



Improving freeform manufacturing using deflectometry

NASA Mirror Tech Days
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Presented By:
Todd Blalock

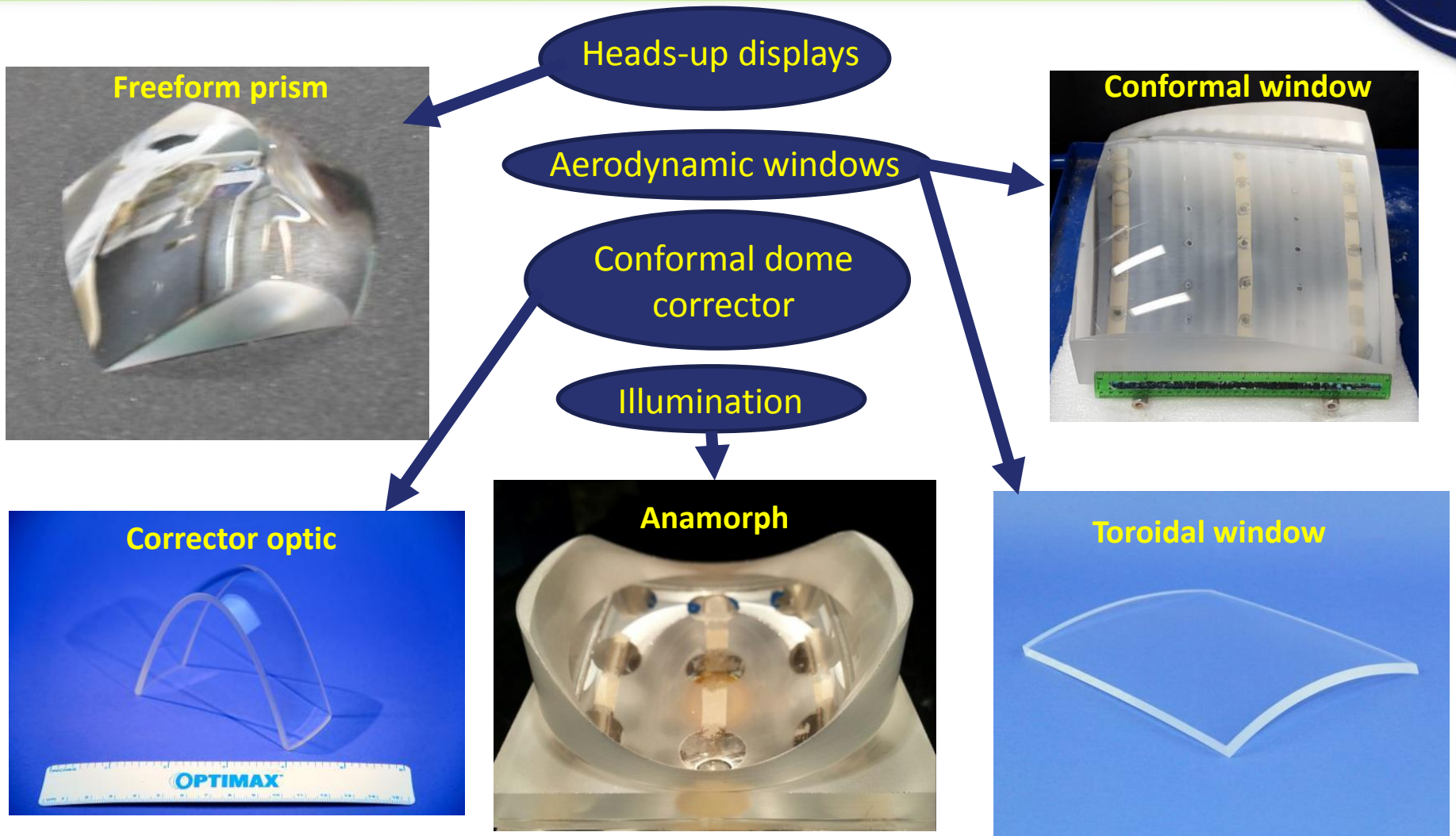
Optimax Systems Inc.

