Join the OptiPro Revolution.

Optical Characterization of Complex Freeform Surfaces

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NASA SBIR Phase I

NASA Mirror Tech Days

Open Session

November 19, 2014

Overview

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Phase I Summary

- Goals and Specifications

Measurement Methods

- Equipment
- Software
- Capabilities

Measurement Examples

- Freeform Arch
- Toroid Window

NASA Phase I Work

- S2.04 Optics Manufacturing and Metrology for Telescope Optical Surfaces
  – Measure a variety of NASA telescope optics
    - Mirror Mandrels (< 0.5 m)
    - Grazing-Incidence Segments (0.5 m – 1 m)
    - Aspheres < 1 m
  – Detect a wide range of spatial frequencies (50 µm – 20 mm)

UltraSurf

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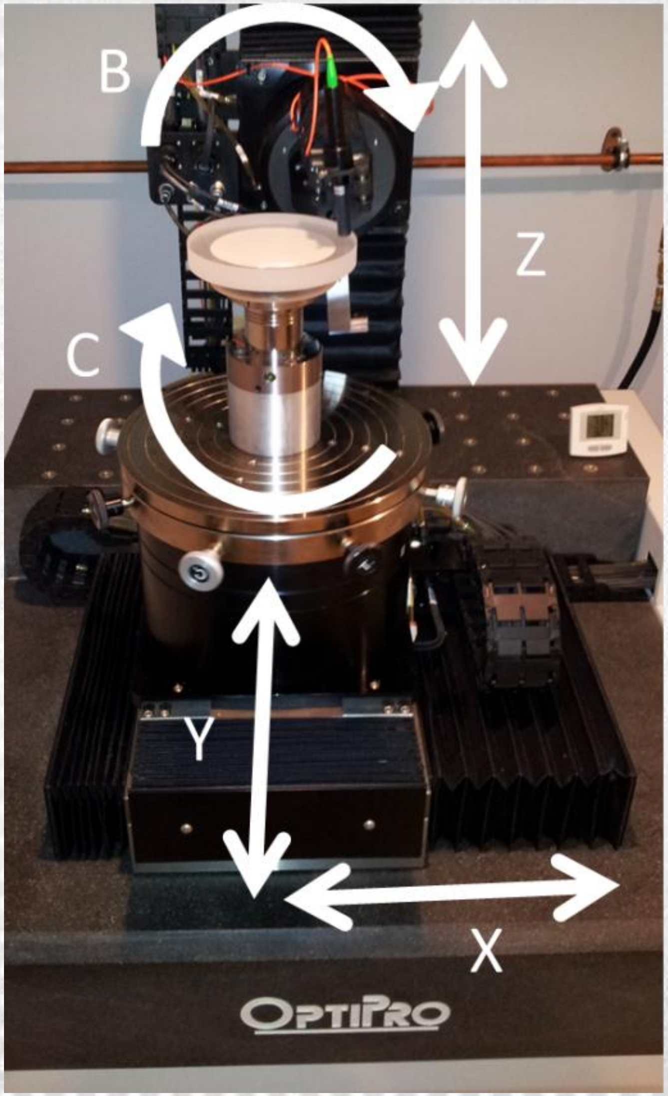
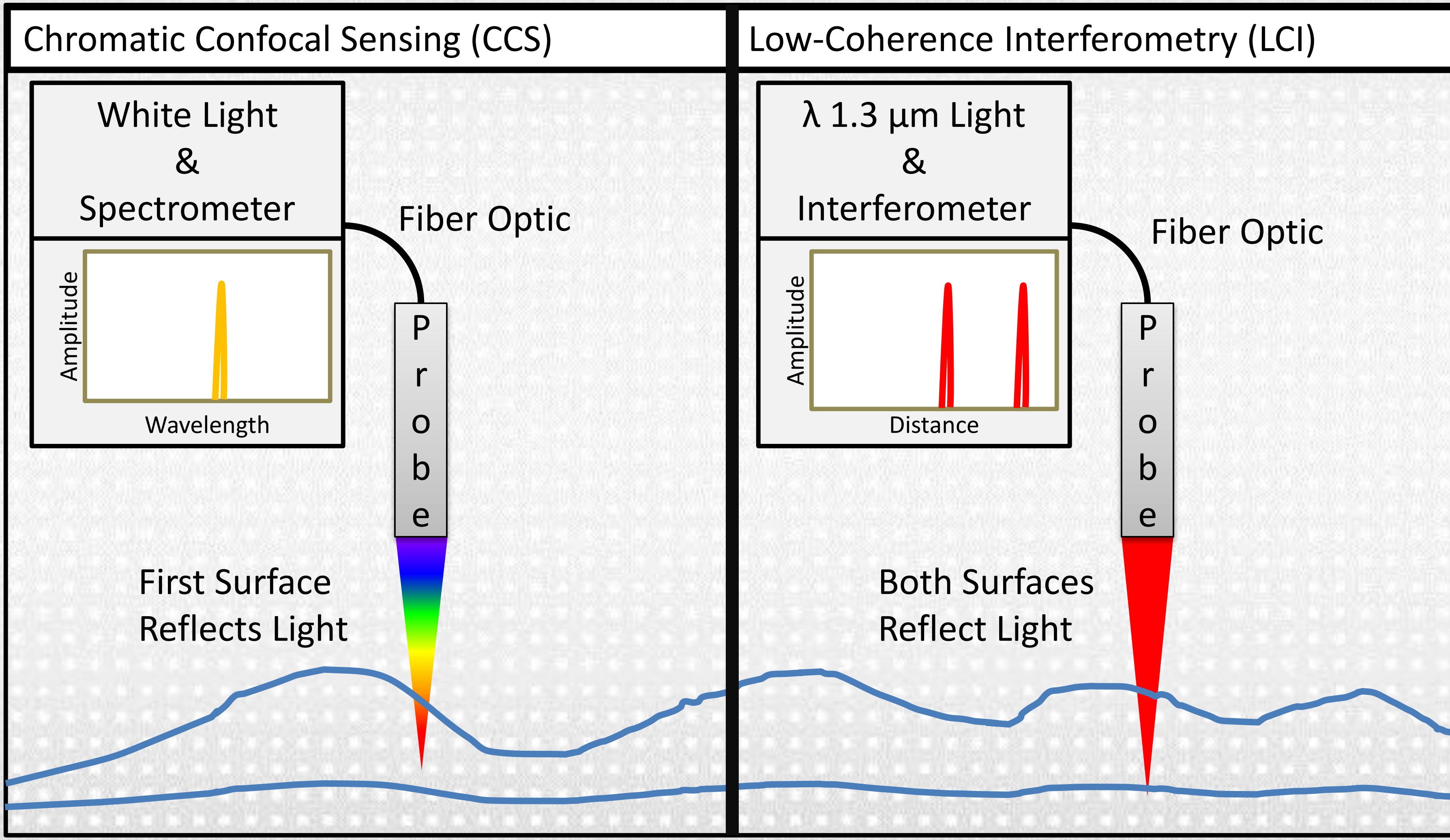


