Mirror Tech Days 2007

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Status and Full-Aperture Measurements of a Convex Asphere from the Four-Point Optical Profilometer

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Topics

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- System overview
  - Overall architecture (hexapod)
  - Metrology
    - Full-aperture, or low frequency (operational)
    - Smoothness, or mid frequency (under development)
    - Micro-roughness, or high freq (under development)
  - Polishing
- Capabilities
- Assembly and first-light test results
  - Full-aperture metrology
  - Polishing removal profile
- Future plans

Overall architecture: An integrated, in situ approach

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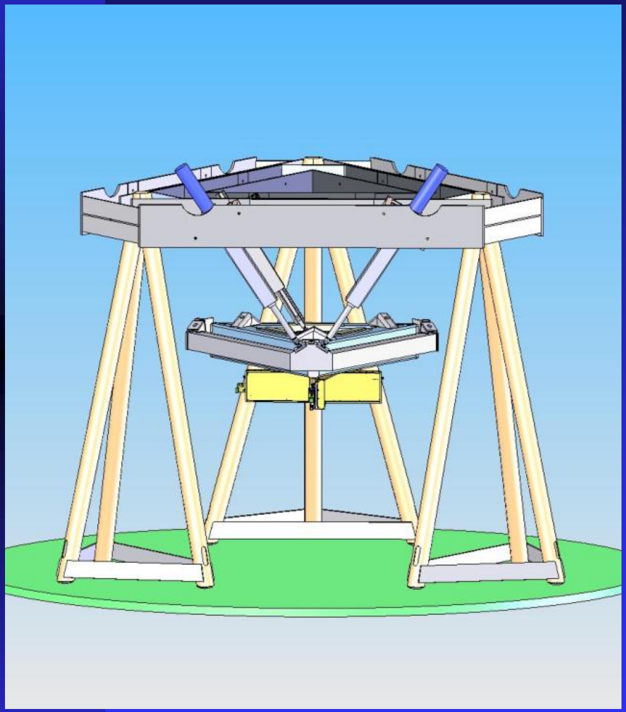

- A hexapod structure moves a “platter” in all degrees of freedom over the substrate
- The platter integrates *all* metrology and polishing functions

Low frequency metrology: The 3 basic principles of 4-point profilometry…

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- If a rotating platter axis intersects the optic center of curvature, then a probe on the platter nominally sees no change in standoff (convex or concave substrate!)
- If four or more probes are on a platter, then there is *some* linear combination of their readings that
  - (1) is insensitive to *all* rigid body motions
  - (2) tells *something* about the shape of the test piece

  A continuous measurement of this linear combination as the platter rotates yields a circular "hoop" profile
- If one measures multiple "hoops" around a test piece, with each overlapping at least two others, then it is possible to "stitch" the profiles to obtain the total surface height map.

3 principles of 4-point profilometry…

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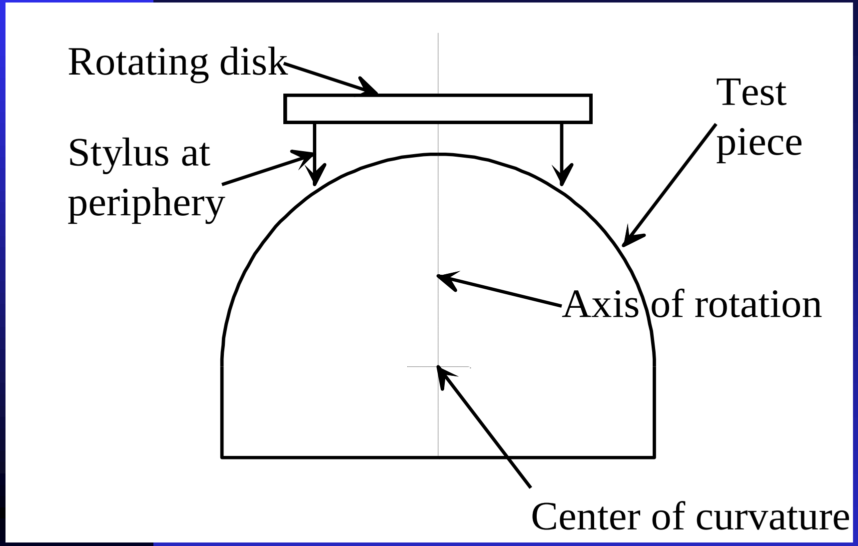
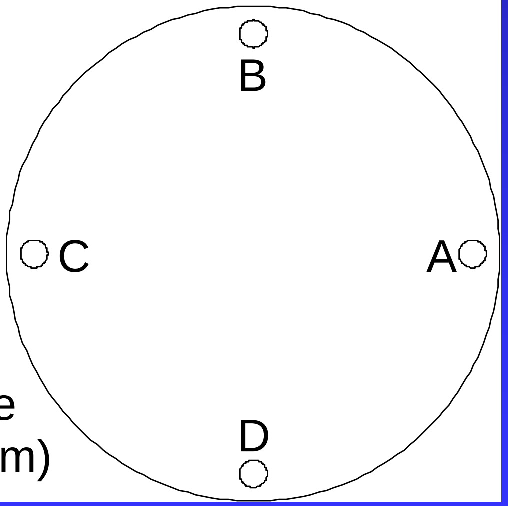
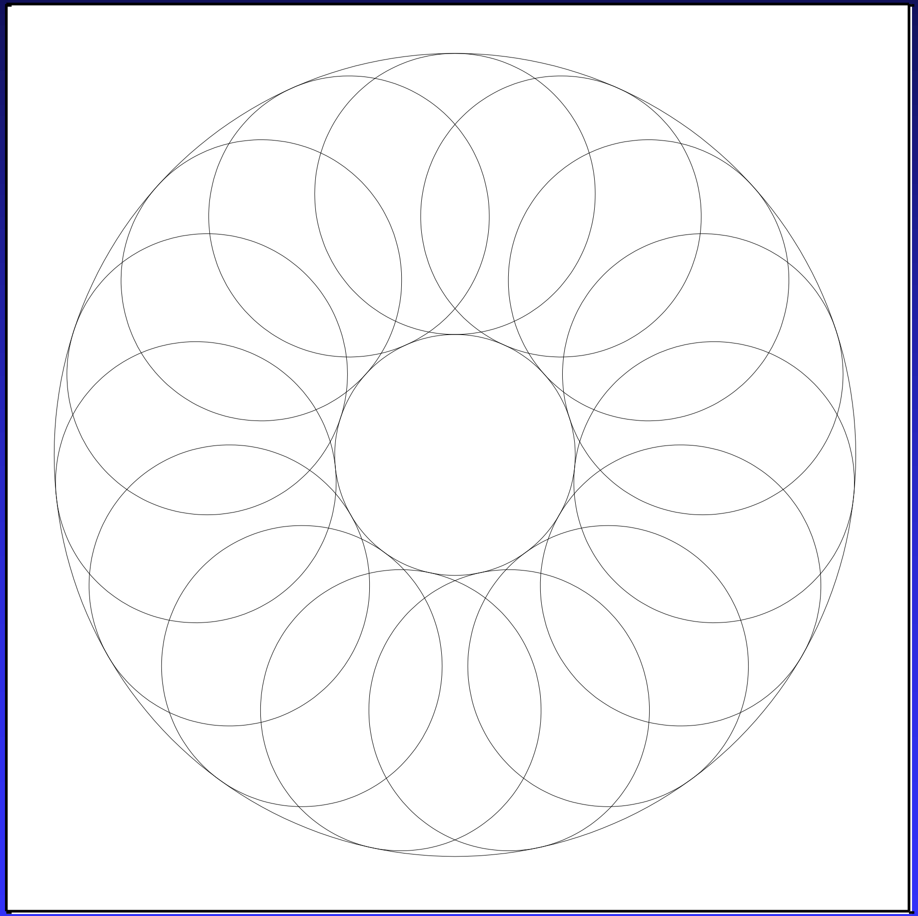


