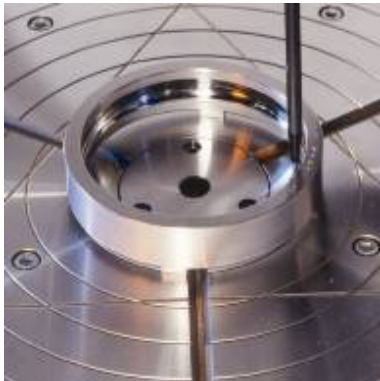


4589

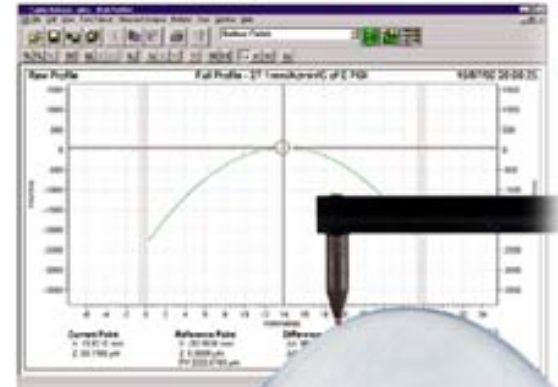
Production Metrology for Steep-sided Aspheric Optics

Presented by
Mark Middleton

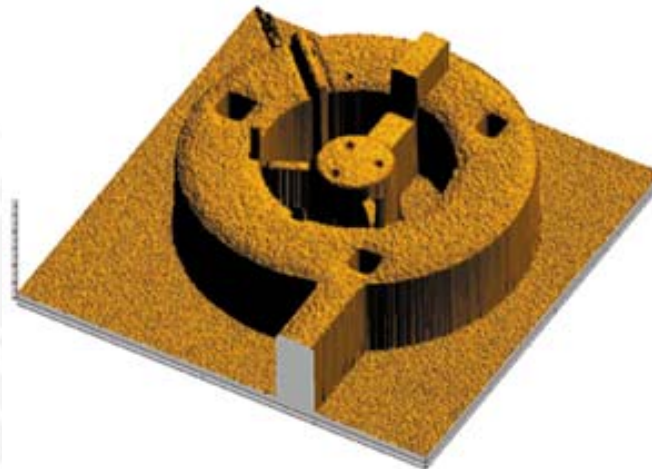
- Manufacturers of world-leading surface measurement solutions



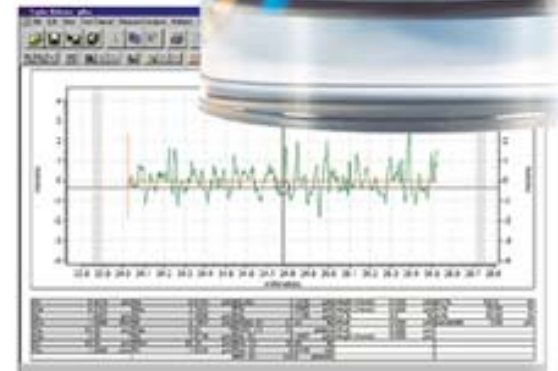
\$80M turnover
\$6M R&D
320 employees



Roundness
Measurement
resolution (1.2nm)



Non-contact 3D Profiling
resolution (0.01nm)



Surface and Form
Measurement
resolution (0.2nm)

