Join the OptiPro Revolution.

Non-Contact Metrology of Freeform Surfaces

By: Scott DeFisher,

NASA Mirror Tech Days

Open Session

November 11, 2015

Overview

Join the OptiPro Revolution.

Measurement Methods

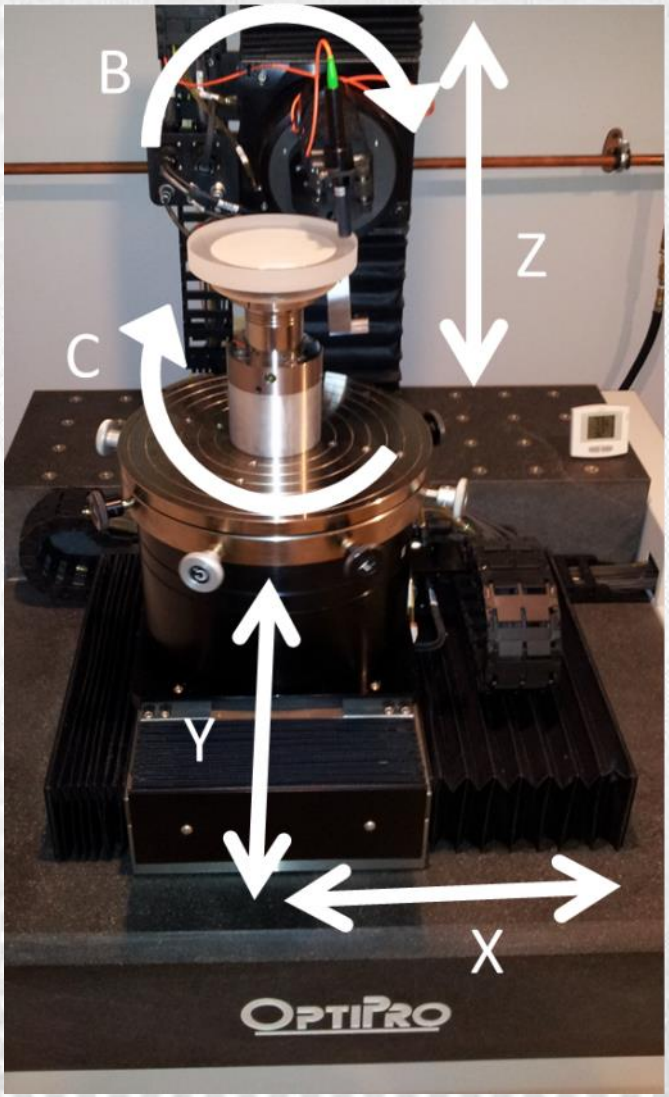
- Equipment
- Software
- Capabilities

Measurement Examples

- Freeforms!

UltraSurf

Join the OptiPro Revolution.

