Wavefront calibration testing of the James Webb Space Telescope primary mirror center of curvature optical assembly

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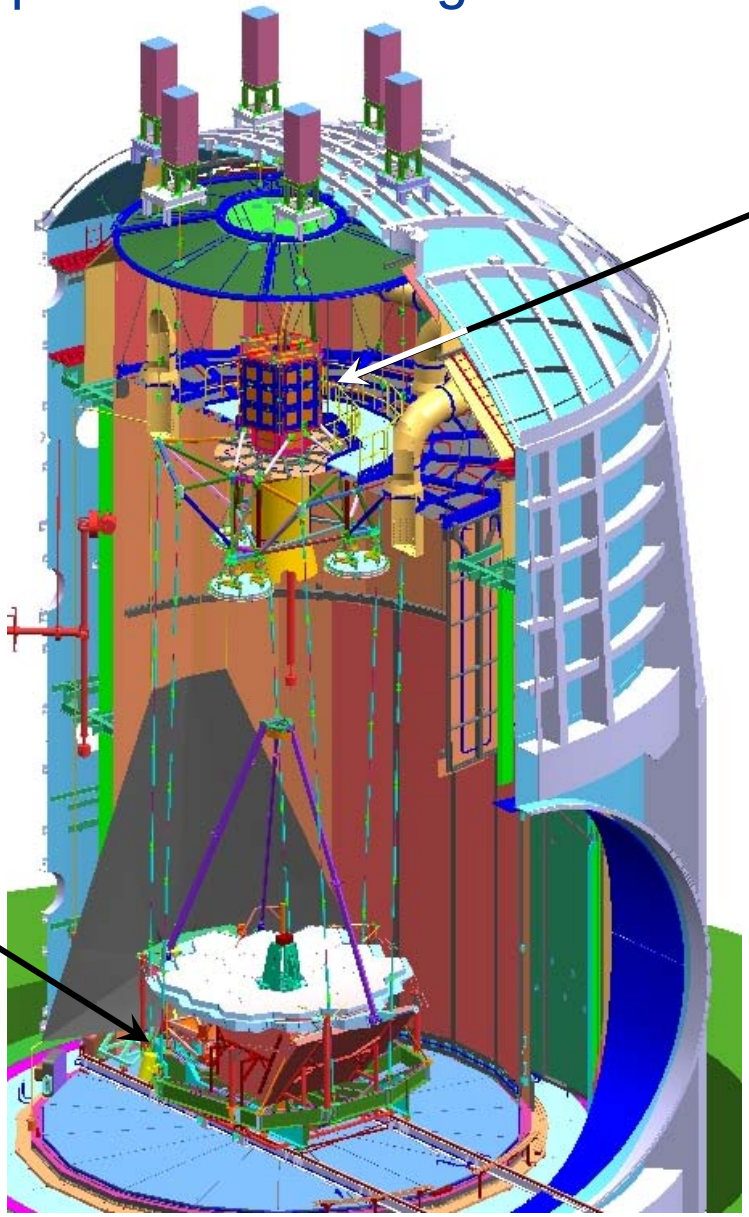
Cryogenic Optical Test Configuration of JWST