Prototype Optics In One Week

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Freeform optics are solving many optical design problems for many applications

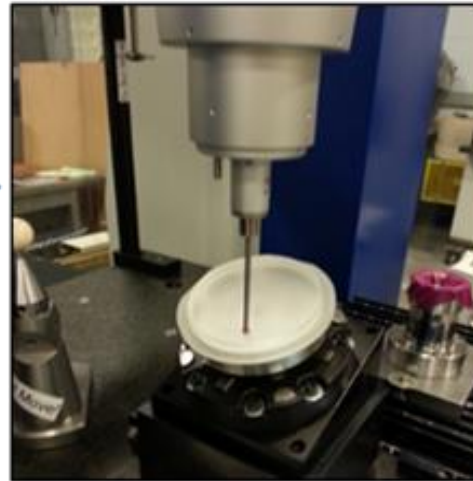
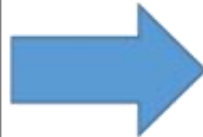


Freeform metrology related to manufacturing

Freeform manufacturing process



CNC Surface
Generation



Surface
Measurement



Deterministic
Polishing



Sub-aperture polishing leads to mid-spatial frequency errors, which must be measured!!

Multiple tools for freeform metrology

Coordinate Measuring Machine



Accuracy $\sim 1 \mu\text{m}$



Panasonic UA3P
profilometer



Accuracy $\sim 50 \text{ nm}$

Deflectometry
System



(In Development)

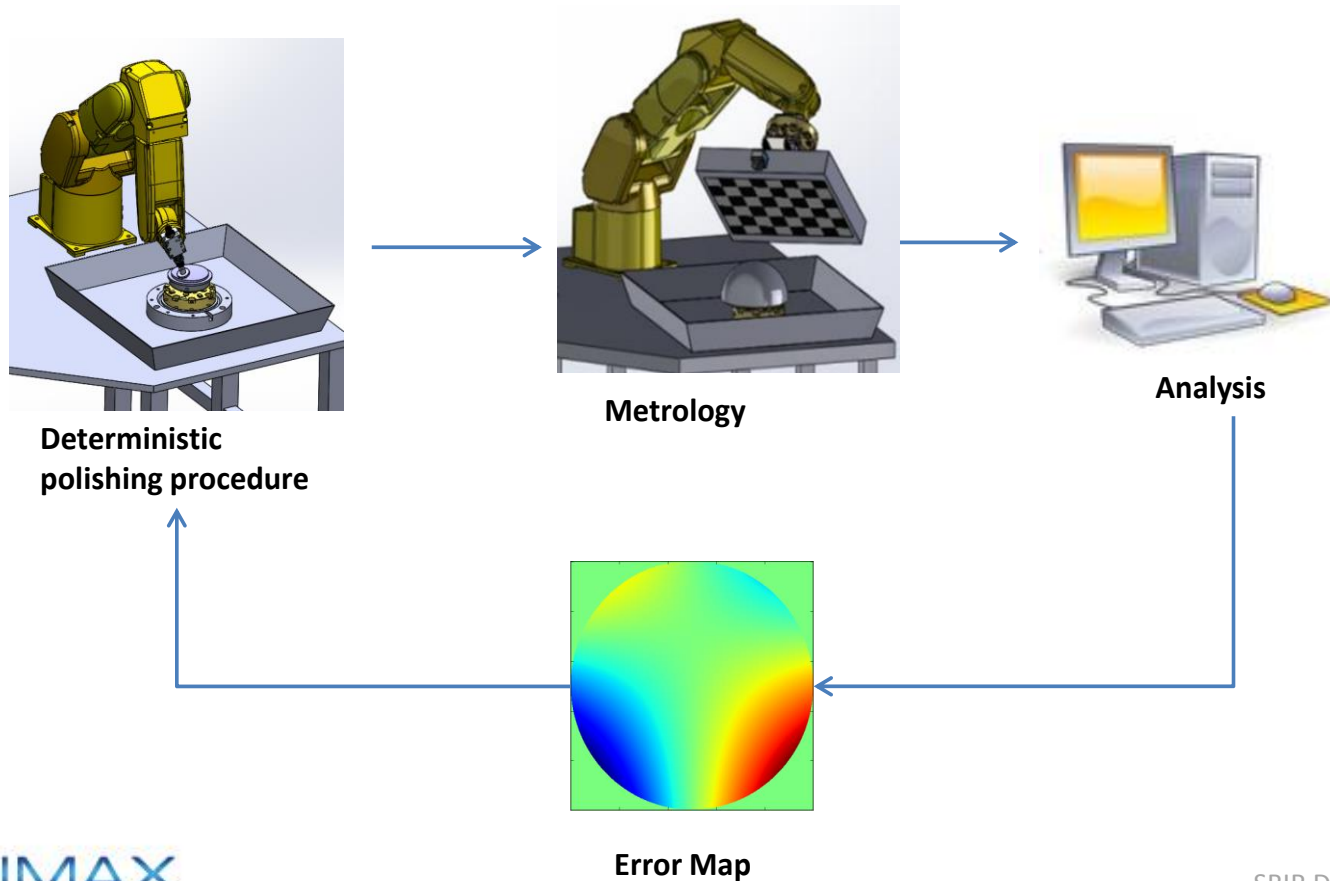
Large freeforms: bring metrology to the part!



