Optical analysis of IBF-polished silicon wafers and cryogenic etching of black silicon coronagraph mask

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About me

- Senior (4th year) physics major, math minor at OSU
- Plan to get a PhD in astrophysics
  - Dark matter/dark energy
  - Interstellar propulsion systems 
- Dream job: JPL
- Place of internship: NASA Goddard Space Flight Center (GSFC)

Project Overview

- Direct imaging of exoplanets requires fabrication of coronagraph masks to control scattering/diffraction of light
- The purpose of this study is to enhance and assess the optical performance of the pathfinder masks for the High-contrast Imager for Complex Aperture Telescope (HiCAT) testbed
- The coronagraph masks are to be etched in black silicon onto small silicon wafers

My part in the project

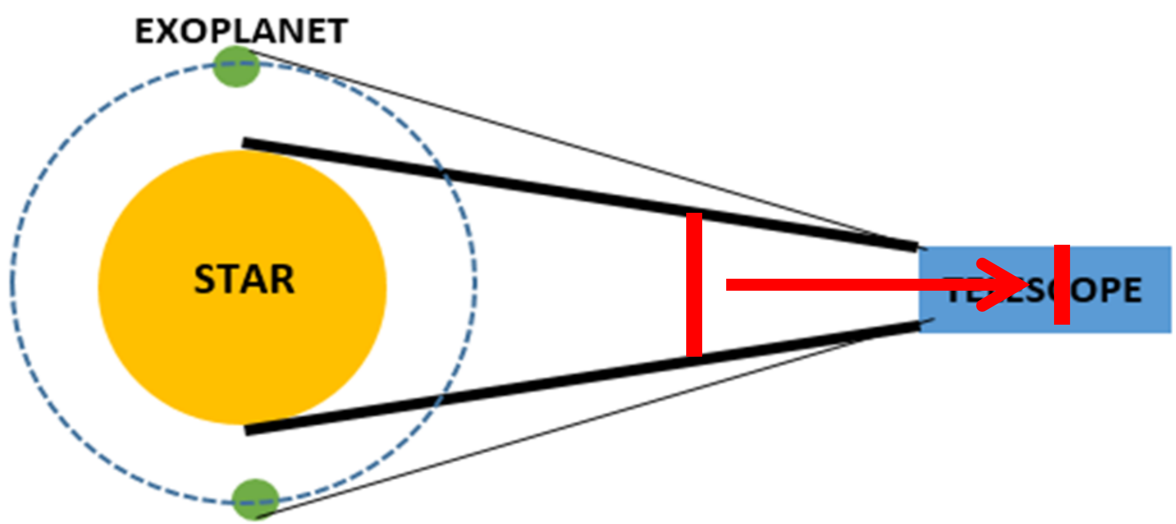
- Before fabrication of the coronagraph masks onto the silicon wafers, the wafers must be polished to a high optical standard
- New method of polishing: IBF
- We want to see how much IBF-polishing improves surface figure errors on optical surfaces
- An analysis of each wafer’s surface was done both pre- and post-IBF polishing
  - Used 2 interferometers (B7 Zygo, B34 4D)
  - RMS
  - PV

Background

- Interferometry:
  - Uses wave interference patterns to “scan” an optical surface and create a surface map
- Ion beam figuring (IBF):
  - Uses a beam of accelerated ions in a vacuum to polish optical surfaces
  - The beam removes a pre-set amount of material based on the surface map
- Coronagraph:
  - Instrument that blocks direct light from a star

Exoplanet direct imaging

- To directly image an exoplanet, the central light in its solar system must be blocked
- Reduce the star’s luminosity by 10 orders of magnitude

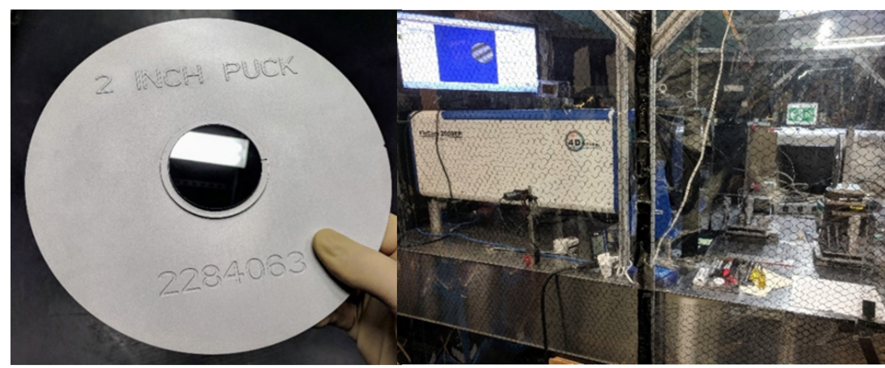


Methodology

- 8 silicon wafers, each 2 inches in diameter
  - 5mm thick: Pucks 1, 2, 16, 17, 18, 19
  - 500 µm thick: ESM1, ESM2
- 2 interferometers:

B7 (Zygo)

B34 (4D)



Methodology

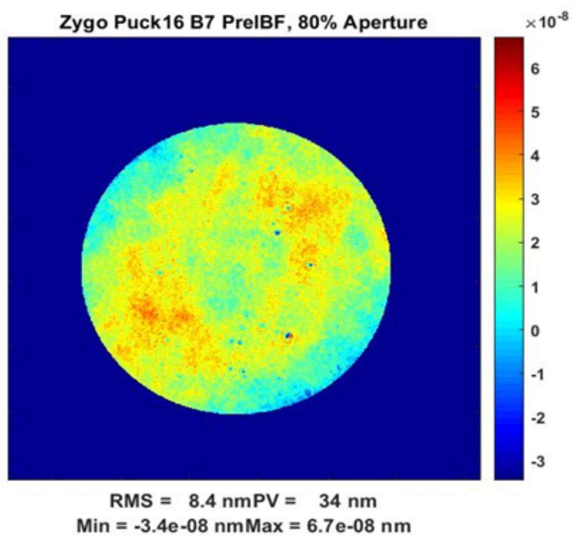
- One set of interferometer readings was taken pre-IBF, one set was taken post-IBF
- Raw interferometer data was run through a Matlab script
  - Generate images of each wafer's surface
  - Calculate RMS and PV
  - Allow for manual change in wafers' apertures (98%, 90%, 80%)
- Next did an Excel analysis to make graphs of pre/post-IBF RMS/PV data

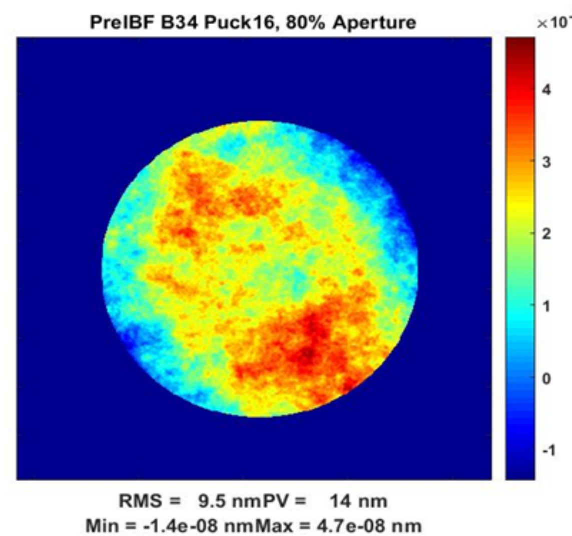
Results: Puck 16

B7 (Zygo)

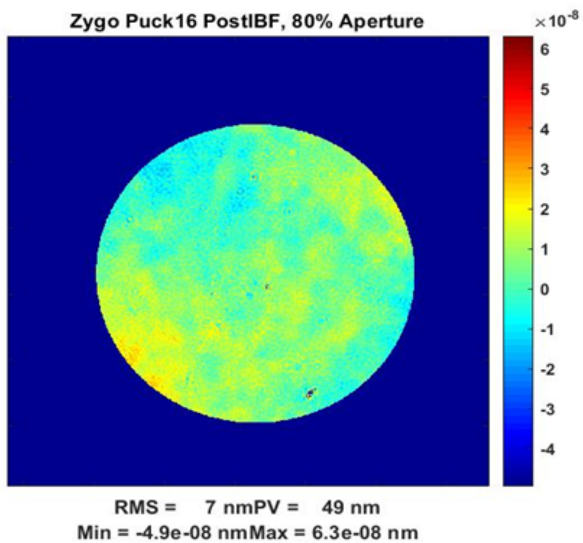
B34 (4D)