- 5-Axis Non-Contact Measuring System
- Scans With Various Non-Contact Probes
- All Air Bearing Axes
- Linear Motors
- Brushless DC Rotary Motors
- X,Y,C move the part
- Z,B move the probe

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



1-10 µm Lateral and 10 nm Vertical resolution

30-50 µm Lateral and 30 nm Vertical resolution

Current Measurement Abilities

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Rotationally Symmetric

- Spheres
- Aspheres
- Ogives
- Parabolas

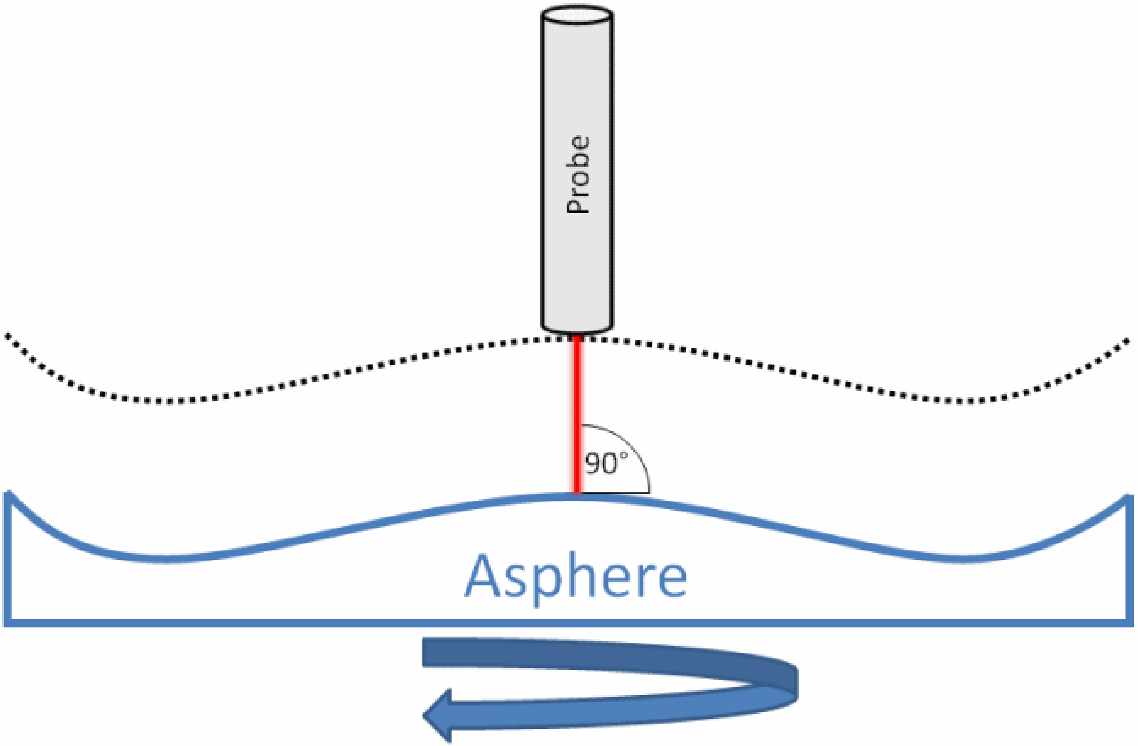
Non-Rotationally Symmetric

- 2-D Flats
- Cylinders
- Profiles

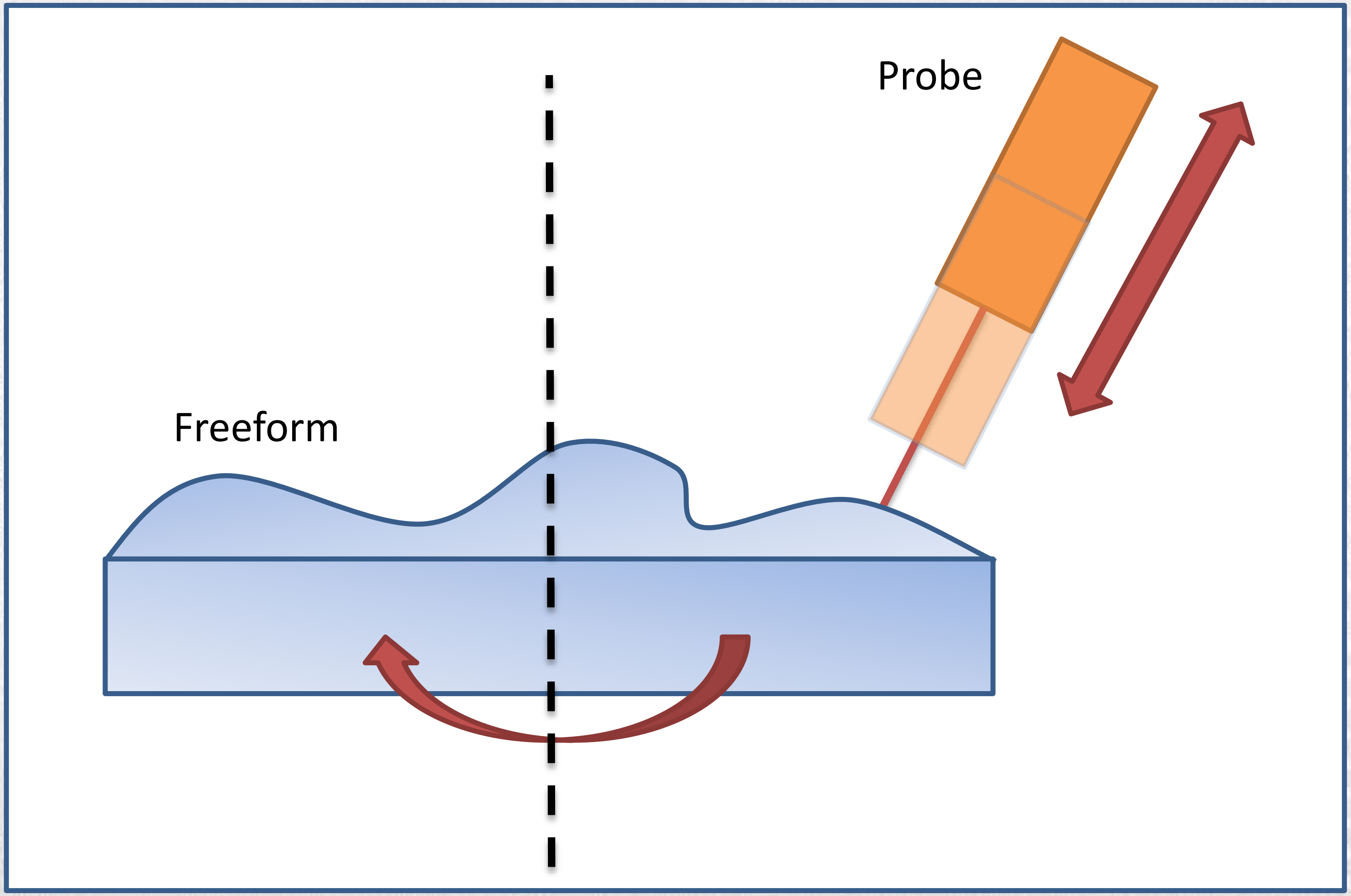
Freeform/Conformal

- Mathematical Equation
