VERSATILE METROLOGY SOLUTION USING A LARGE HOLOGRAPHIC STITCHING TECHNIQUE

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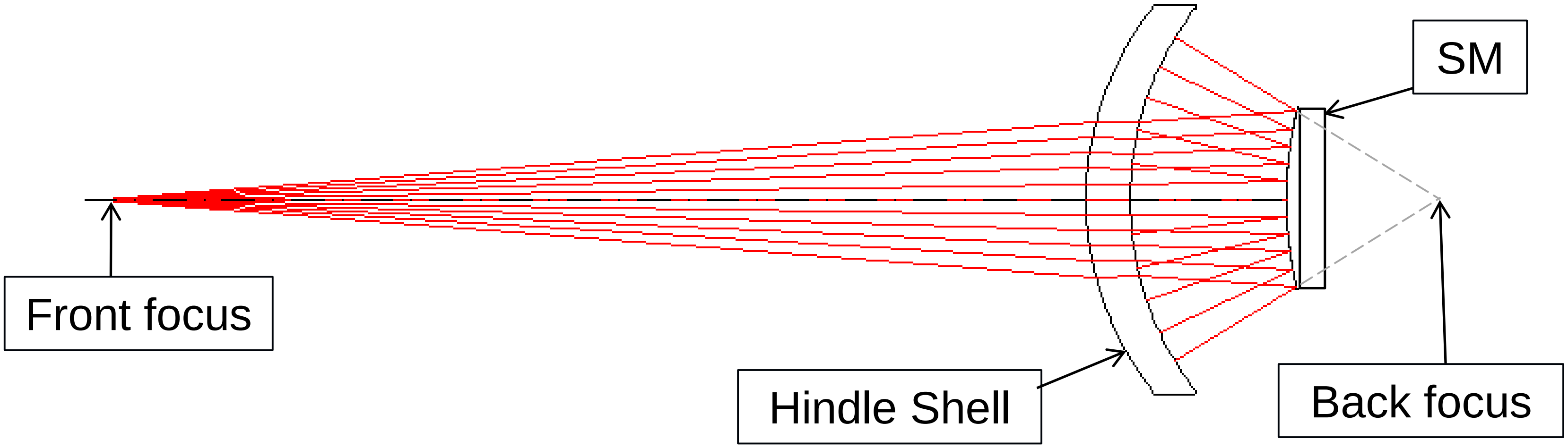
Outline

- **Convex Optical Metrology Primer**
- **Convex Versatile Metrology Technique Primer**
- **Holographic Testing Breadboard Demo**
- **LSST Test Configuration**

Convex Optical Metrology Primer: Hindle Shell Test



- Materials Needed
  - Hindle Shell
  - Calibration Sphere
- Example of optical design for Hindle test of ~20” asphere
  - Hindle diameter ~35”
  - 3.5” of sag on concave surface
  - Transmissive quality critical
- Presents significant schedule and budget challenges for convex optics

Convex Versatile Metrology Technique Primer

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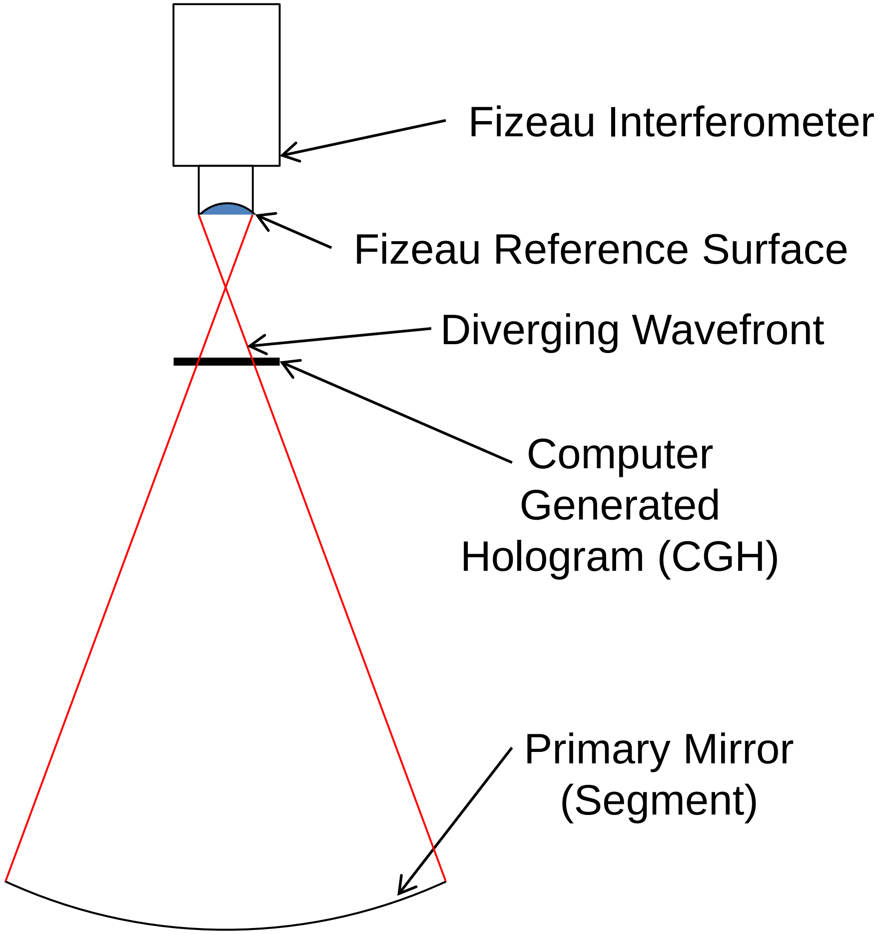
- Standard Accepted Test Configuration for Primary Mirror (Segment)
- A CGH is used to convert a spherical wavefront coming from the interferometer into an aspheric wavefront to match the intended prescription of the Primary Mirror
- Three degree of freedom alignment of the interferometer to the CGH is critical
- Five degree of freedom alignment of the Primary Mirror to the CGH is critical
    - 6 DOF for off-axis segment
- This configuration does not work for convex mirrors
    - The rays would need to start from a test aperture that is larger than the optic to be tested, to converge toward the center of curvature



