Co-Phasing a Segmented Aperture with a dynamic Zernike WFS

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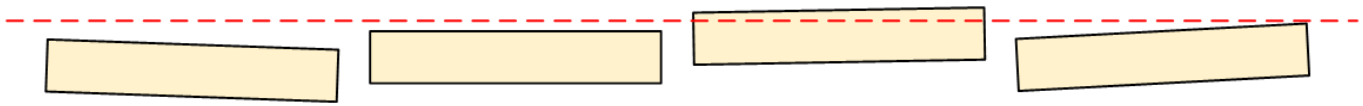
Outline

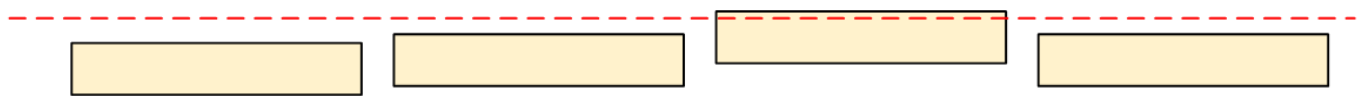
- Statement of the alignment problem
- Guiding principles for alignment
- The alignment methodology
- Performance Simulations
- Technology Development
- Status of Laboratory Demonstration

The segmented aperture alignment problem

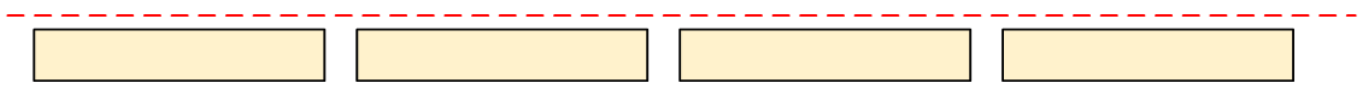
Two key steps in segment aperture correction



1. Co–aligning: overlapping all the individual segment PSF's in the focal plane



2. Co-phasing: aligning the segments in piston to within a small fraction of a wavelength.

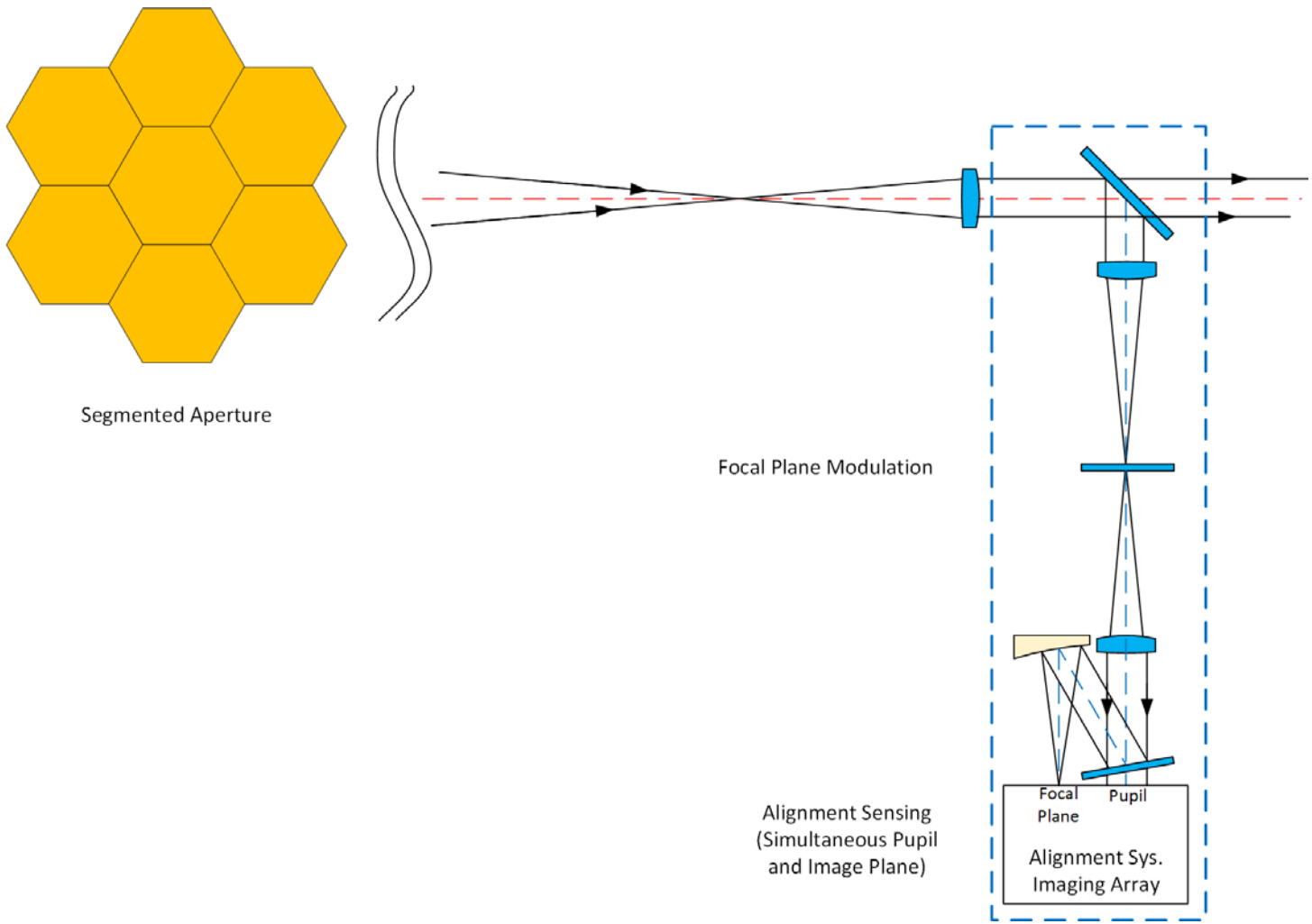


Guiding Principles of Alignment

When performing alignment of apertures, the following are highly desirable:

1. Maintain near-nominal operation of the system
2. Minimize the number of iterations
3. Maximize sensitivity
4. Minimize the number of moving parts
5. Monitor and maintain co-phasing continuously