Trivial example:
Sum=A-B+C-D
Piston invariant
X-tilt invariant
(A incr, C decr)
Y-tilt invariant
(B incr, D decr)
Sees some shape
(e.g., astigmatism)





Summary of advantages

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- Does not work from center of curvature, thus not requiring a massive test tower
- Equally able to test concave and convex optics
- Completely self referencing
- Insensitive to rigid body motions of the test piece during measurements
- (Specially developed laser gauge probes provide absolutely reliable scale factor and mm-class range)
- By replacing the laser gauge probes with coarse probes (touch probes or non-contact alternatives), the instrument can measure optics in their ground state. Thus, one metrology instrument can take an optic from generation through final polish.

Mid frequency metrology (to be implemented)

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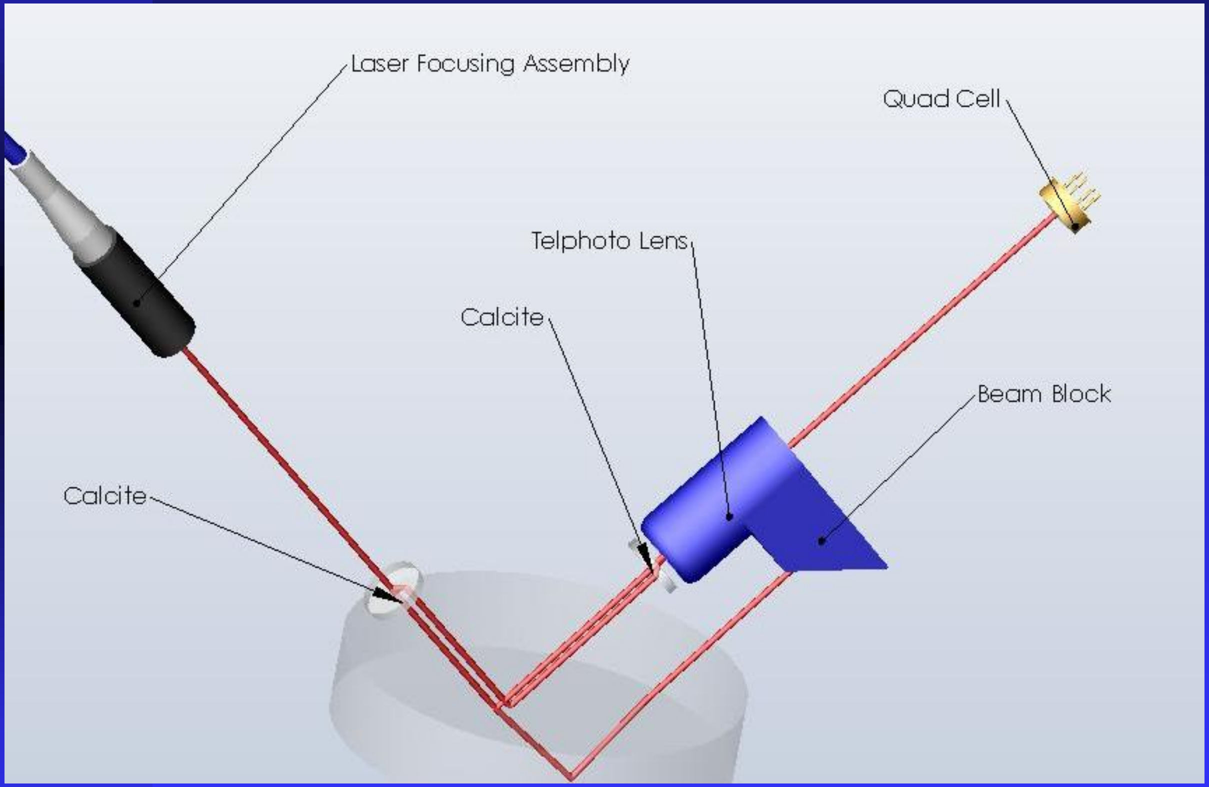

- Optical measurement of curvature profile, based on Bauer's Model 100 Profilometer
- Probe is placed on same "probe circle" as the 4-point sensor probes
- Accuracy ~ 1-2 Angstroms over 25 mm

High frequency metrology (to be implemented)