Configuration 1

This test method has been used for many programs including the JWST Primary Mirror Segments

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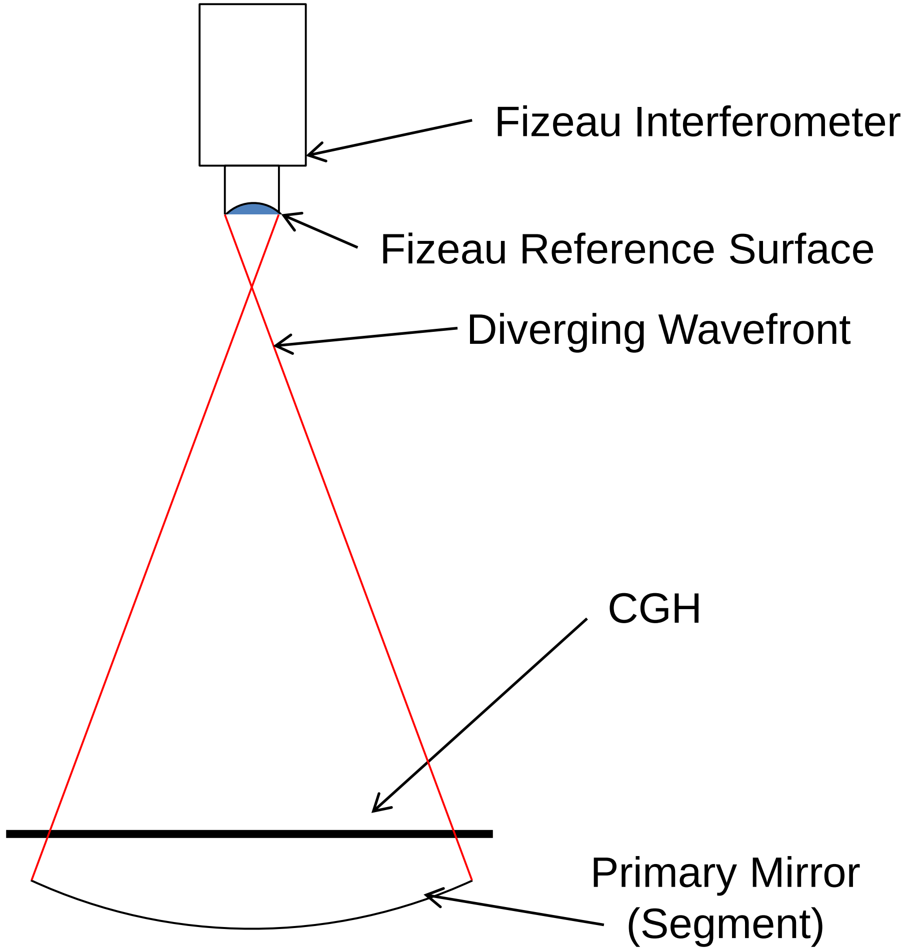
- The PM test could easily be reconfigured to look like this
  - The Phase Equation defining the CGH is more easily defined
    - This configuration is just the aspheric departure of the mirror under test
    - The typical configuration is typically extremely hyperbolic with many higher order terms (can be > 10 terms to define properly)
- This isn’t typically done because the small CGH is much easier to obtain
- The configuration as drawn still requires careful alignment between the interferometer and the CGH; and the CGH to the PM
  - Z distance between the CGH and PM is considerably easier to monitor