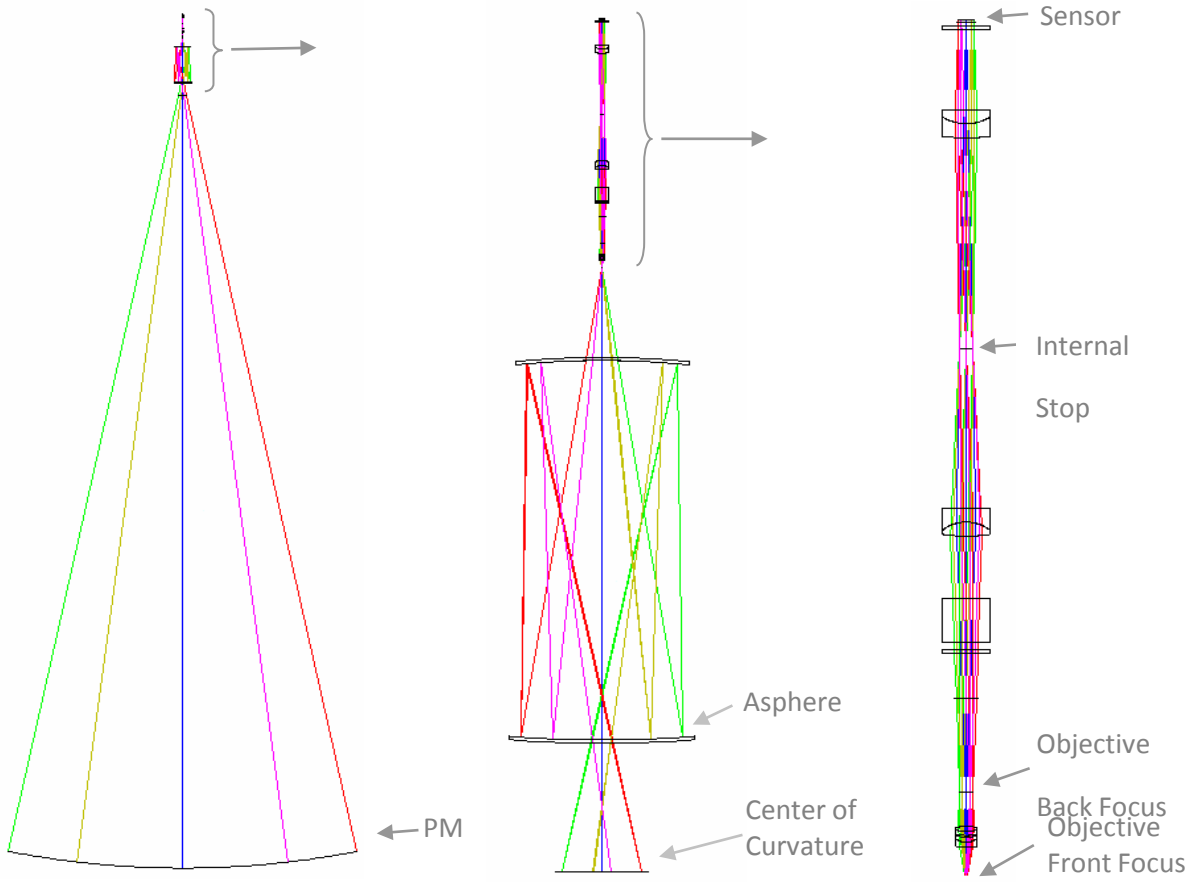


Center of Curvature Optical Assembly (COCOA)

- Interferometer, null, calibration equipment
- Coarse/fine PM phasing tools
- Displacement Measuring Interferometer

- Absolute Distance Meter

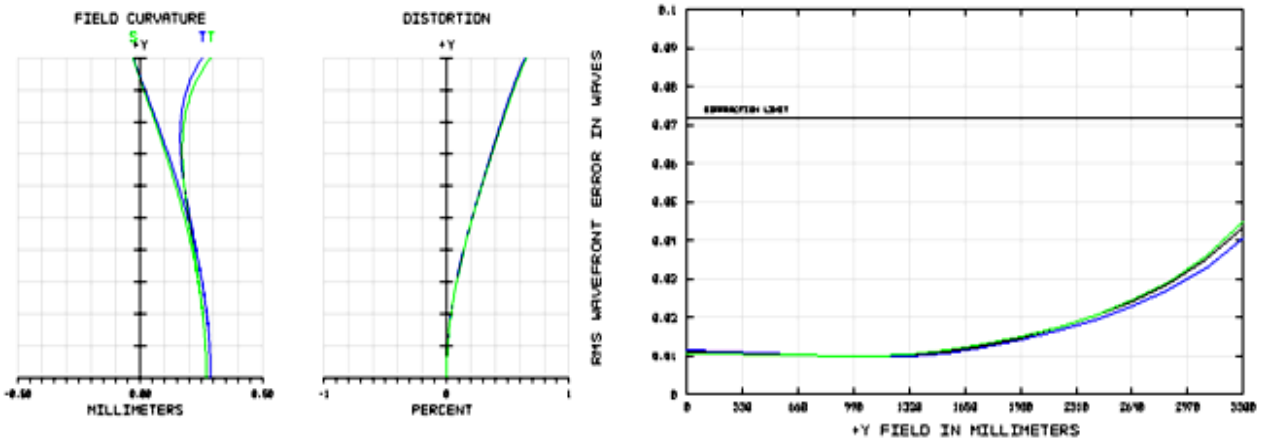
Optical System In Test



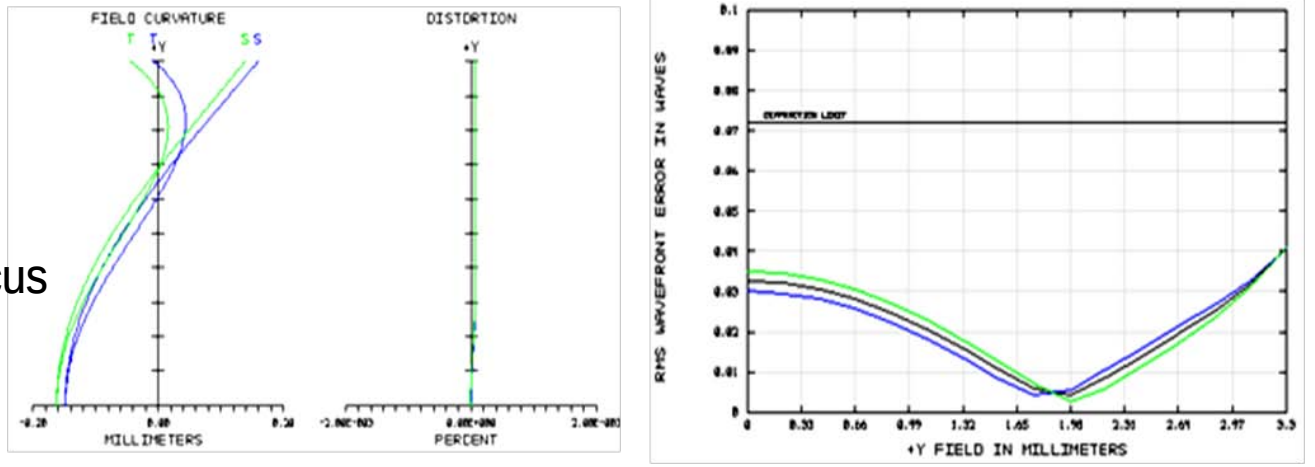
- Ray tracing of the system for finite conjugates with the primary mirror (PM) as the object reveals the interferometer imaging properties