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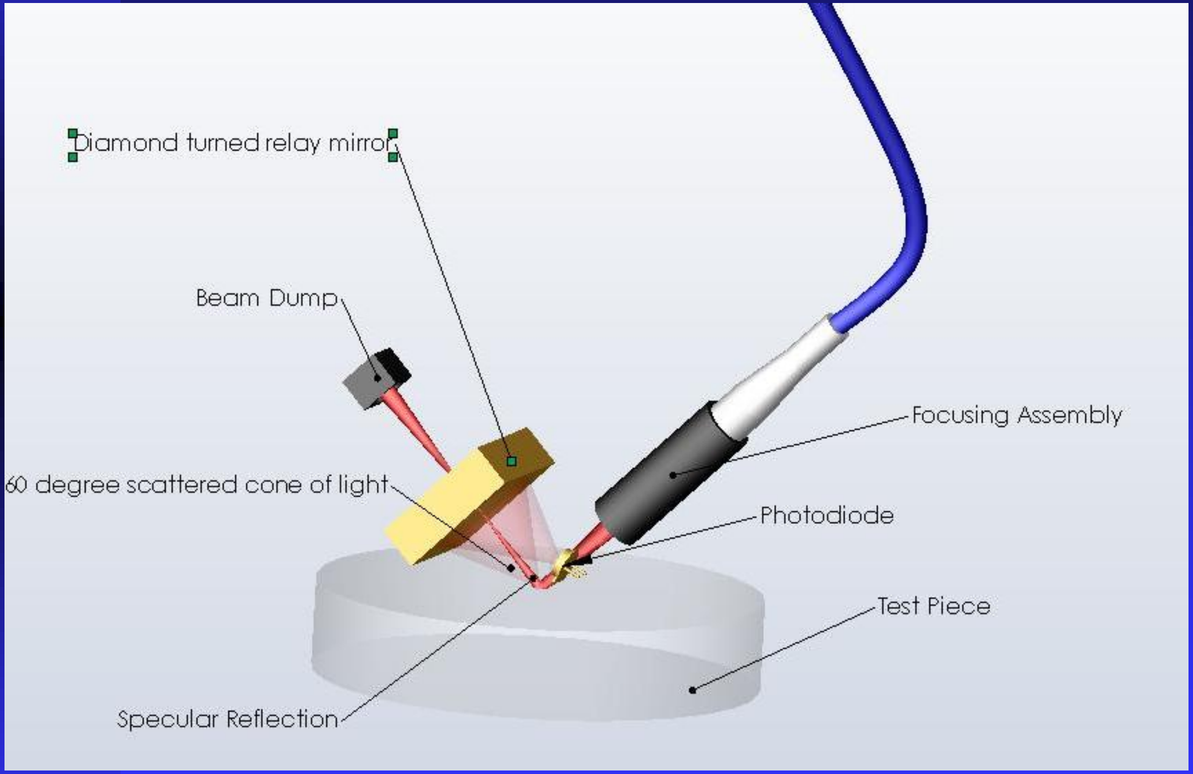

- Micro-roughness is characterized with Total Integrated Scatter (TIS)
- Probe is placed on the same "probe circle" as the others
- Sensitivity ~ 1 Angstrom

Polishing

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- Top: Inside of lid
- Bottom: Outside of lid (guard removed)

- Baseline approach is Fluid Jet Polishing (FJP)
- FJP apparatus is incorporated on a bottom “lid” under the platter, thereby using the *same* hexapod infrastructure as the metrology
- This is key to our integrated, in situ approach

Capabilities

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- Maximum diameter of mirror with mount: 2.0 meters
- Range of testable "speeds": f-0.7 concave to f-0.7 convex
- Maximum testable diameter:
  - 1.3 meters over full f-0.7 range
  - 1.5 meters for much slower "speeds"
- Testing time: ~1 minute per "hoop" (50-200 hoops typical)

Predicted ultimate performance

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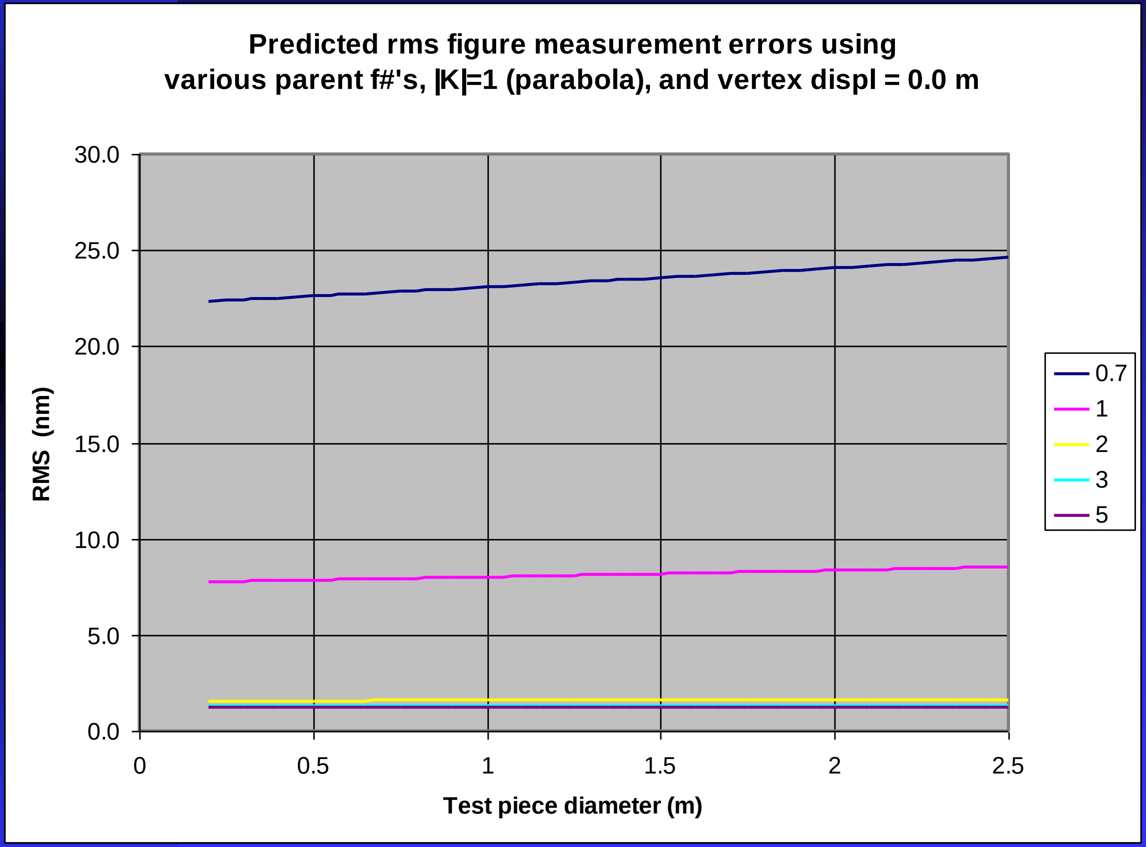

- Assumptions:
  - K=-1 (parabola)
  - On-axis
- F-numbers examined:
  - F-5 to F-0.7
- Diameters examined:
  - Zero to 2.5 meters
  - Current machine is 1.3 meters