System architecture



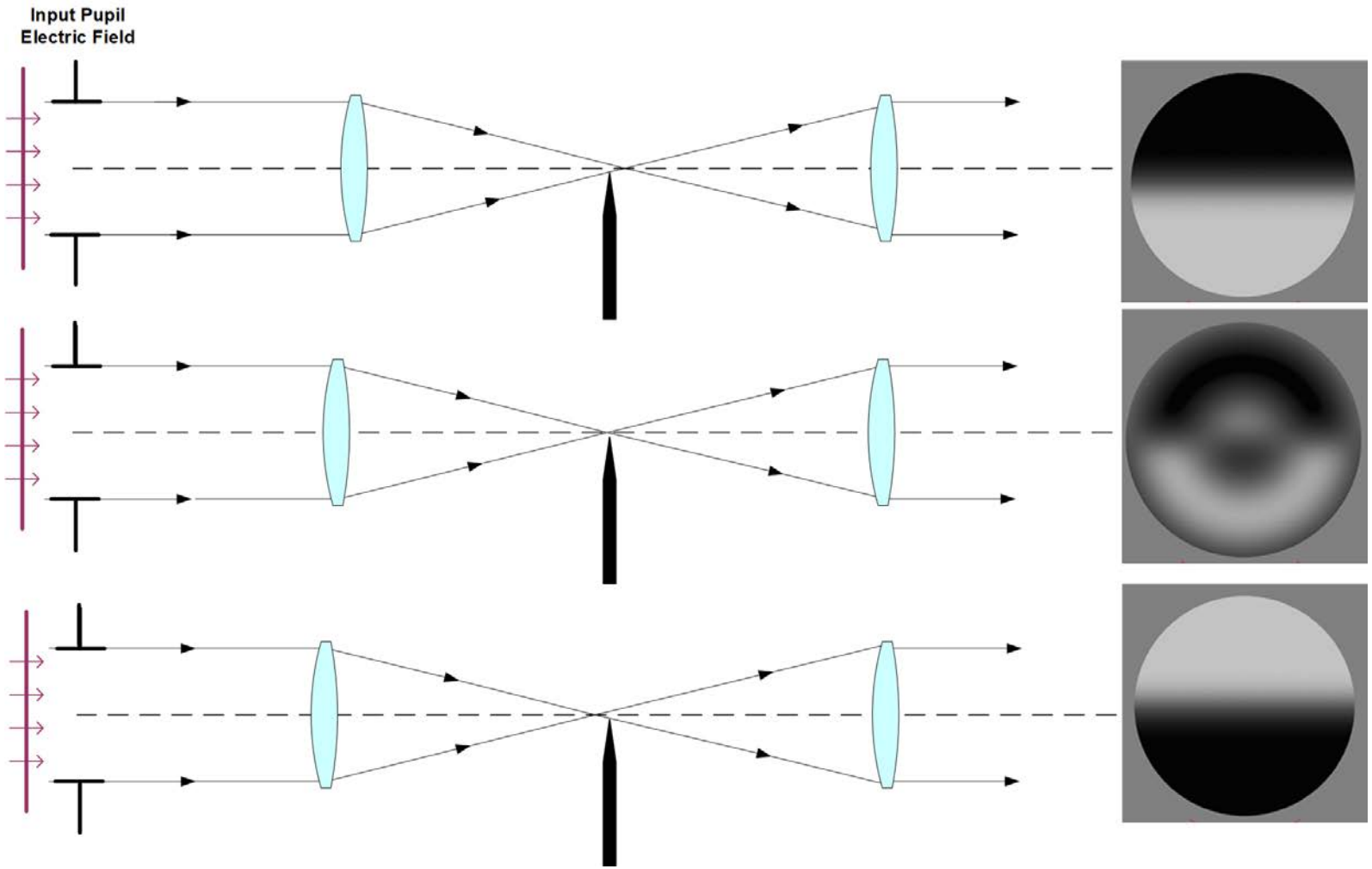
The alignment method

Two steps:

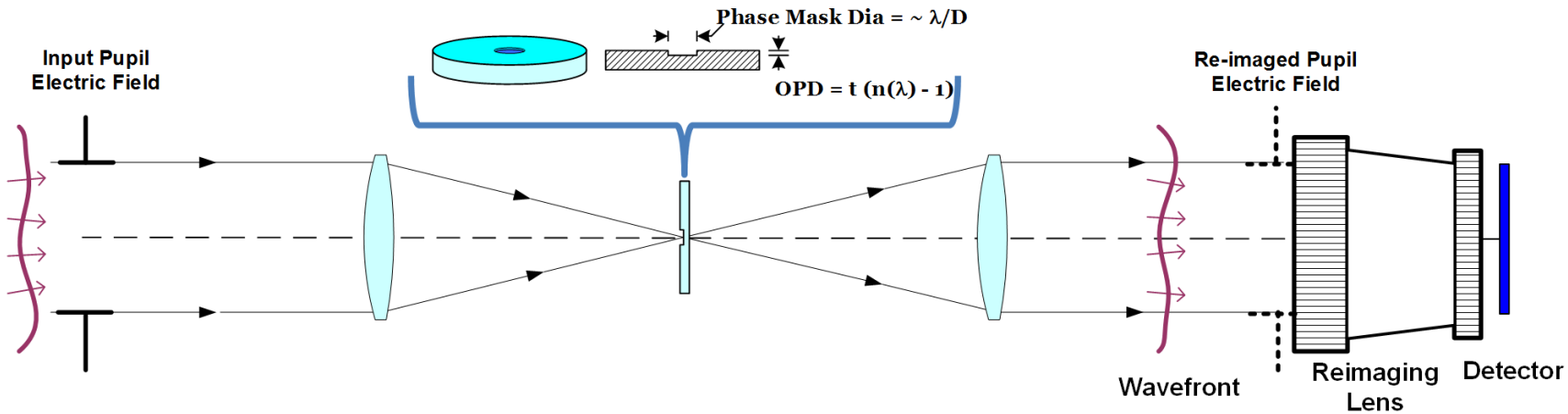
Step 1: Co-alignment with a dynamic knife-edge (focal-plane amplitude mask)

Step 2: Co-phasing with a dynamic Zernike sensor (focal-plane phase mask)