Innovative metrology for demanding applications

4589



Talyrond 395
Automatic Roundness
and Cylindricity



Talysurf CCI 'shop floor'
Ruggedised Non-Contact 3D
Flatness & Roughness

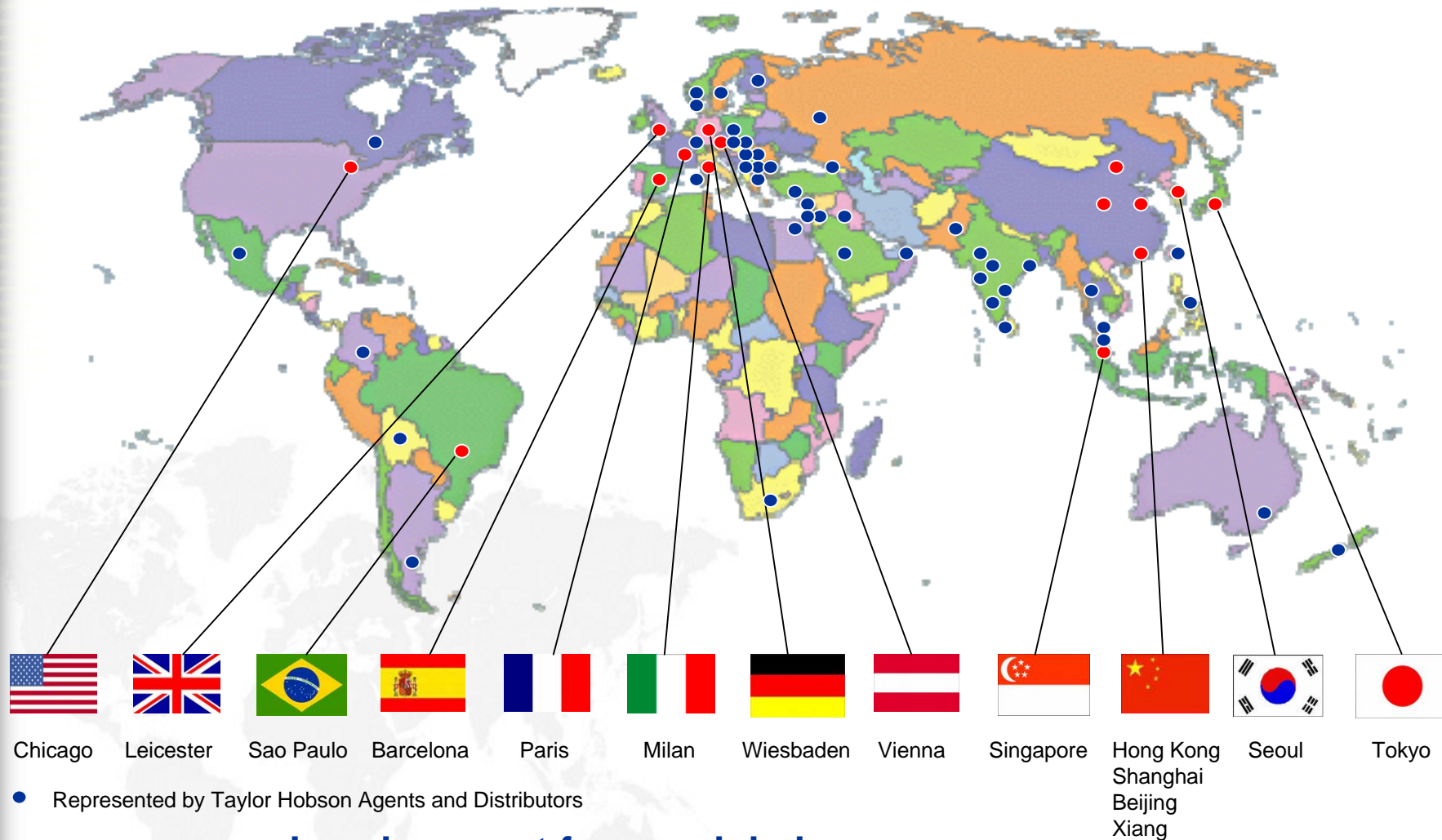


Talysurf PGI 1250
Form and Surface
Roughness

100+ years of innovation

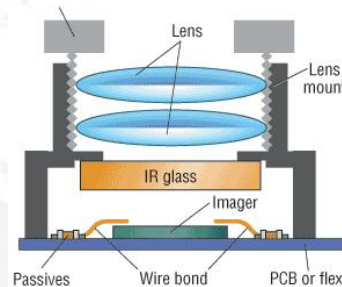
Founded 1886 in Leicester, England

4589

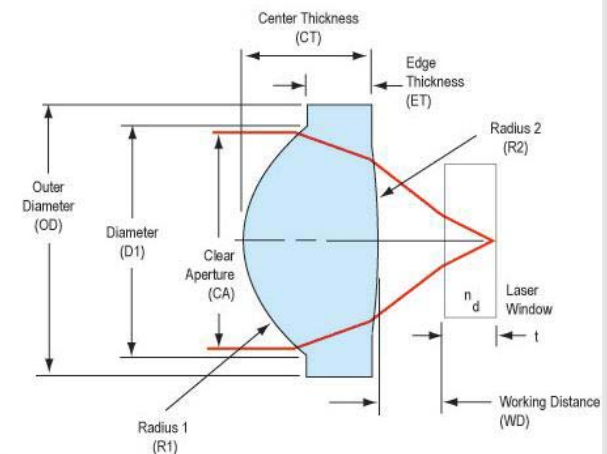


Local support from a global company

- Vast amount of markets and applications
 - Sub-mm wafer-optics \Rightarrow large area military IR lenses
- Focus on high growth production applications such as:
 - Cellphone and Digital Camera lenses
 - CD / DVD / Blu-ray lenses
 - LED lenses (for domestic / automotive applications)
 - High power laser optics



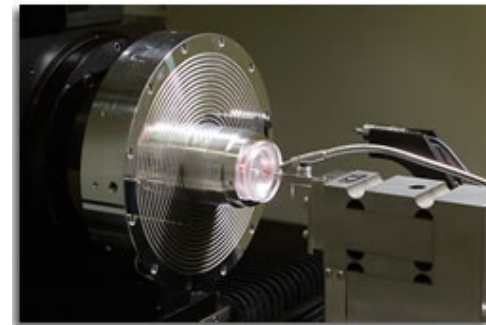
- Strong migration from Spherical to Aspheric designs
 - Improvement in Performance (minimises aberrations)
 - Reduction in size and weight (fewer components)
 - Potential to reduce cost
 - Enhancement in design flexibility
 - Exotic designs can produce 2 or more focal spots (eg DVD lenses)
- Aspheric designs are becoming more extreme
 - Higher spherical departure
 - Steeper sloping edges (**NA > 0.85**)
- More difficult to accurately measure



- Methods of Production Include
 - Diamond Turning
 - Moulding
 - Grinding
 - Polishing - Pad polish / MRF (Magnetorheological Fluid)

} Preferred Method for Bulk Production

- Diamond Turning (making mould)
 - Sub 10 minute cycle time
 - Form accuracy around +/-100nm (Pt)
 - Primary error causes include
 - Tool radius and form errors
 - X and Y offset error



- Injection Moulding (making lens)
 - Primary error causes
 - Differential cooling
 - Material shrinkage



- **Need metrology that can measure mould AND lens**

Essential Metrology Requirements

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- Measurement Capability
 - High aspheric departures and steep slopes
 - Slope angles > **80 degrees**
 - Accuracy and Repeatability
 - Form measurement better than **$\lambda/10$** (Pt < 50nm)
 - Accuracy maintained even at high NA
 - 3D measurement for surface astigmatism
- Key Production Demands
 - Reliable and robust operation
 - Downtime is expensive
 - Ease of use
 - Programming and operation
 - Automation
 - Single click operation is needed
 - Automatic corrective feedback to machine tool
 - High throughput
 - Complete cycle times better than 5 minutes

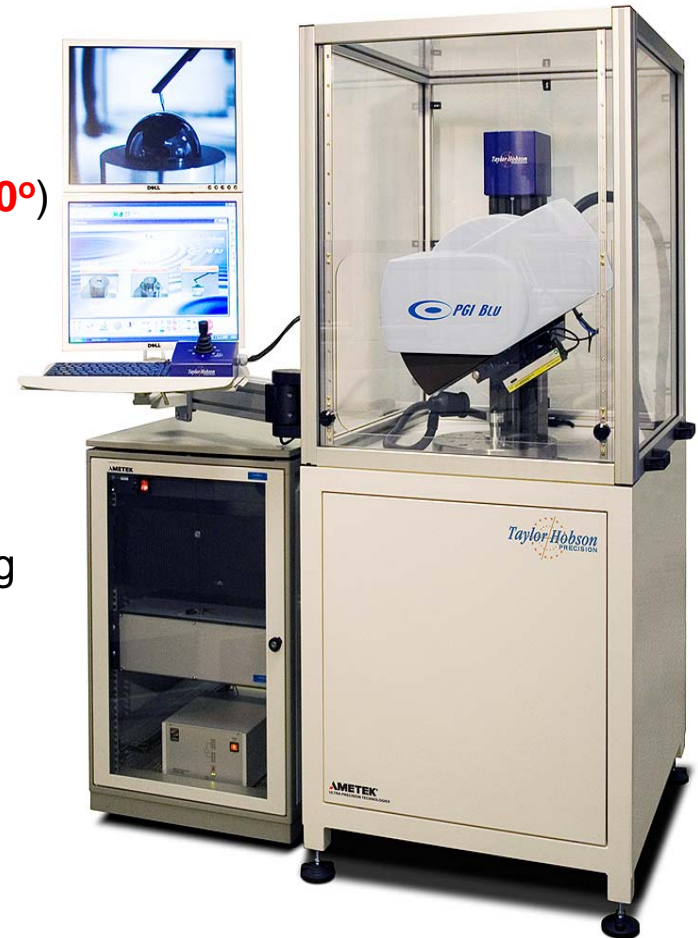


Form Talysurf PGI 1250A

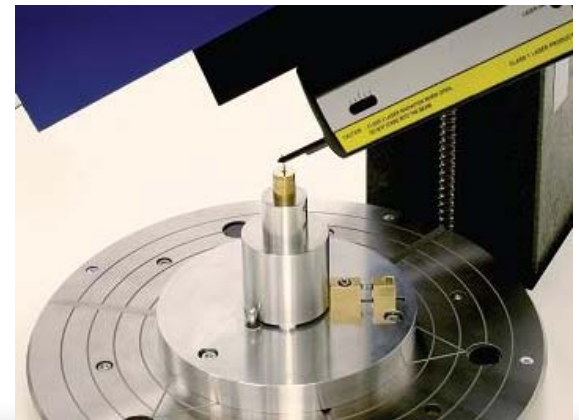


- Key Features

- Measurement Capability
 - Form measurement $P_t < 50\text{nm}$ ($\lambda_s = 25\mu\text{m}$)
 - No loss of accuracy at high NA (**slopes $> 80^\circ$**)
 - High gauge resolution (**0.2nm**)
 - Indication of surface texture
- Measurement Options
 - 2D or 3D (astigmatic) analysis
 - Diffractive analysis
 - Full suite of TH aspherics analysis, including
 - SAG table generation
 - Derived coefficients
 - Base radius optimisation
 - etc
- Fully automated (with new Production Interface)
 - **Seamless measurement and analysis**
 - Transparent profile fusion and 3D interpolation