Assembly…

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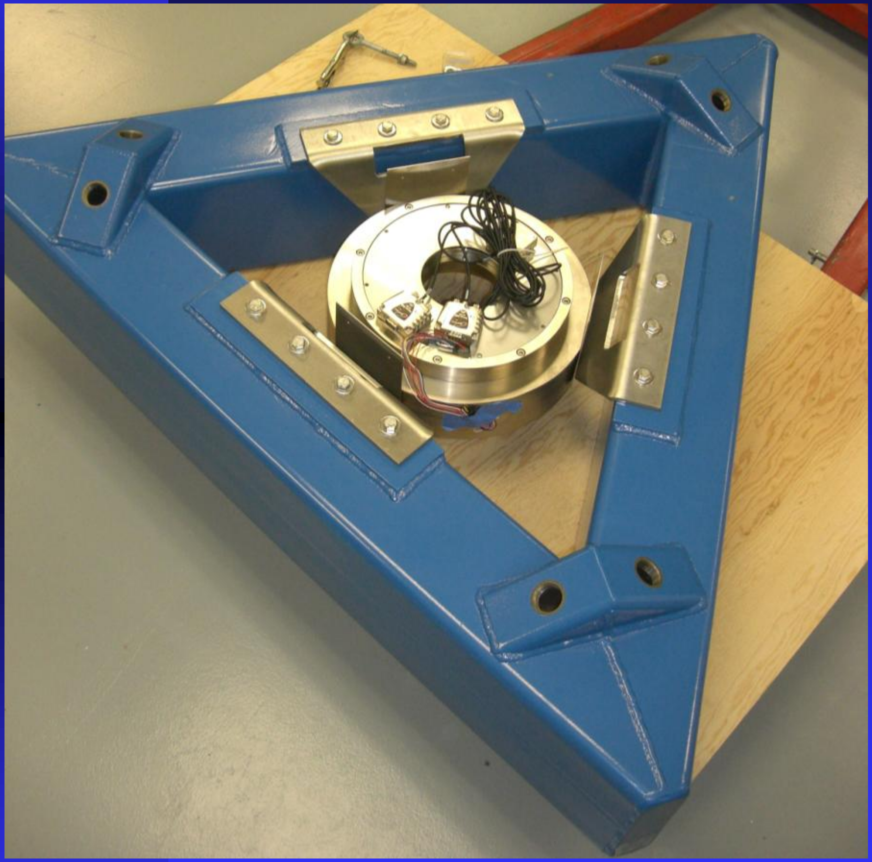

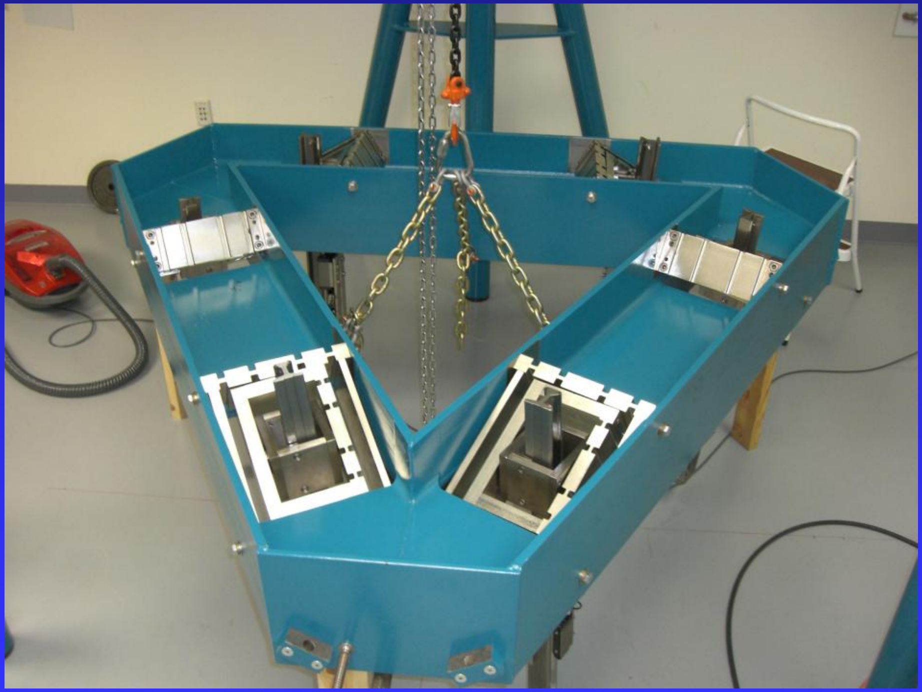

Assembly…

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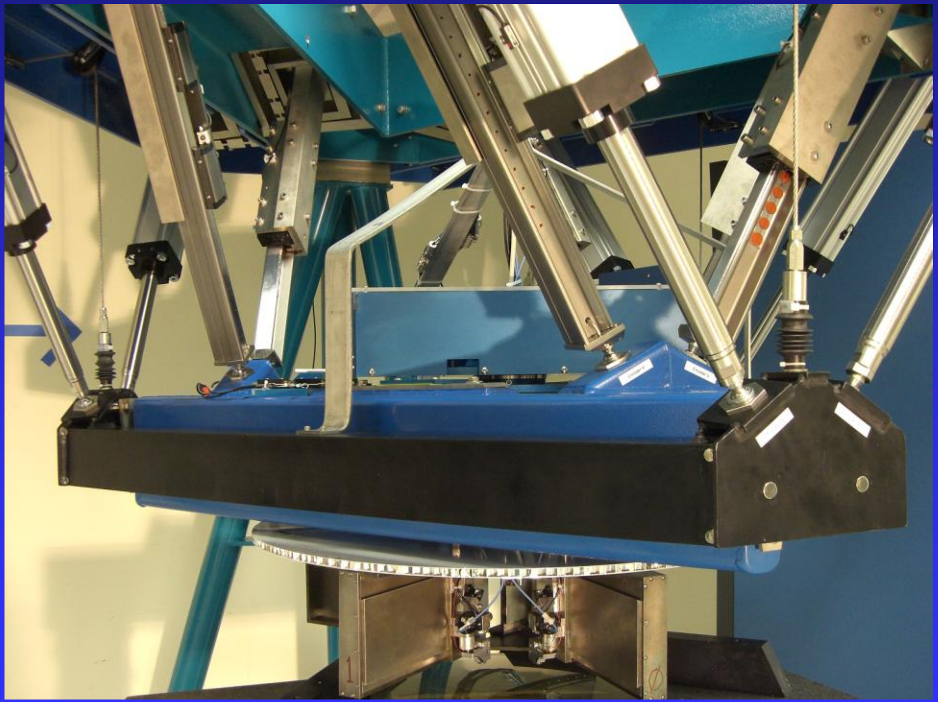