Configuration 2

Repositioning of the CGH simplifies the test

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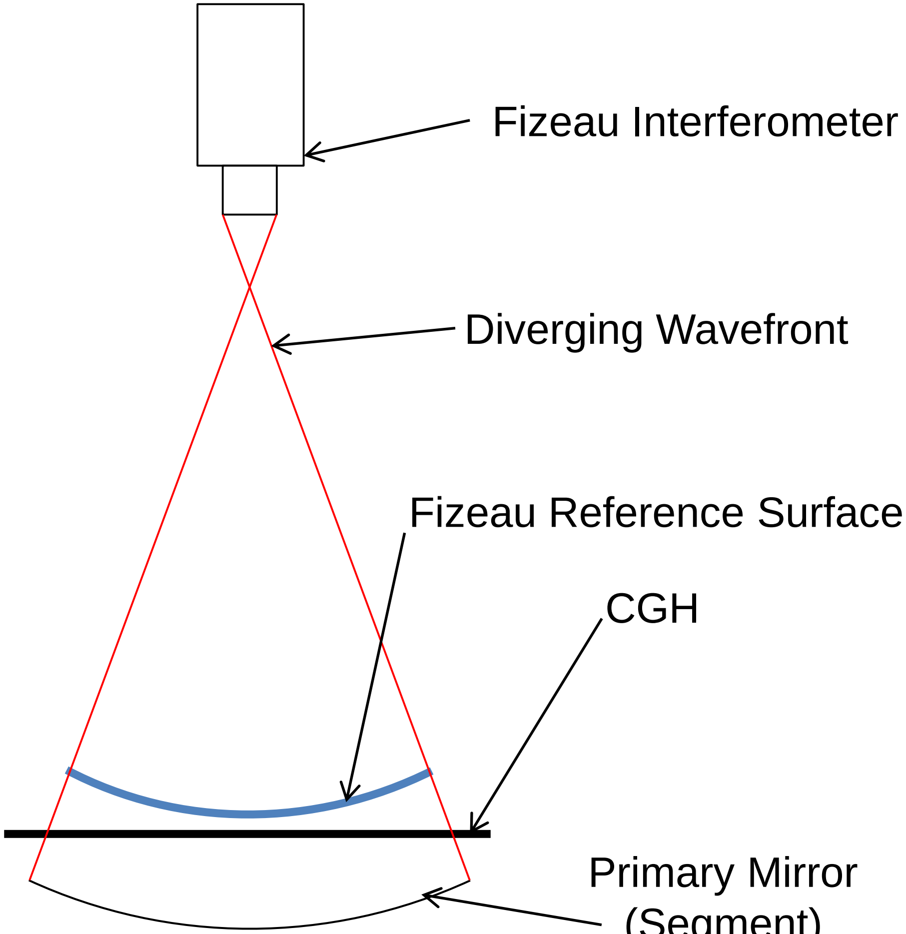
- All of the same alignment requirements apply
  - 3 DOF reference to CGH
  - 5 DOF CGH to Mirror
  - The close proximity of these surfaces to one another simplifies the monitoring of this alignment



Configuration 3

Moving the Fizeau Reference Surface does little to change the nature of the test

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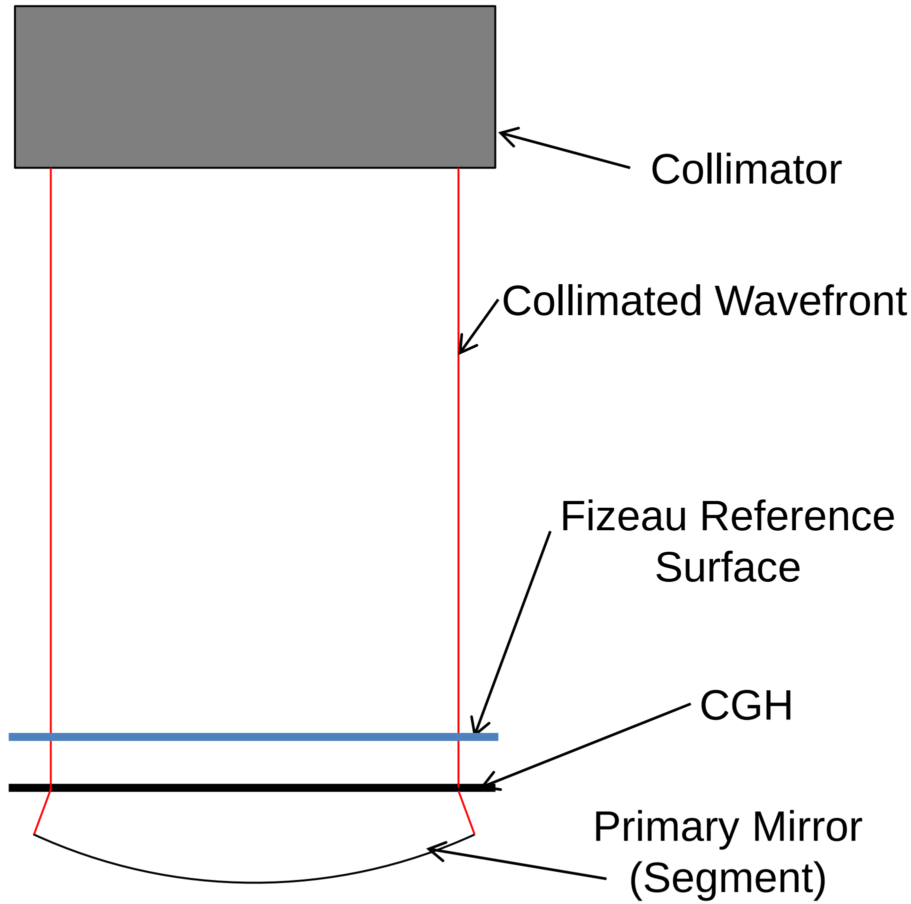
- The alignment of the Fizeau reference surface to the CGH and the CGH to the mirror are still important
  - The collimated input simplifies the alignment of the Fizeau Reference to the CGH
  - 2 DOF (tilt/tilt) alignment only
- The CGH prescription now includes the power difference between the flat and the nominal RoC
  - Still a more simple phase equation than the Configuration 1
- Compressing the cavity can reduce noise