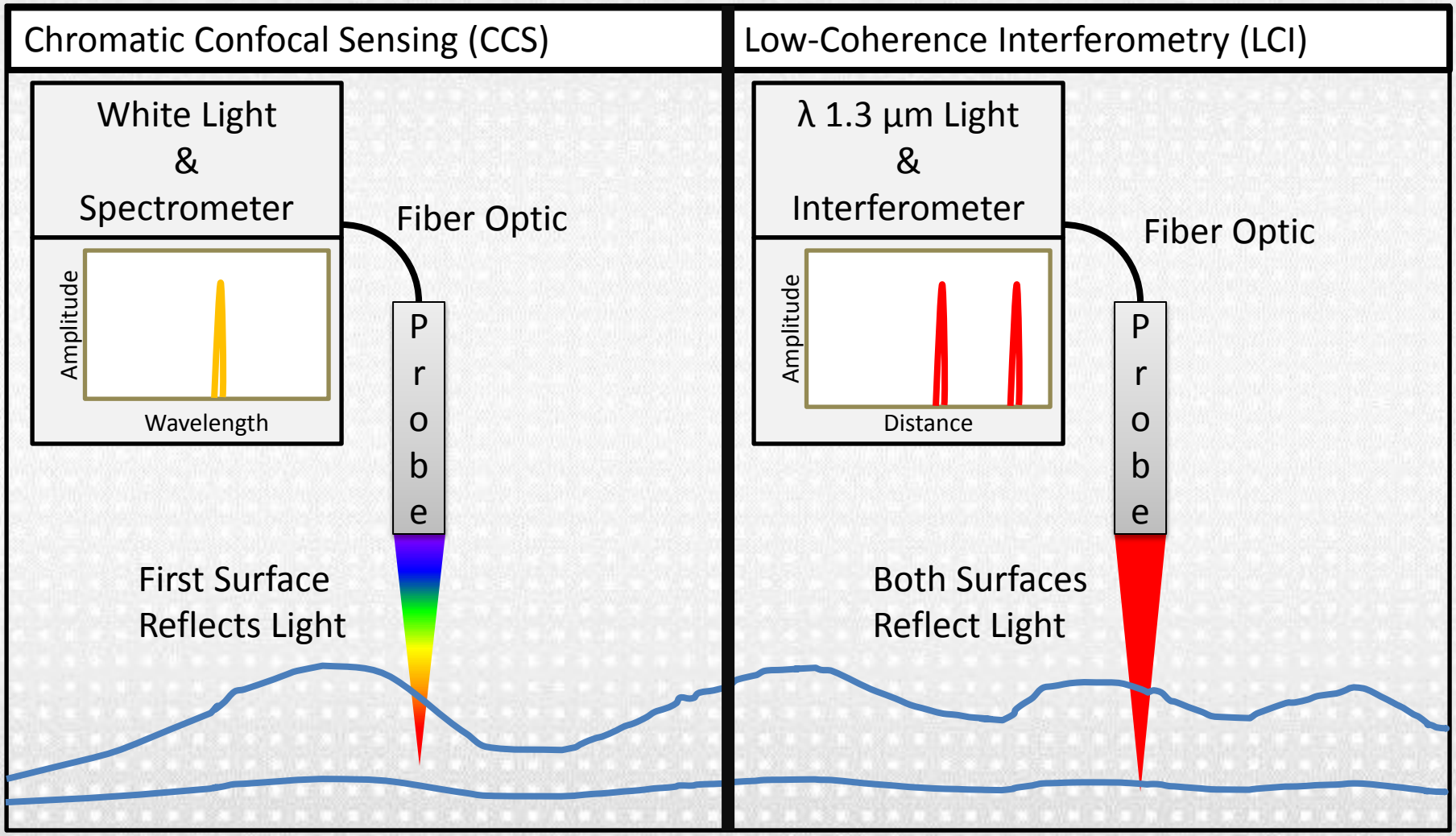


- 5-Axis Non-Contact Measuring System
- Scans With Various Non-Contact Probes
- All Air Bearing Axes
- Linear Motors
- Brushless DC Rotary Motors
- X,Y,C move the part
- Z,B move the probe

Axis:	X,Y,Z	B	C
Travel:	200 mm	360°	360°
Resolution:	5 nm	0.02 second	0.01 second
Max. Velocity:	20 mm/s	6 RPM	6 RPM

Non-Contact Probes

Join the OptiPro Revolution.



1-10 µm Lateral and 10 nm Vertical resolution

30-50 µm Lateral and 30 nm Vertical resolution

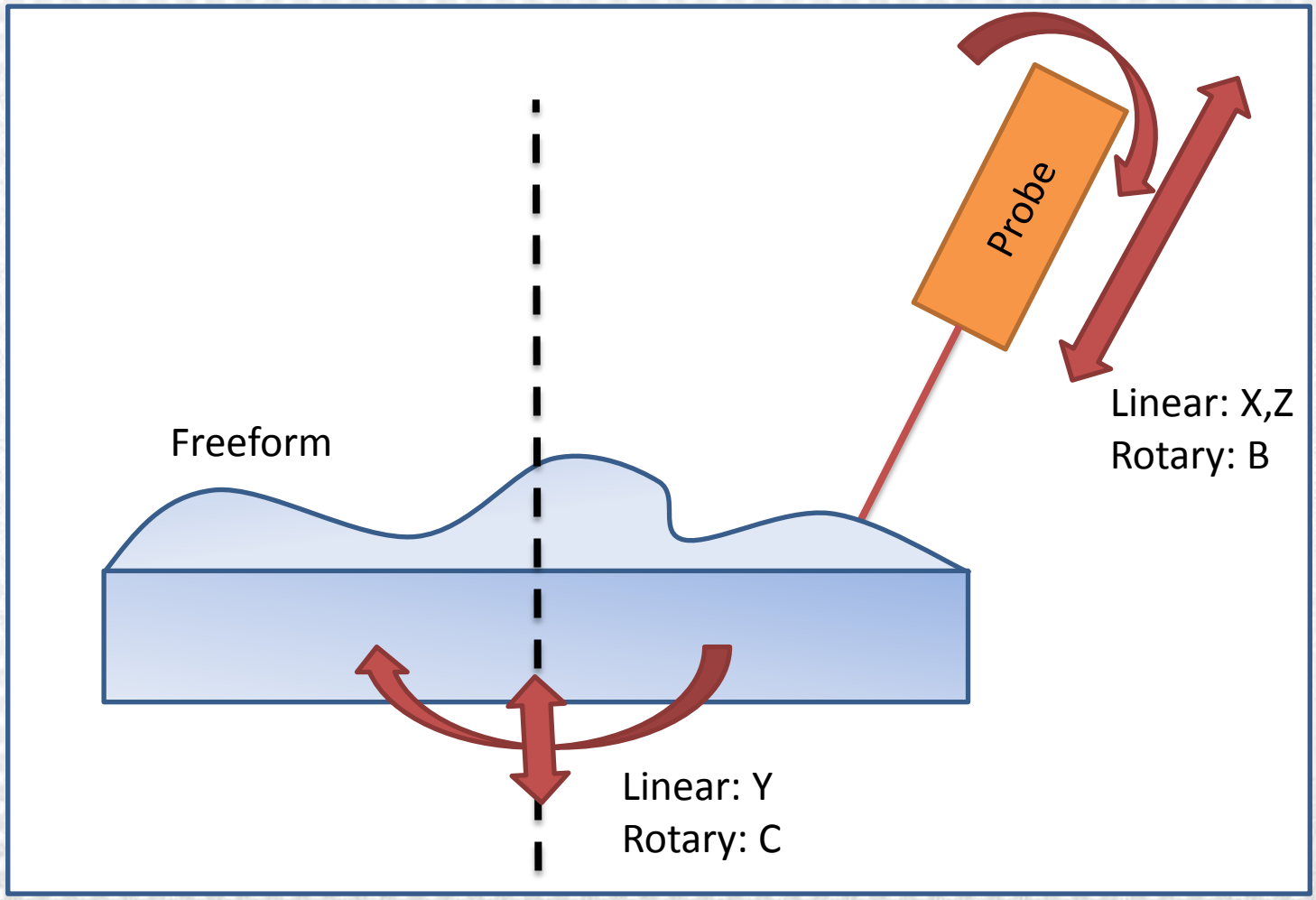
Current Measurement Abilities

Join the OptiPro Revolution.

Rotationally Symmetric	Non-Rotationally Symmetric	Freeform/Conformal
Spheres	2-D Flats	Mathematical Equation
Aspheres	Cylinders	Cloud of Points
Ogives	Profiles	CAD
Parabolas		

5-Axis Freeform Example

OPTIPRO
Join the OptiPro Revolution.