Knife-edge method: co-alignment



Zernike for Co-phasing



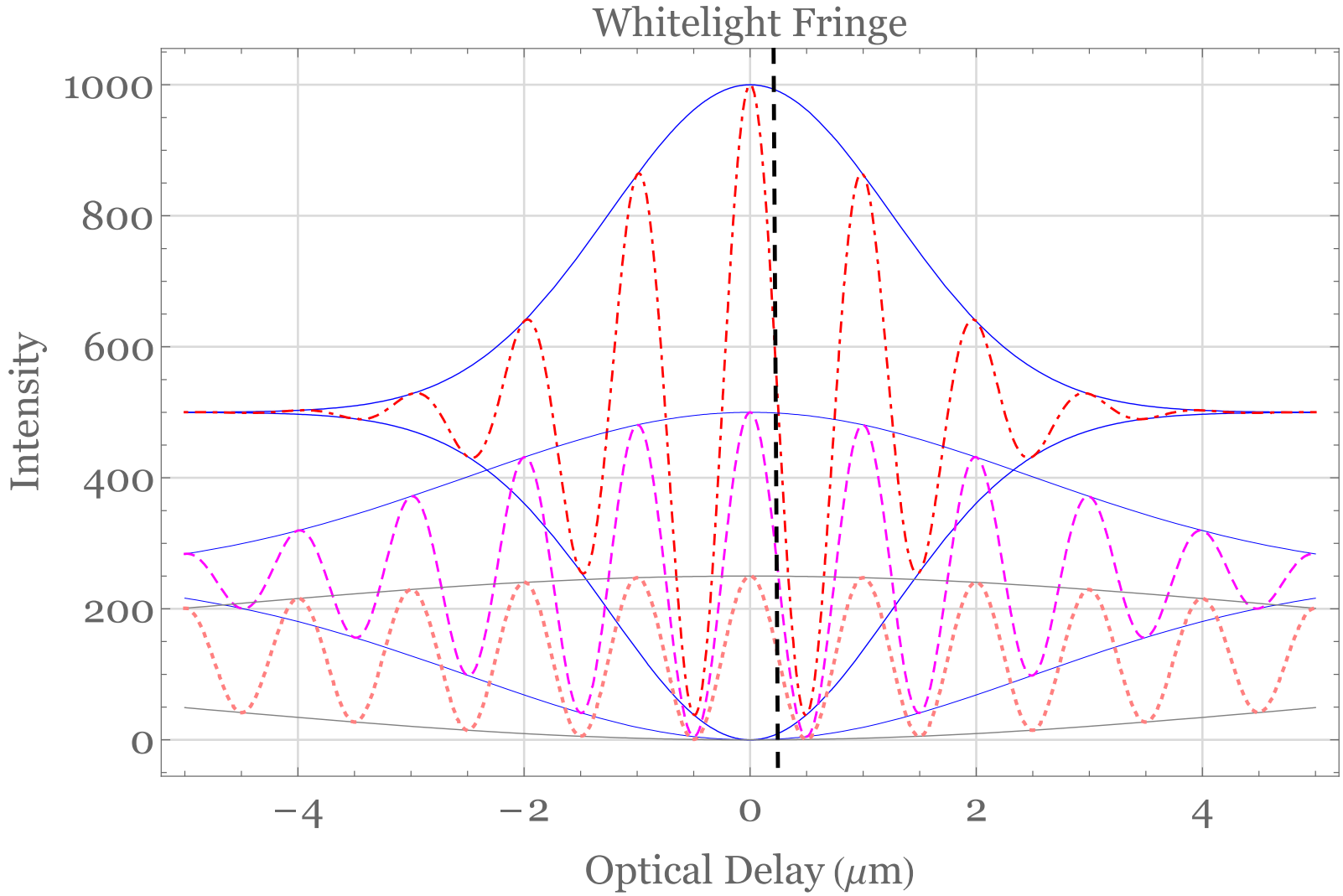
The Zernike WFS is a common-path interferometer.

Interfering the phase-shifted, low-spatial frequency E-field in the pupil plane.

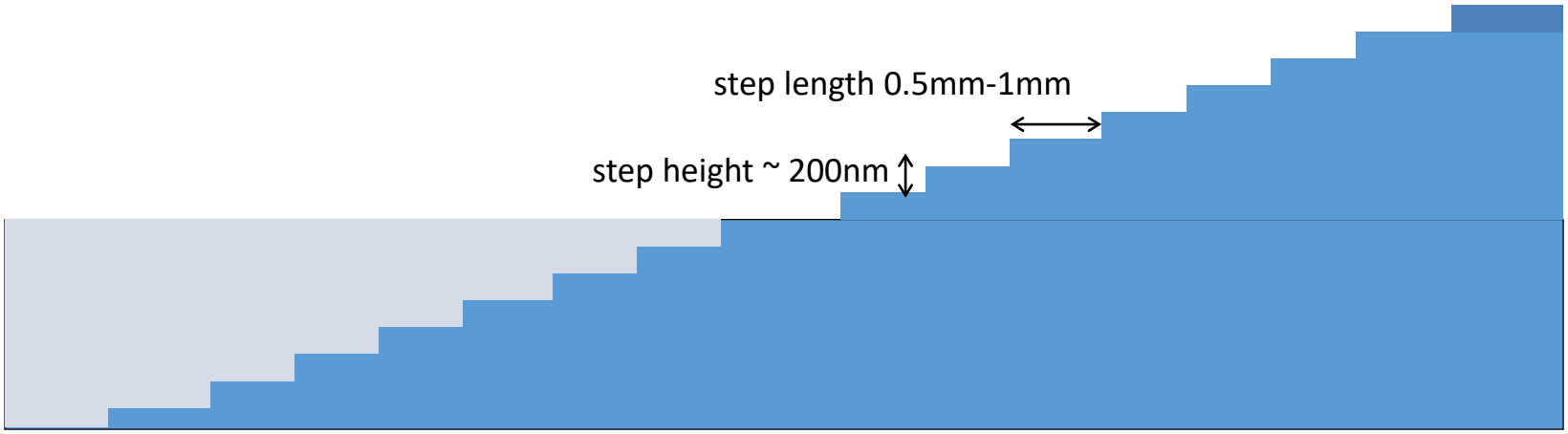
Think of the dynamic range limitation for the static ZWFS as set by the phase dimple.