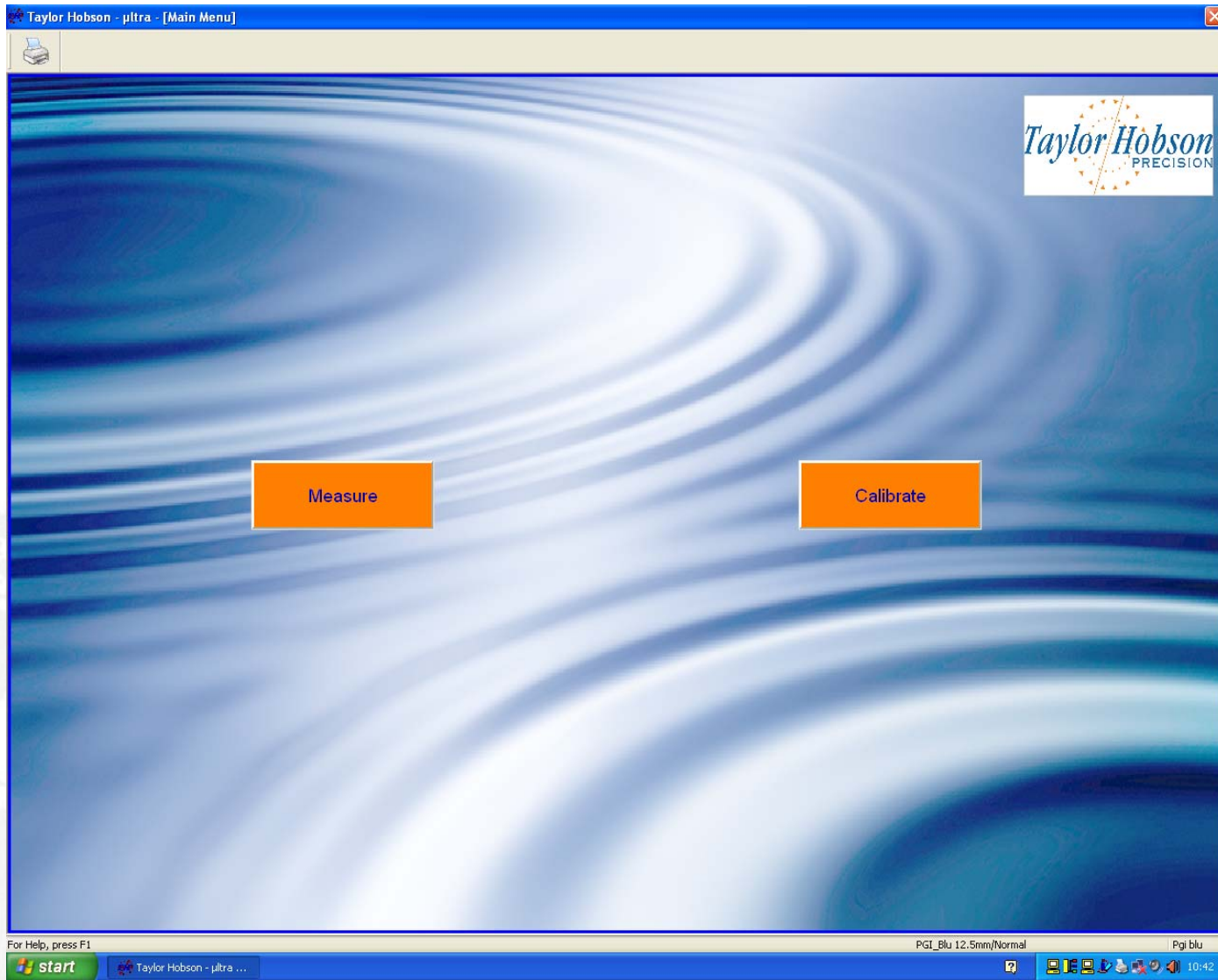


- Combination of Talyrond & PGI Technologies
 - Precision PGI Gauge and Traverse Unit
 - Specialized Air-bearing Spindle with Centre & Levelling table
 - Inclined traverse angle for high NA measurement
 - Able to measure slopes > 80 degrees
 - Traverse can be set horizontal for 'standard' measurements
 - Active Anti-vibration
- Automatic centre and level along component's axis
 - No need to y-crest on component
- Automatic calibration routines



Operating Procedure – Production Interface

4579



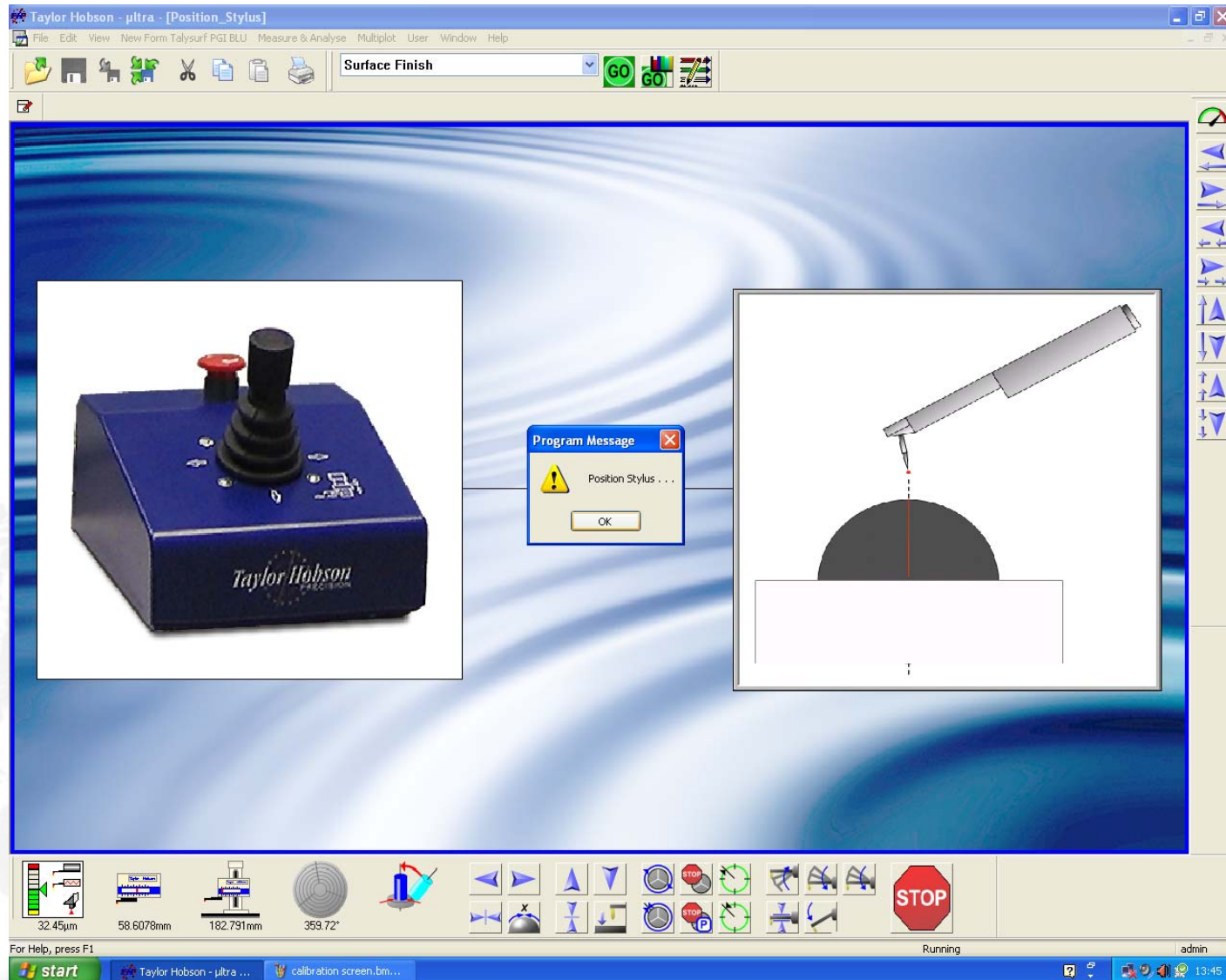
Calibration

4589

The screenshot displays the 'PGI Blu' Calibration software interface. The window title is 'Ultra - PGI Blu: Optics'. The main header includes 'PGI Blu' on the left, 'Calibration' in the center, and the 'Taylor Hobson PRECISION' logo on the right. The central panel, titled 'Instrument Configuration', contains three sections: 'Stylus' with a 'Type' dropdown set to '112-4054'; 'Calibration Standard' with a 'Ball ID' dropdown set to '112-4051' and a 'Ball radius' input field set to '12.4995 mm'; and 'Traverse Unit' with a 'Tilted' radio button set to 'Yes'. A vertical toolbar on the right side of the configuration panel contains three buttons: a green checkmark, a red 'X', and a question mark. The Windows taskbar at the bottom shows the 'start' button, several open applications, and the system tray with the time '13:13'.