Configuration 4

Changing the input wavefront to a collimated beam is a conceptually trivial modification

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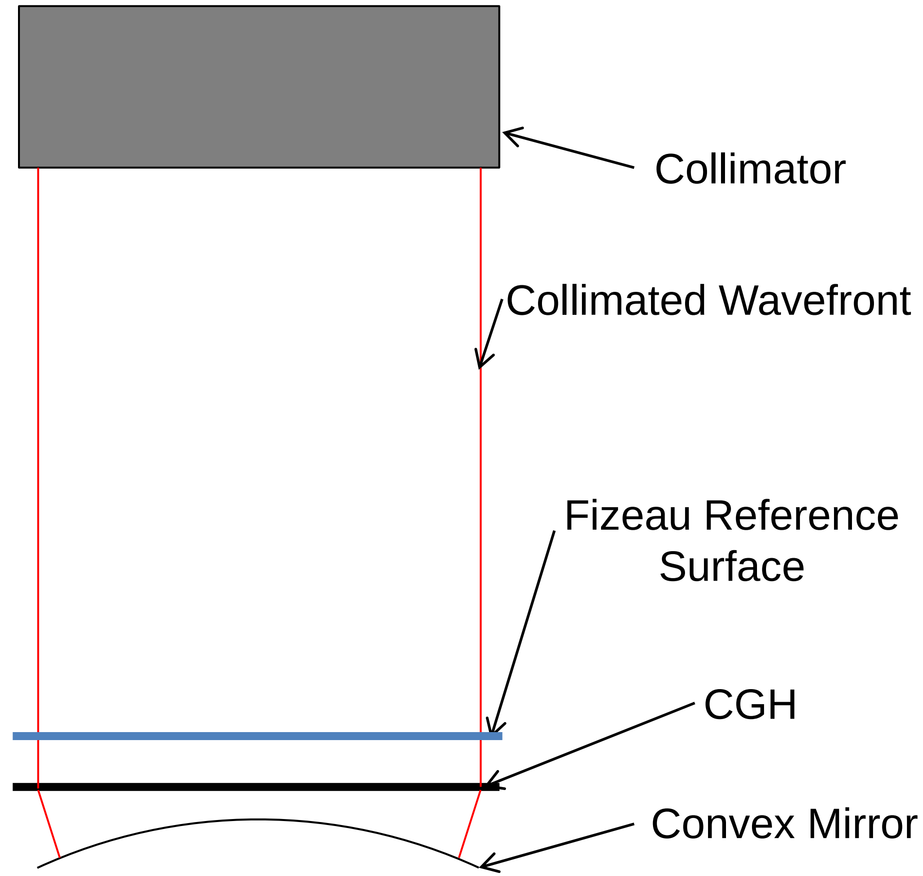
- In practice there is no difference between this test configuration and the one described in the previous slide.
- The application of this test technology to the LSST M2 will require all of the same attention to error sources as is paid to the test of a primary mirror as described in Configuration 1
- For very large optics, such as LSST M2, this test needs to be done as a sub-aperture test
  - Any single subaperture measurement of M2 is nearly identical to a primary mirror segment measurement
  - Using a large number of subapertures ultimately reduces the uncertainty of the test wavefront