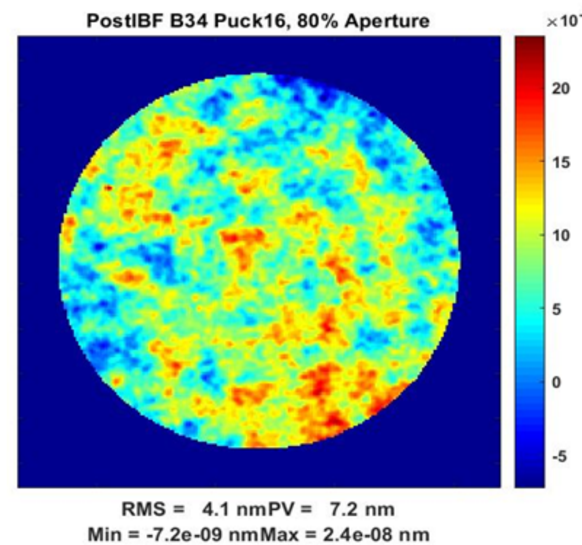
Pre-IBF



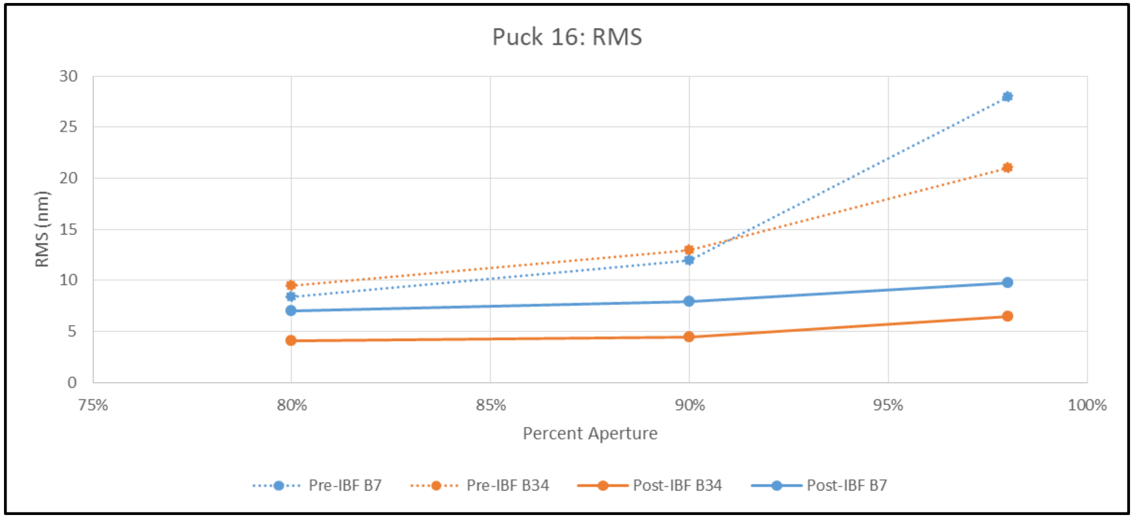


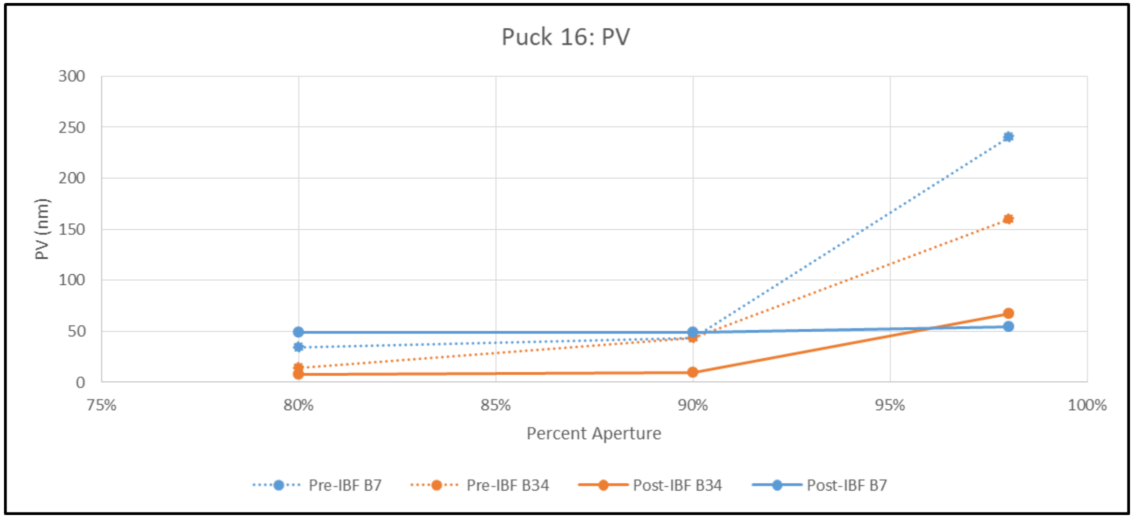