Imaging Performance In Test

Single Pass:
PM to Sensor

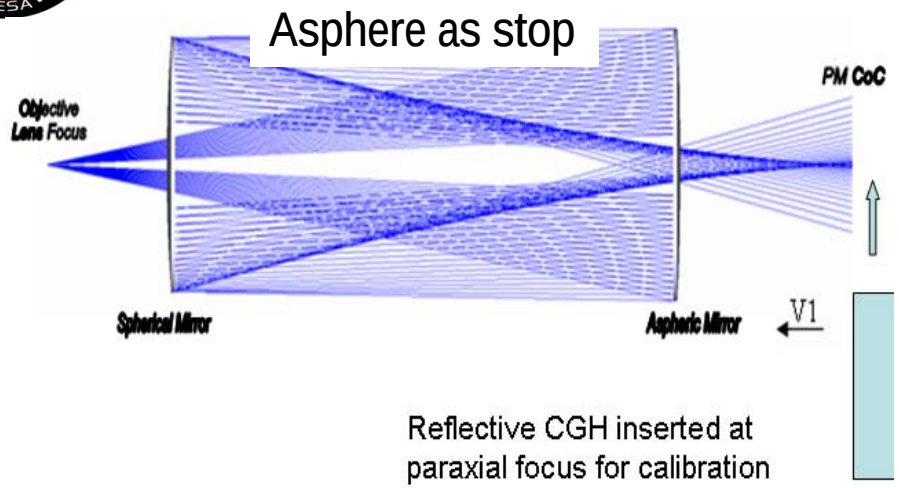


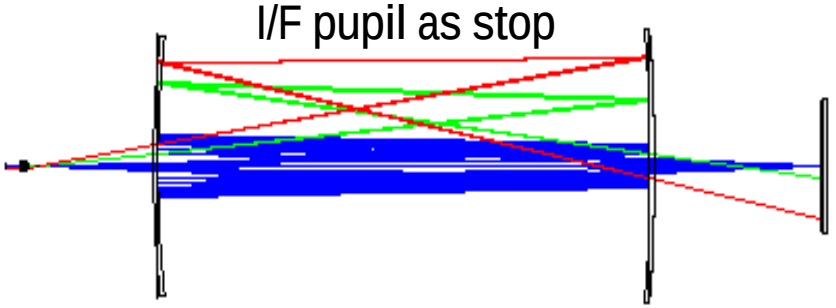
Double Pass
Objective Back Focus
to Objective Back Focus



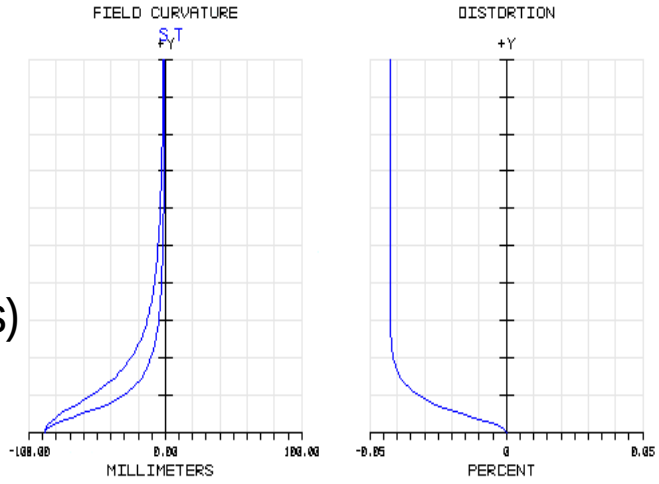
- The test system has little distortion and diffraction limited imaging performance