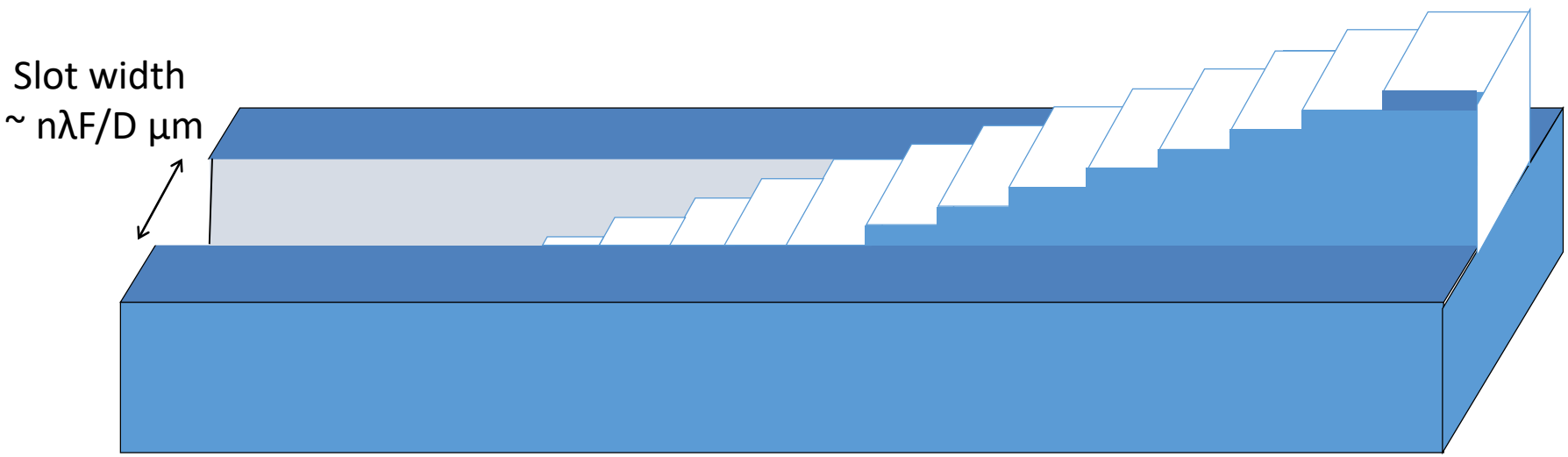
If the delay is made larger for larger phase errors, interference would return.