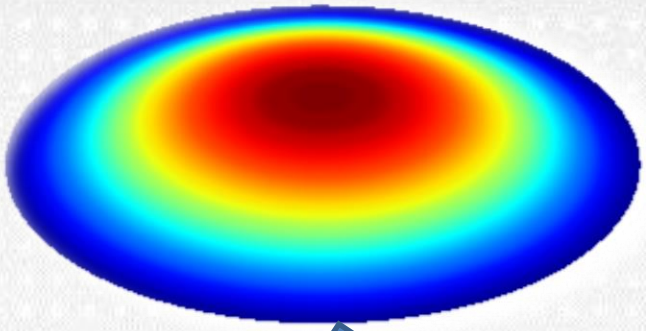


Point Cloud Registration

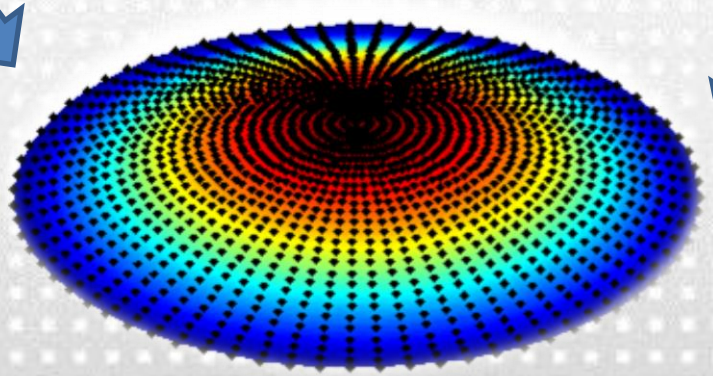
Join the OptiPro Revolution.

Measured Point Cloud

Ideal Shape

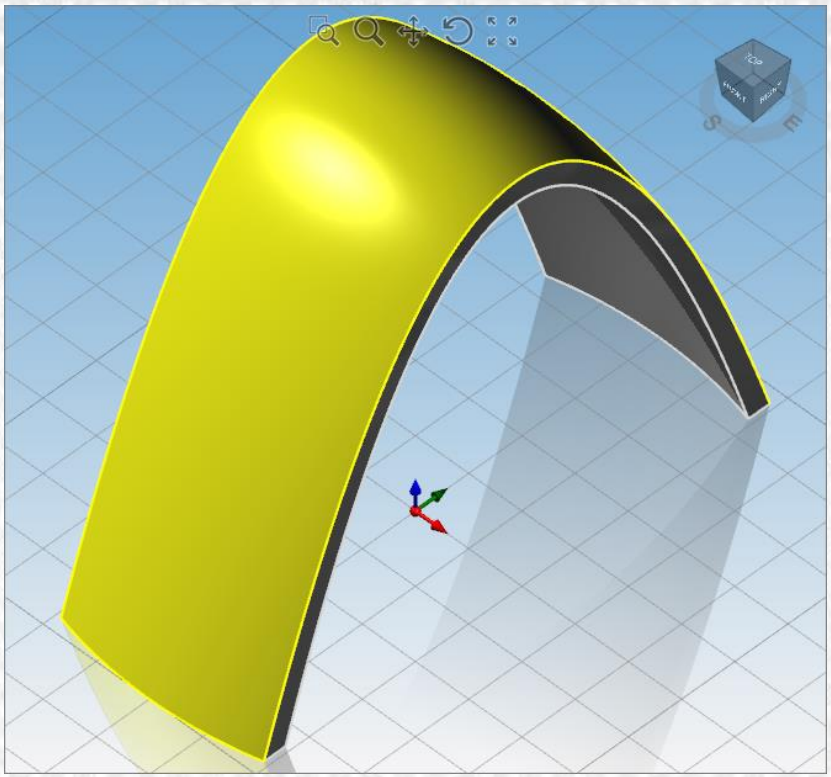


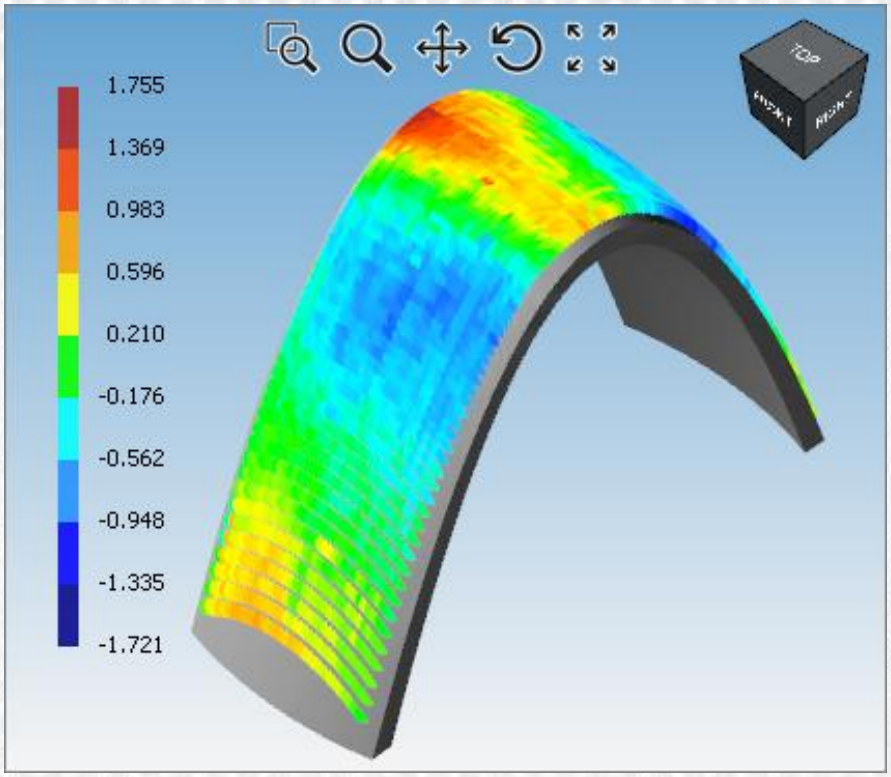
Final Point Cloud Fit



UltraSurf 3D Interface

Join the OptiPro Revolution.