- Cloud of Points
- CAD

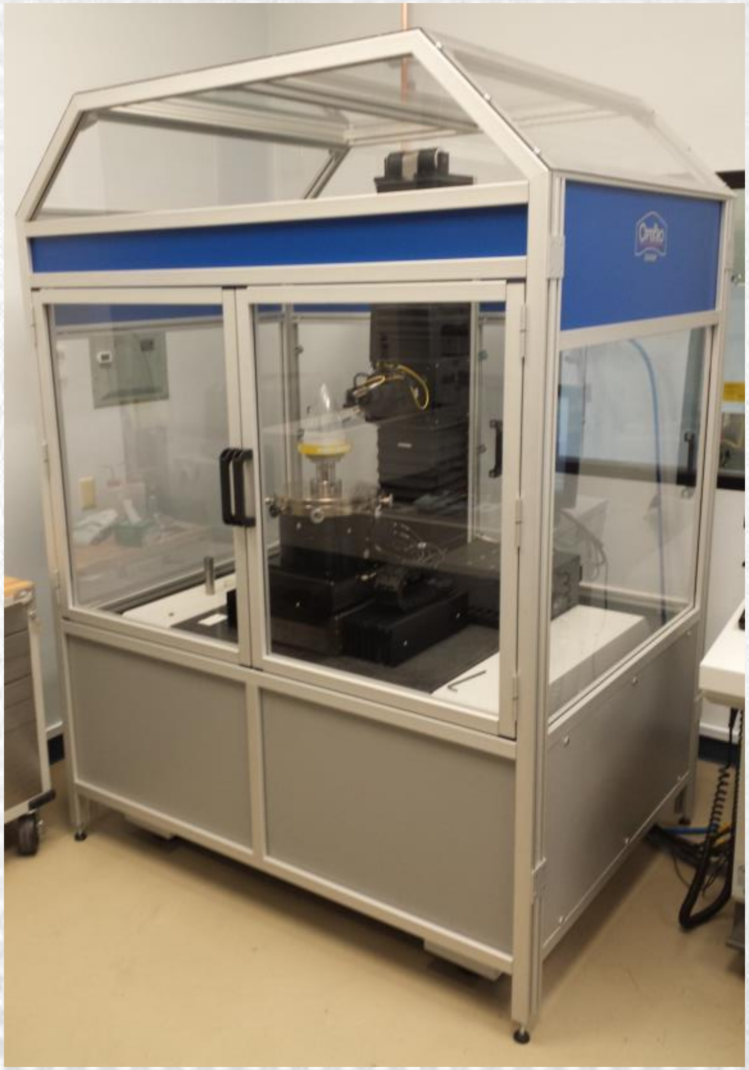
Measurement Method

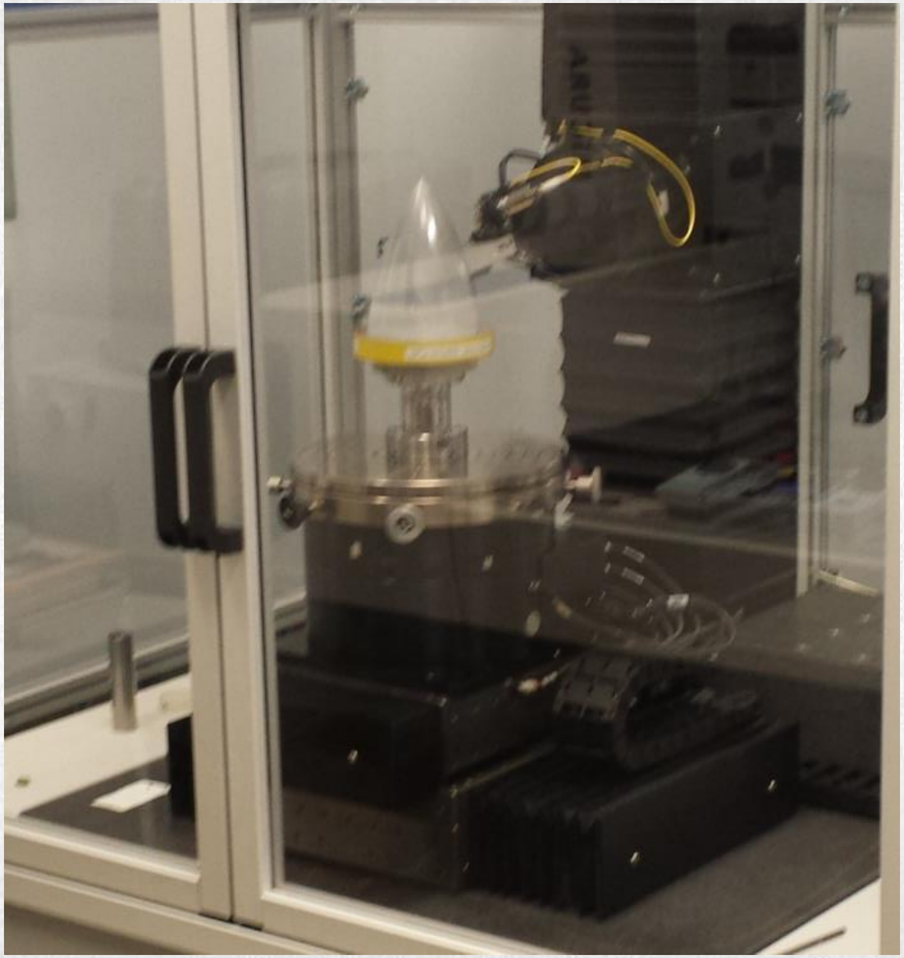


Freeform Example



Aerodynamic Dome





Mirror Mandrel

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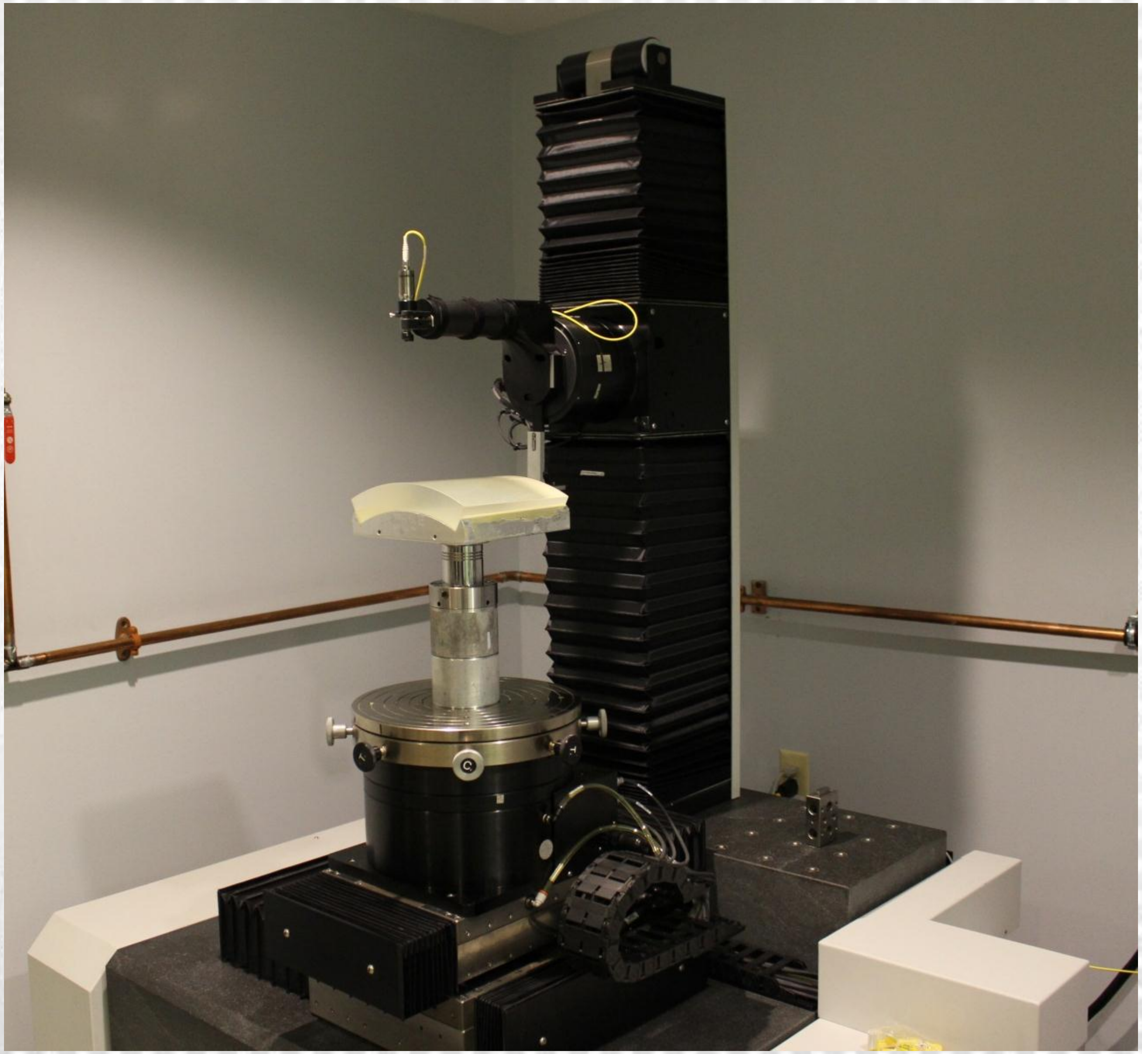
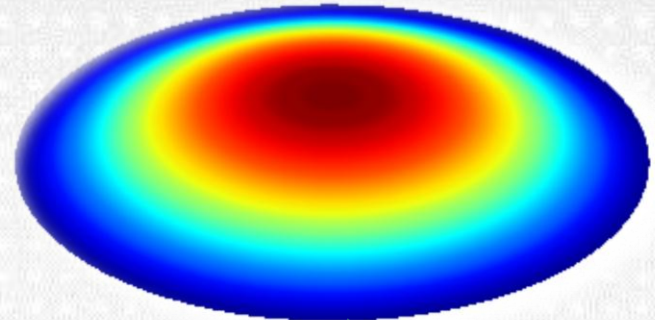


