Virtual Research Presentation Conference

Metasurface Optics for Zernike Wavefront Sensing

Principal Investigator: John Steeves (355L)
Co-Is: J. Kent Wallace (3262), Christian Kettenbeil (355L), Jeffrey Jewell (398L)
David Doelman, Frans Snik, Christoph Keller (U. of Leiden)
Program: Topic RTD

Assigned Presentation #: RPC-103

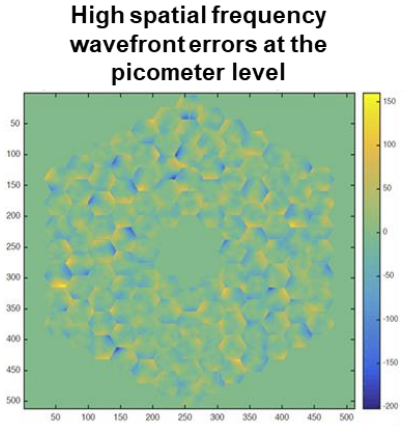
Jet Propulsion Laboratory
California Institute of Technology

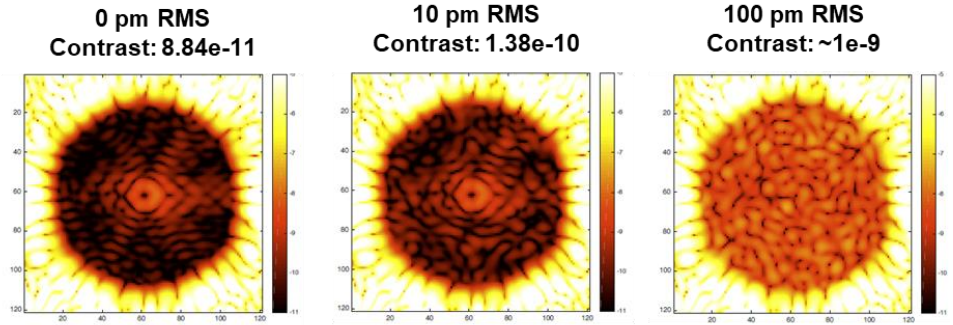
Tutorial Introduction

Abstract

Direct detection of Earth-like exoplanets via coronagraphic imaging requires the ability to sense and correct for picometer wavefront errors in an optical system. The Zernike Wavefront Sensor (ZWFS) has been proven capable of sensing errors at this level, but is limited in dynamic range. Here we intend to extend the dynamic range as well as the bandpass of the technique using a vector implementation of the ZWFS based on polarization-selective metasurface devices.