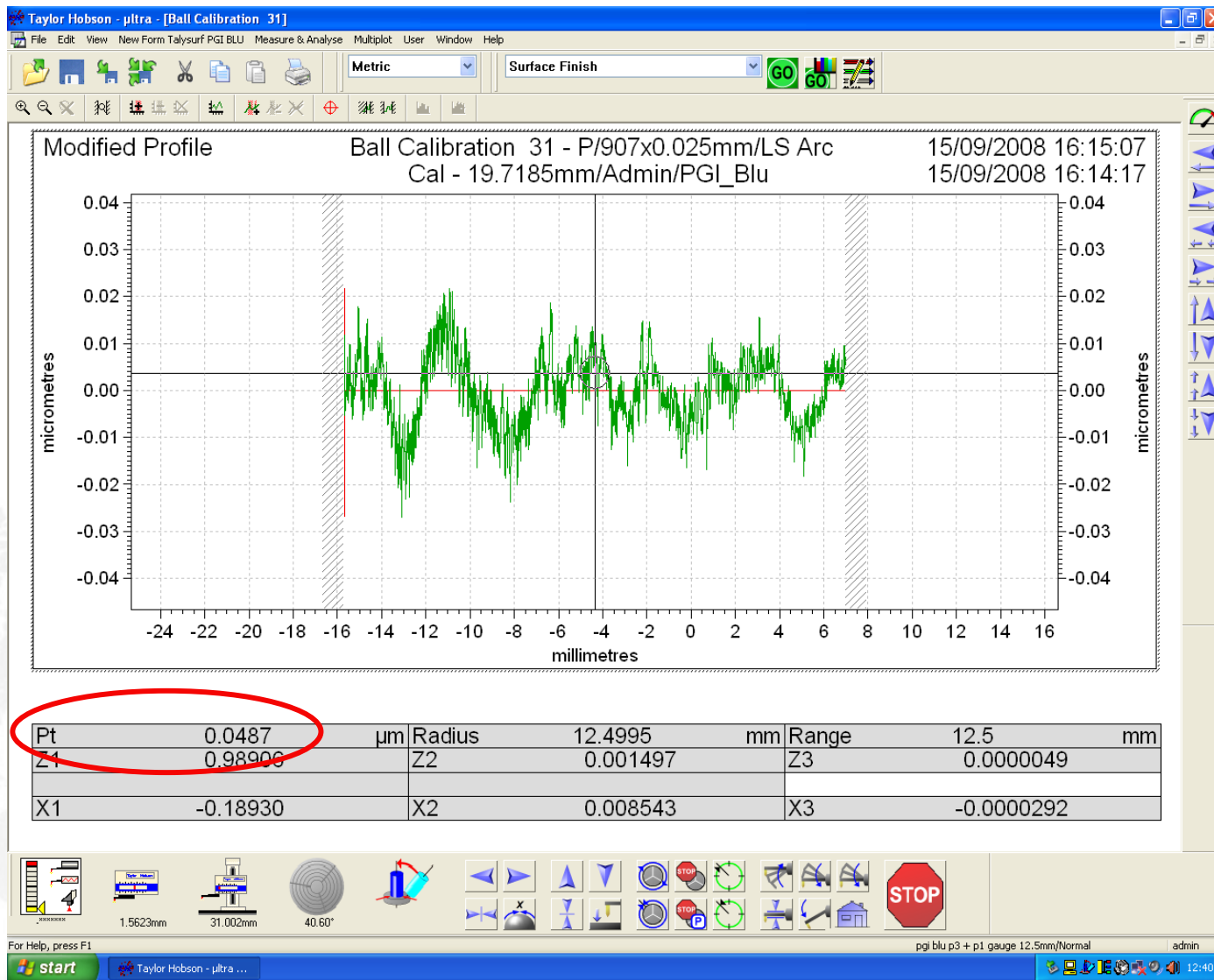
Calibration Set-up

4589



Calibration Result

4589



Main Screen

4589

Ultra - PGI Blu: Optics

Production Interface

ID: 1129a_3

Type 3: Concave - Sides Not Parallel

PGI Blu

Taylor Hobson
PRECISION

Aspheric Design

Conic Form Settings

Conic constant: 0.000000E+000
Base radius: <mandatory> mm
Shape: Concave

Aperture / Land

Clear aperture (CA): <mandatory> mm
Full aperture (A): <mandatory> mm
Land (useable): <mandatory> mm

Analysis

Use optimized base radius
 Data density: 4000
Ls Filter: 0.0025 mm

Coefficients

Name	Value
A1	0.000000E+000
A2	0.000000E+000
A3	0.000000E+000
A4	0.000000E+000
A5	0.000000E+000
A6	0.000000E+000
A7	0.000000E+000
A8	0.000000E+000
A9	0.000000E+000
A10	0.000000E+000

Invert coefficients
 Show even coefficients only
Source:

Instrument Configuration

Stylus

Type: 112-3161

Stylus Configuration

Calibration Standard

Ball ID: 112-4051
Ball radius: 12.4995 mm

Traverse Unit

Tilted: Yes No

Measurement Settings

Maximum part height: mm Enabled
Overlap (X): -0.100 mm
Speed: 0.25 mm/s
Rotational spacing: 45 °

Presentation Settings

Measurement

File name: 1129a_3 Increment
Results folder: C:\PGI_Blu_Results

Talymap

Auto-run Talymap
 Open new document

Talymap template:
 Default
 User-defined:

Component Diagram

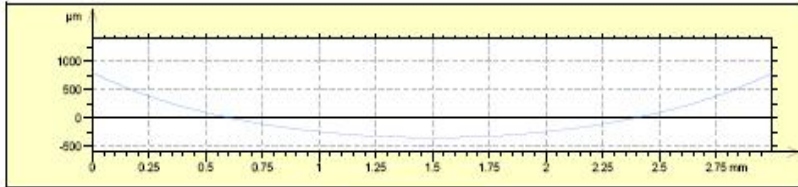
The diagram shows a cross-section of a concave aspheric lens. The 'Land' is the flat outer edge, 'A' is the full diameter of the lens, and 'CA' is the diameter of the clear aperture.