Post-IBF





Results: Puck 16





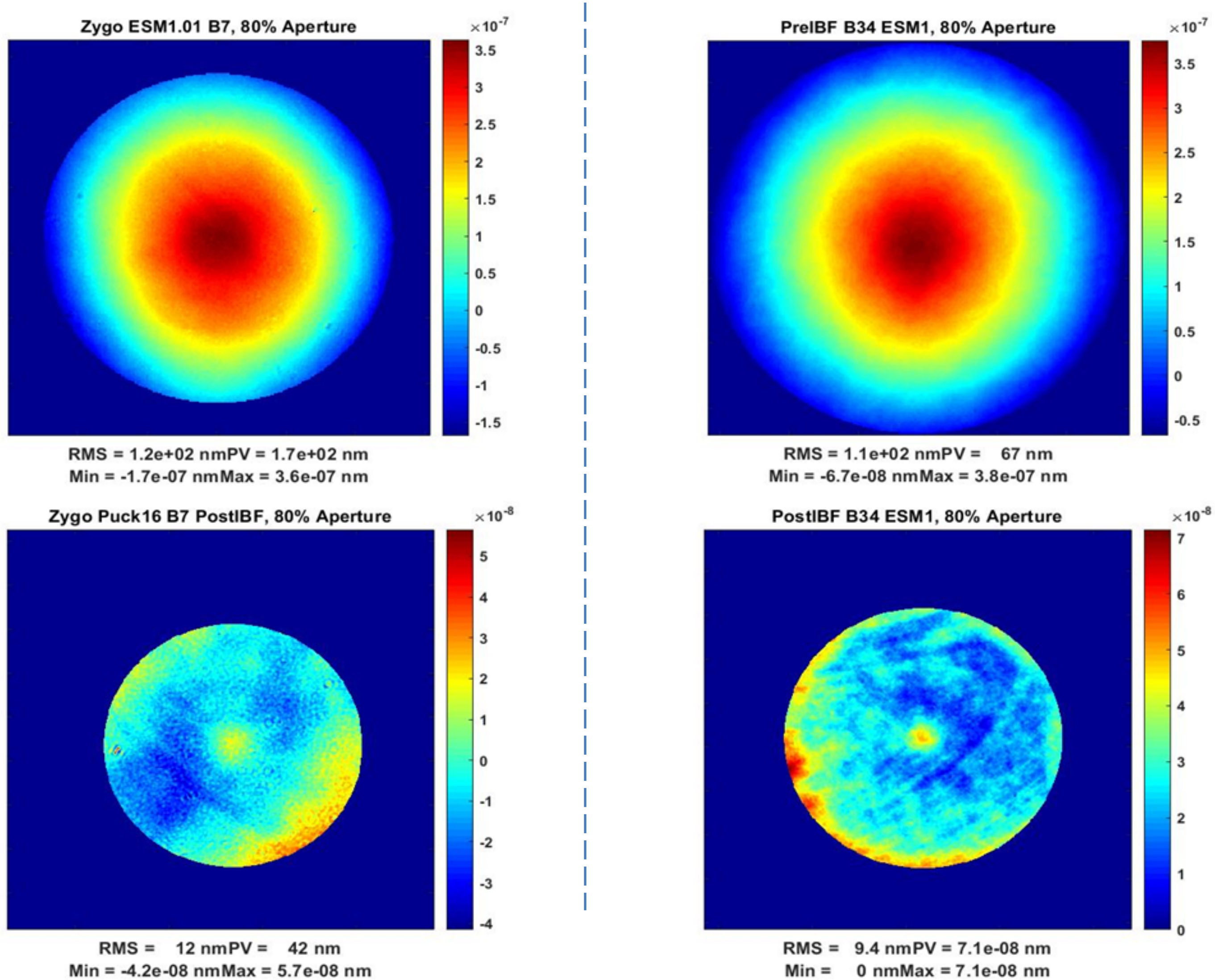
Results: ESM1

B7 (Zygo)