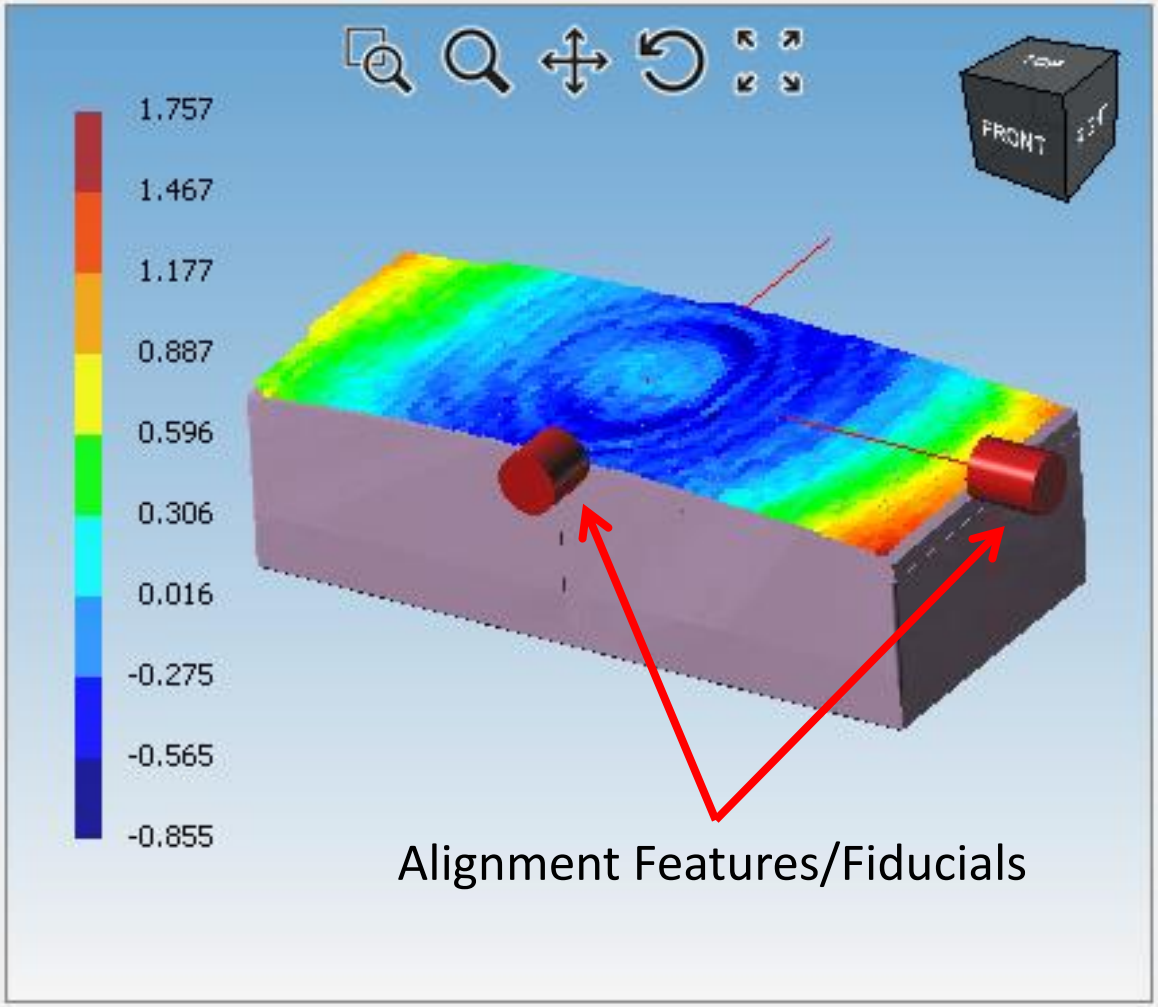


- Developing a 3D interface for freeform shapes
- CAD file importation for measurement path and data analysis
- Significantly easier for user to setup measurements and visualize data
- Dual Surface Definitions
  - CAD for visualization, measurement path planning
  - Equation or point cloud for analysis and error calculation

UltraSurf 3D Interface

Join the OptiPro Revolution.