Windows: start | Taylor Hobson - ultra ... | Images | Ultra - PGI Blu: Optics | untitled - Paint | 13:05

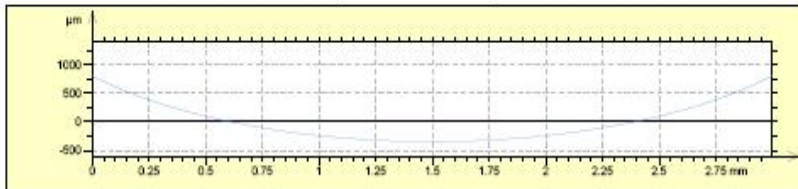
Measurement Result (1)

4589

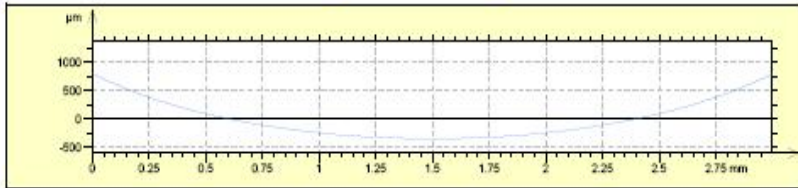
0 - 180 DEG



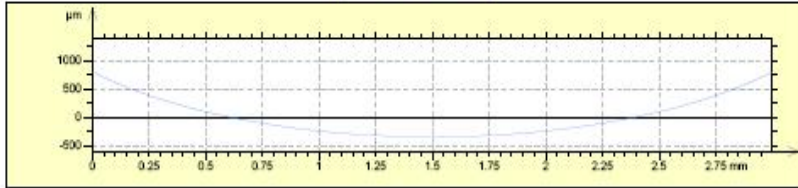
45 - 225 DEG



90 - 270 DEG



135 - 315 DEG



Raw Profiles

0 - 180 DEG

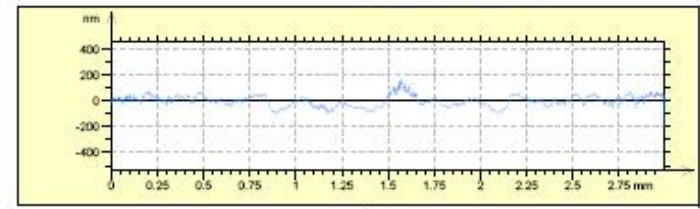


Fig = 0.0375 um
 Pa = 0.0342 um
 Pt = 1.22 um
 Smn = 0.304 deg
 Smx = 45.6 deg
 Tilt = -0.00329 deg
 Xp = 68.6 um
 Xv = -0.603 mm
 Xt = 1.5 mm
 RMS = 0.0464 um

45 - 225 DEG

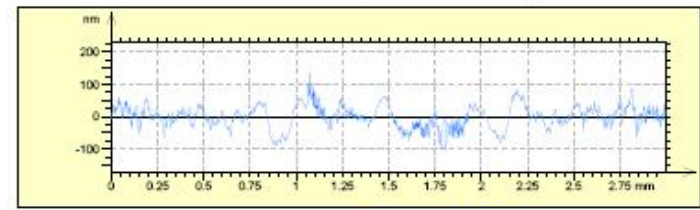


Fig = 0.0524 um
 Pa = 0.0277 um
 Pt = 0.277 um
 Smn = 0.334 deg
 Smx = 3.51 deg
 Tilt = 0.00208 deg
 Xp = -0.423 mm
 Xv = 0.311 mm
 Xt = 1.5 mm
 RMS = 0.0351 um

90 - 270 DEG

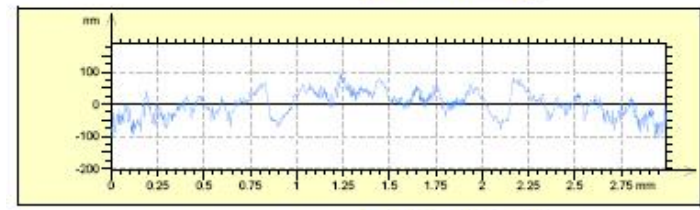


Fig = 0.0222 um
 Pa = 0.0325 um
 Pt = 0.221 um
 Smn = 0.284 deg
 Smx = 2.03 deg
 Tilt = 0.00177 deg
 Xp = -0.265 mm
 Xv = 1.44 mm
 Xt = 1.5 mm
 RMS = 0.0392 um

135 - 315 DEG

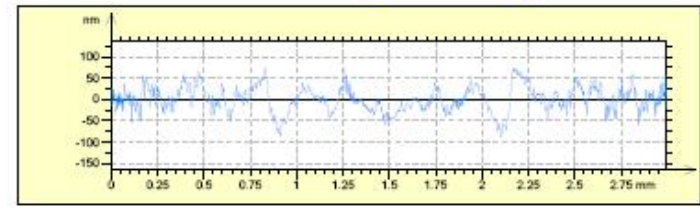


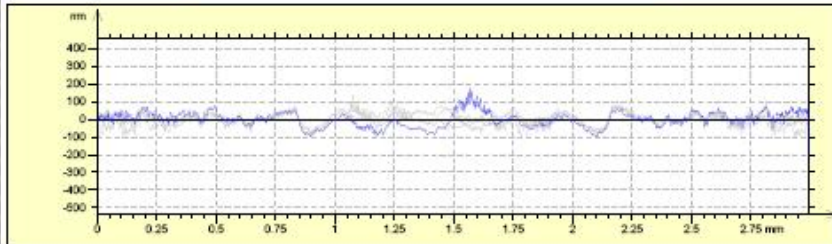
Fig = -0.0423 um
 Pa = 0.0238 um
 Pt = 0.165 um
 Smn = 0.255 deg
 Smx = 2.04 deg
 Tilt = 0.000615 deg
 Xp = -0.246 mm
 Xv = 0.604 mm
 Xt = 1.5 mm
 RMS = 0.0296 um

Error Maps

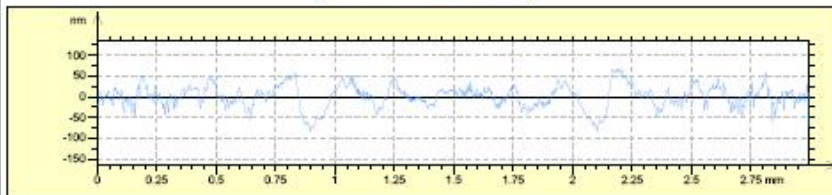
Measurement Result (2)

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MULTIPLE TRACE 2D ASTIGMATISM PLOT

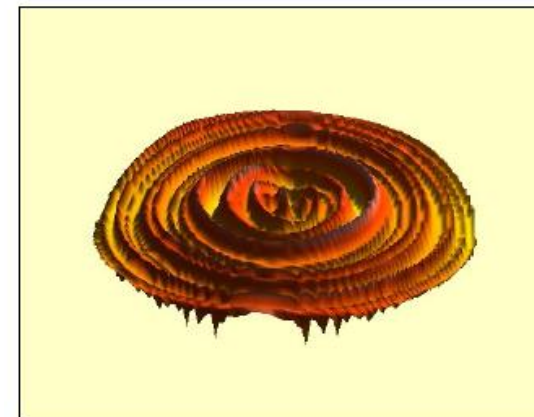
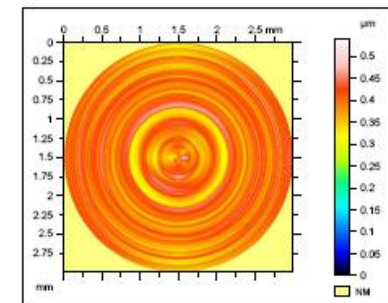


MEAN PROFILE



Aspheric parameters for Run 1_0001_04_OUT.mod
Fig = -0.0423 μm
Pa = 0.0238 μm
Pt = 0.165 μm
Smin = 0.255 deg
Smx = 2.04 deg
Tilt = 0.000615 deg
xp = -0.246 mm
xr = 0.604 mm
xt = 1.5 mm
RMS = 0.0296 μm

