QUANTITATIVE MEASUREMENT OF MID-SPATIAL FREQUENCY ERROR USING A TEST PLATE

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Overview

- **Background**
- **In process testing**
- **Test execution**
- **Example data**

Large Synoptic Survey Telescope (LSST)

Objectives of LSST:

- **Image the entire sky every few days, creating movies of our universe**
- **Explore the mysteries of dark matter and energy**
- **Find potentially hazardous asteroids and new solar systems**

Harris is on contract to process, mount, and deliver the secondary mirror assembly of LSST.

3.42 meter secondary mirror

Movement of LSST at Harris

Expensive to move between buildings for initial polishing, final figuring, and test

An inexpensive test was needed to quantify the midspatial errors before moving optic between buildings for final figuring.

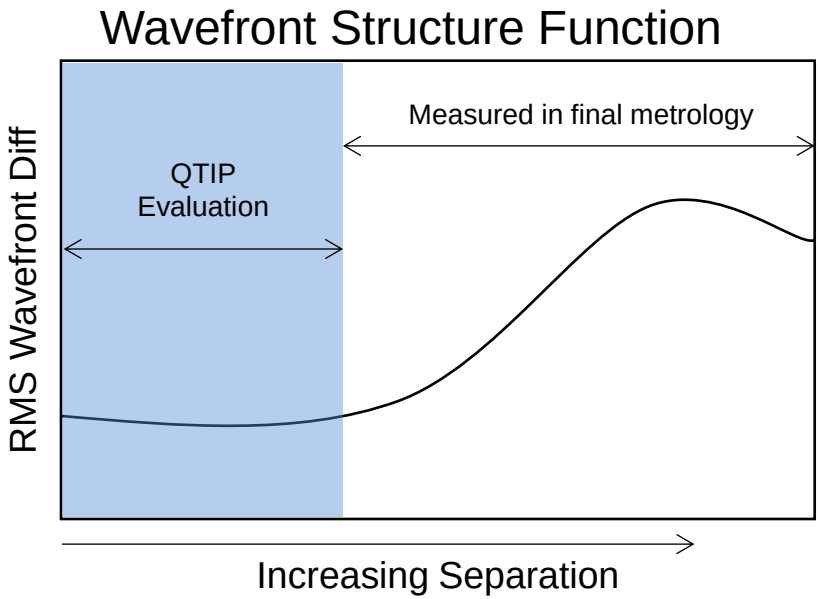
Testing on large aspheric convex optics

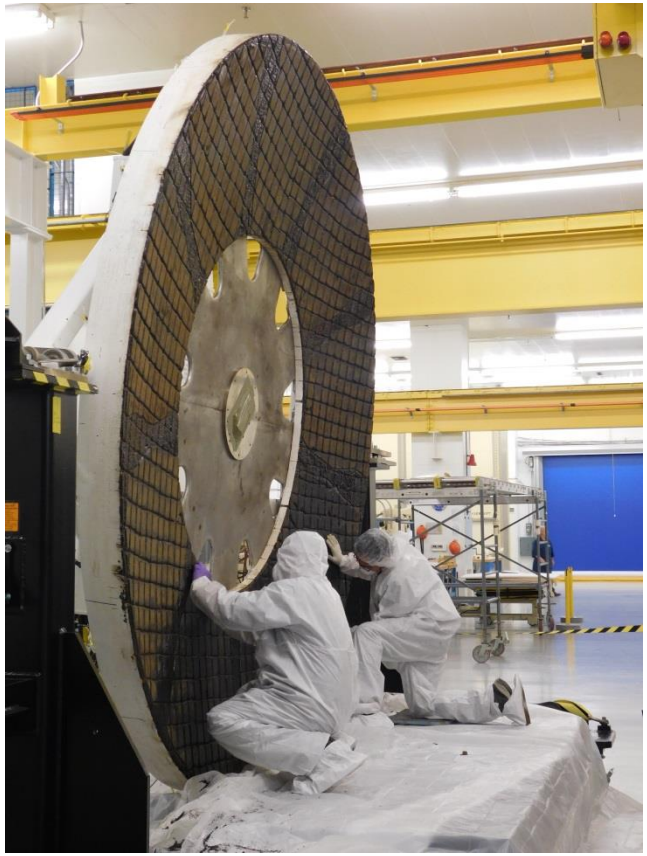
- **Looking for a low cost means of measuring midspatial errors of the surface before moving LSST to secondary building**
- **LSST is a very large convex part**
  - Testing is not trivial
    - Large mounting frames
    - Large and expensive test optics
    - Fixturing and handling test equipment around the optic in a safe way can be challenging