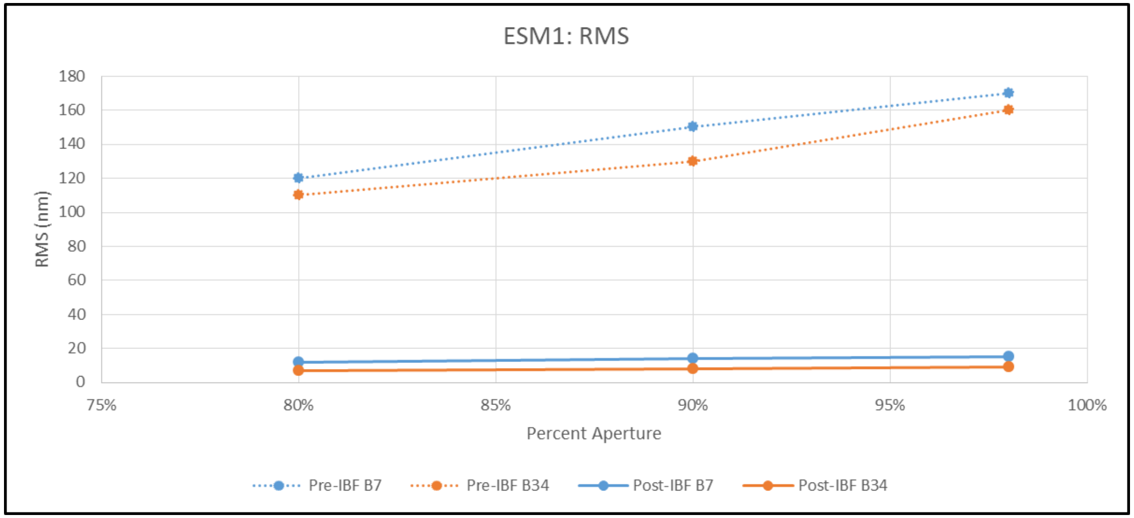
B34 (4D)

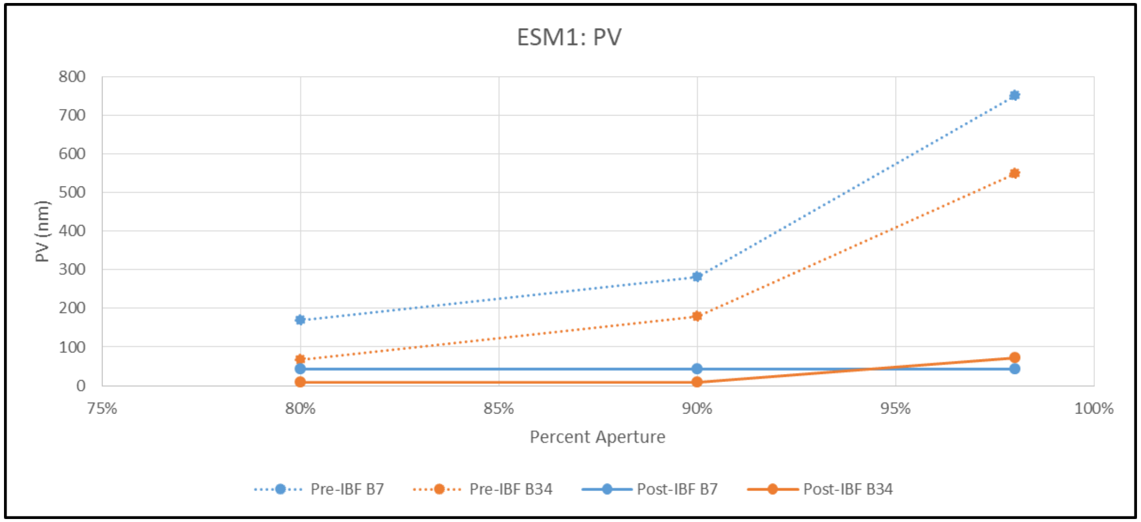
Pre-IBF

Post-IBF



Results: ESM1





Conclusion/Next steps

- IBF polishing significantly decreases the surface figure error of the silicon wafers
- The two interferometers yield roughly the same results
- Next: black silicon coating