3D ASTIGMATISM PLOT

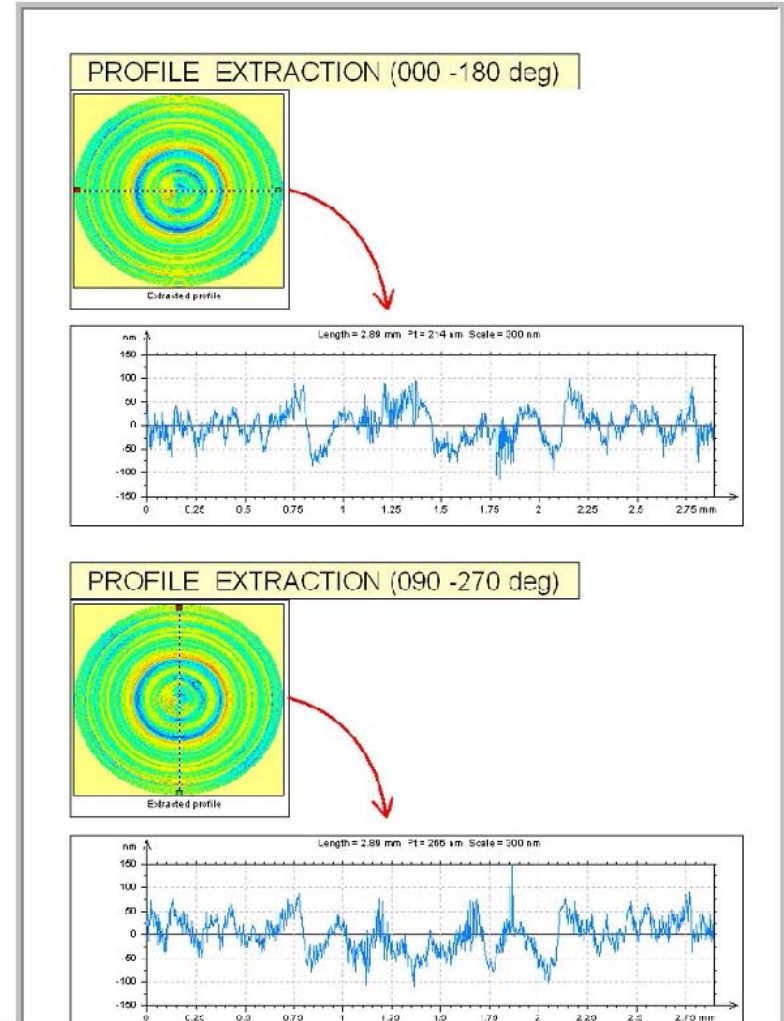
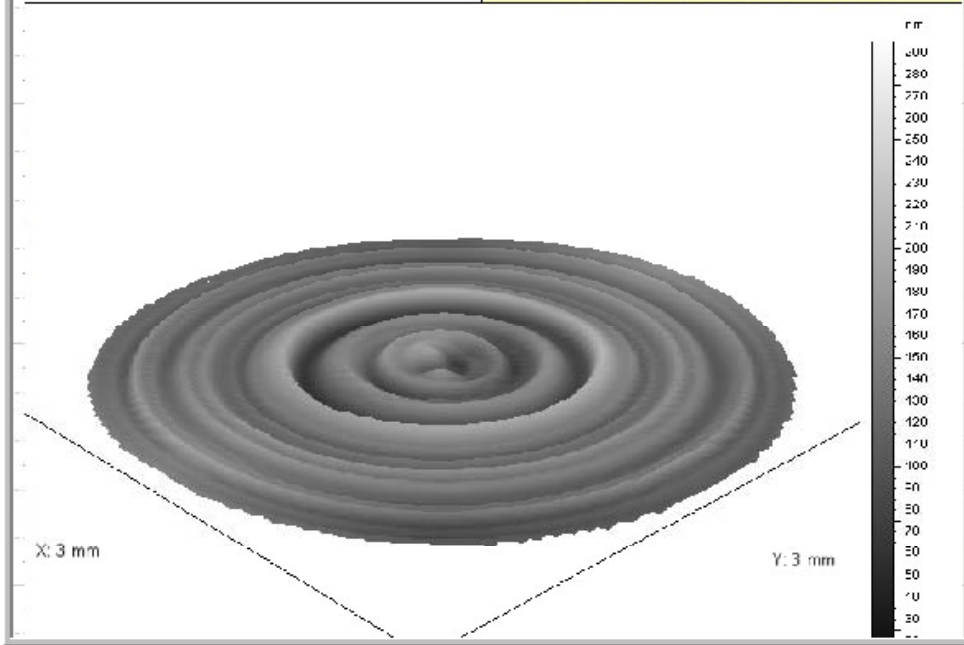
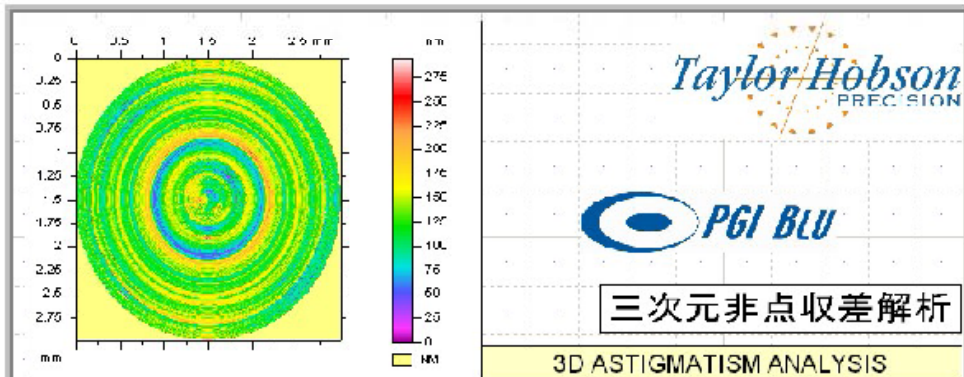


ISO 25178	
Height Parameters	
Sq	0.0312 μm
Sk	-0.267
Sku	3.3
Sp	0.145 μm
Sv	0.365 μm
Sz	0.54 μm
Sa	0.0249 μm

Average Error Map (for TPG)