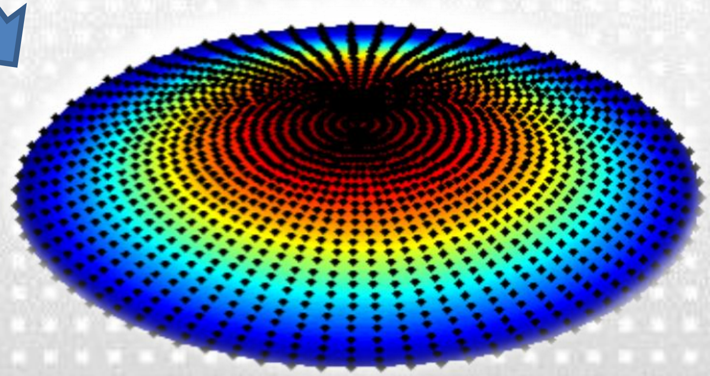
Point Cloud Registration

Measured Point Cloud

Ideal Shape



Final Point Cloud Fit



UltraSurf 3D Interface

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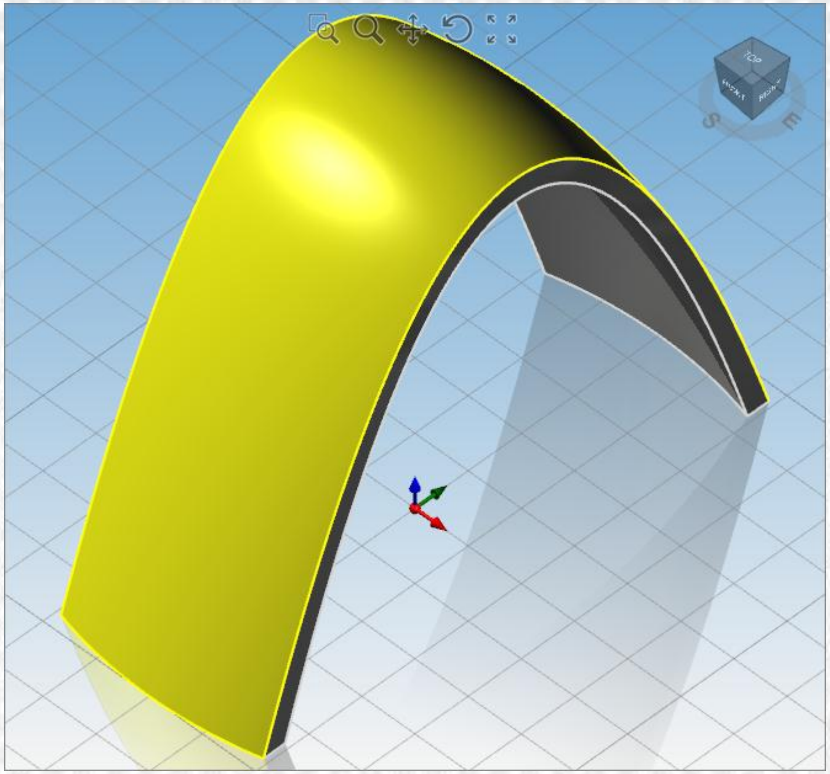
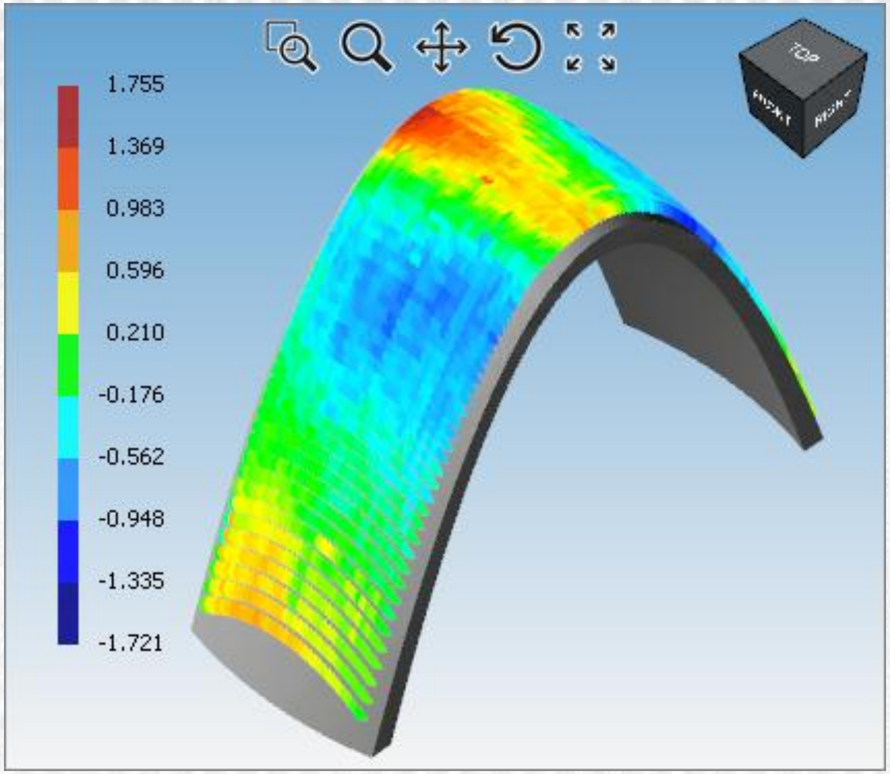

- Developing a 3D interface for freeform shapes
- CAD file importation for measurement path and data analysis