Fused quartz, 23" x 20" ... 130 lbs. post-generation weight

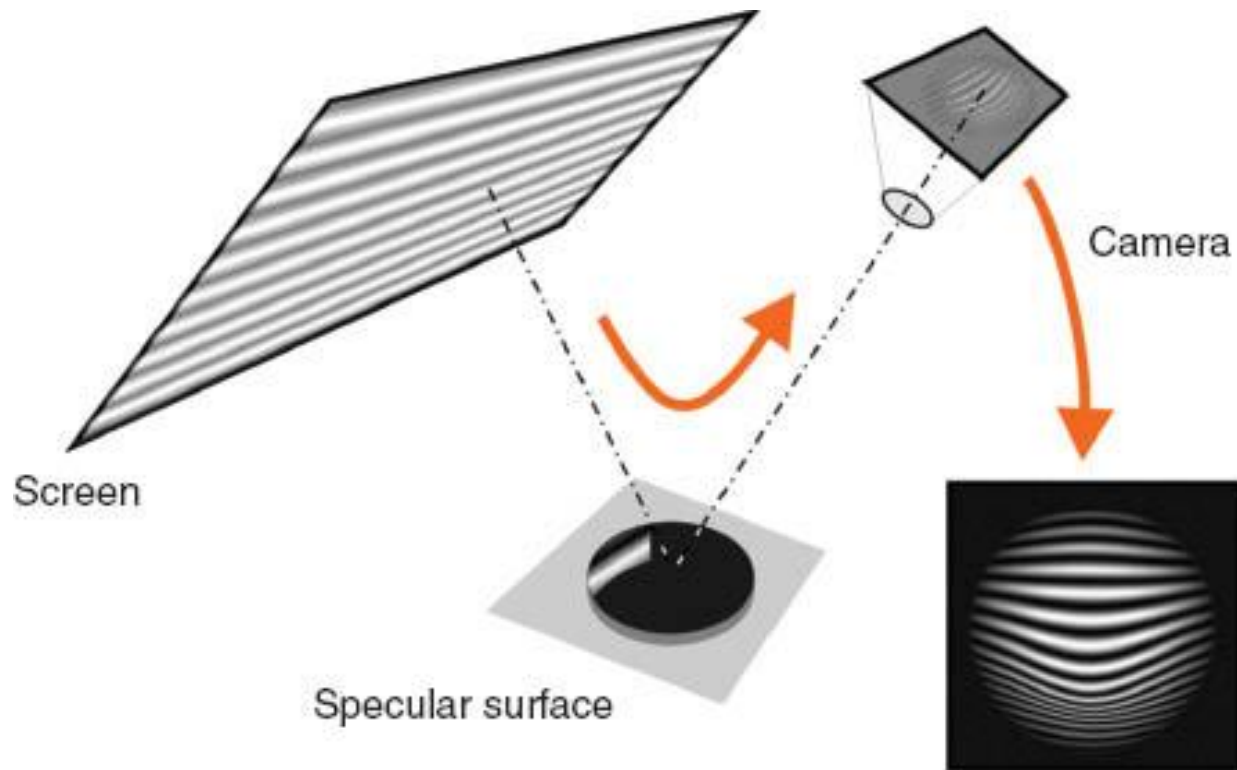
Closed loop manufacturing

Tightening the loop in deterministic robotic polishing by integrating fringe reflection deflectometry as in-situ metrology to provide surface metrology immediately to the optician