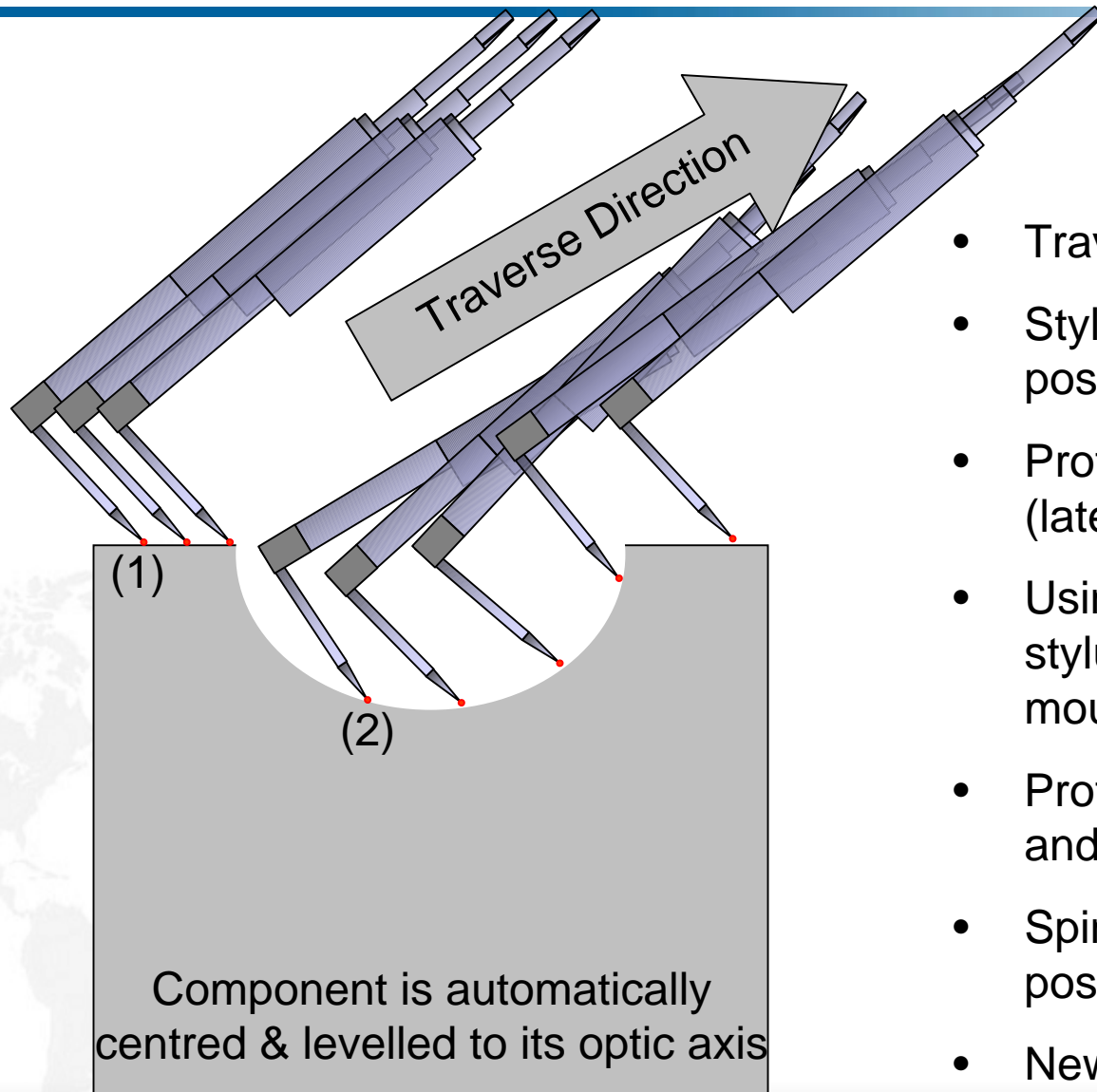
Surface Astigmatism

- Easily created in Talymap – for example:



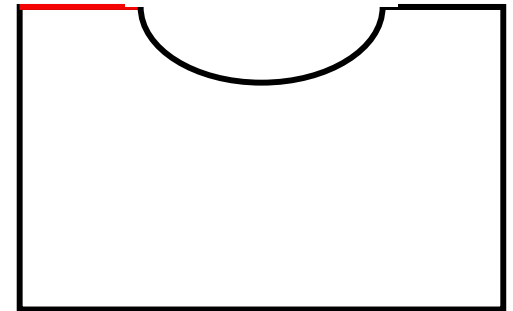
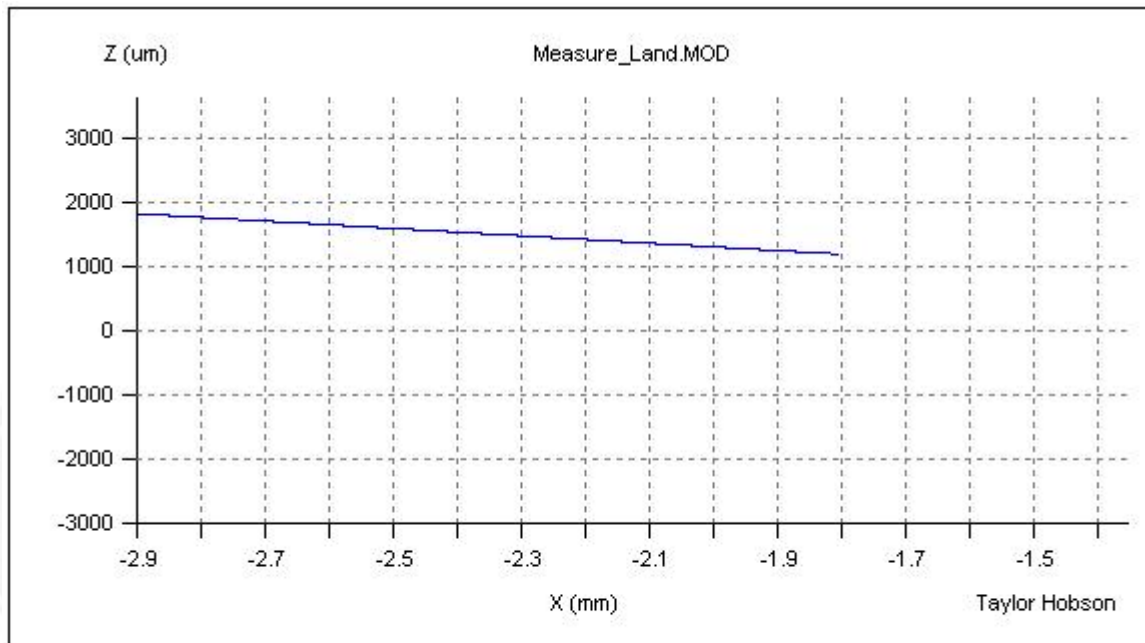
Measurement Routine

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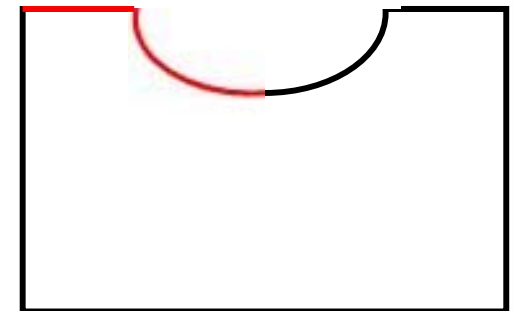
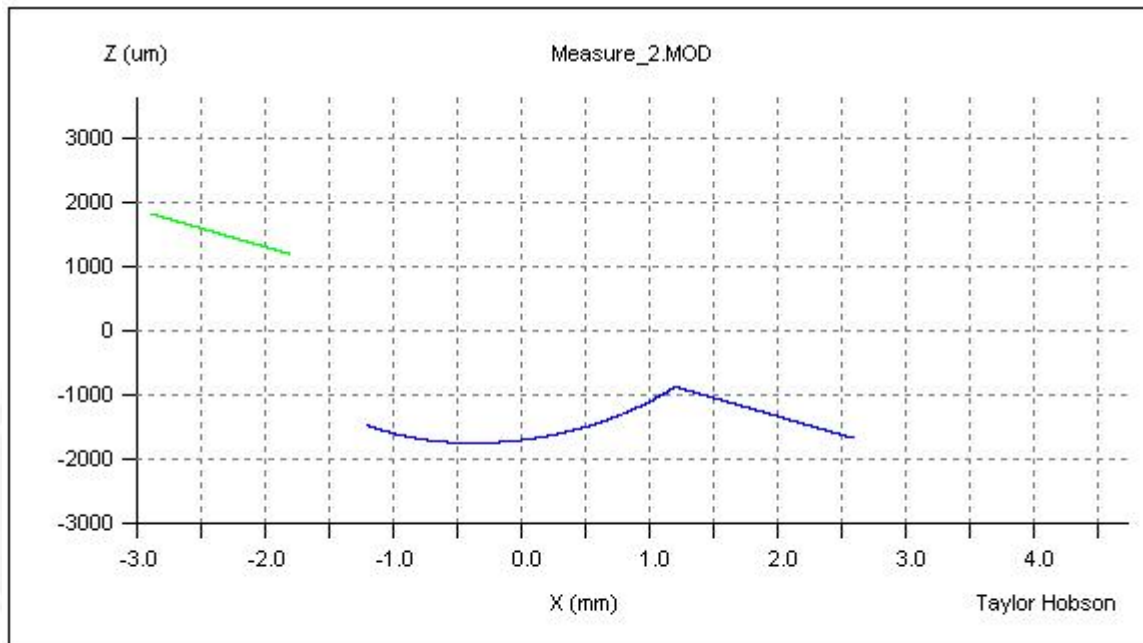
- Traverse is set to incline
- Stylus is automatically positioned at position (1)
- Profile taken to aid fusion (later)
- Using automatic lift / lower, stylus is positioned near mould's centre (2)
- Profile taken through mould and along remaining flat
- Spindle rotates to next position (30, 45, 90 or 180°)
- New profile is taken