First-light test article

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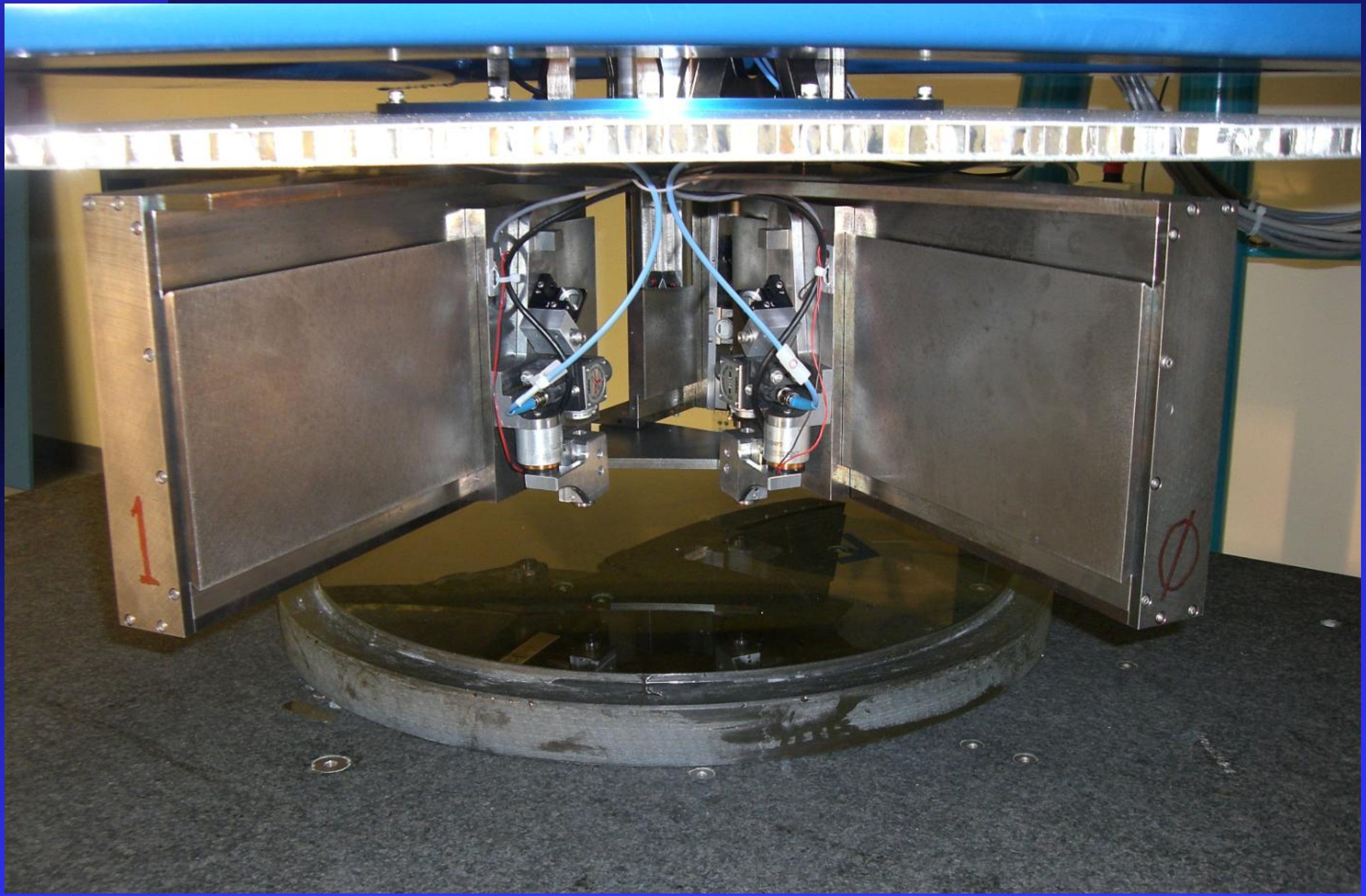

- Convex
- Uncoated
- f-2.3
- 43-cm diameter
- *Many* isolated surface defects

Scanning demonstration

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First-light results

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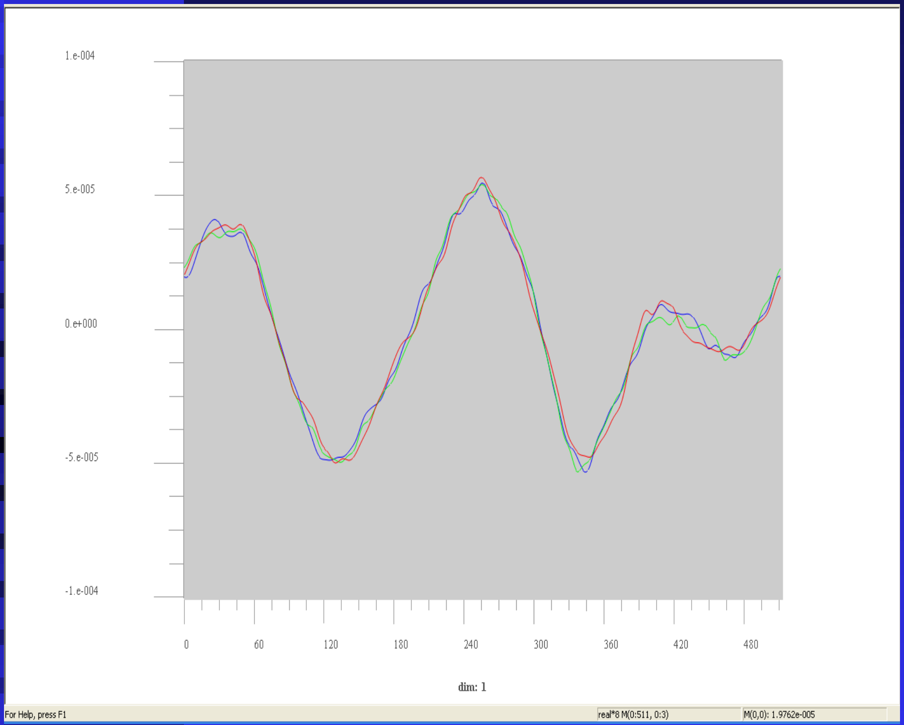