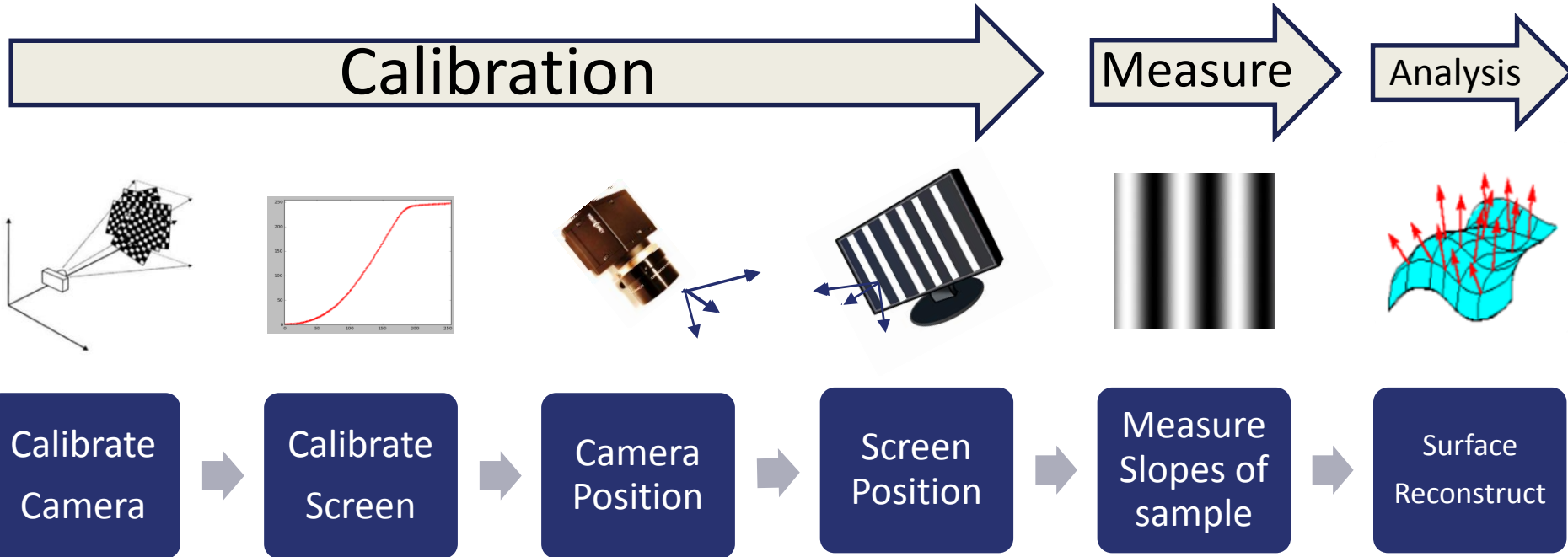
What is deflectometry?

Deflectometry is a non-coherent imaging technique that measures the local slope by imaging encoded patterns reflected off the surface.



M. Knauer et al., "Phase Measuring Deflectometry: a new approach to measure specular freeform surfaces", Proc. SPIE 5457,366-376 (2004).

Deflectometry process

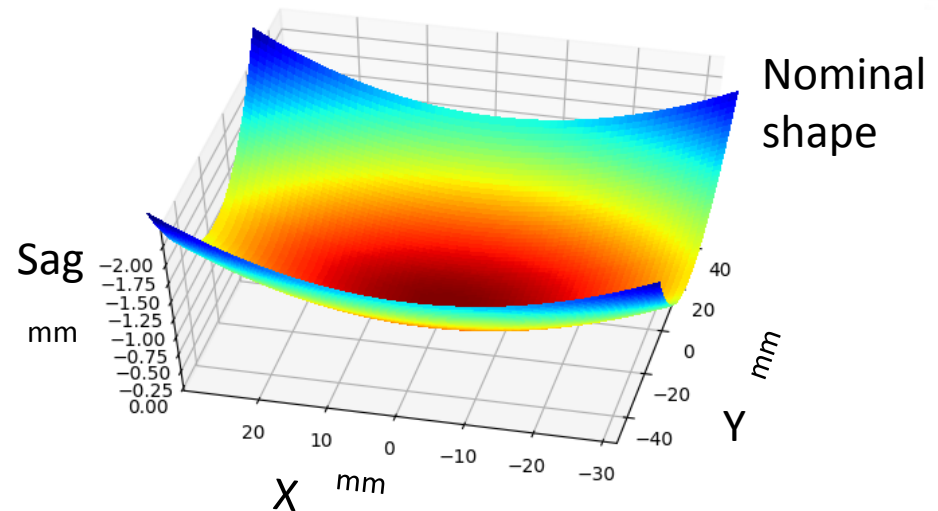
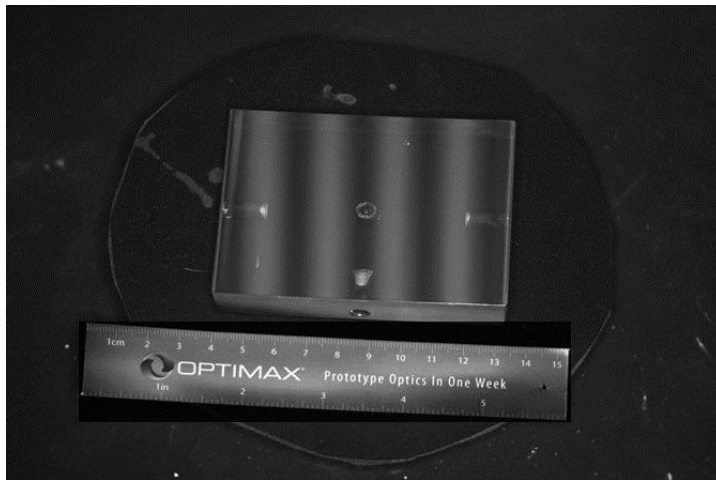