Operations preparing LSST M2 for measurement

QTIP on LSST M2

- **This test focused on mid-spatial frequencies from 10mm to 100mm**
  - spatial bands of concern for full tool smoothing





Operations prepping the tool for polishing

QTIP – Quantitative Test Interferometric Plate

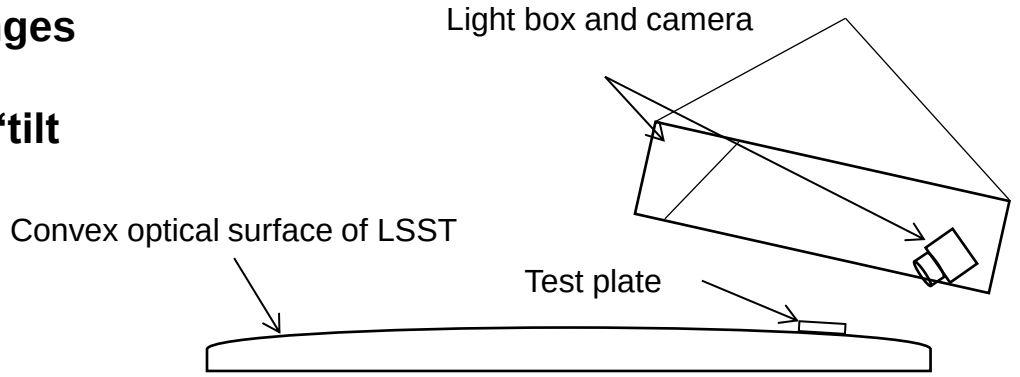
A means of digitally retrieving surface data using an optical test plate

- A quantitative test to analyze work done on the midspatial errors with full tool smoothing
- Minimal delay to measure surface
- Simple inexpensive equipment:
  - Monochromatic light box
  - Digital camera and lens
  - Shim to introduce tilt fringes
  - Spherical Test Plate
  - Utilizes well understood ‘tilt carrier’ analysis

Test Plate on convex surface

Requirements:

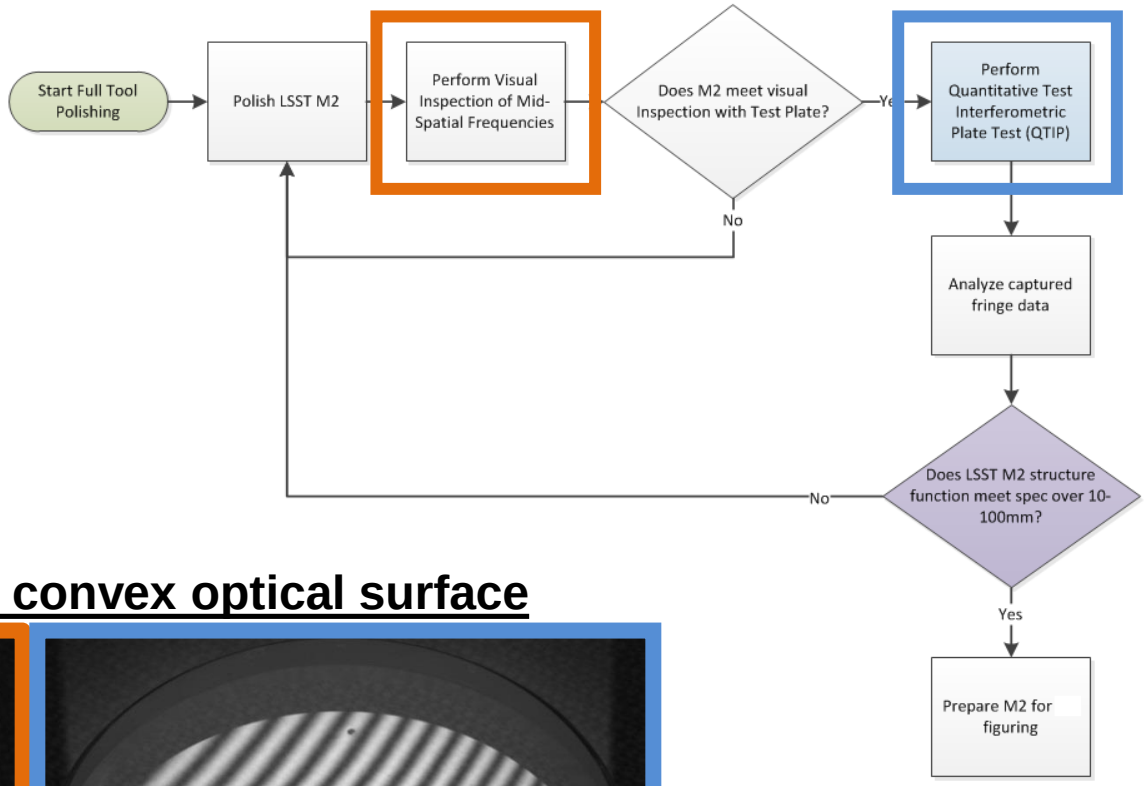
- Measure spatial frequency of 10-100mm
- Accuracy < 0.02wav RMS
- Simple and repeatable



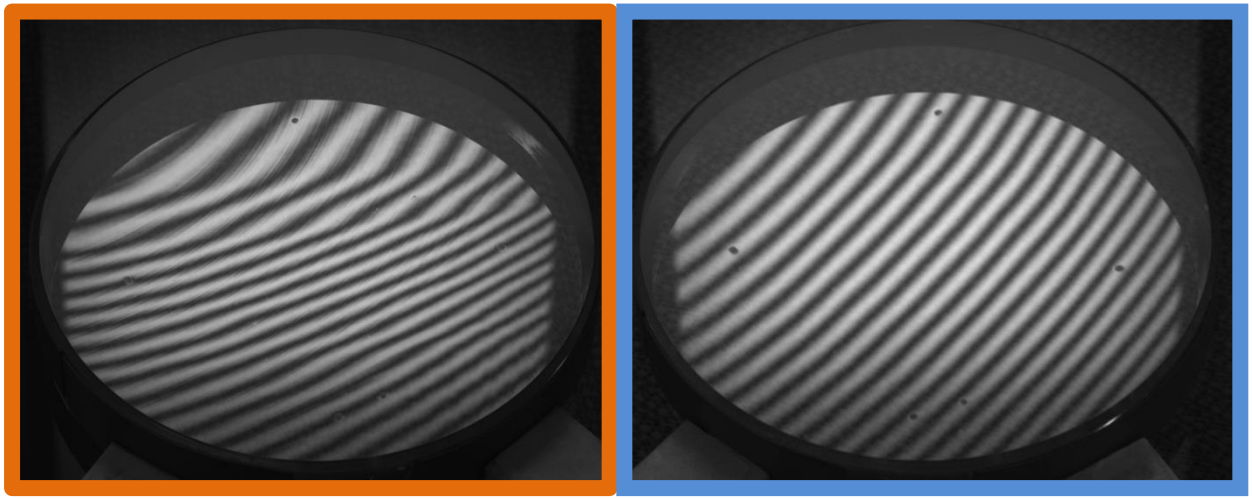
QTIP – Test Diagram

QTIP – In Process Flow

- Allows for individual to assess surface quality subjectively before brining in more equipment
  - Quick turn around time to evaluate full tool polishing
- Additional equipment allows for quantitative assessment of midspatial errors.