- Significantly easier for user to setup measurements and visualize data
- Dual Surface Definitions
  - CAD for visualization, measurement path planning
  - Equation for analysis and error calculation

UltraSurf 3mm x 3mm

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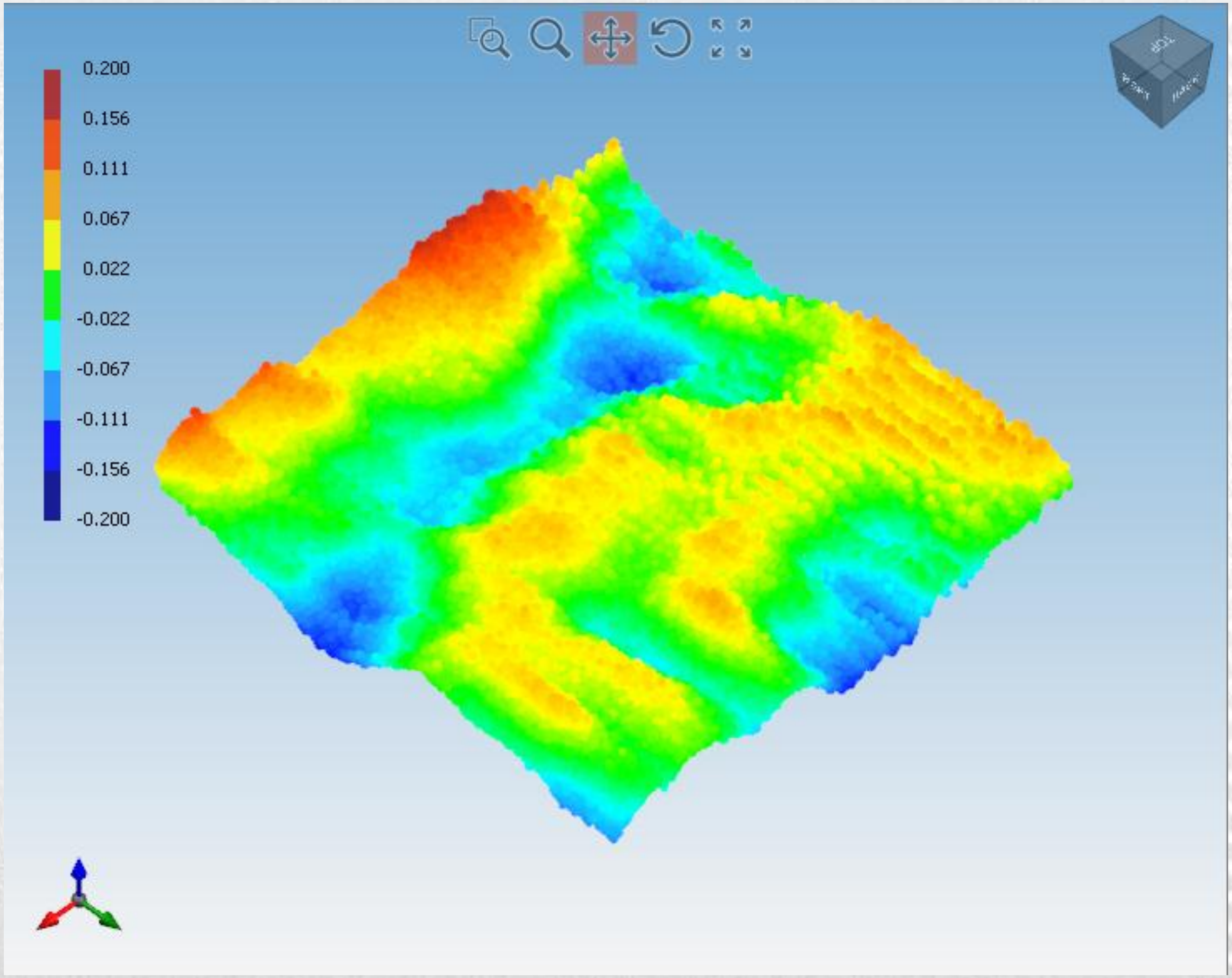
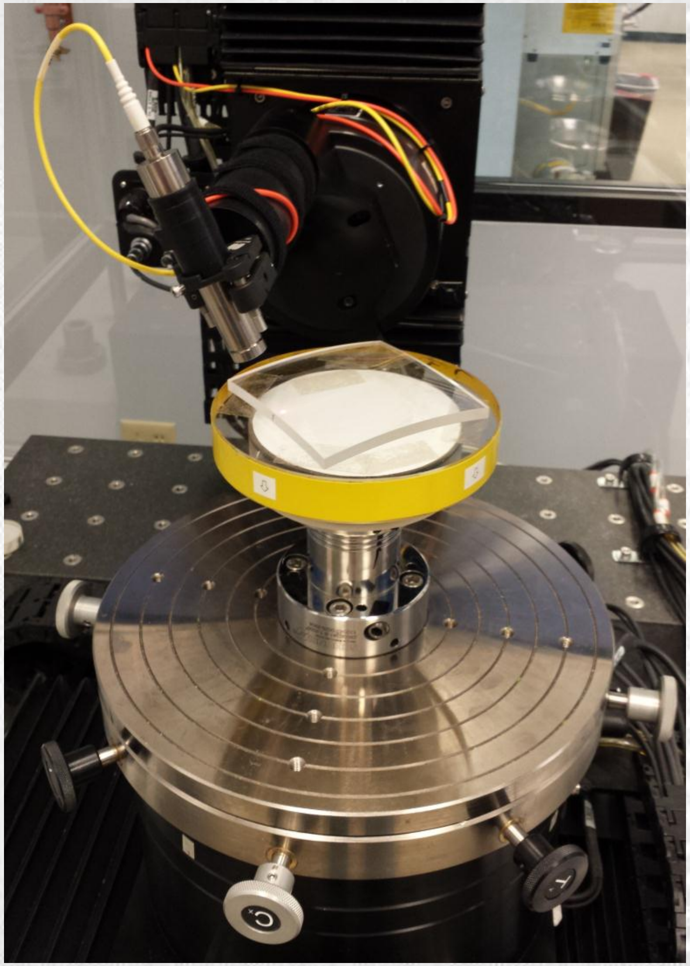
High resolution (<10 µm / point), small sub-aperture to inspect texture