Pros – Easily integrated into manufacturing, non-contact, FAST acquisition

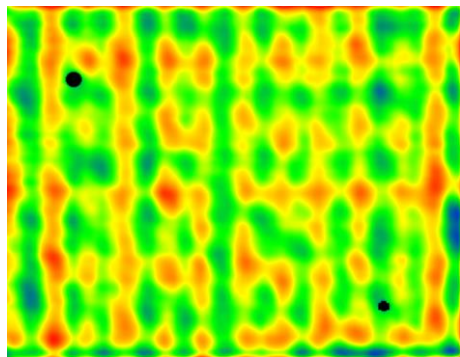
Cons – Calibration intensive, low order errors, cannot measure relative to fiducials, software intensive

Deflectometry/CMM/UA3P data comparison

Uncoated freeform mirror based on 4th order X-Y polynomial

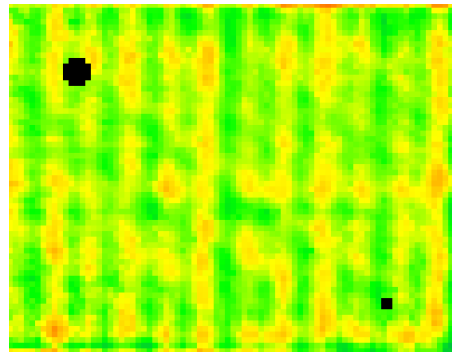


Deflectometry PV = 6.4 μm



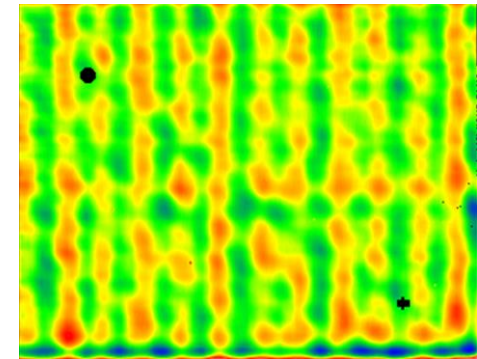
1 min acquisition time

CMM PV = 4.2 μm



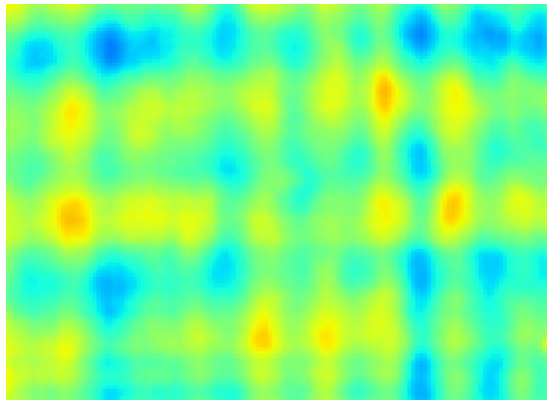
100 min acquisition time

UA3P PV = 5.0 μm



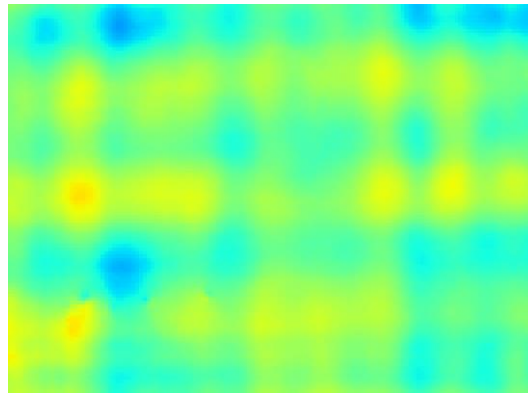
Deflectometry can detect small changes in mid-spatial frequency error