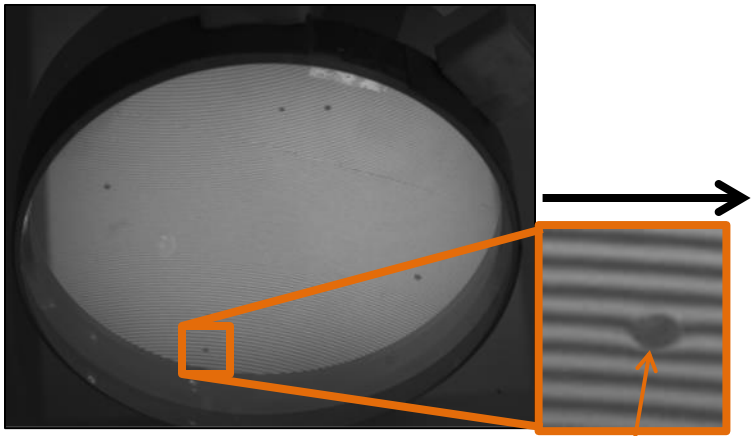
Visual Inspection of convex optical surface



Needs more smoothing

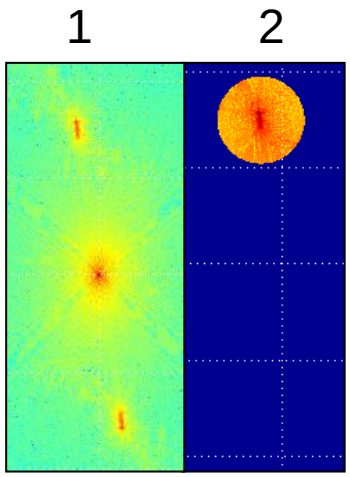
QTIP testing needed

QTIP – Test Flow

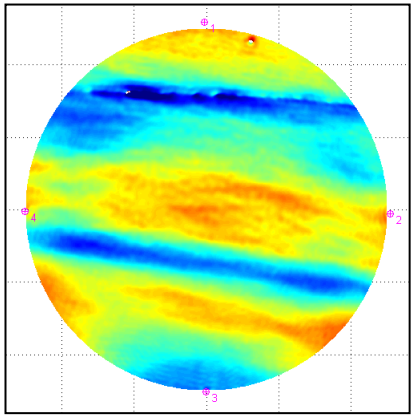


Capture Image '.tif'
>5 fringes per 10mm
>10px per fringe

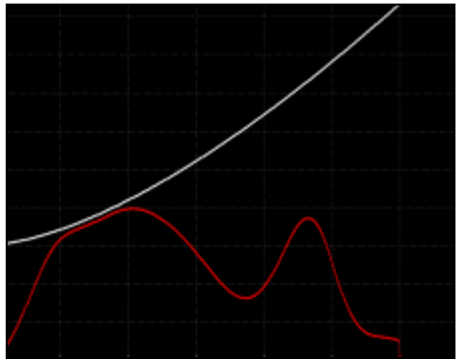
Fiducial



FFT, Mask, and
Unwrap Phase



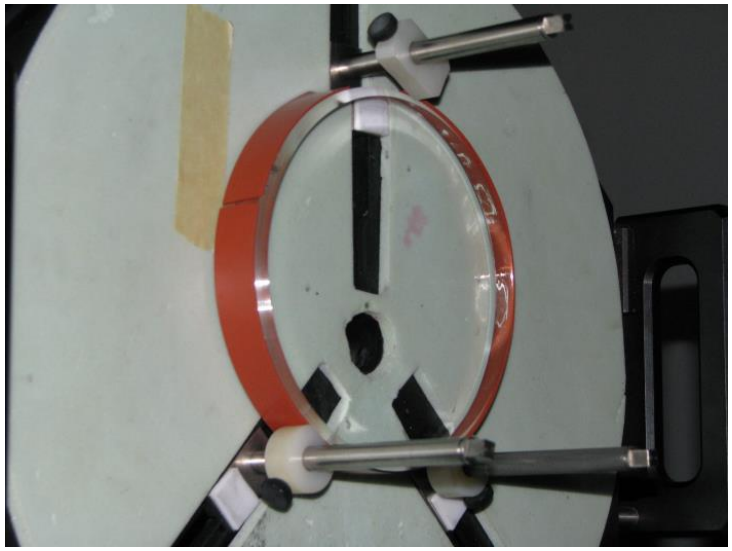
Undistort,
remove test plate
backout, remove
Tilt, Power, Astig,
Coma, Trefoil