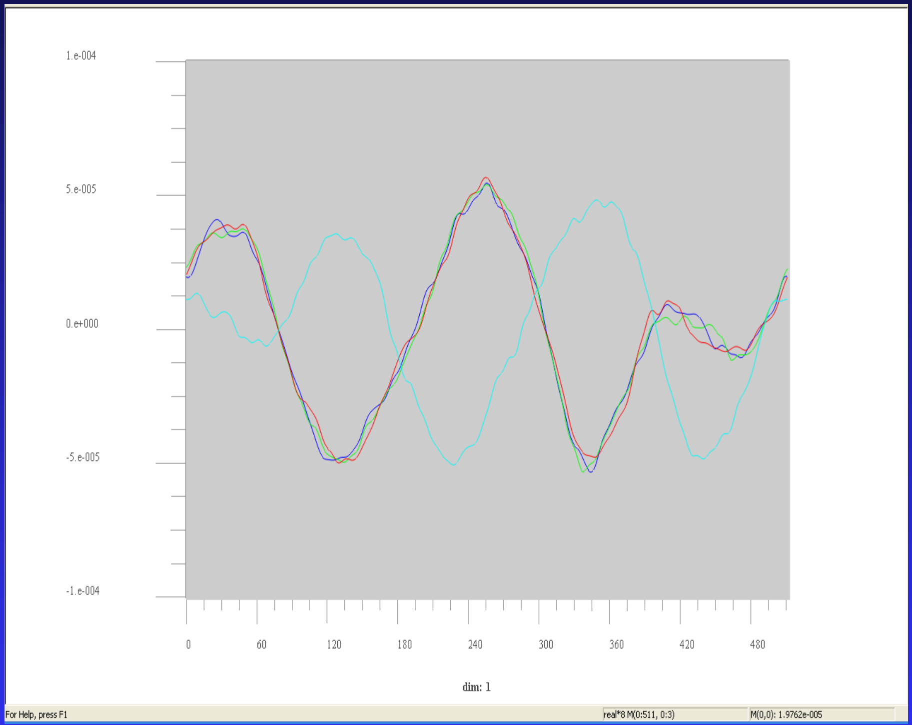

- Three independent, centered hoops to show repeatability (~1.6 nm rms) (note the 3 humps, ~0.1 micron – they agree well with FEA of self weight)
- Superposition of fourth hoop, taken after *rotating* test piece by 68.2 degrees

First-light results

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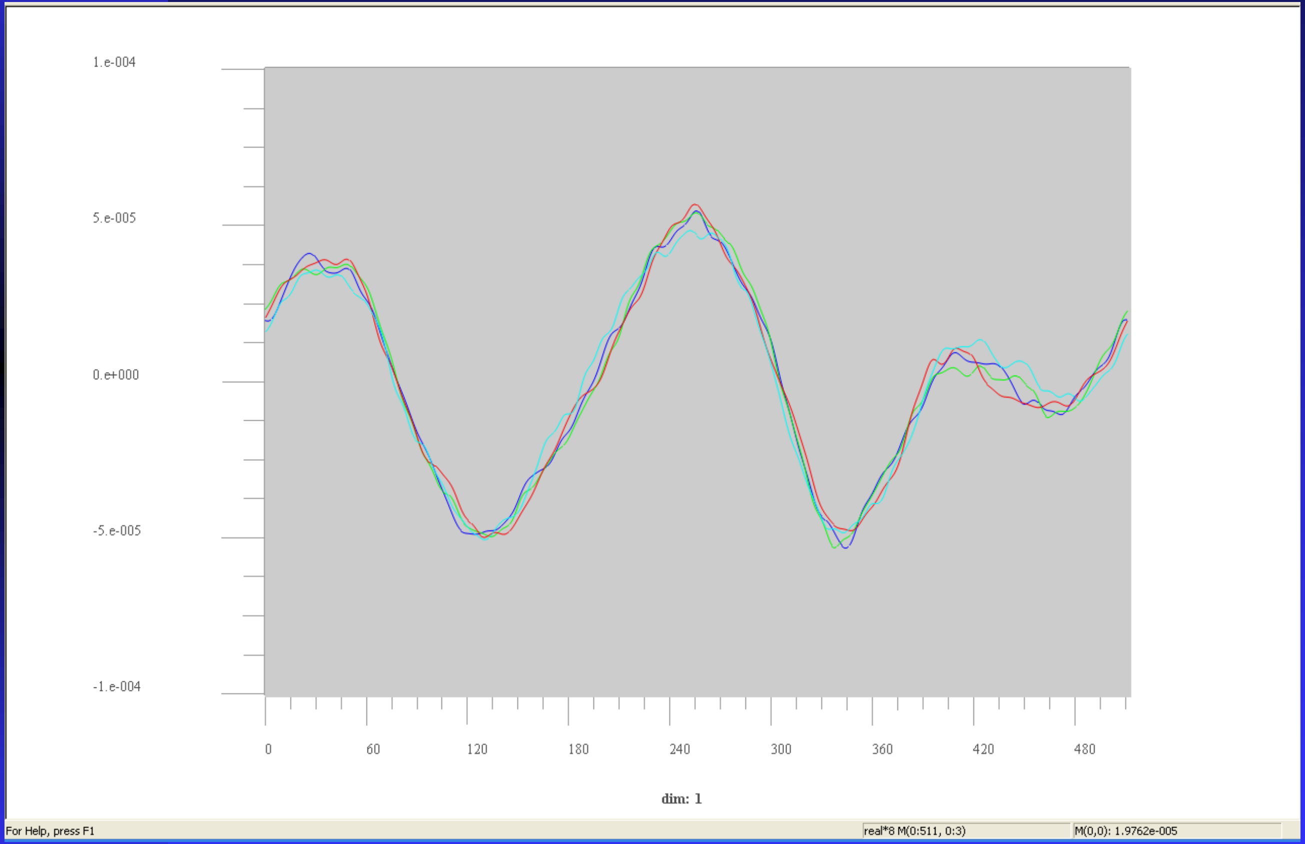

- Result of telling *software* to *derotate* fourth scan by 68.2 degrees
- Repeatability essentially unaffected