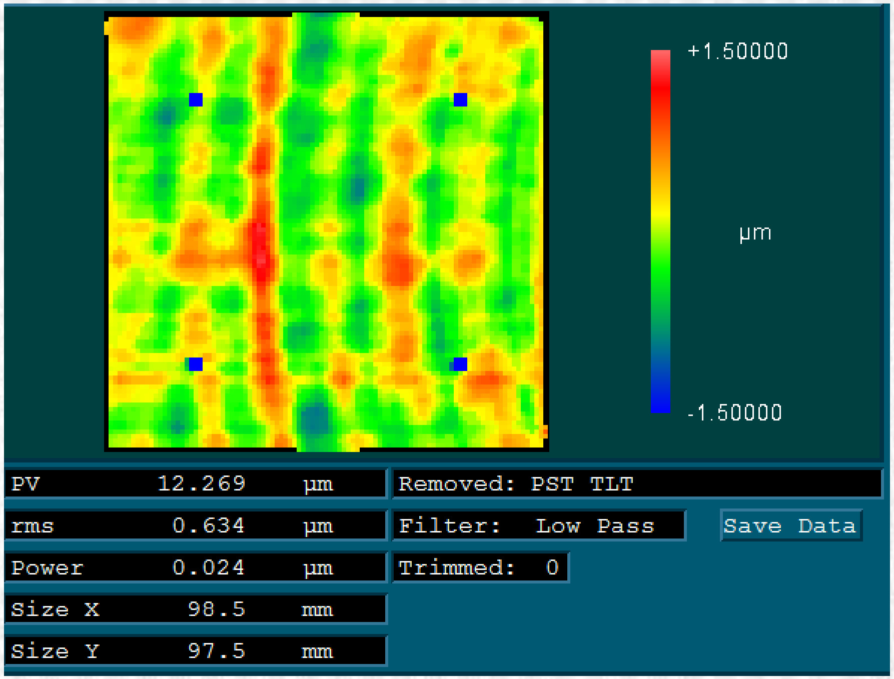


Toroid Comparison

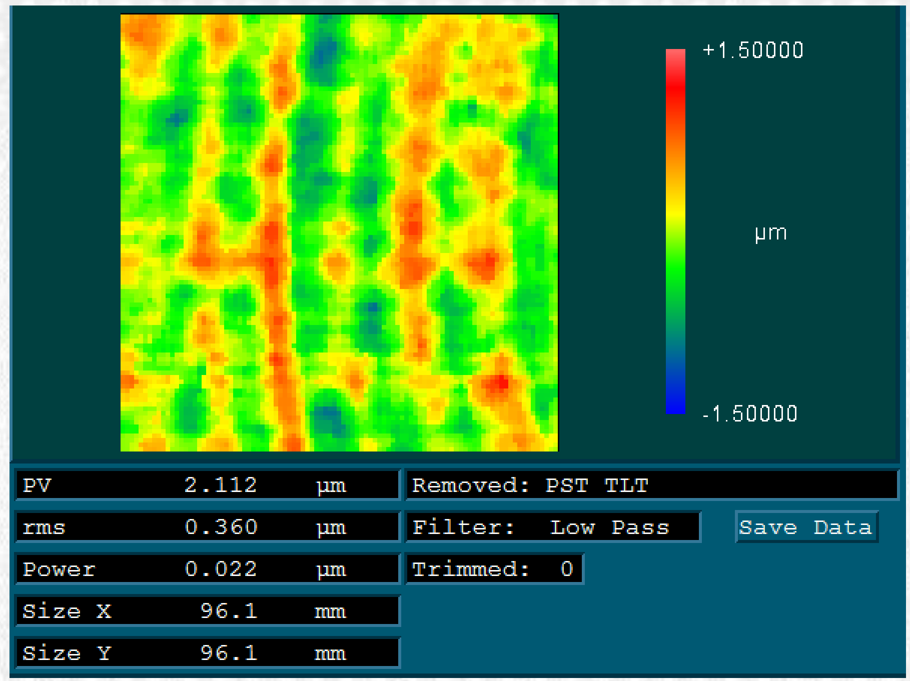


Convex Comparison

Zeiss Micura CMM



UltraSurf

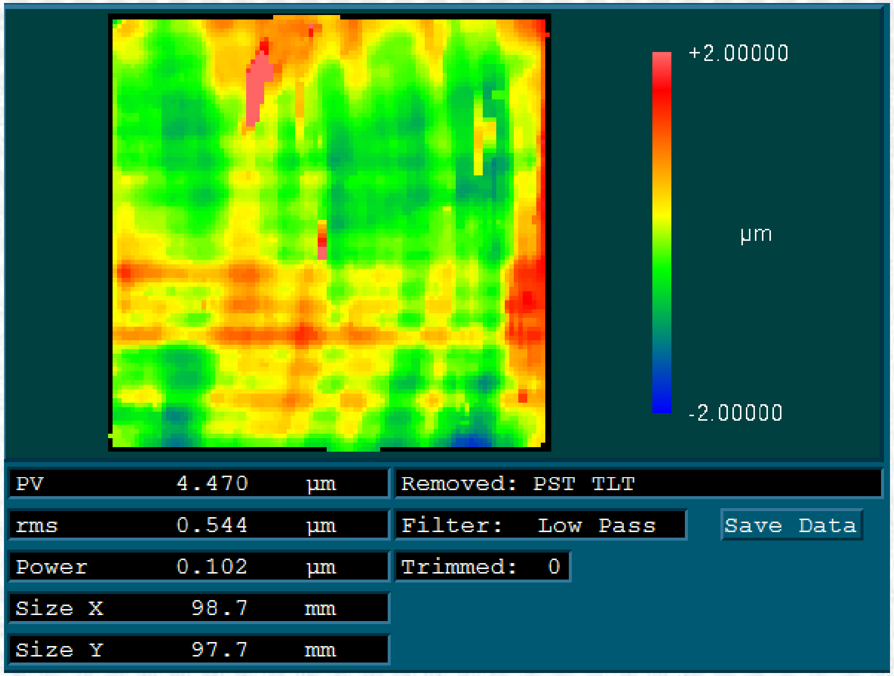


Parameter	UltraSurf	CMM	Difference
Convex R1	293.667 mm	293.679 mm	0.004 %
Convex R2	450.452 mm	450.280 mm	0.038 %

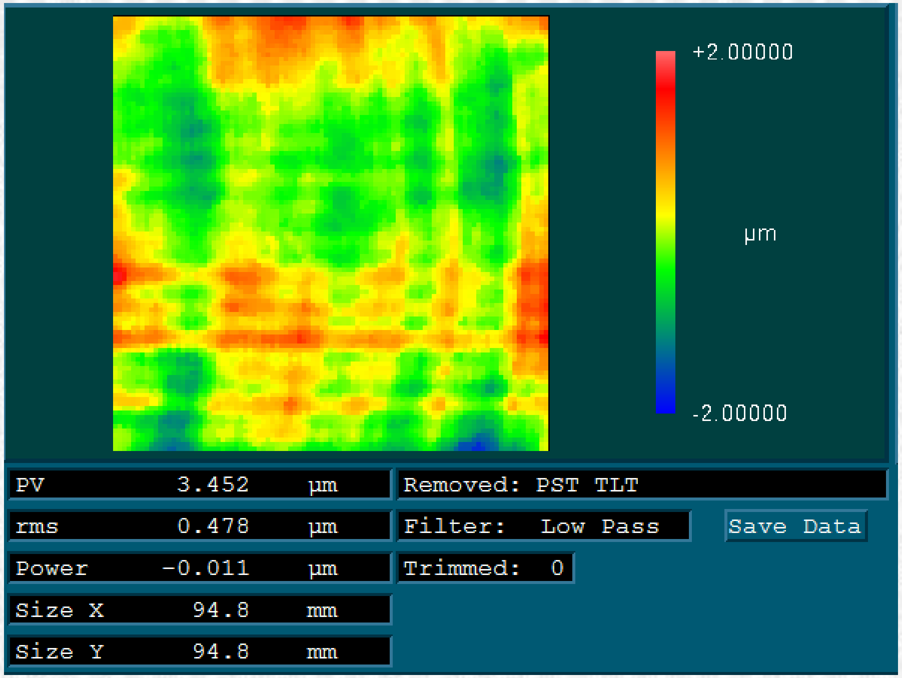
Note: 3 x 3 median filter used to reduce salt and pepper noise

Concave Comparison

Zeiss Micura CMM



UltraSurf

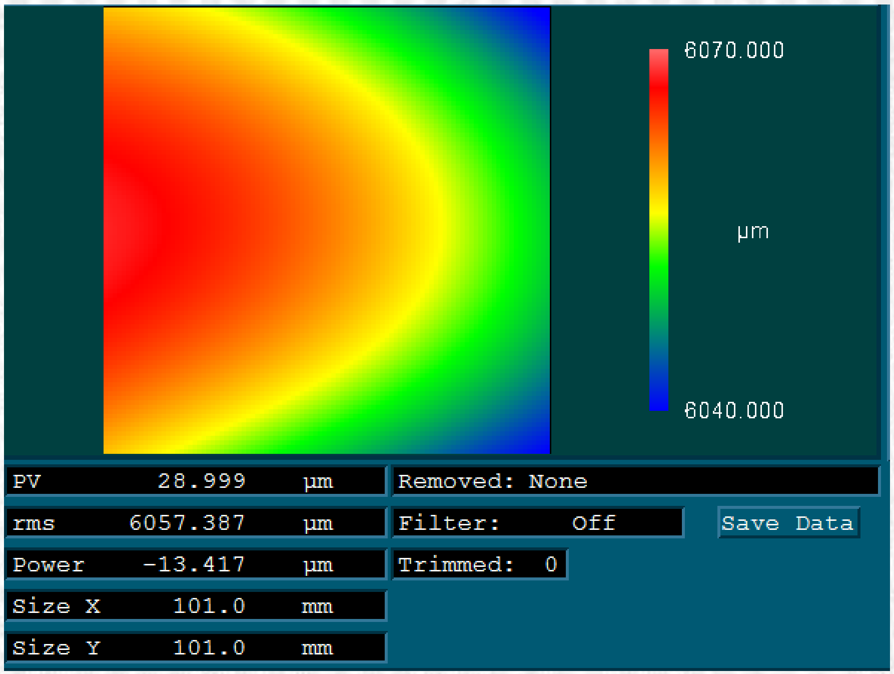


Parameter	UltraSurf	CMM	Difference
Concave R1	288.561 mm	288.582 mm	0.007 %
Concave R2	445.068 mm	444.950 mm	0.027 %