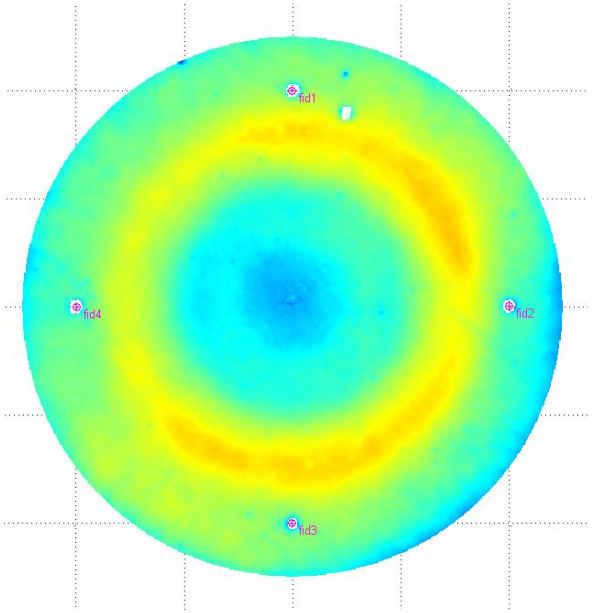
Analysis of structure function

Spherical Test Plate

- **6” Test plate**
  - **1/20λ**
- **Permanent Fiducials etched into plate for backout and distortion correction**
  - **Easily cleanable**
  - **Negative thickness fids**
- **Best fit sphere to optic prescription**



Test plate on radius bench

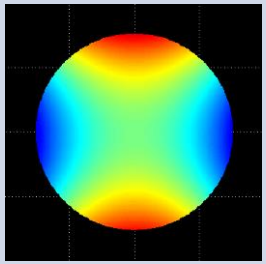
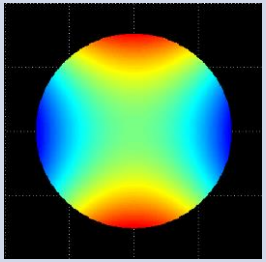
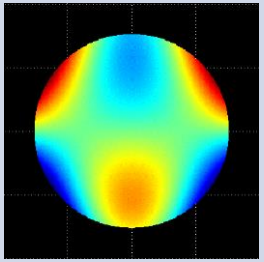
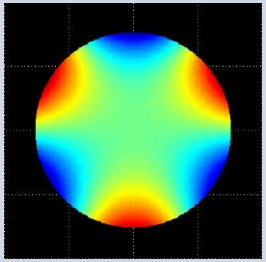
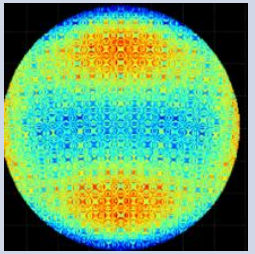
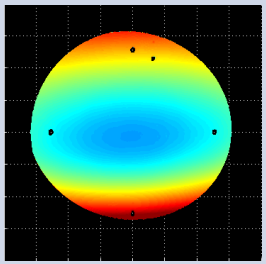
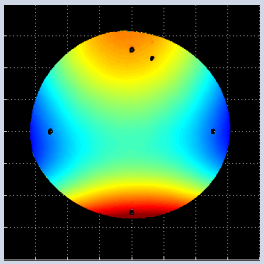
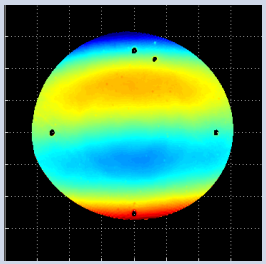
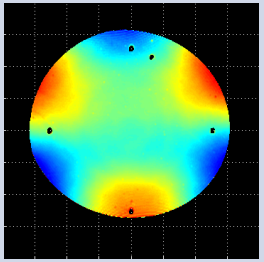
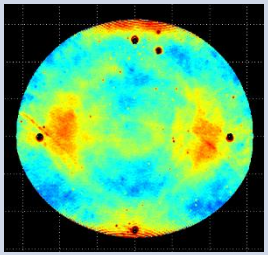