Pre-smoothing



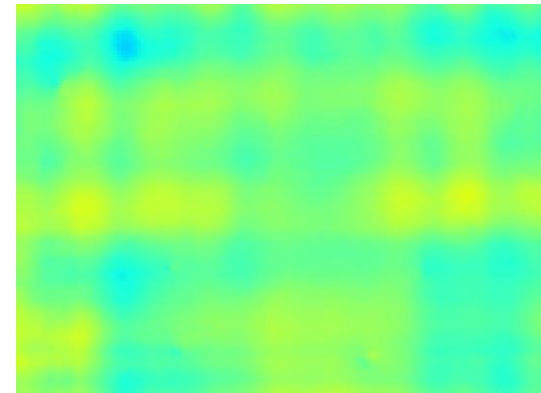
PV = 1.2 μm

Smoothing Run 1



PV = 0.84 μm

Smoothing Run 2



PV = 0.64 μm

1.5 μm



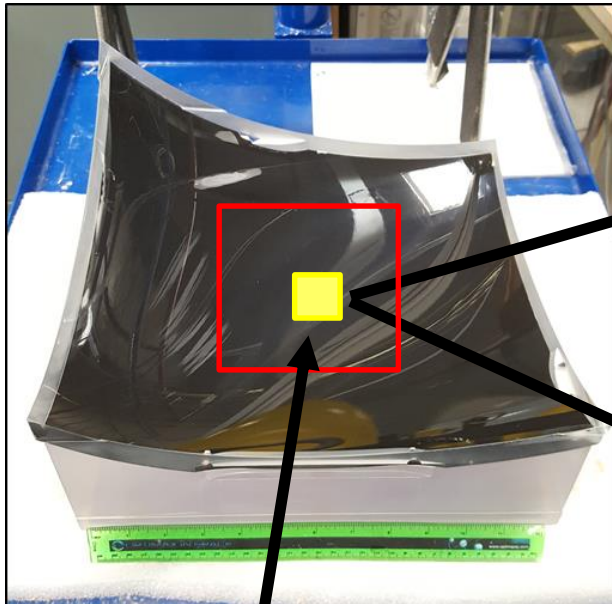
-1.5 μm

60x50 mm measurement area

Large conformal window deflectometry data

Large Conformal window
(320 x 320 mm)

6 hr acquisition time

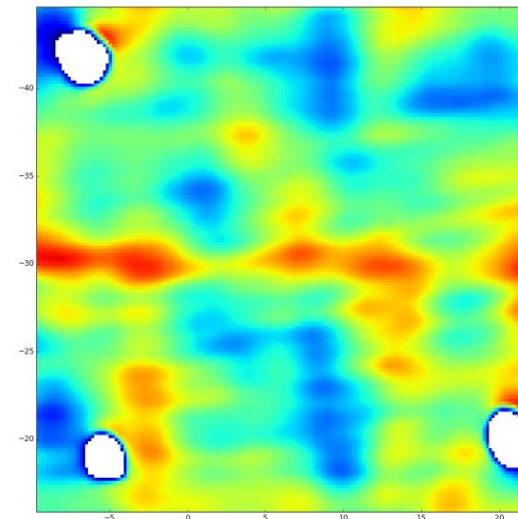
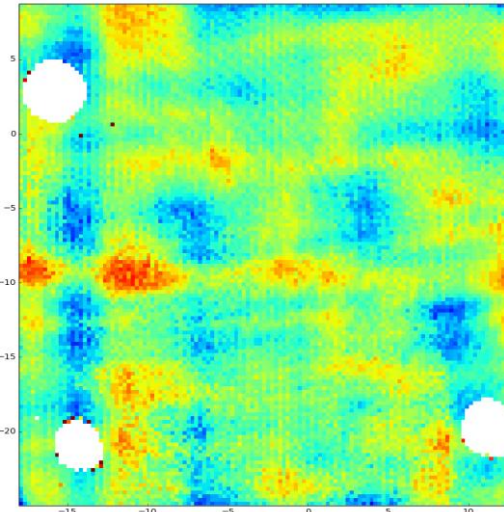