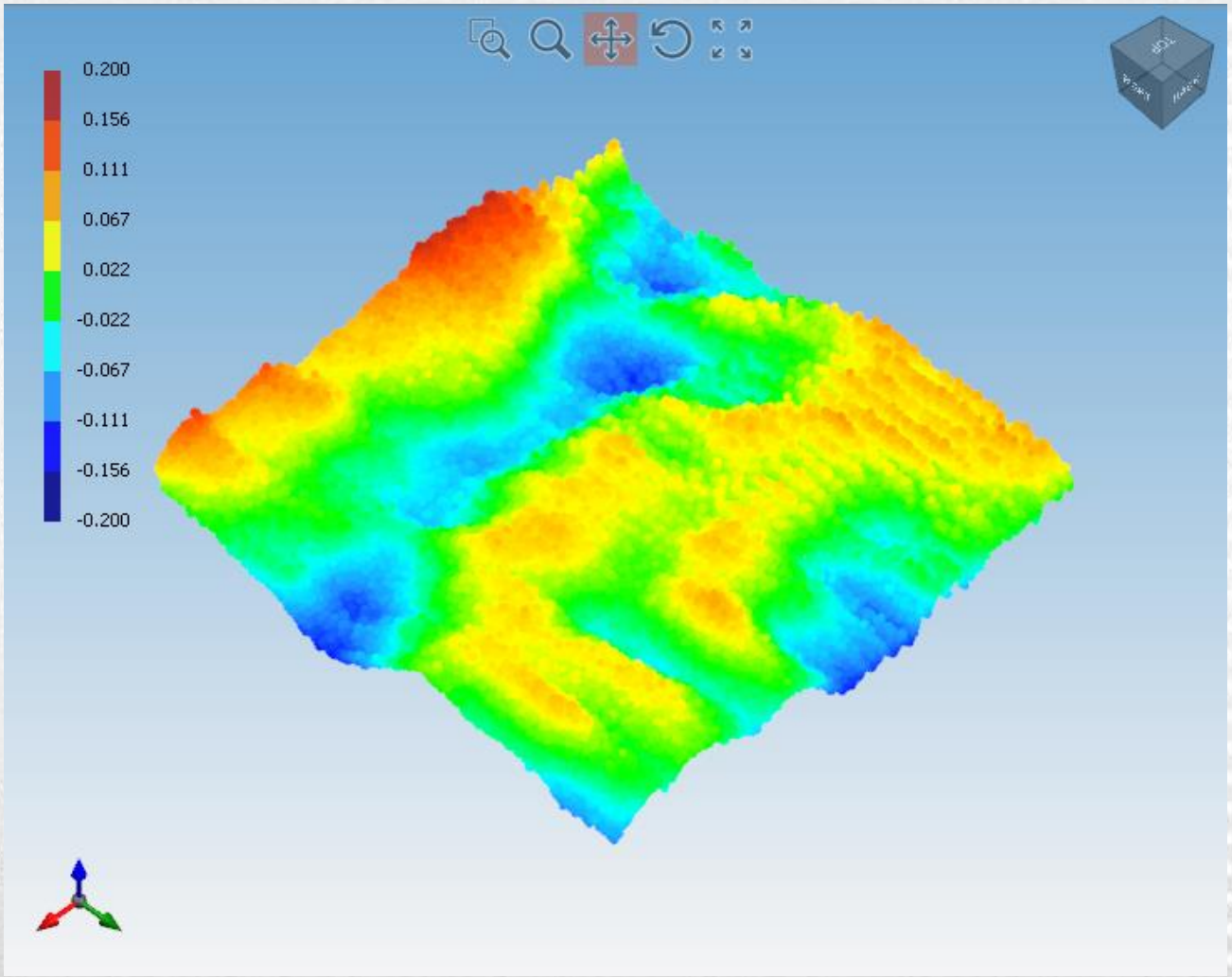
Freeform Measurement (With CAD)



UltraSurf 3mm x 3mm

Join the OptiPro Revolution.

High resolution (<10 µm / point), small sub-aperture to inspect texture



Join the OptiPro Revolution.

Freeform Measurement Example

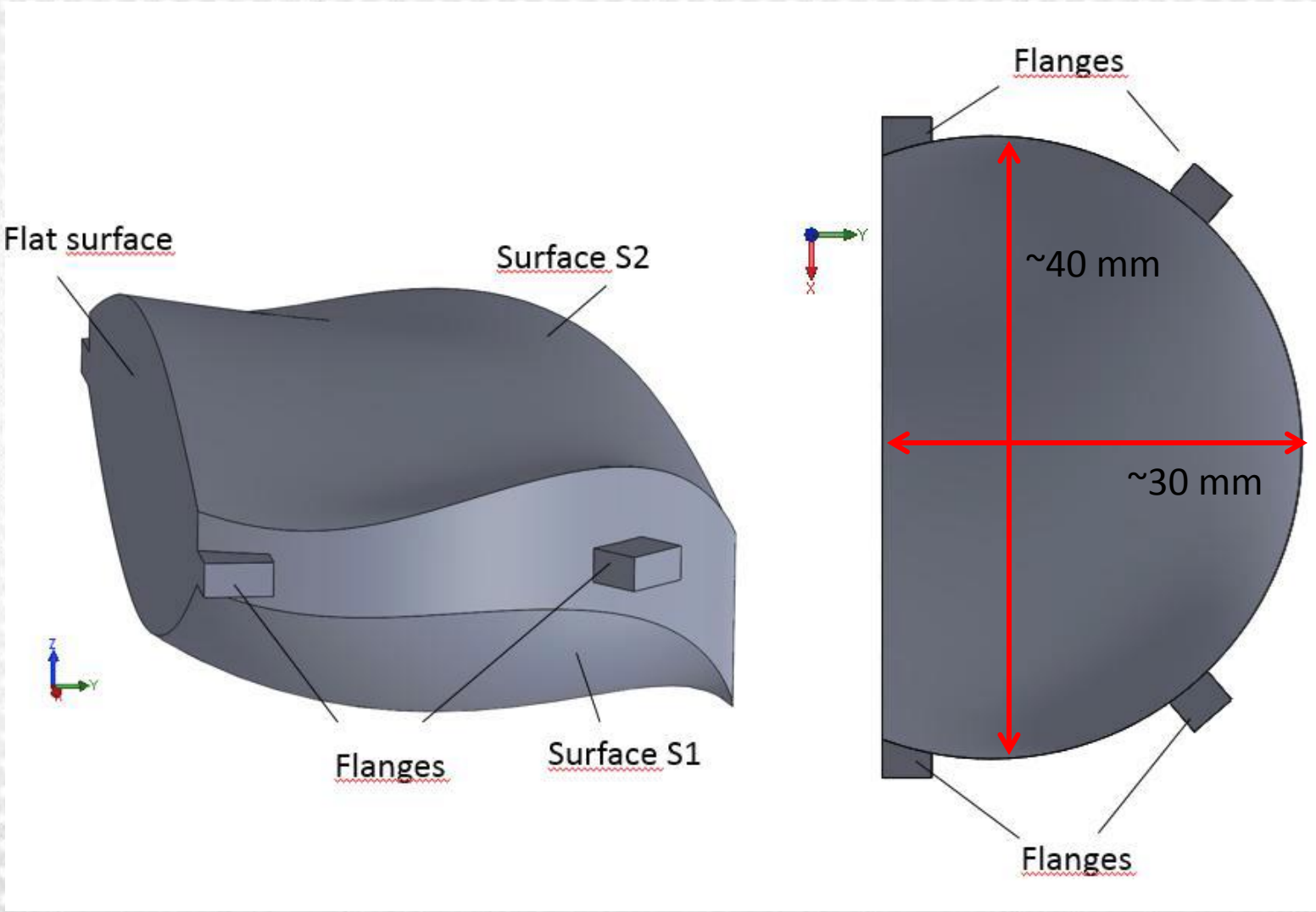
CeFO (Center for Freeform Optics)