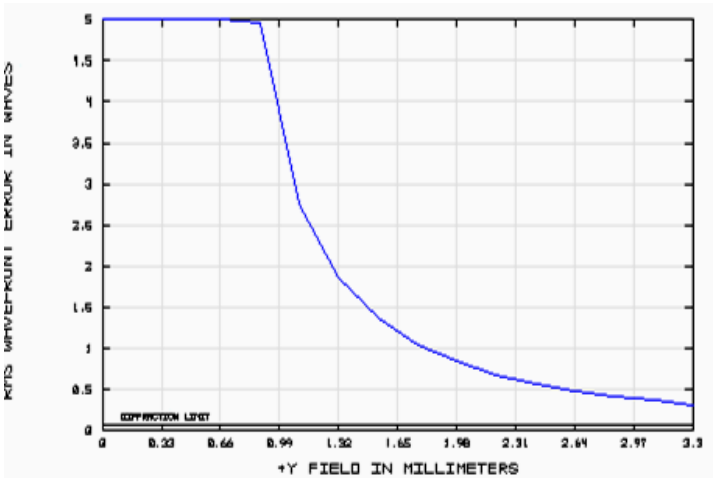
System Wavefront Test (SWFT) i.e. Calibration





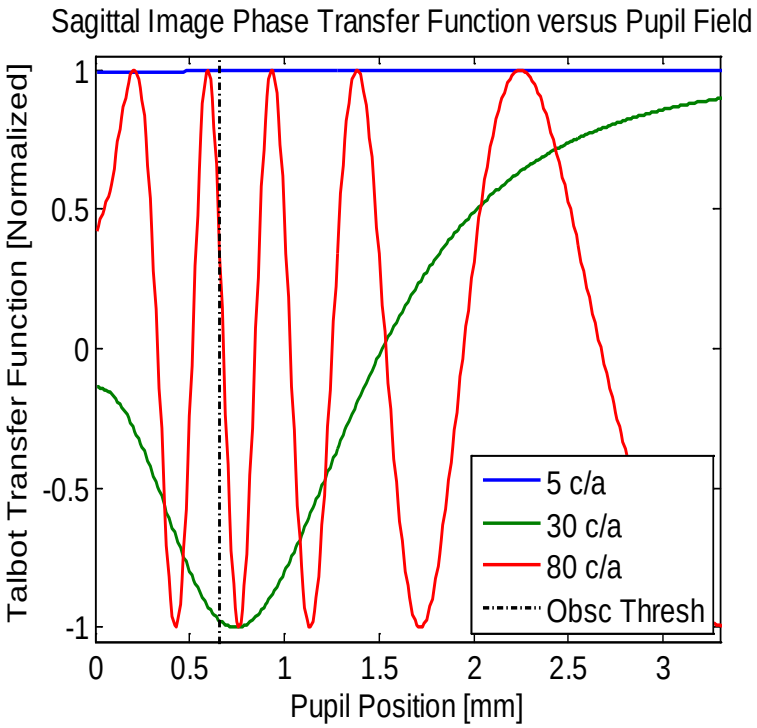
Imaging the Asphere to the interferometer Pupil (first pass)