Test plate surface map

Spherical test plate lends itself to conventional polish and low midspatial errors

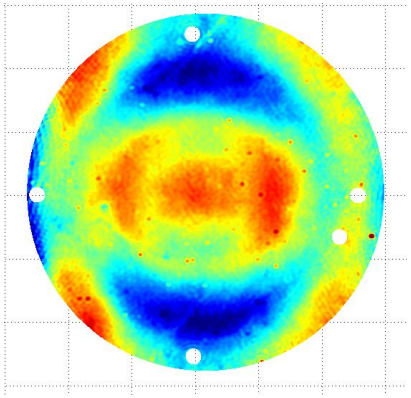
Model Simulation of Test plate

- Repositioning testplate across a convex aspheric prescription resulted in large changes in low order errors
  - Addressable in final figure process
- Removing Zernike terms up to trefoil, left residual surface errors <0.001 wav RMS

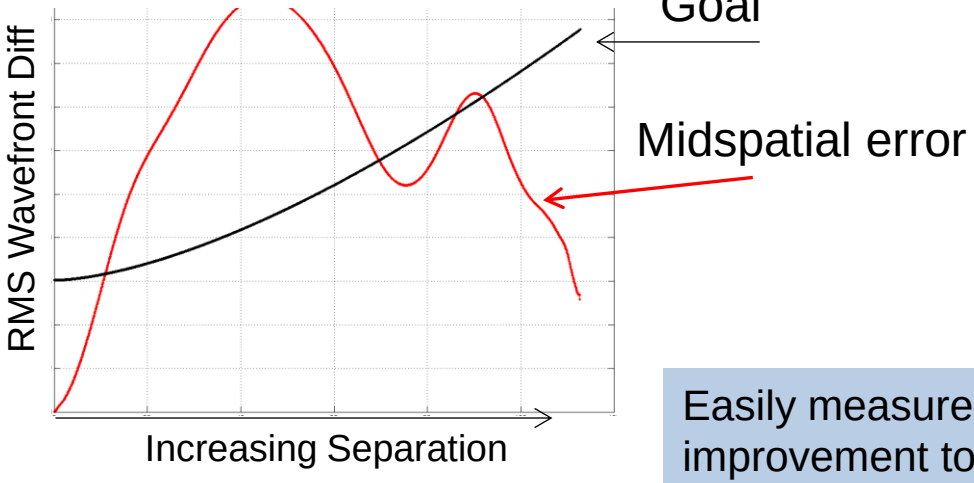
	Original	Power Removed	Power + Astig Removed	Power + Astig + Coma Removed	Power + Astig + Coma +Trefoil Removed
Code V Model					 <0.001 wav RMS
	Original	Power Removed	Power + Astig Removed	Power + Astig + Coma Removed	Power + Astig + Coma +Trefoil Removed
Experimental Data					 <0.02 wav RMS