ZWFS Chromaticity

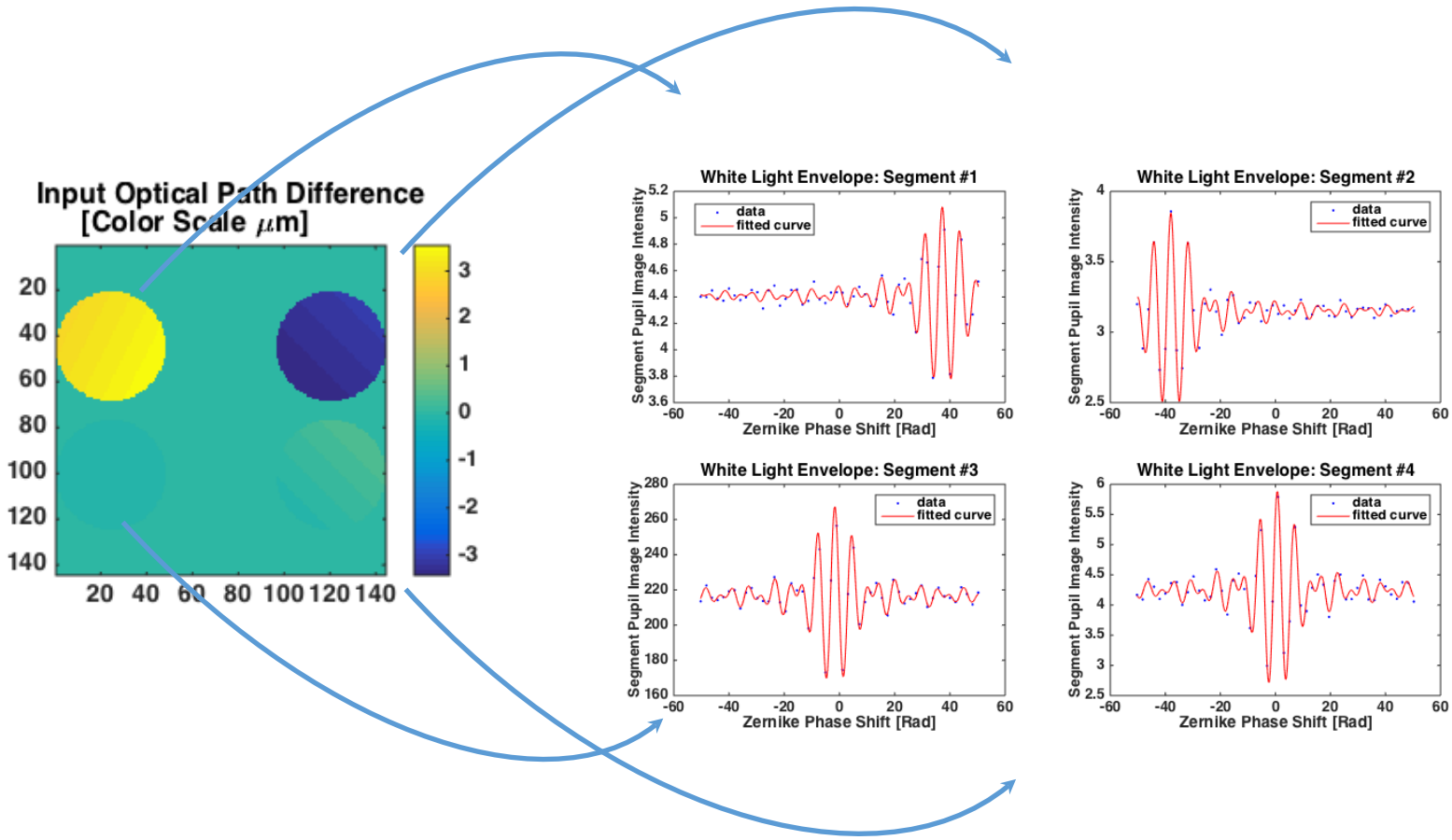


Dynamic Zernike Method

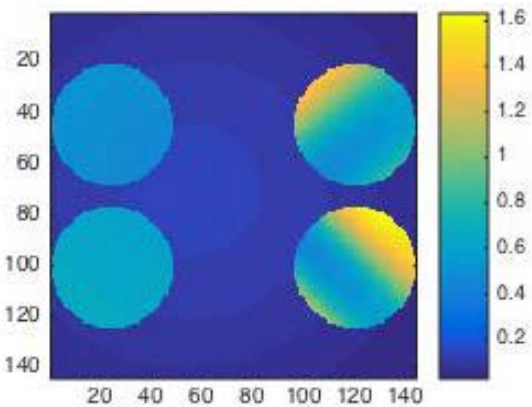


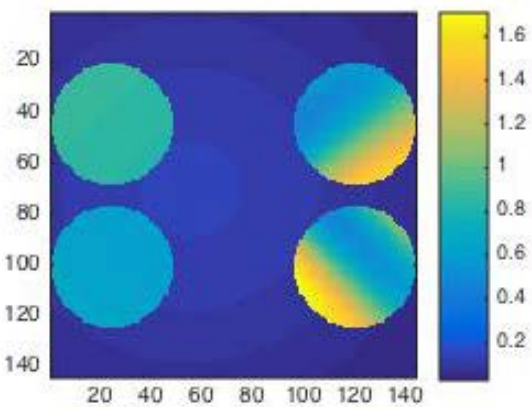


Dynamic Zernike: coarse phasing



Dynamic Zernike: Fine Phasing

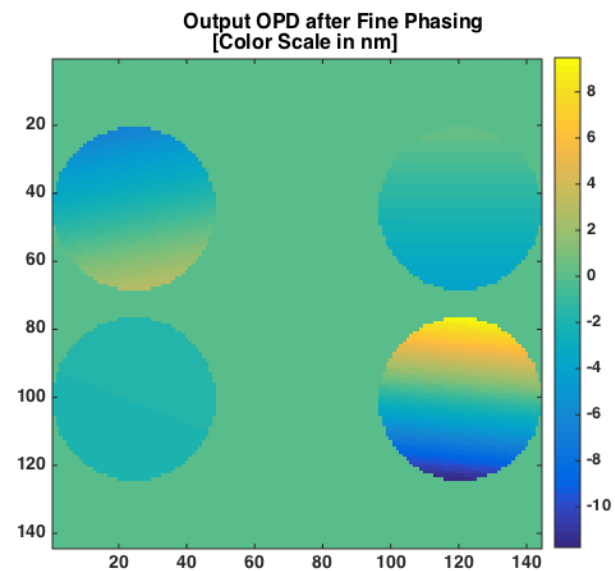




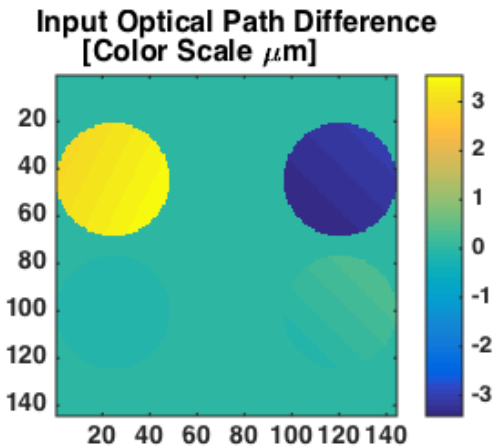
- Take Pupil Images for phase shifts of $\pm\pi/2$
- Use equation to compute ϕ at all points.

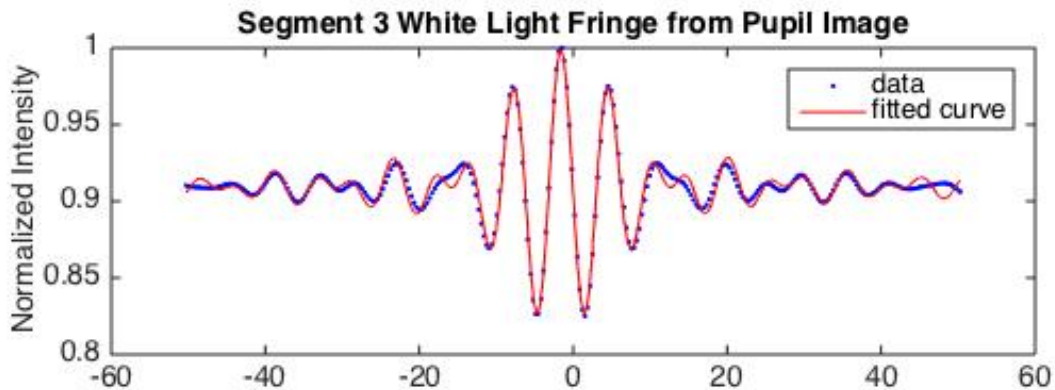
$$\phi = \frac{I_3 - I_1}{4I_0}$$

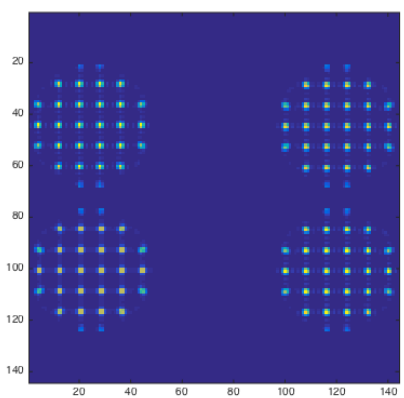
- Subtract computed phase from OPD (command the rigid body actuators)