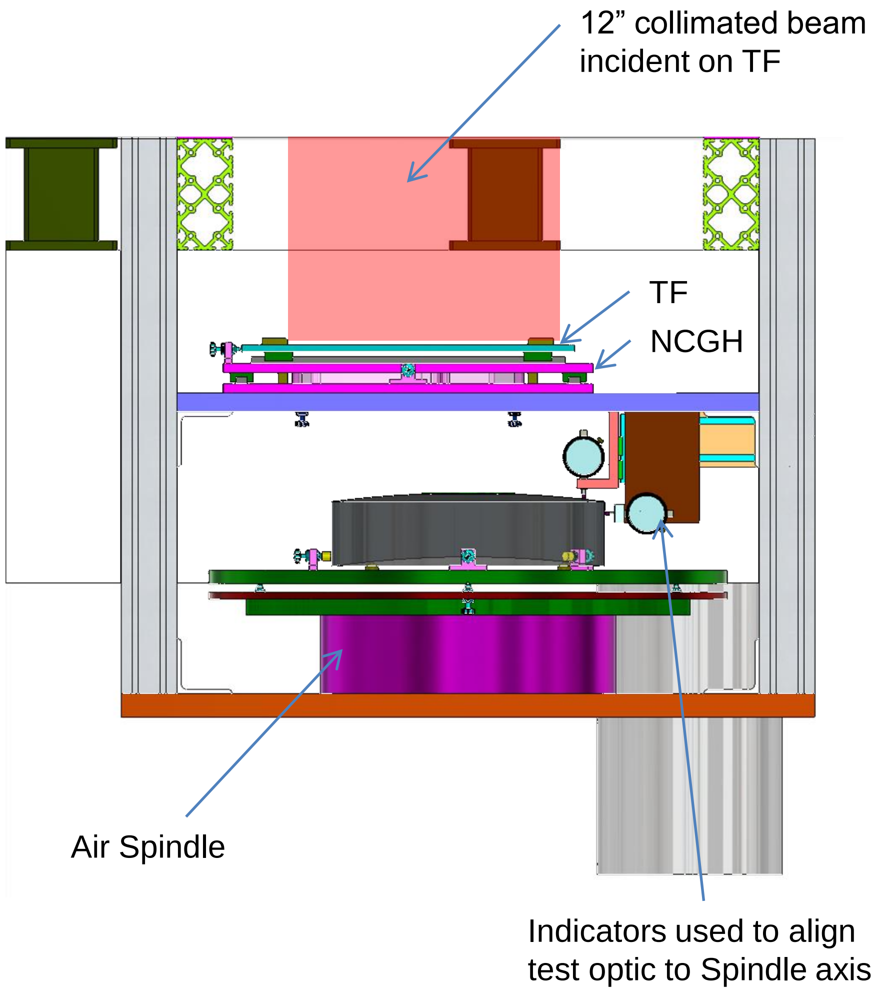


Configuration 5

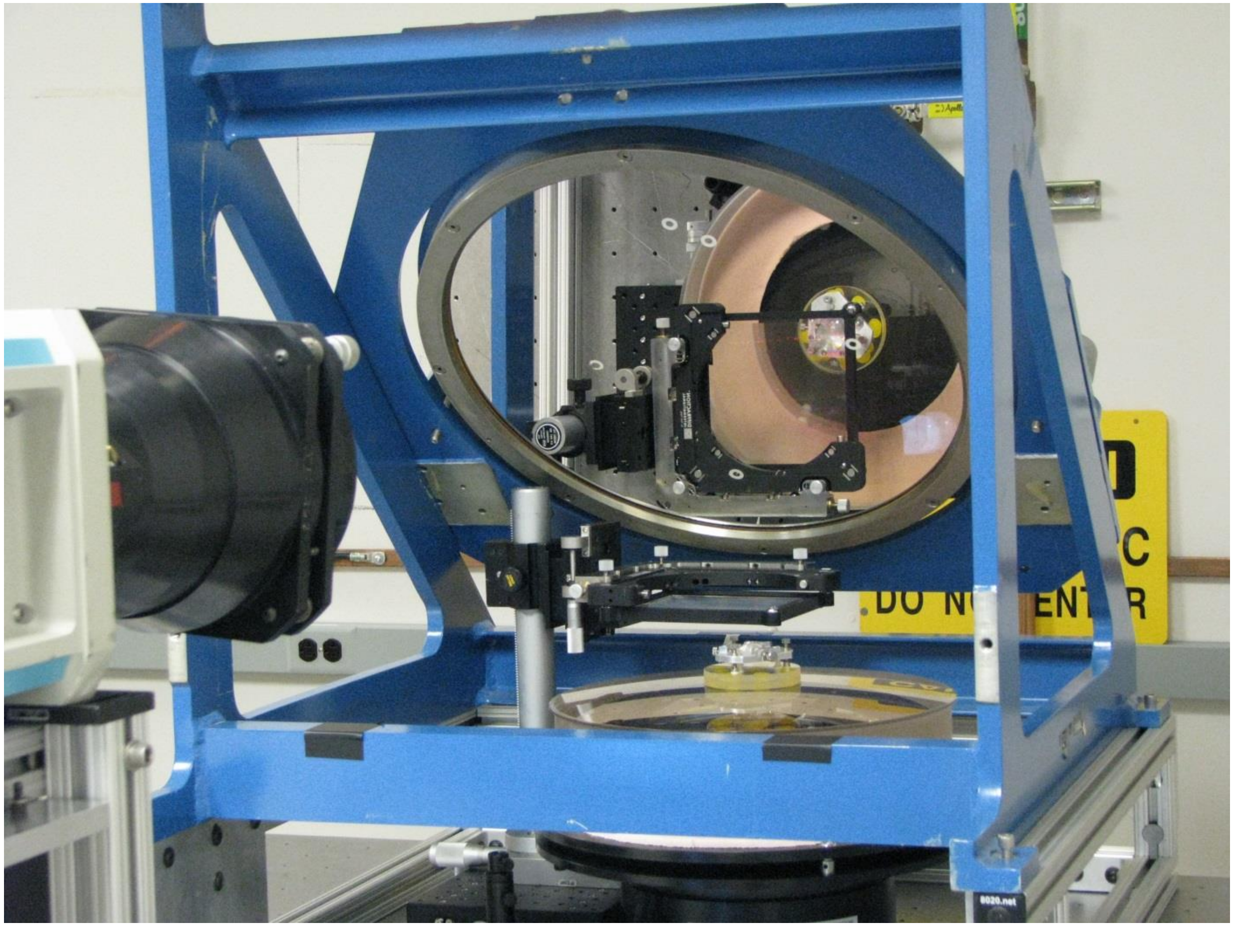
Adapting this test to a convex mirror is just a change in the sign of the diffraction order