Experimental Results – Improvement of midspatial error using full tool polish

Full Tool Polish – Halfway through process

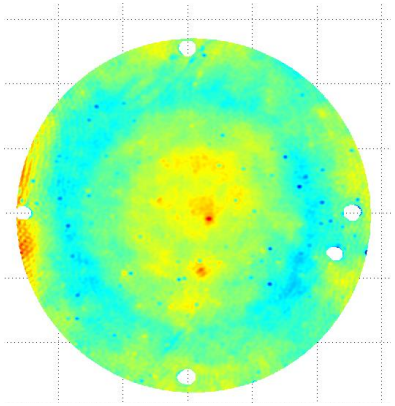


<0.03 wav RMS

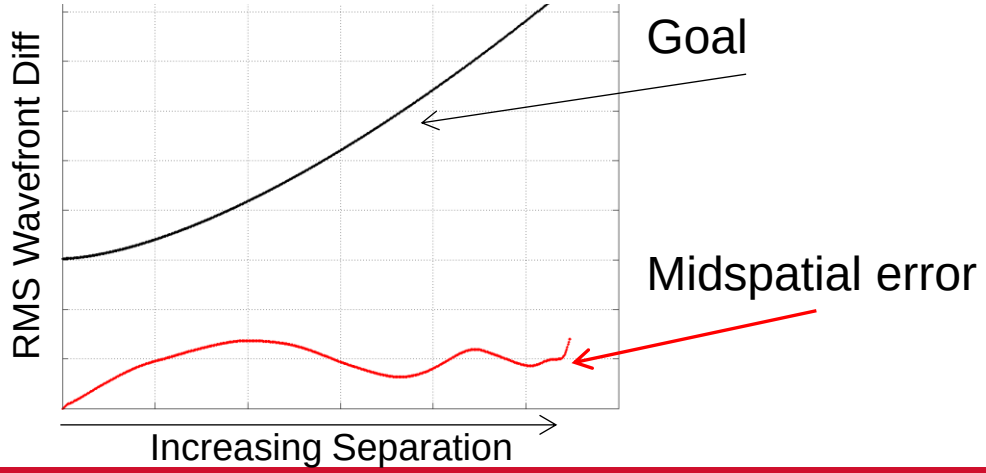


Easily measured improvement to midspatial error through the full tool polishing process

Full Tool Polish – End of process



<0.011 wav RMS



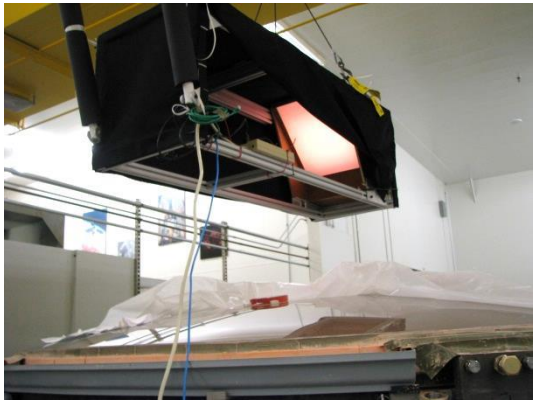
Summary

An inexpensive, highly portable, and accurate test has been developed for use on large convex optics.

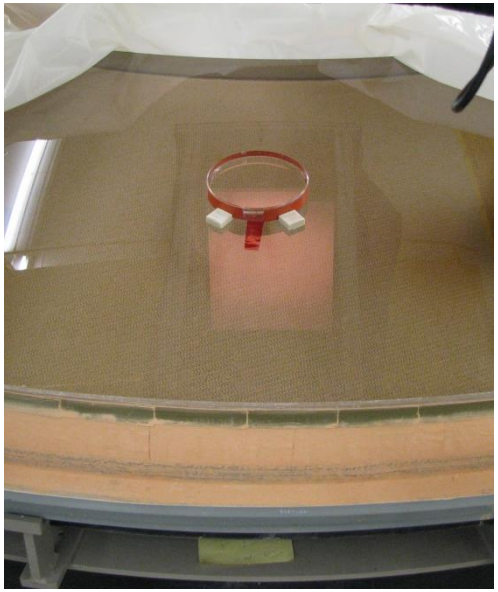
- Accuracy in measuring midspatial errors <0.01wav RMS has been demonstrated
- Inexpensive and easily customizable test plates may be used on a variety of optical prescriptions

Lightbox

Digital Camera



Lightbox suspended over LSST



Testplate on LSST