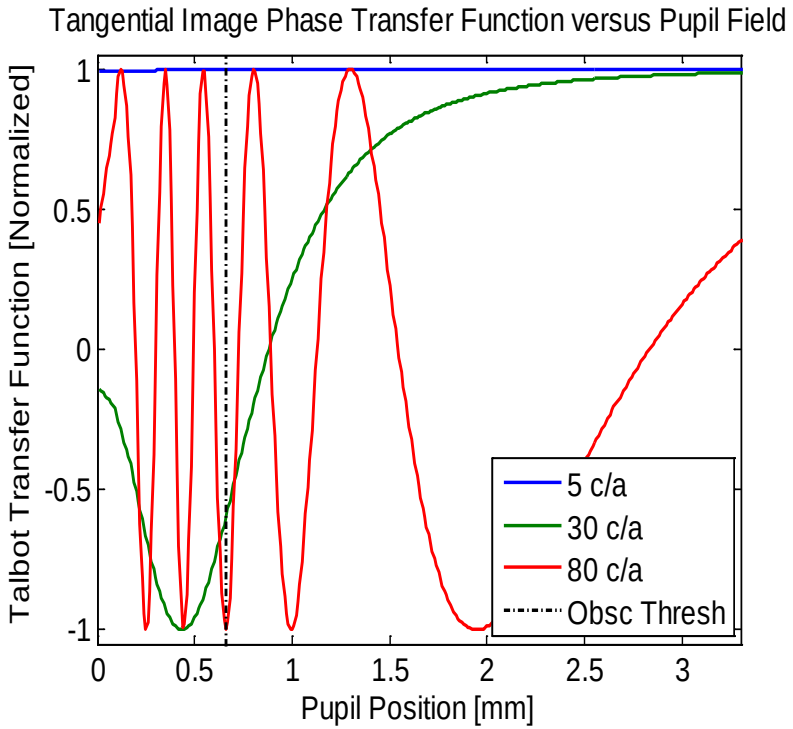




- During calibration the imaging performance is significantly degraded

Talbot Imaging Analysis In Calibration

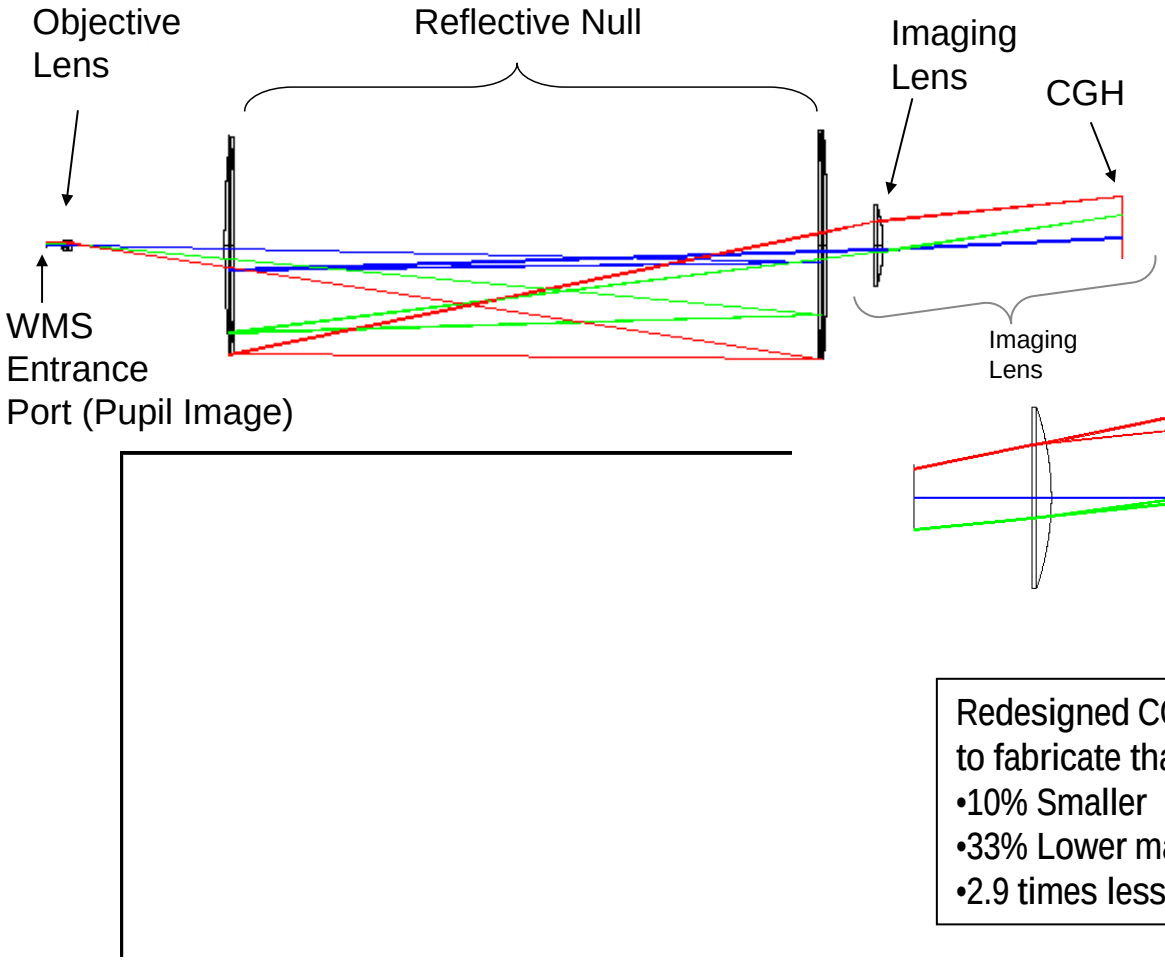


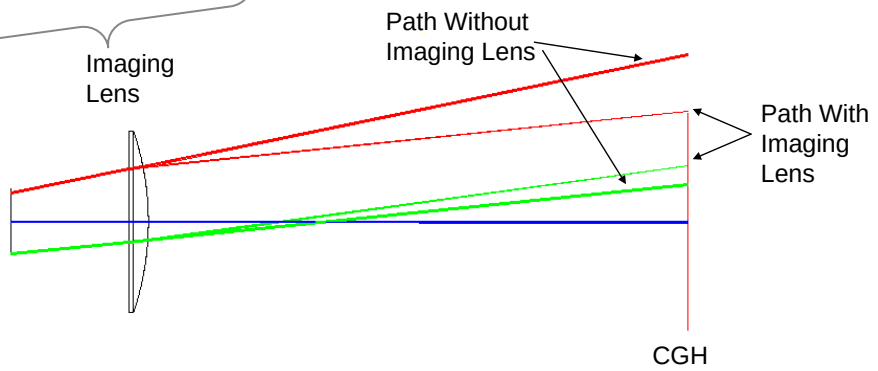


Method discussed by Zhao and Burge (Reference 3) $TF = \frac{W'}{W} = \cos\left(\frac{\pi\lambda z}{d^2}\right)$