Holographic Testing Breadboard Demo

- Collimated light passes through transmissive CGH (transmissive null)
- Light reflects off surface under test, back through CGH and collimator to camera
- Part rotates on precision air spindle
- Tilt carrier allows for instantaneous phase collection of high density sub-aperture interferograms
- Air spindle encoder triggers camera data acquisition for multiple overlapping sub-apertures
- Post processing software stitches sub-aperture data
  - Demodulates interferogram to obtain phase map using tilt carrier method
  - Stitches sub-apertures using angular encoder knowledge



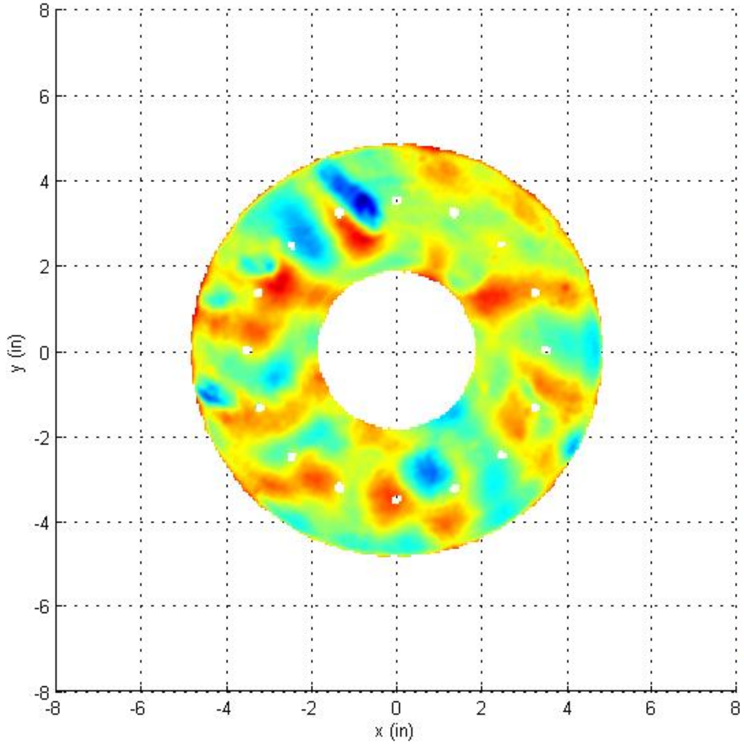
Holographic Testing Breadboard Demo



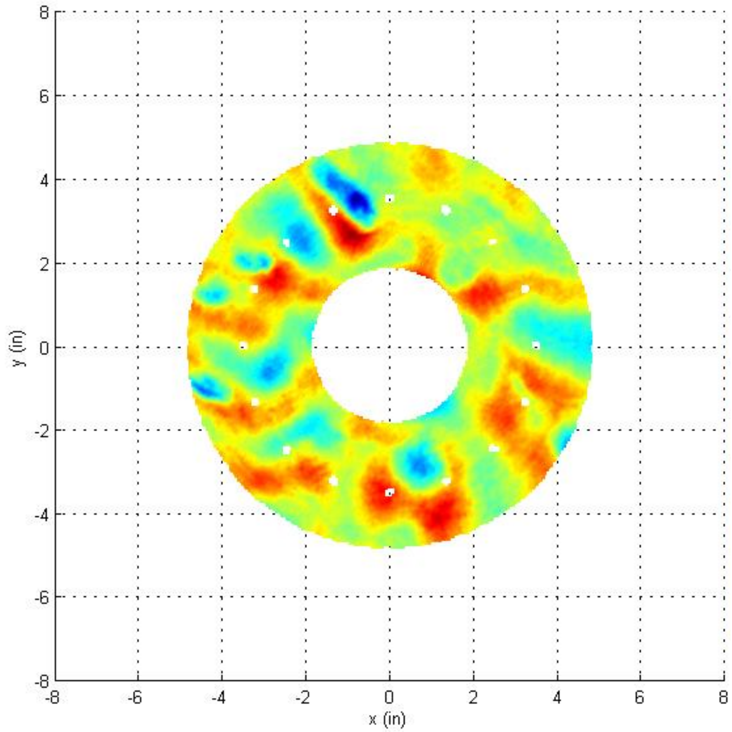
Used Holographic Test method to measure previously characterized convex surface

Holographic Testing Breadboard Demo

Stitched Map (Holographic Technique)