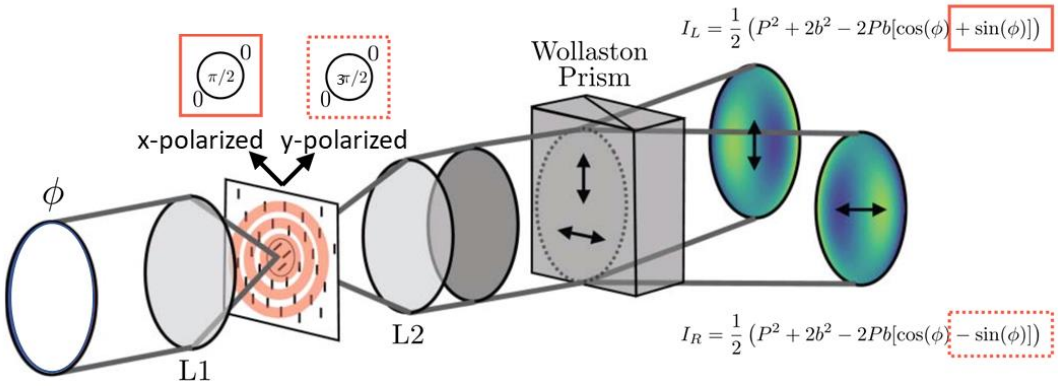
Problem Description





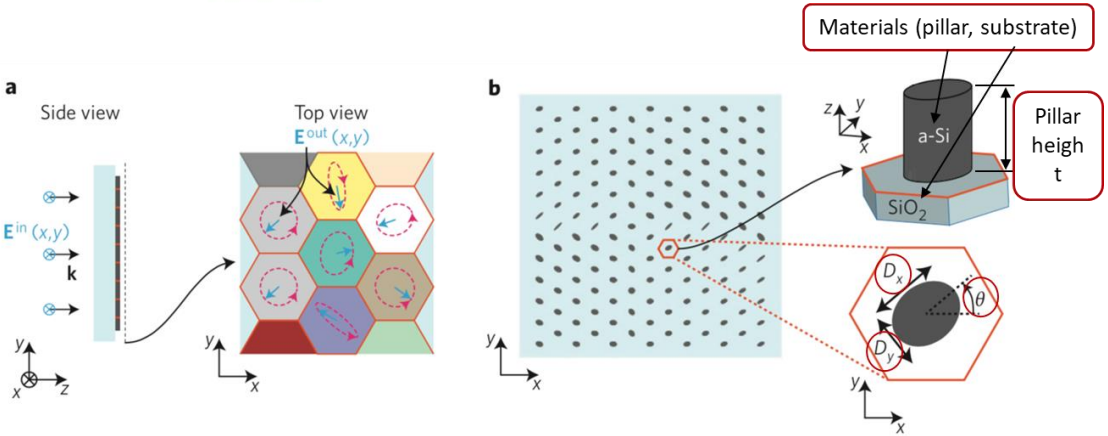
- Wavefront stability on the order of 10-40 picometer RMS required to maintain 1e-10 contrast
- *Necessary to develop wavefront sensing techniques with:*
  - *Picometer sensitivity*
  - *High dynamic range*
  - *High spatial-frequency resolution (~100 cycles per aperture)*
  - *Photon efficiency*
  - *Computationally efficiency*

Methodology

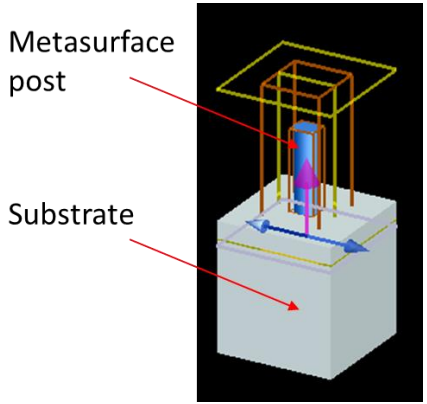


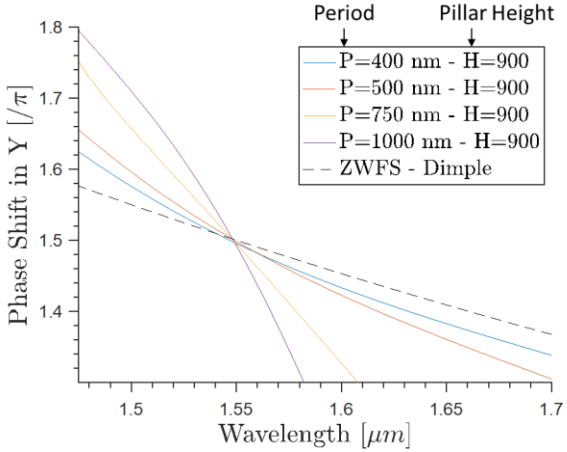
Vector ZWFS (vZWFS): Common-mode WFS, that produces two interfered pupil images with phase shifts dependent on polarization state

Metasurface Device: arrangement of subwavelength features that provide unique phase shifts (+/- pi/2) to x/y polarized light



Design/Fabrication





Deposition of amorphous silicon (Si) on silica (SiO_2)