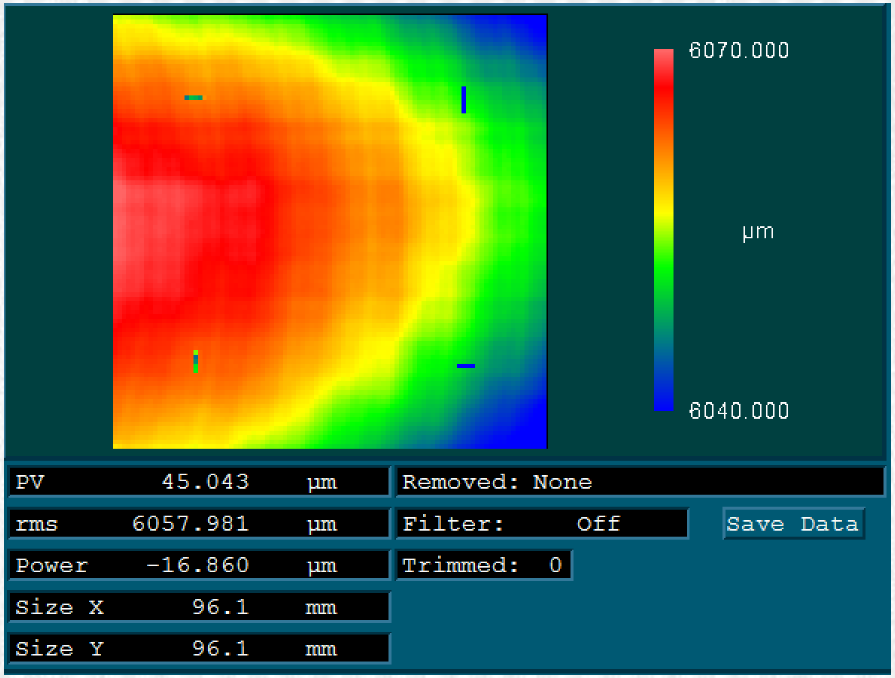
Note: 3 x 3 median filter used to reduce salt and pepper noise

Thickness Comparison

Drop gage



UltraSurf



Only 9 equally spaced points were measured with drop gage, cubic interpolation used for comparison

Summary & Conclusions

- UltraSurf is a flexible platform for optical surface metrology for NASA's requirements
- Current 3D interface is making progress, and will soon provide an easy to use interface for freeform shapes
- UltraSurf displays very good correlation with other metrology methods
- There is on-going work to qualify freeform and high-departure measurement to the sub-wave level!
- UltraSurf could be scaled to larger platform to measure parts that are larger than the current configuration

Acknowledgements

- NASA Phase I: NNX14CM21P
  - Optical Metrology of Aspheric and Freeform Mirrors
  - CTOR: Mikhail Gubarev

- NASA Phase II: NNX13CM02C
  - Optical Fabrication and Metrology of Aspheric and Freeform Mirrors
  - CTOR : W. Scott Smith and Roy Young

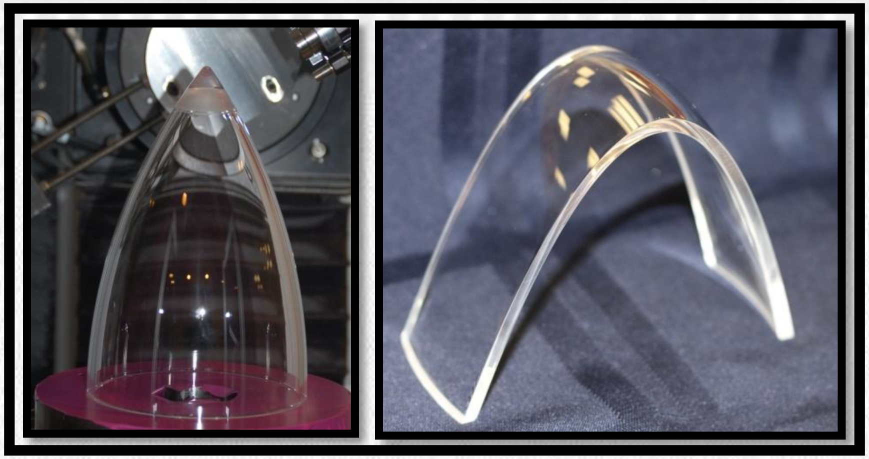
Small
Business
Innovation
Research

Optical Characterization of Complex Freeform Surfaces

OptiPro Systems, LLC
Ontario, NY

INNOVATION

The UltraForm Finishing (UFF) and the UltraSurf platforms developed by OptiPro Systems deterministically polish and measure complex aerodynamic and conformal shapes made of difficult to manufacture glass, crystal and ceramic materials.



Tangent Ogive and Bi-Aspheric Arch

ACCOMPLISHMENTS

- 2008 OSA – Paul Forman “Excellence in Engineering Award” for first affordable Computer Controlled Optical Machining Center.
- Optical fabrication companies and prime contractor suppliers are embracing the new technology to cost effectively manufacture axisymmetric domes and optics for newly designed defense systems.
- The integration of the UFF (CNC controlled finishing platform) and the UltraSurf (Automated non-contact measurement device) provides a deterministic fabrication solution for a wide range of newly developed windows , domes and mirrors.

COMMERCIALIZATION

- UltraForm Finishing (UFF) : Asphere, Axisymmetric Dome , Freeform Polisher
  - Private Sector installations at Universities, Material manufacturers and Precision optical component manufacturers
  - US Patent No. 7,662,024 B2 : “Method and Apparatus for precision polishing of Optical Components”
- UltraSurf : Non-Contact Asphere, Axisymmetric Dome measurement platform
  - Private Sector Asphere and Dome Measurement System for production
- Optical fabrication and measurement of spherical domes, aspheres, parabolic mirrors, torics and conformal/freeform shapes is OptiPro’s primary market.
- Private sector investment into the UFF and UltraSurf platforms has been through Beta site partners and production level machine purchases.
- OptiPro Systems, LLC has alliances with material manufacturing firms who require new manufacturing techniques to test and enhance their prototype components and determine the pathway to production level quantities

GOVERNMENT/SCIENCE APPLICATIONS

- NASA Contract Numbers: NNX14CM21P, NNX14CM23P, NNX13CM02C
- DOD Contract Numbers W31P4Q-05-C-R048 and W31P4Q-04-C-R101 awarded by the Defense Advanced Research Projects agency (DARPA); and Contract Numbers N41756-05-M-1390, N68936-06-C-0010, N68936-12-C-106, N68936-12-C-0089, N68936-12-C-0094 and N68936-09-C-0079 awarded by the Navy Engineering Logistics Office and NAVAIR.
- Toric , Acylinder and other freeform geometric shapes made from Si and SiC.
- Materials Include : Spinel, ALON™, CeraLumina™ , Si, SiC, ceramics & standard optical glasses

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