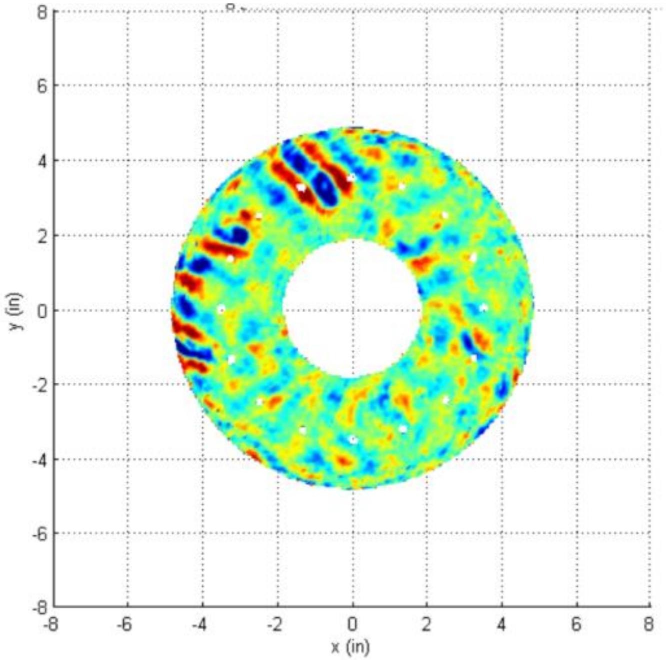
Reference Map



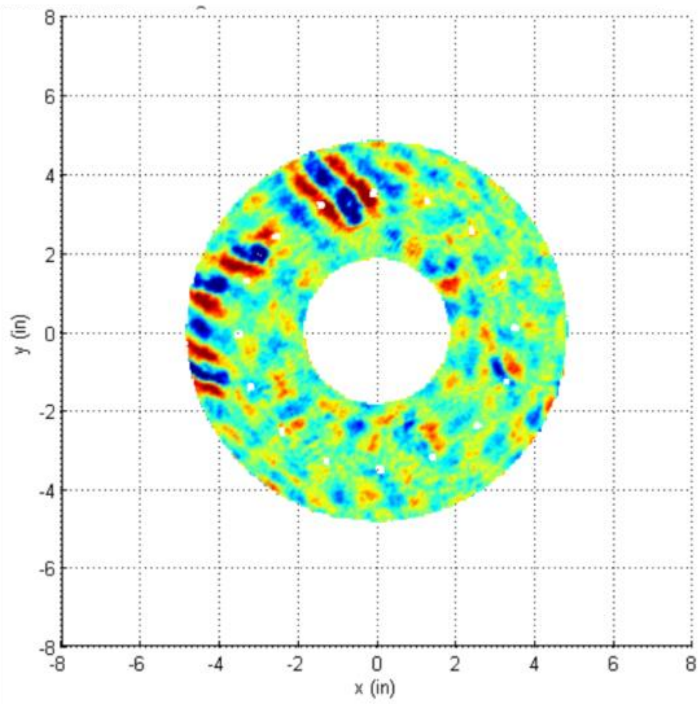
Agreement within 0.008λ RMS SFE, consistent with typical PM test uncertainty.

Holographic Testing Breadboard Demo

Stitched Map (Holographic Technique)
(High Frequency Content)



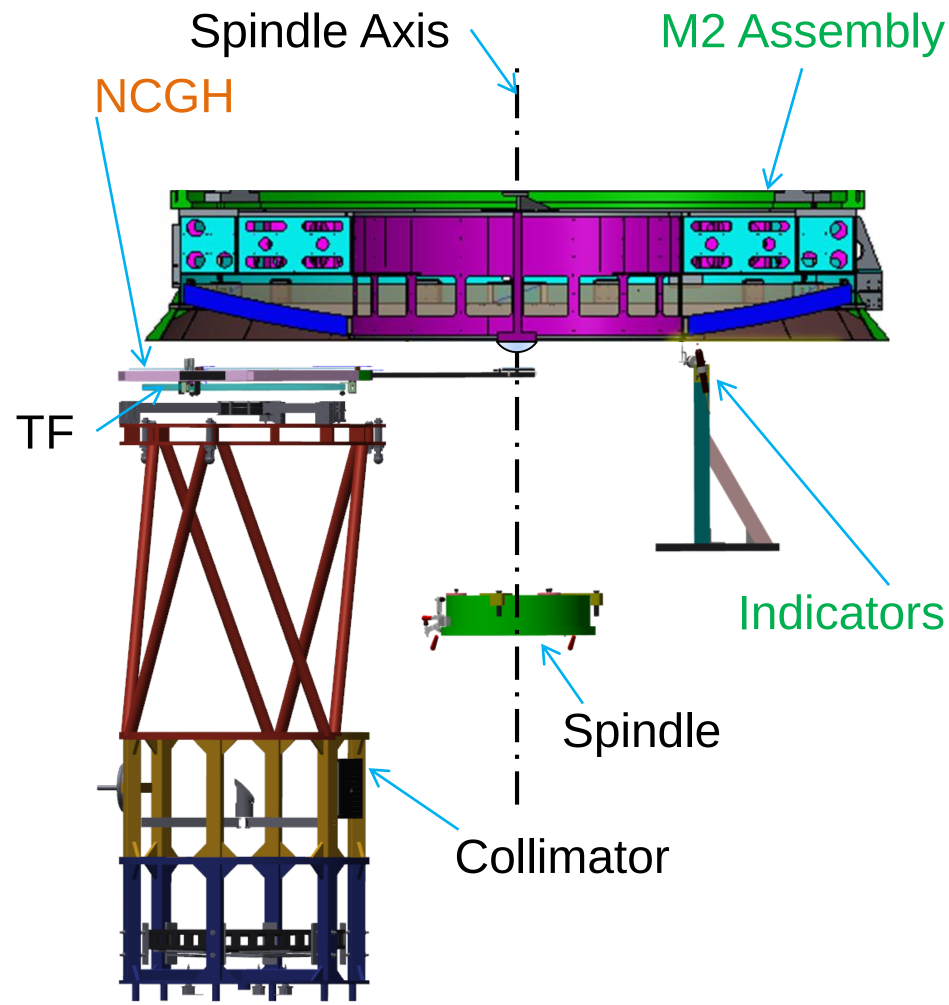
Reference Map
(High Frequency Content)