25x25 mm
measurement area
(yellow box)

CMM

Deflectometry

1 min acquisition time

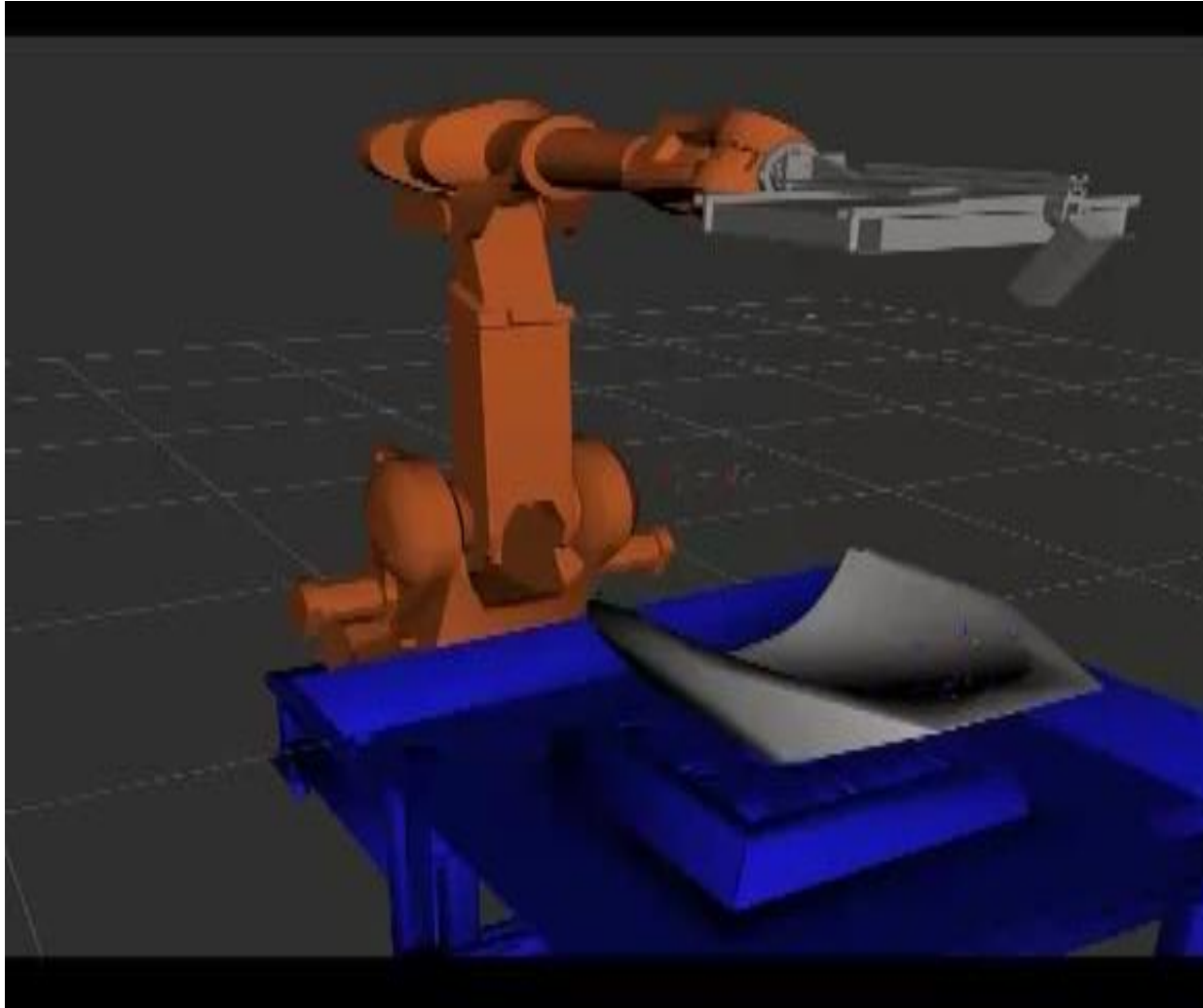


1.0 μm



-1.0 μm

Robot mounted deflectometry to get full aperture measurement of large freeforms



- Simulate robot paths
- Collision detection
- Calculate proper deflectometry positioning
- Coordinate communication between robot and deflectometry system
- Stitching algorithm to combine sub-aperture data