- Analysis predicts more loss of pupil detail at the inner pupil at mid to high spatial frequencies

The Imaging SWTF (I-SWFT)

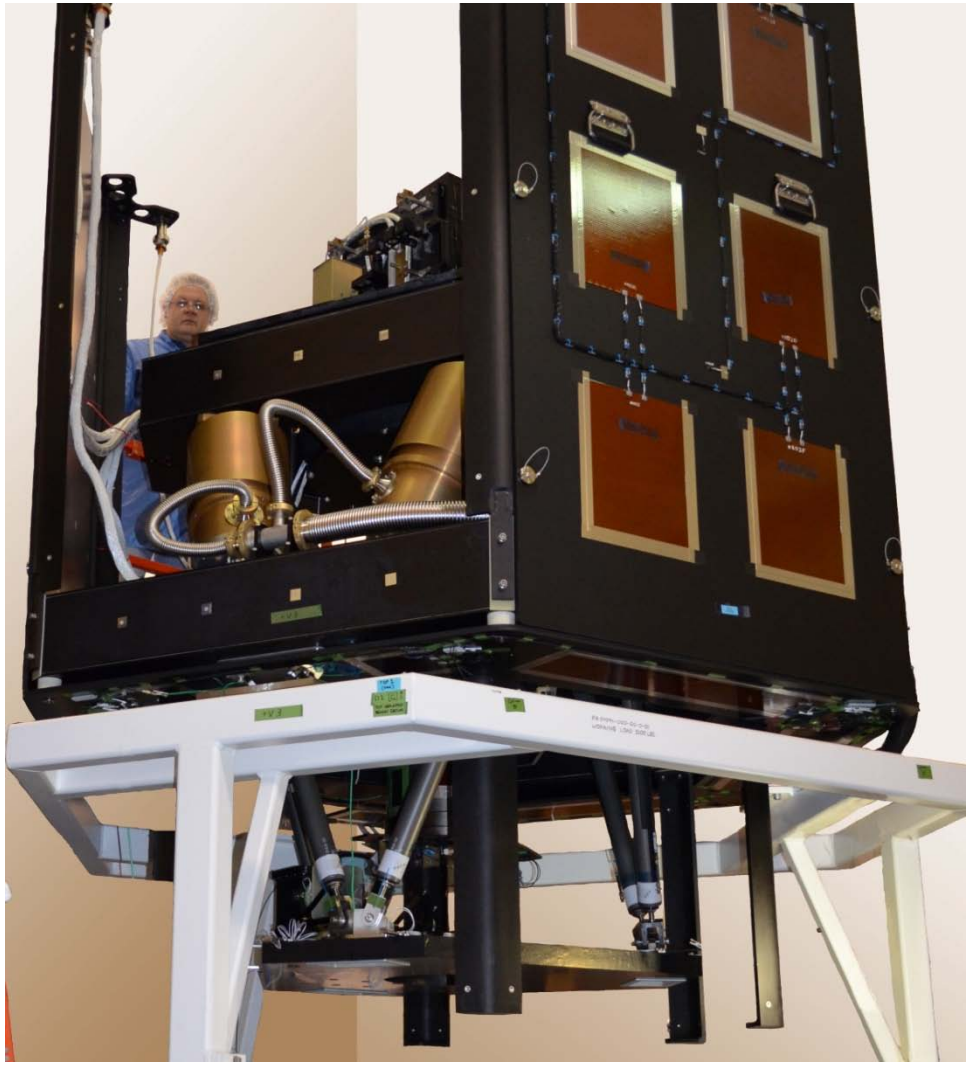




Redesigned CGH is easier to fabricate than the baseline CGH
- 10% Smaller
- 33% Lower maximum line density
- 2.9 times less aspheric