&

University of Rochester

Optical Component

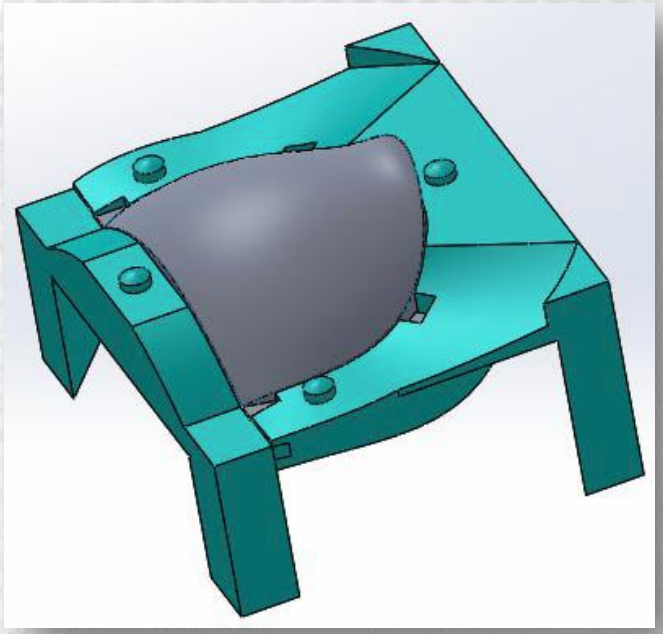
Join the OptiPro Revolution.

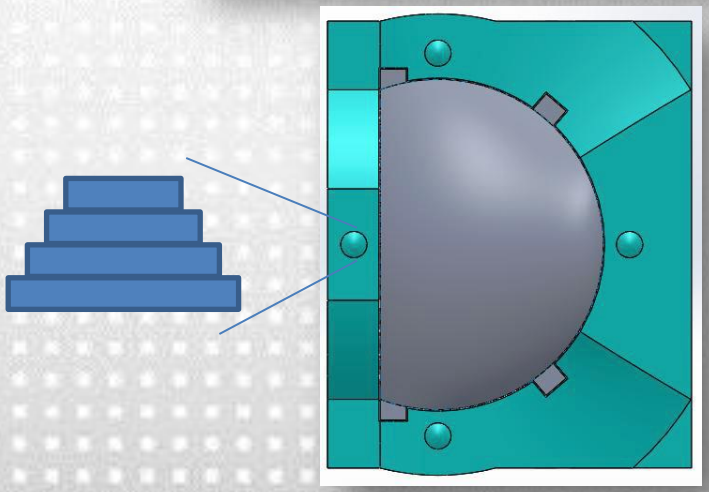


Part Setup

Join the OptiPro Revolution.

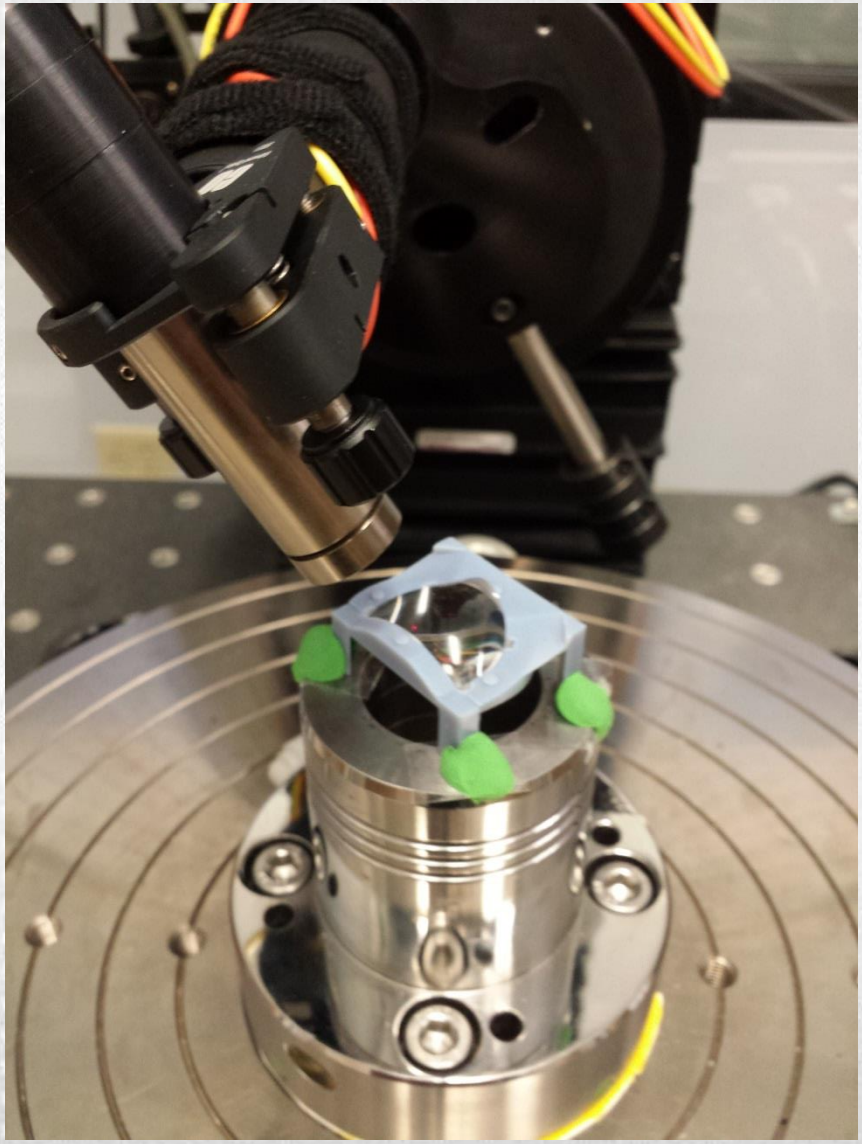
- Part secured by a 3D printed fixture, S1 facing up
- Fixture has 4 reference “spheres” for locating the position of the part
- The reference spheres were not very spherical, finding their apex was difficult
  - This is attributed to “flat” areas on top of the sphere created by the 3D printed contour
  - The spheres locations were well documented to the measurement easier, but…
  - The heights of the spheres did not correlate well to the optical surface, according to the document
- 3D Printed fixture may have warped or was misprinted