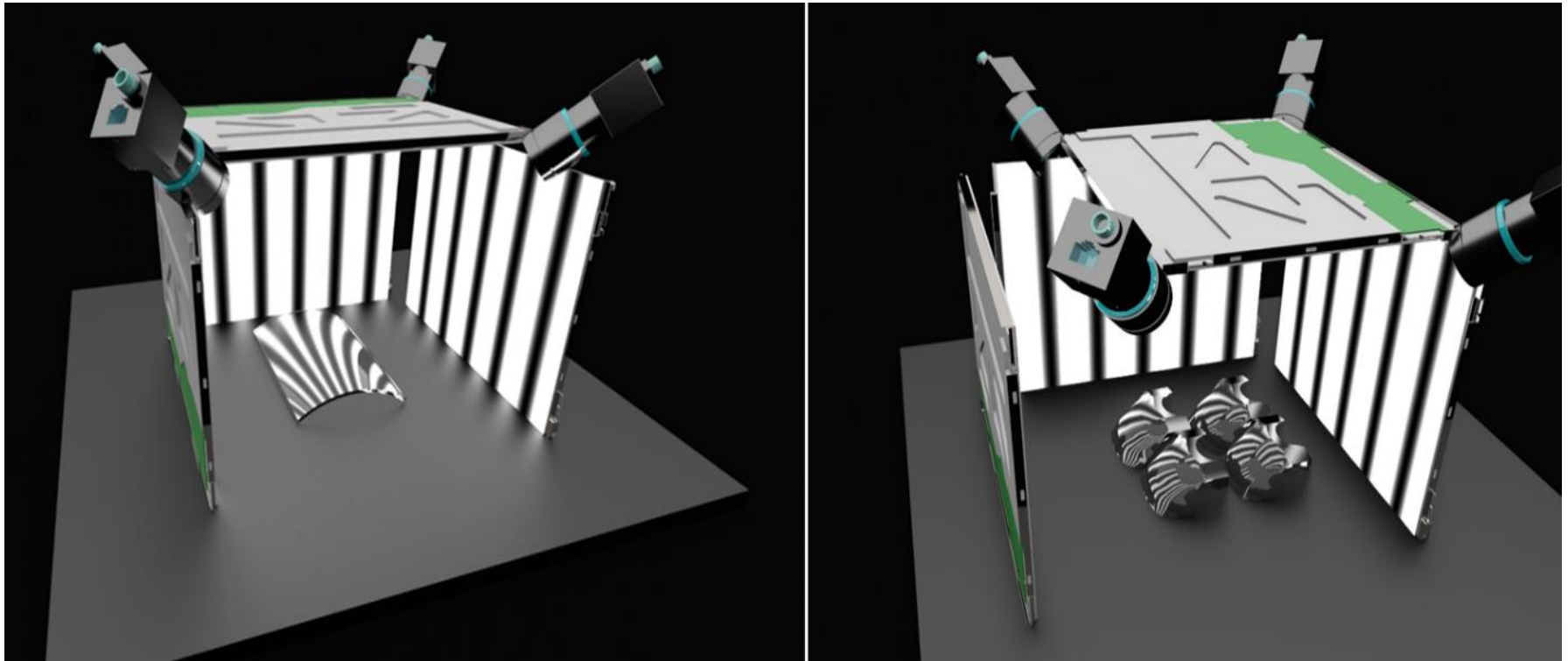
Summary

- To address the need of mid-spatial frequency error metrology of large freeforms, Optimax is developing a robot mounted deflectometry system
- Deflectometry has been shown to have good measurement correlation with existing metrology methods (CMM and UA3P)
- Deflectometry can save metrology time in manufacturing which can reduce cost

How do we apply deflectometry for the manufacturing a smaller , high precision, freeforms (NASA needs) in production without the complexity of robotic platform?.....

NASA SBIR Phase 1..... in progress

S2.04-4372 – *Improving freeform manufacturing using a unique deflectometry enclosure.* Contract 80NSSC18P2063



Goal: Reduce metrology time to measure mid-spatial frequencies on smaller freeforms during manufacturing from hours to minutes

Improving freeform manufacturing using deflectometry

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