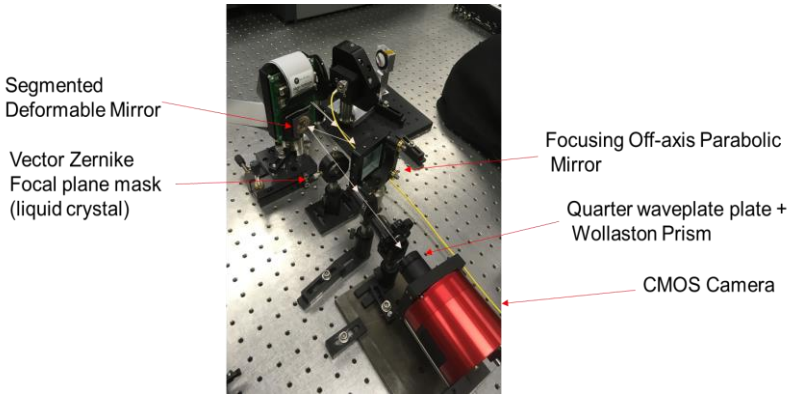
E-Beam Lithography

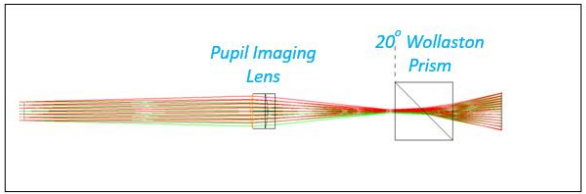
Silicon Etch

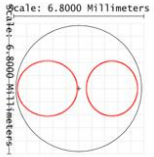
Liftoff – Resist Removal

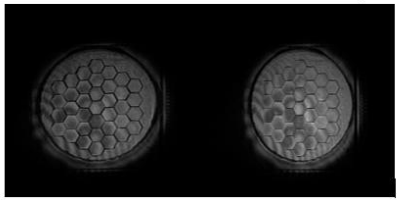
- Lumerical finite-difference time-domain (FDTD) simulations performed to design metasurface device
- Designs for metasurface devices have been created
- Nanofabrication processes under development in collaboration with MDL

vZWFS Testbed



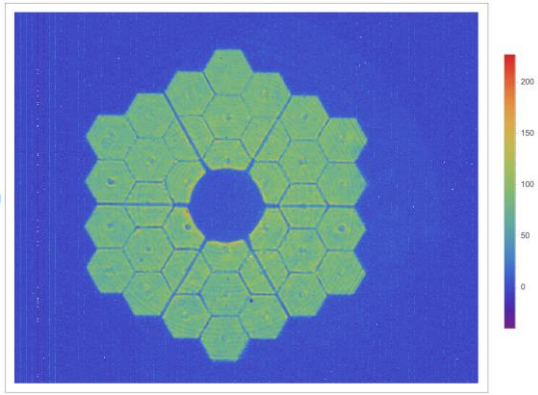




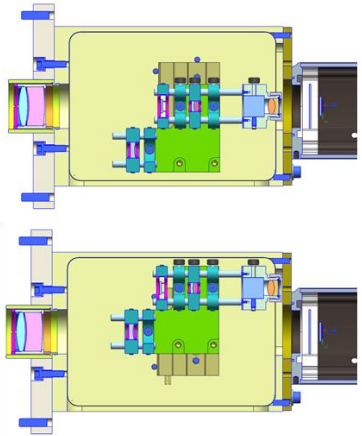


- Optical testbed to characterize vZWFS devices has been established
- Preliminary data has been collected using liquid-crystal version of the device

KPIC Implementation



Keck pupil image on KPIC



- Static Zernike phase mask installed, aligned and tested on the Keck Bench.
- Optical design for vZWFS on Keck is complete.
- Opto/mech hardware has been fabricated and is awaiting metasurface devices

Publications and References

Steeves, J., Wallace, J. K., Kettenbeil, C., Jewell, J. (2020). Picometer Wavefront Sensing using the Phase-Contrast Technique. Optica **7**, 1267-1274 (2020)

Doelman, D.S., Auer, F.F., Escuti, M.J., Snik, F, “Simultaneous phase and amplitude aberration sensing with a liquid-crystal vector-Zernike phase mask”, Optics Letters, 44 (1), pp. 17-20 (2019).

Ruane, G., Wallace, J. K., Steeves, J., et al. (2020). Wavefront sensing and control in space-based coronagraph instruments using Zernike's phase-contrast method. JATIS, under review.