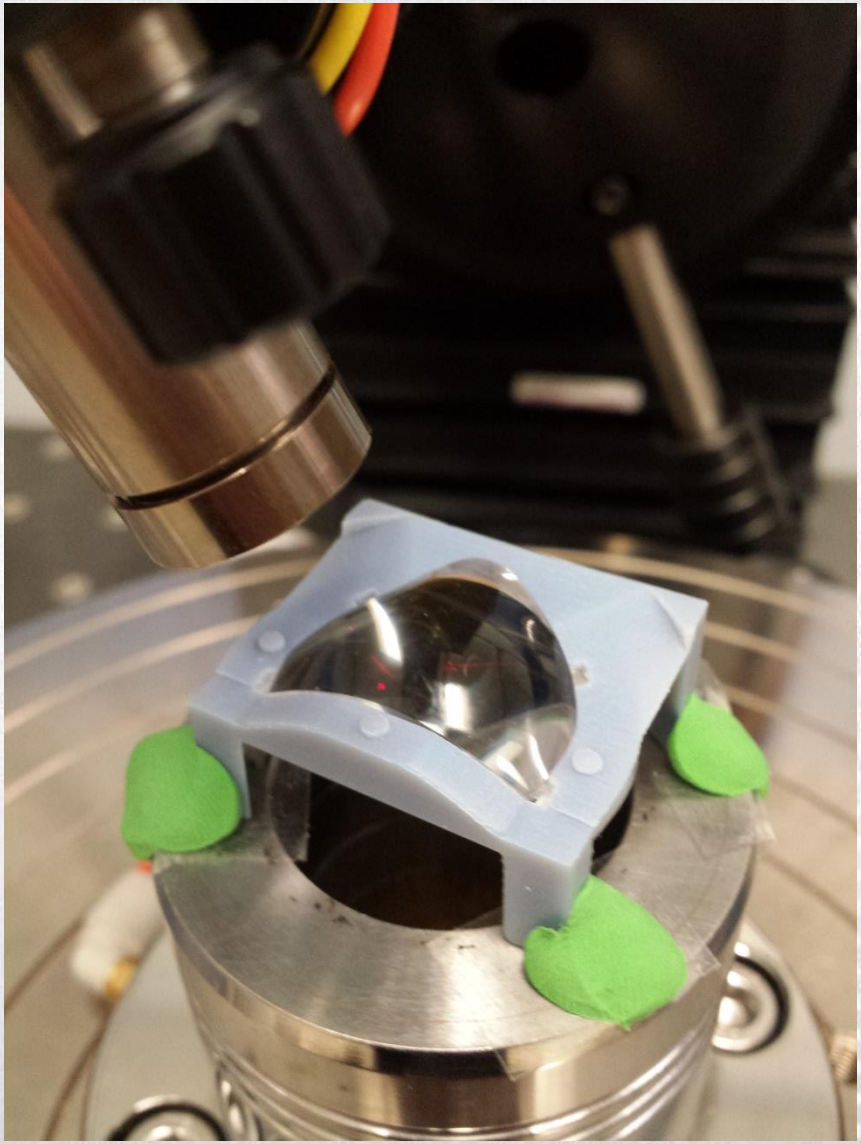




Measuring on UltraSurf

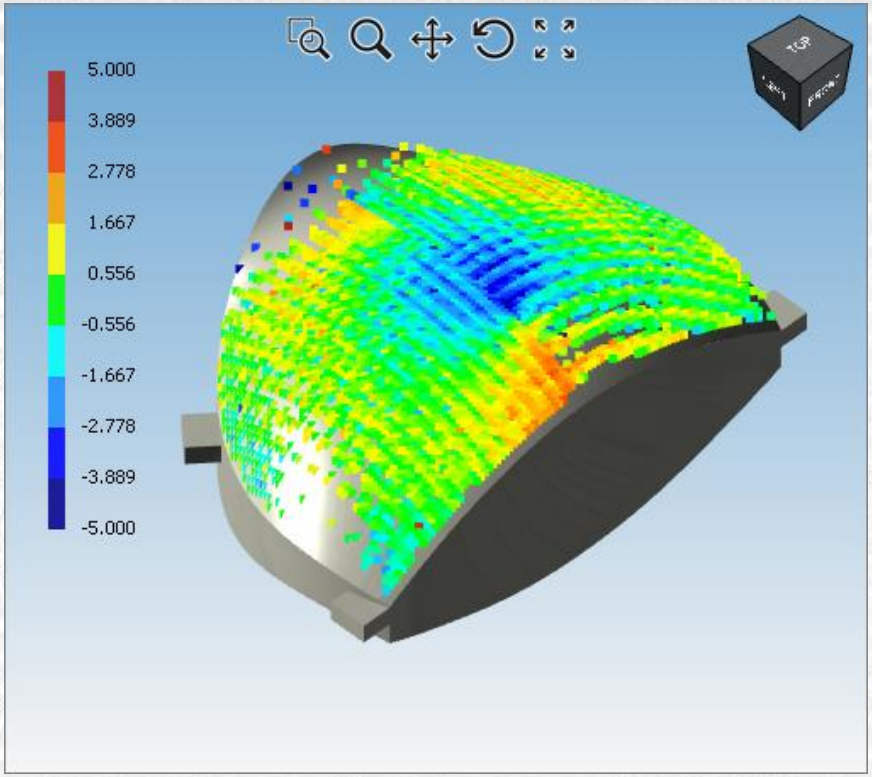
OptiPro
Join the OptiPro Revolution.