Agreement of high frequency surface content demonstrates stitching artifacts do not impact surface measurement accuracy

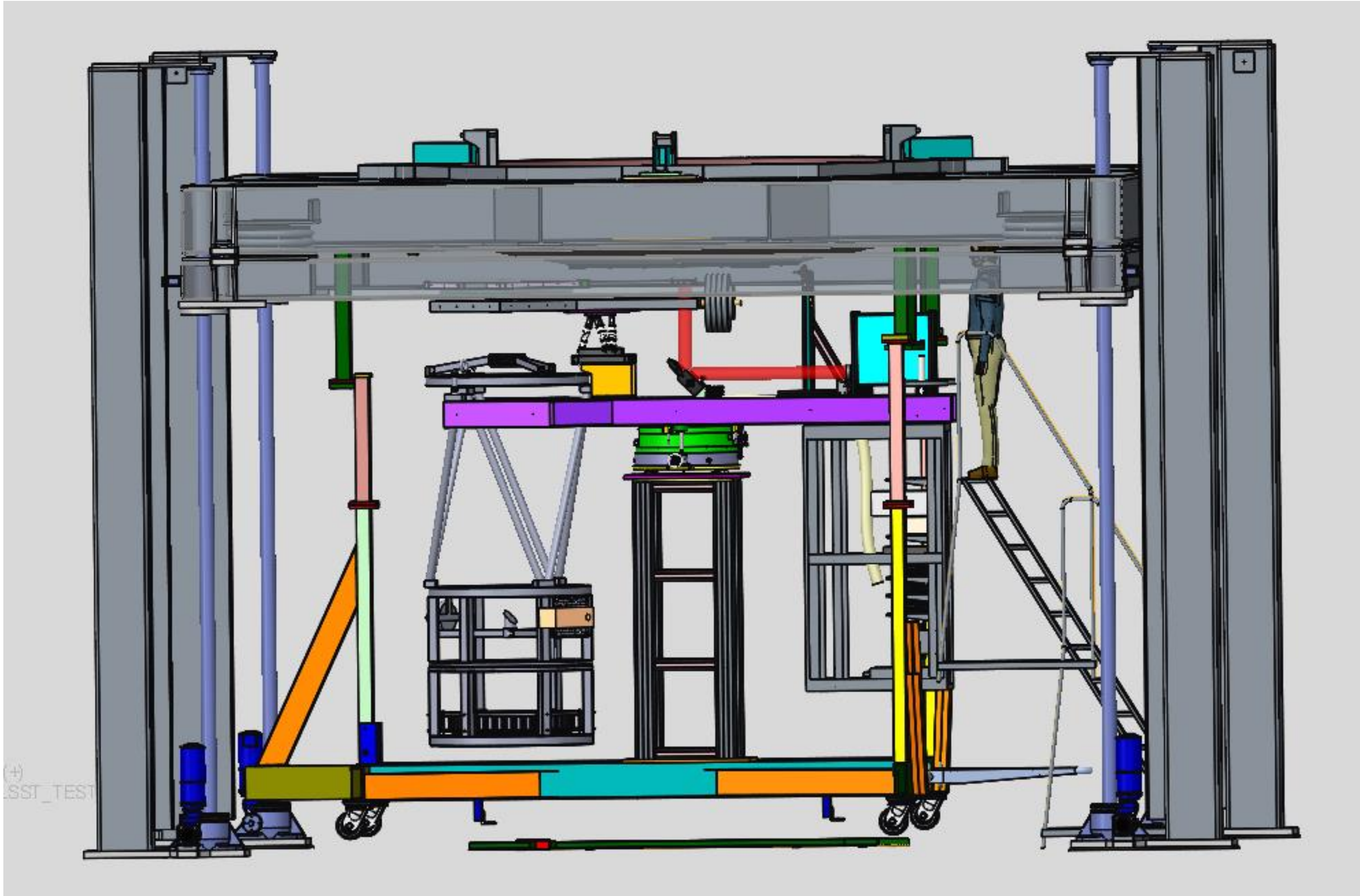
LSST Test Configuration

- Fizeau test configuration
  - Collimated wavefront in
  - Flat test plate (Transmission Flat)
  - CGH (in test path only) used to diffract wavefront to null condition for M2
- Test Plate together with Nulling CGH and Alignment Reference makes up the Monolithic Holographic Assembly Testplate (MHAT)
- The MHAT test aperture covers the full radius of the M2 annulus
- M2 remains stationary. Test set components (interferometer, collimator, MHAT) rotate on spindle



The M2 test is a sub-aperture version of the test described as Configuration 5

Test Design Overview



LSST Test Tower Rotation