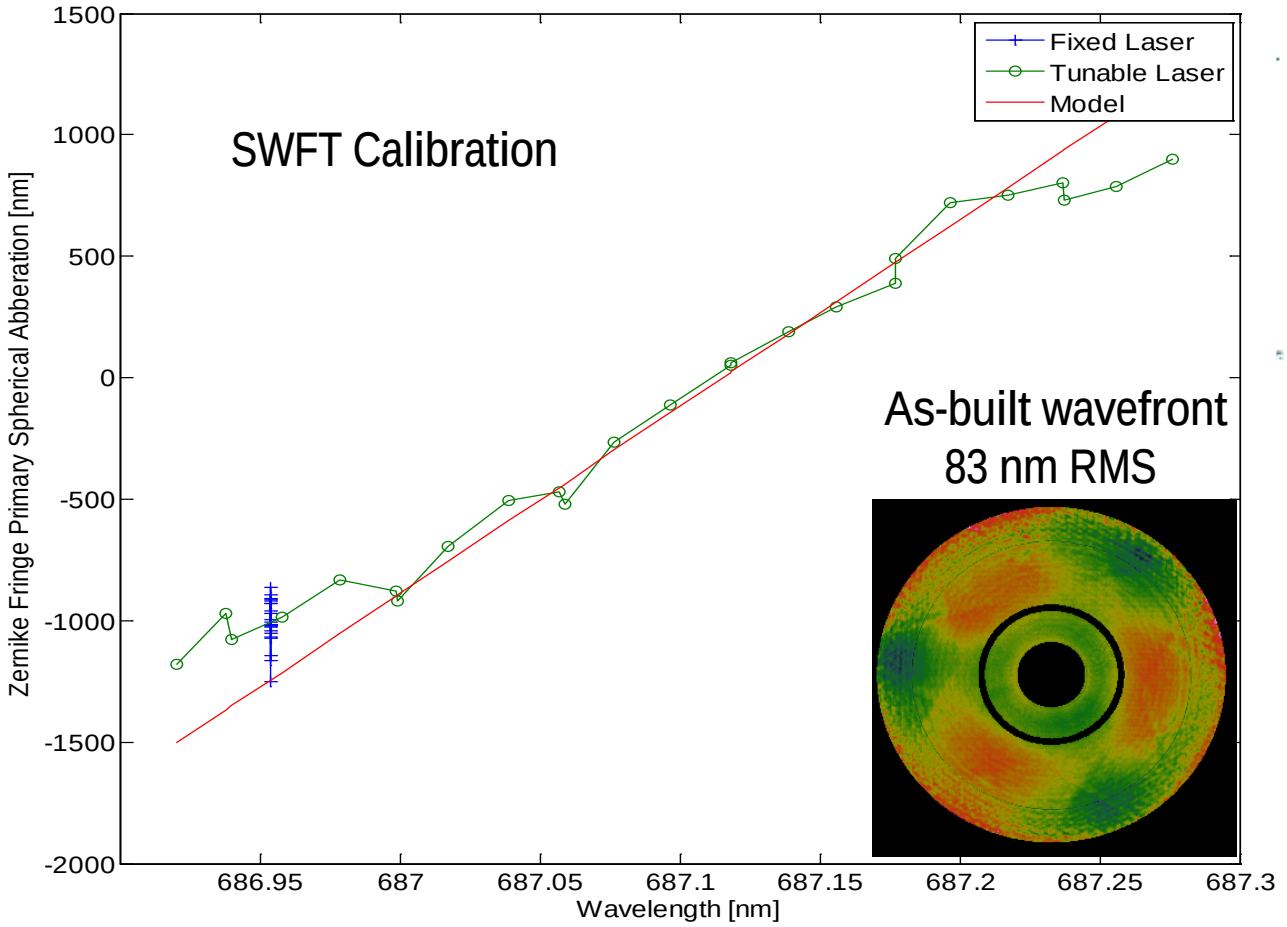
- A lens in the calibration path forms a pupil image on the CGH
  - Diffraction limited pupil imaging performance is restored
  - New complication of characterizing and aligning the lens

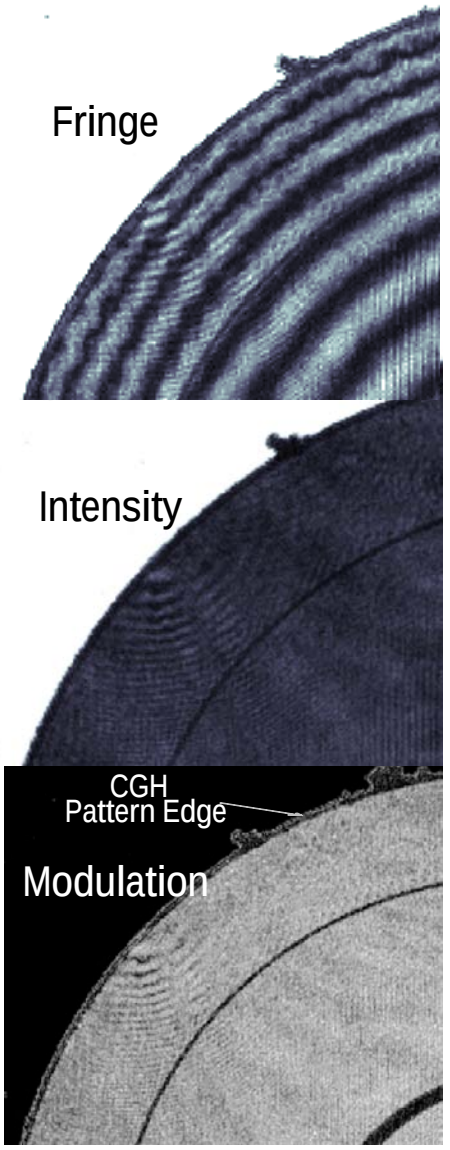
Initial Testing



- Initial testing performed at a clean assembly facility (Micro Automated in Rochester, NY)
  - Not at optical test facility
  - Vibration was okay
  - Temperature variations well beyond interferometer operation range
    - Much larger that in-use case