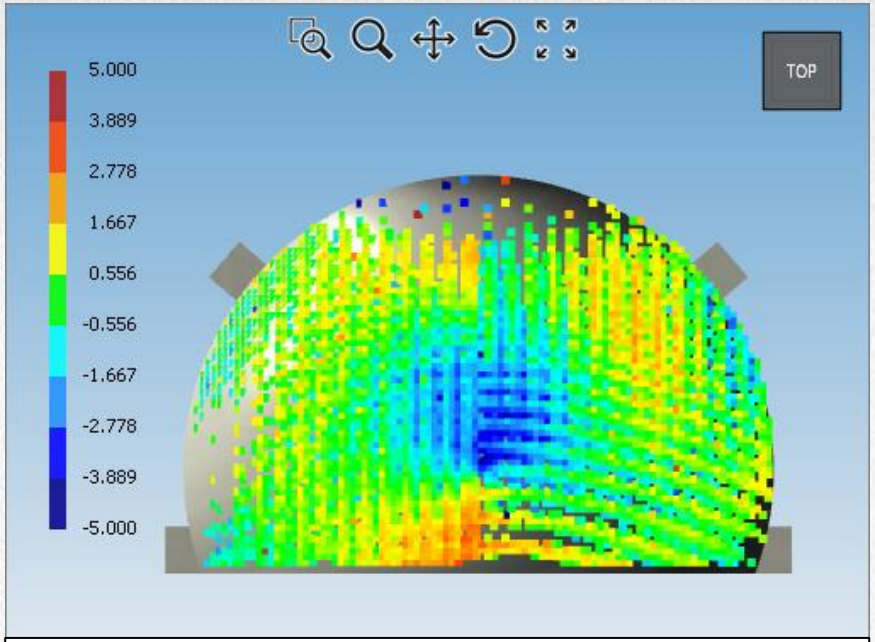




Measurement Results

Join the OptiPro Revolution.





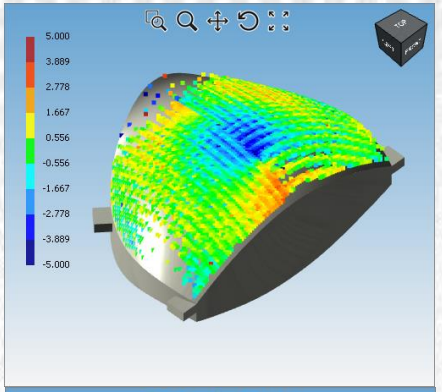
0.25 mm by 0.25 mm lateral resolution
2 hour measurement time, 15 minute setup time
Number of Points Attempted: 5662

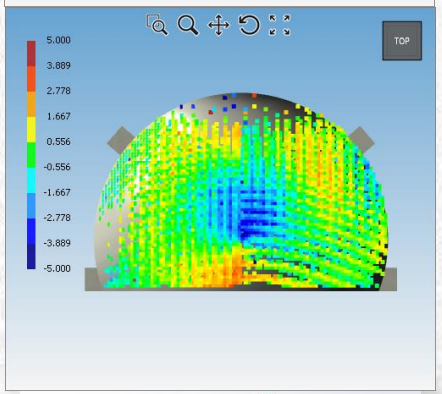
- Color scale +/- 5 um
- Most error falls between +/- 2 um
- Grid lines apparent,
- Drop out due to non-perpendicular metrology
  - The chosen probe must stay +/- 2 degrees parallel to surface normal
  - 78% Coverage (4429/5662)
  - Part was diamond turned in two orthogonal orientations, causing the grid

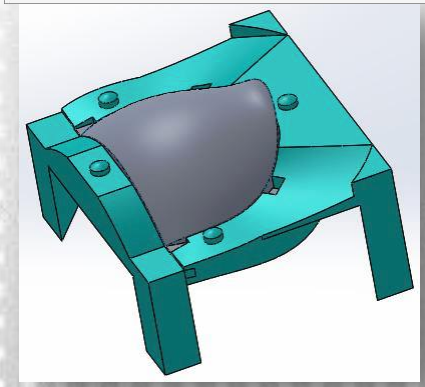
Freeform Measurement Lessons

Join the OptiPro Revolution.

- Better location of the part would keep the probe in the +/- 2 degree angle limitation
  - The CCS probe has a +/- 25 degree angle limitation, but measures closer to the part
- The 3D printed fixture could be improved by
  - Increase rigidity or structural accuracy
  - Use a large flat base instead of 4 small legs, this would give more area to secure the surface
  - Improve the sphericity of the locating surfaces, or change their shapes. Conical?







Summary & Future Work

Join the OptiPro Revolution.

- UltraSurf is a flexible platform for freeform optical surface metrology
- 3D printing and additive manufacturing can provide fixtures and alignment features for freeform optics
- Current 3D interface is making progress, and will soon provide an easy to use interface for freeform shapes
- We are working to reduce scanning time to increase throughput of deterministic corrections
- We are also working on a process to communicate the shape, orientation, and location of freeform surfaces with regards to manufacturing and metrology