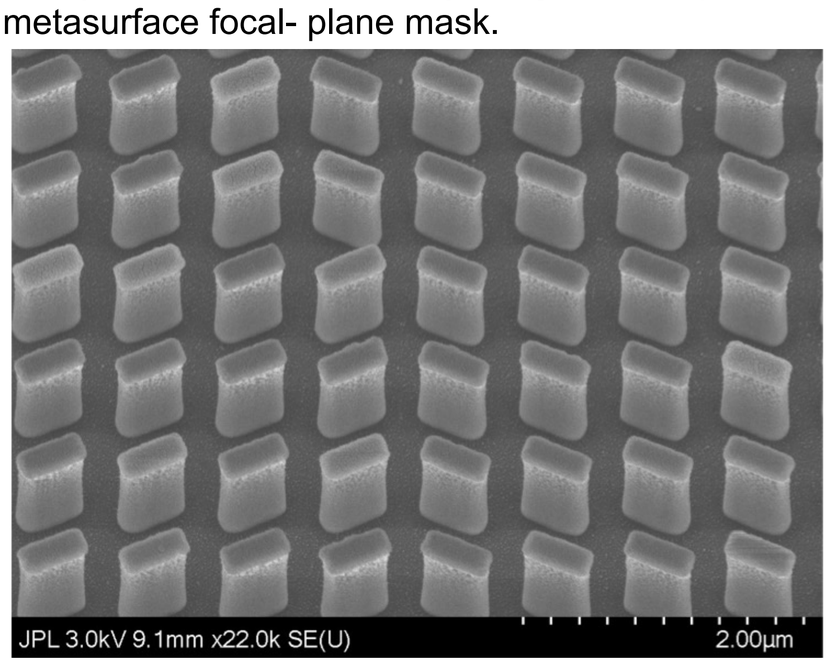

Figure 3. The different orientation of the nanopillars on the left and right side of image causes the phase of the electric field to be different between these two boundaries..

Approach and Results:

- We successfully completed the design and fabrication of metasurface devices.
- We implemented these devices on the Keck Telescope with the KPIC instrument.
- We are in the process of testing these devices on the sky.

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Publications:

Maaike A. M. van Kooten, Sam Ragland, Rebecca Jensen-Clem, Yinzi Xin, Jacques-Robert Delorme, and **J. Kent Wallace**, "On-sky Reconstruction of the Keck Primary Mirror Piston Offsets Using a Zernike Wavefront Sensor," 2022 June 21 ApJ 932 109

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