Model Versus Measured Performance

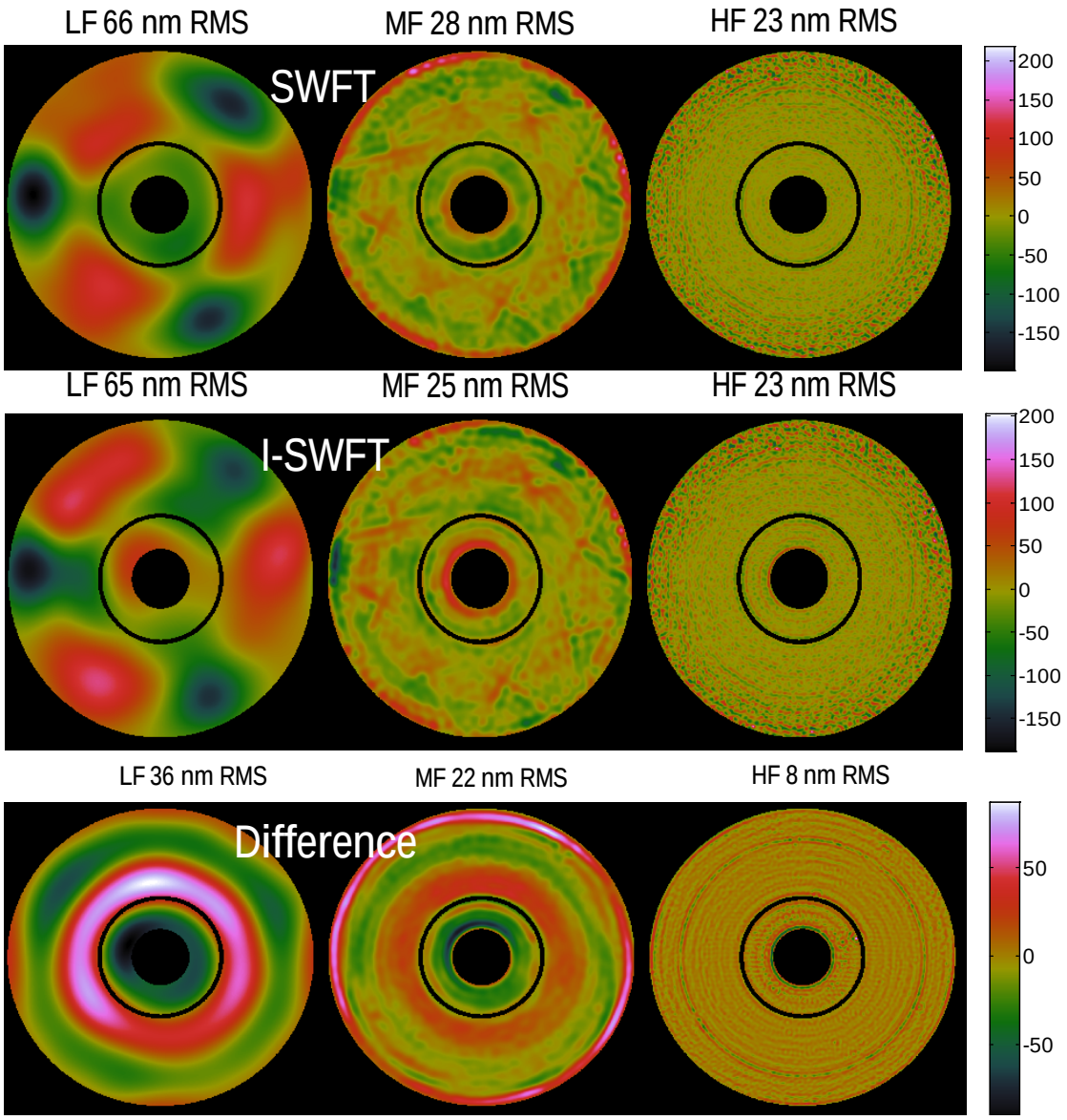




Precision in radial normalization is important for interpretation of data for radius and conic estimation

Test Results by Spatial Frequency

- Low spatial frequency error: largely trefoil
- Mid spatial frequency error: largely asphere stitching artifacts
- High spatial frequency error: largely asphere tooling marks
- Difference between SWFT and I-SWFT: largely spherical aberration



Concluding Remarks

- Initial tests of the JWST COCOA have been completed
- Results to date show good agreement with optical/mechanical models
- As built performance of the null meeting the wavefront error budget
- Testing in controlled ambient and vacuum environments is ongoing
  - Calibration methods for fusing SWFT and I-SWFT data will be refined using updated test results