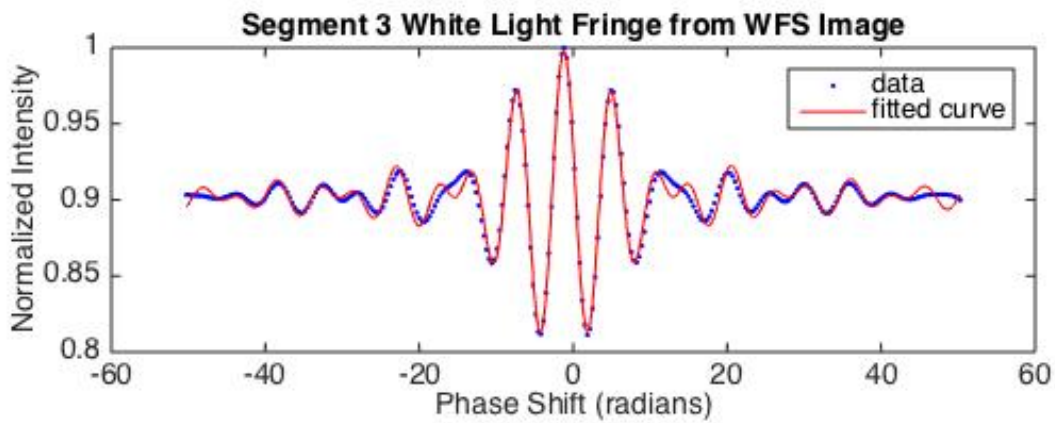


Hybrid Shack-Hartmann and Zernike

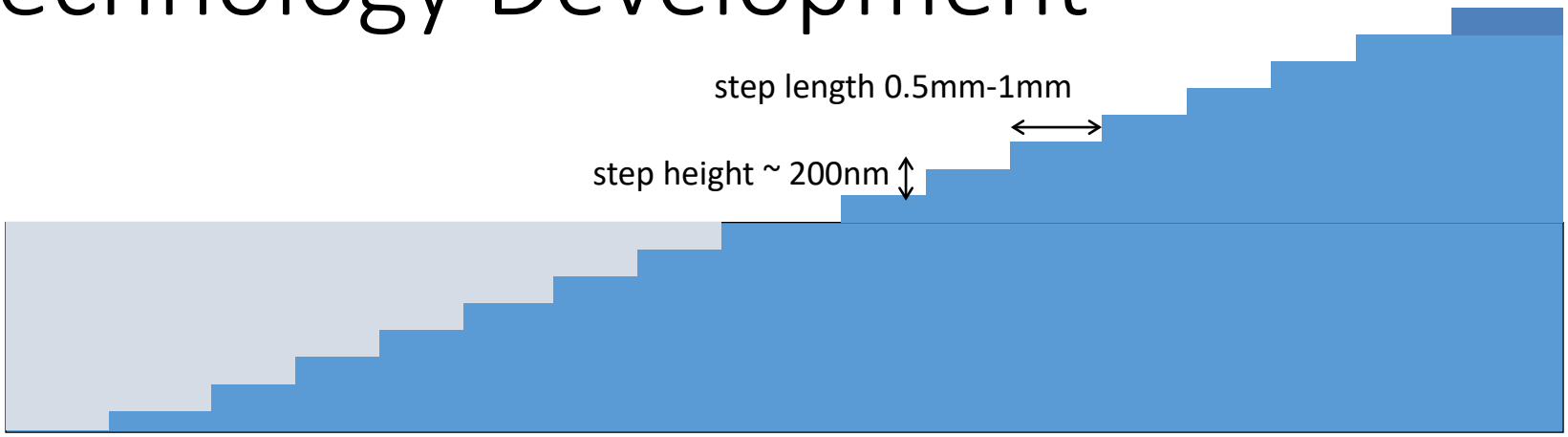


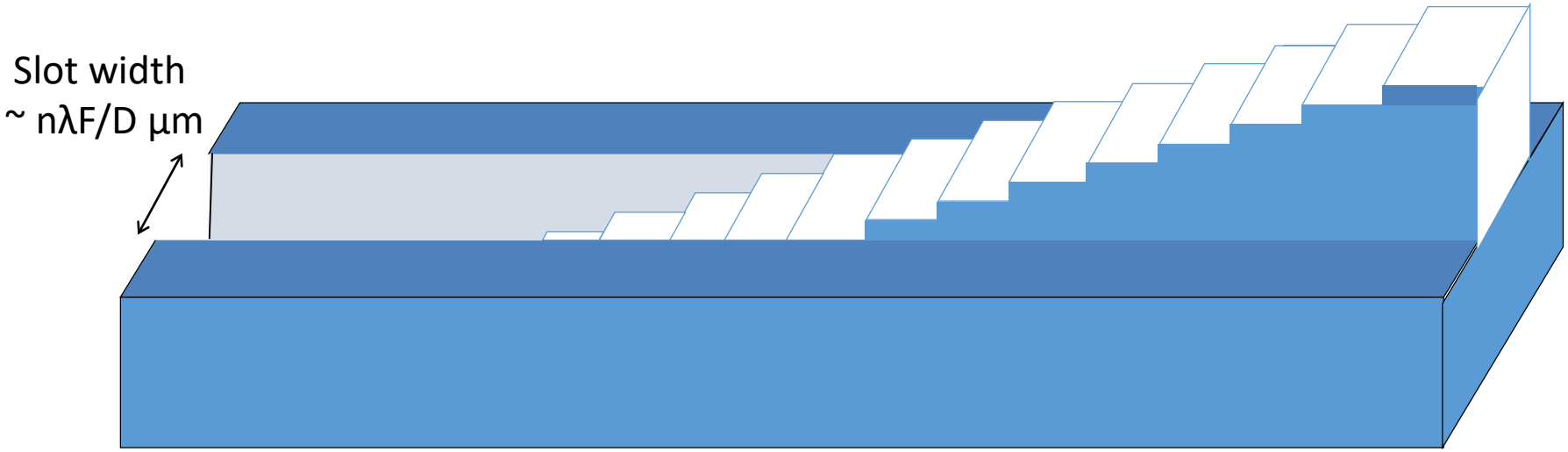




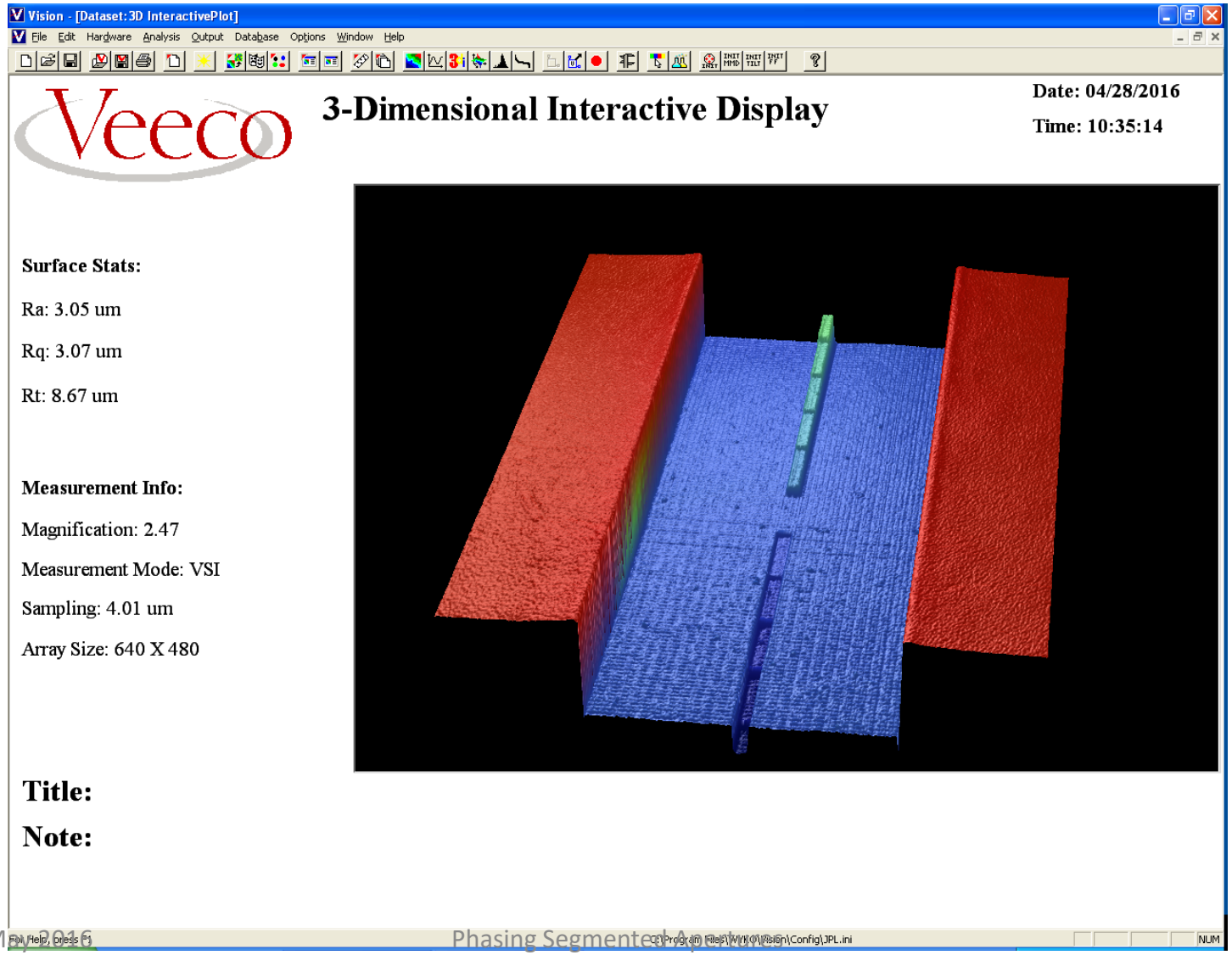


Technology Development

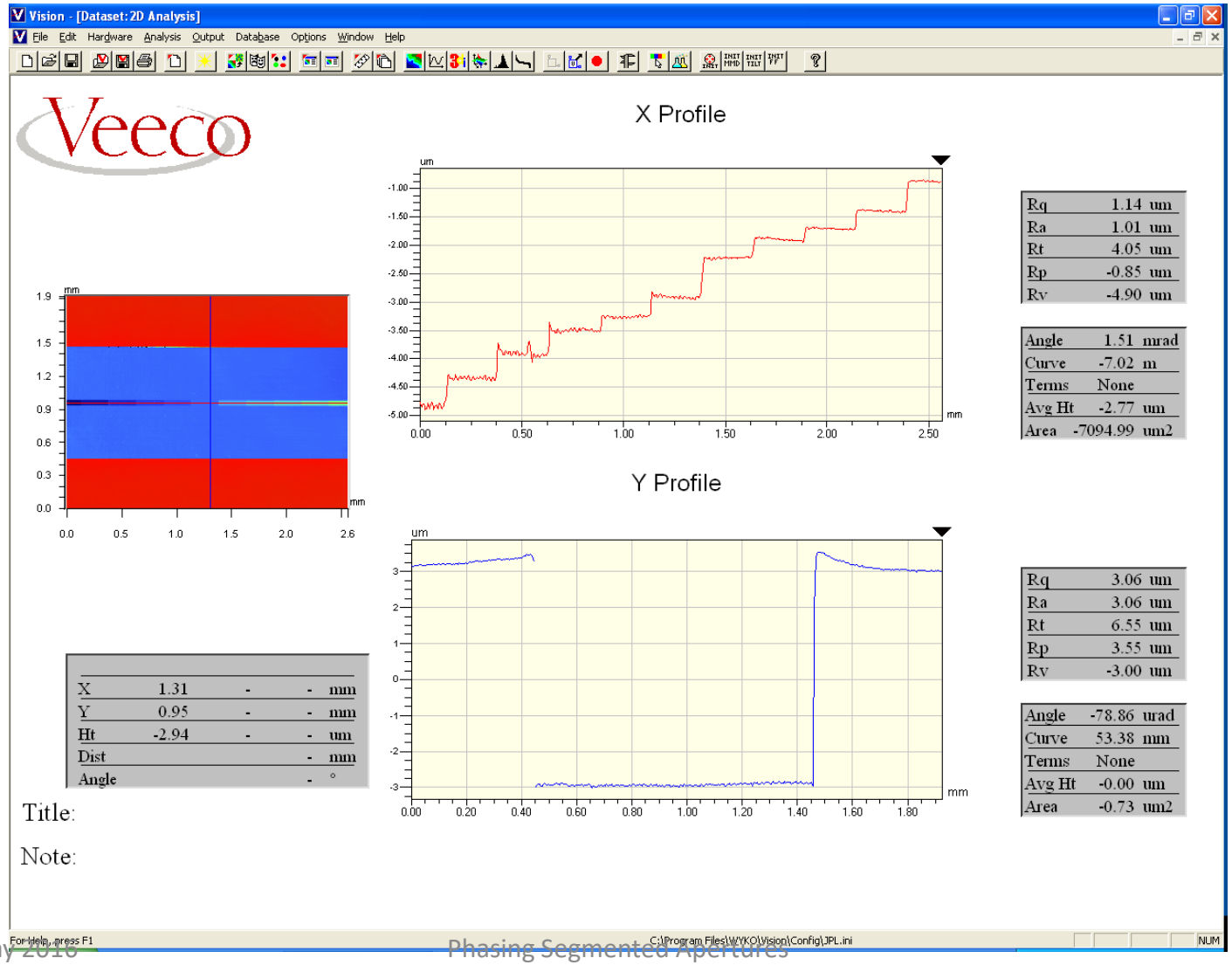




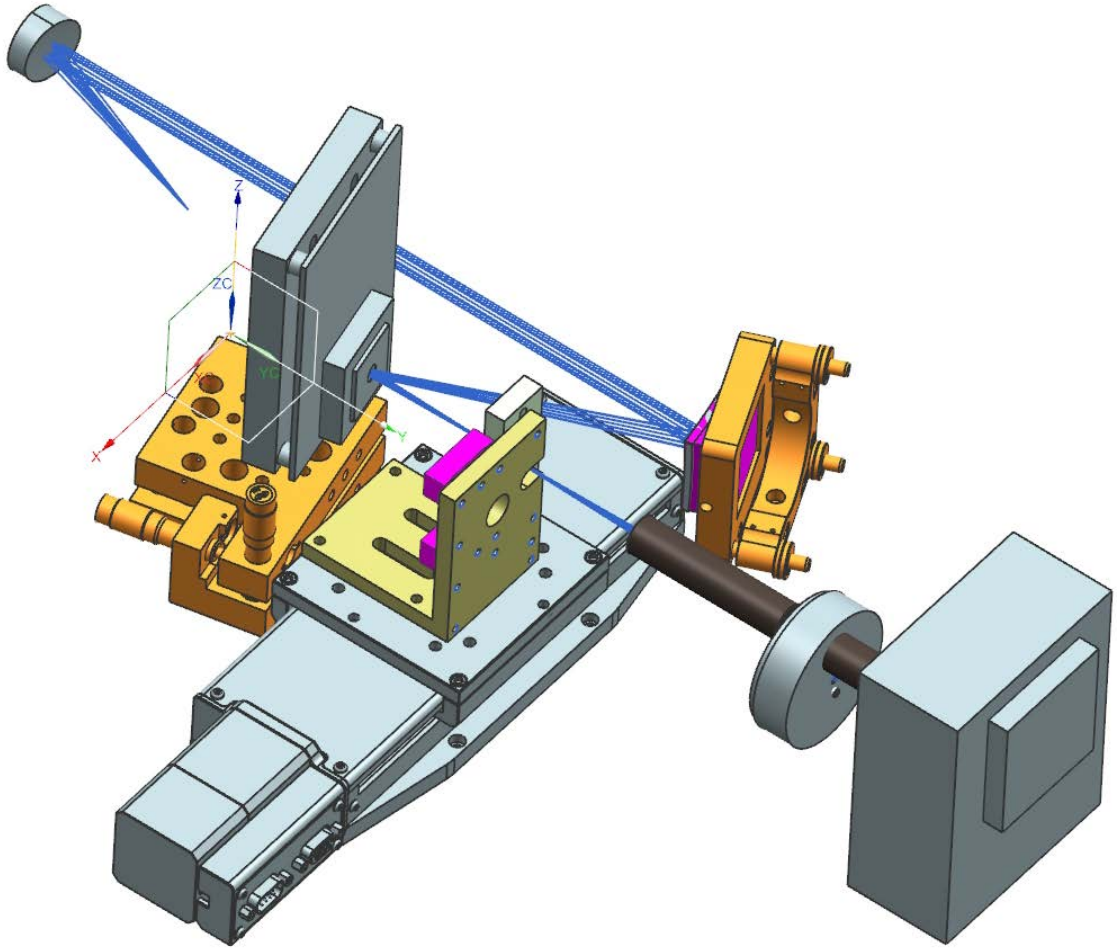
MDL Results: Zernike Device



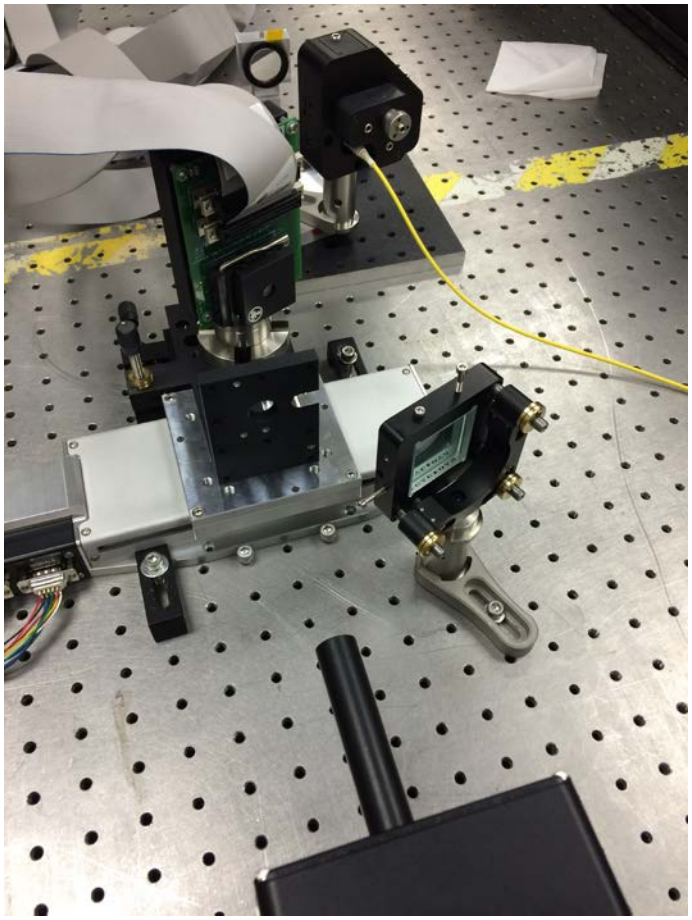
MDL Results: Zernike Device



Laboratory Demonstration



Laboratory Demonstration: Hardware



Dynamic Zernike Performance

When performing alignment of apertures, the following are highly desirable:

1. Maintain near-nominal operation of the system ✔☐
2. Minimize the number of iterations✔☐
3. Maximize sensitivity ✔☐
4. Minimize the number of moving parts ✔☐
5. Monitor and maintain co-phasing continuously ✔☐

Summary

- A hybrid knife-edge and dynamic Zernike WFS is well suited to the phasing of segmented apertures.
- The knife-edge co-aligns segments in tip-tilt, and does a coarse co-phasing
- A dynamic Zernike WFS extends the capture range of the classic, static ZWFS
- When used as a static WSF, the Zernike can maintain segment phasing.