First-light results

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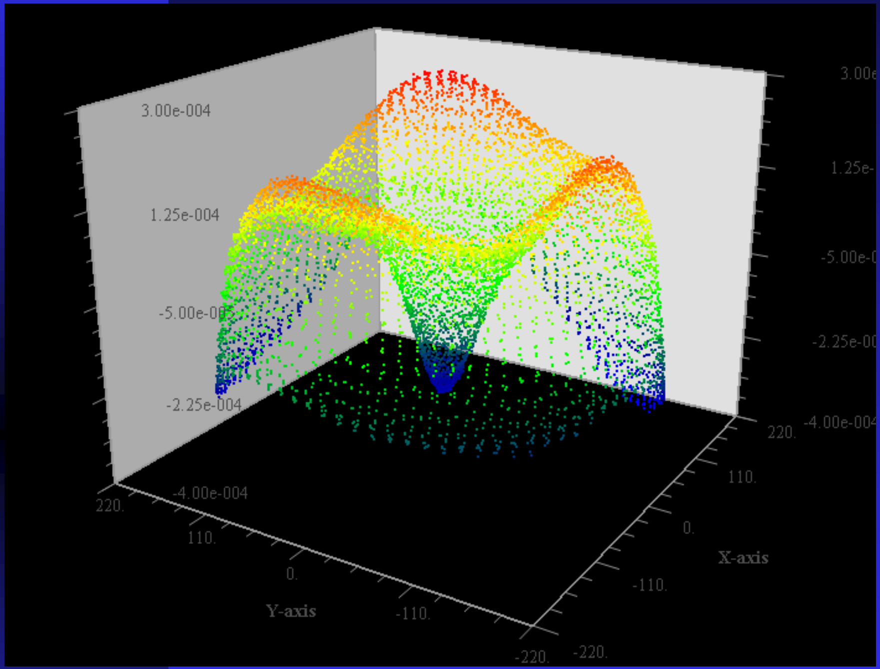

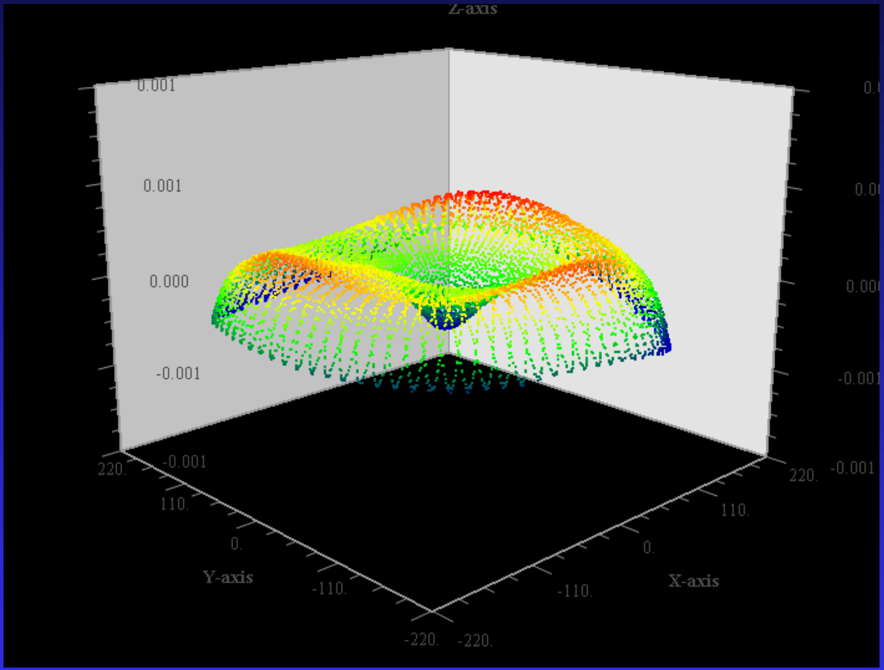

- Full-surface scan (200 hoops stitched together)
- Pointillated views of the discrete hoop data points
- Plots differ only in vertical scale
- Note the three humps from self-weight deflection

First-light results

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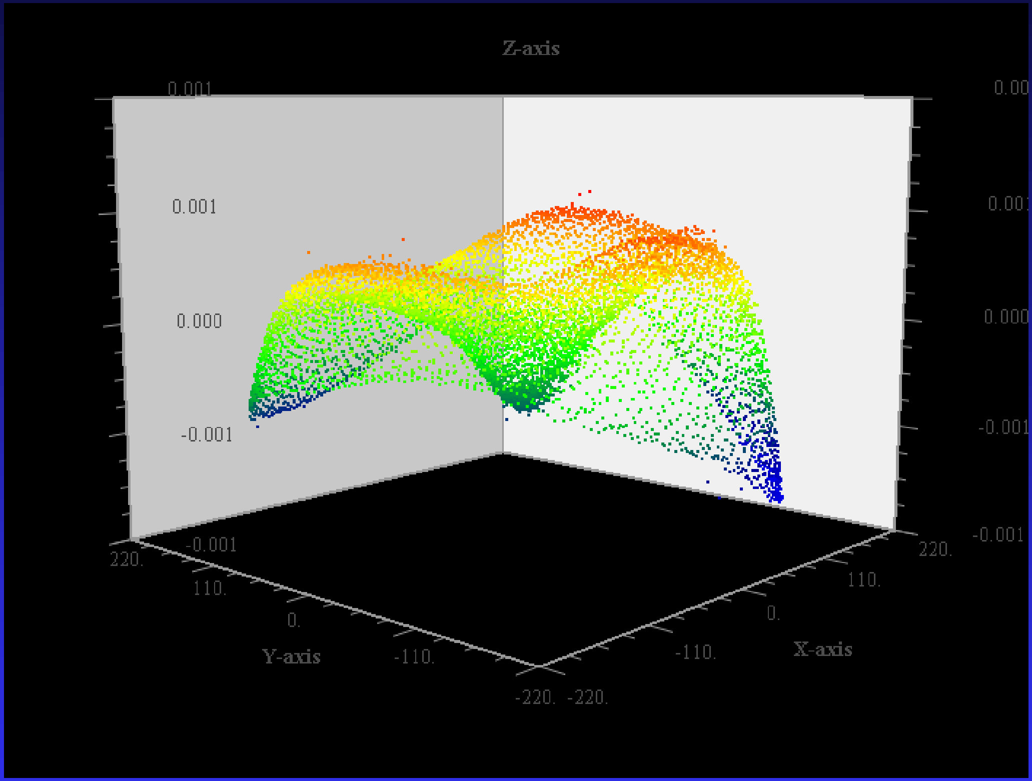

- Another 200-hoop scan of the same piece, tipped by 3 degrees to demonstrate that the gravity direction does not induce a systematic measurement error

First-light results

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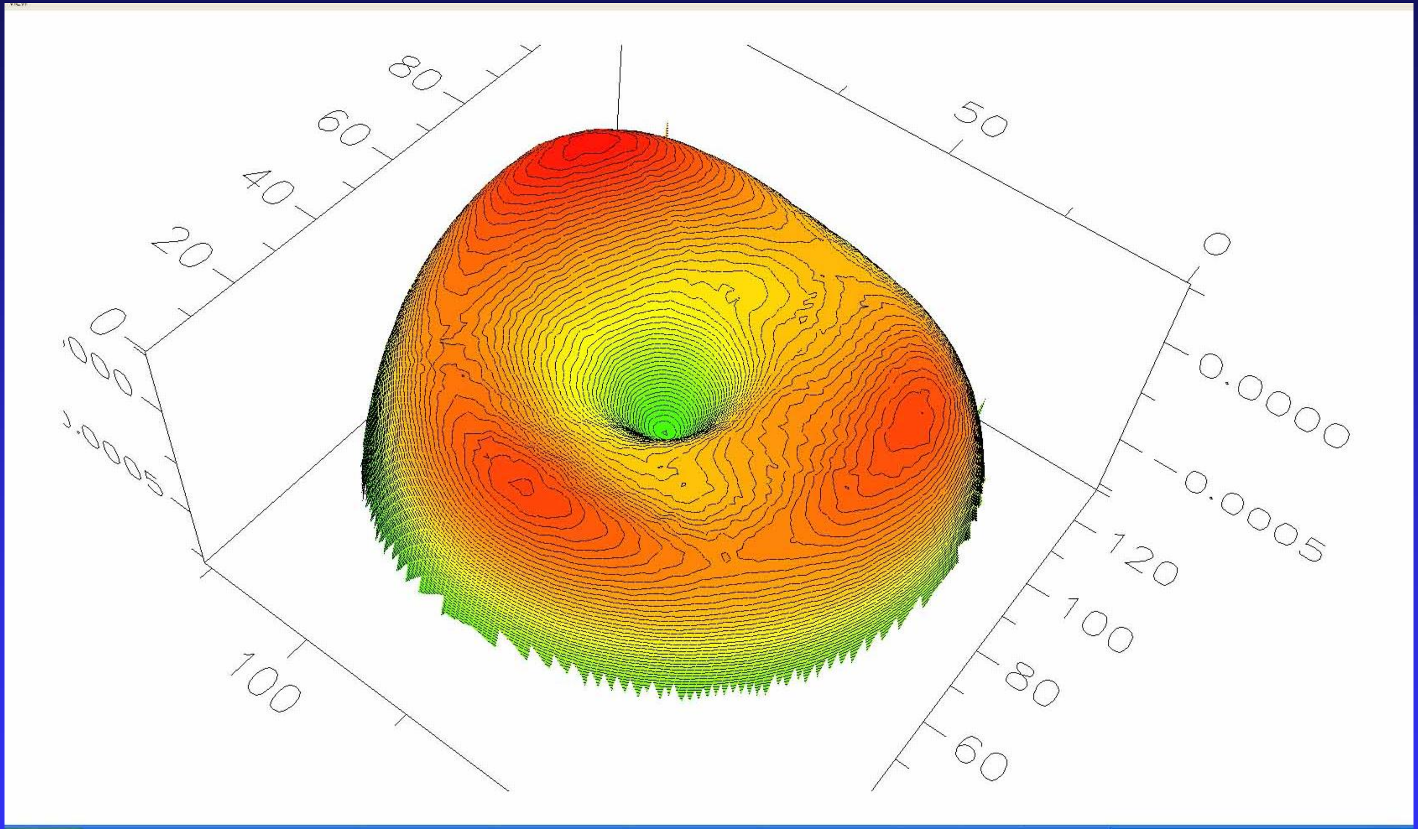

- Demonstration of the software's ability to interpolate the stitched data onto a rectangular grid

Polishing wear profile

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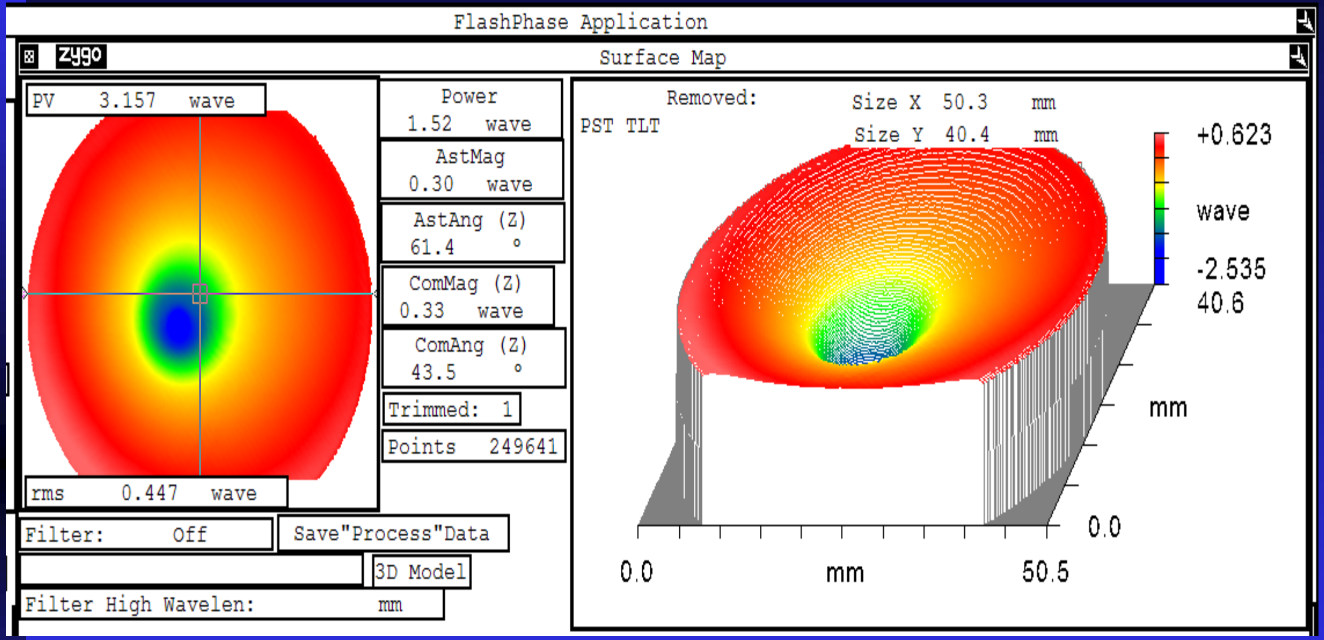

- The first Fluid Jet Polishing (FJP) trials gave a very smooth, symmetric, Gaussian-like wear profile
- Full-width half max (FWHM) of 6 mm closely matched the jet size, which is easily variable
- There was no noticeable increase in roughness after three waves of removal
- Process parameters need optimizing, but this first result shows promise

Future plans

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- Continue validation analyses on current test article
- Obtain and test a larger convex test article, with a pedigree, for comparison
- Implement mid frequency / high frequency metrology head
- Continue polishing implementation