- Radially opposing profiles are fused
 - Automatic (production user does not see this)



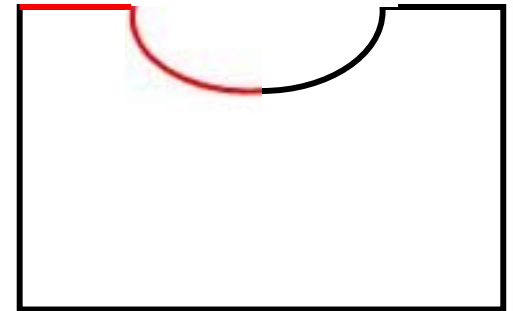
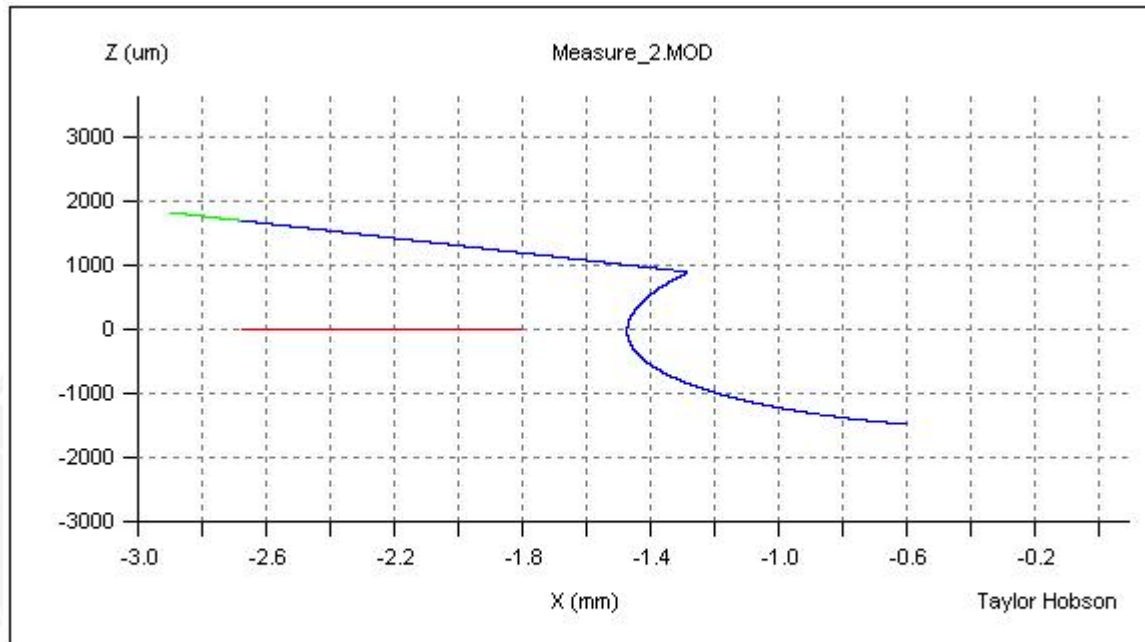
Initial 'Land' is Imported and used as Reference

- Radially opposing profiles are fused
 - Automatic (production user does not see this)



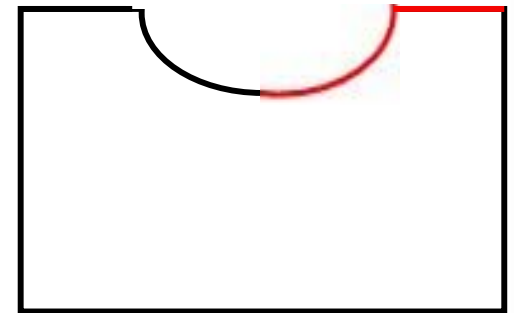
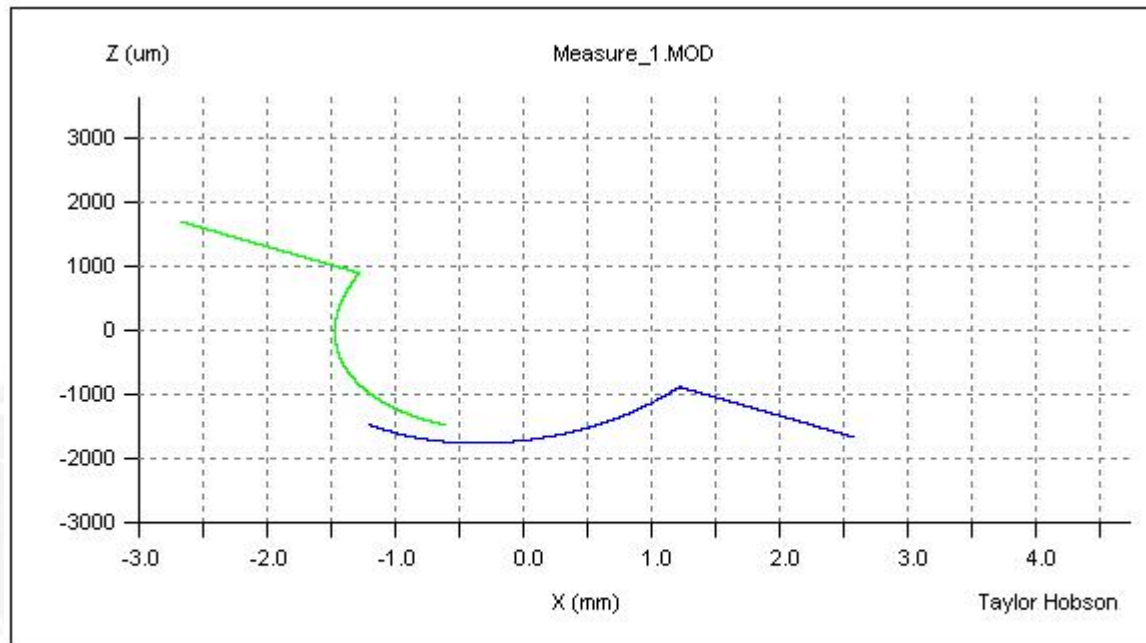
‘Land’ is set as Reference – neighbouring trace is Imported

- Radially opposing profiles are fused
 - Automatic (production user does not see this)



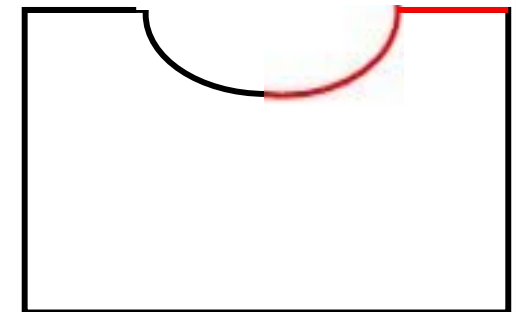
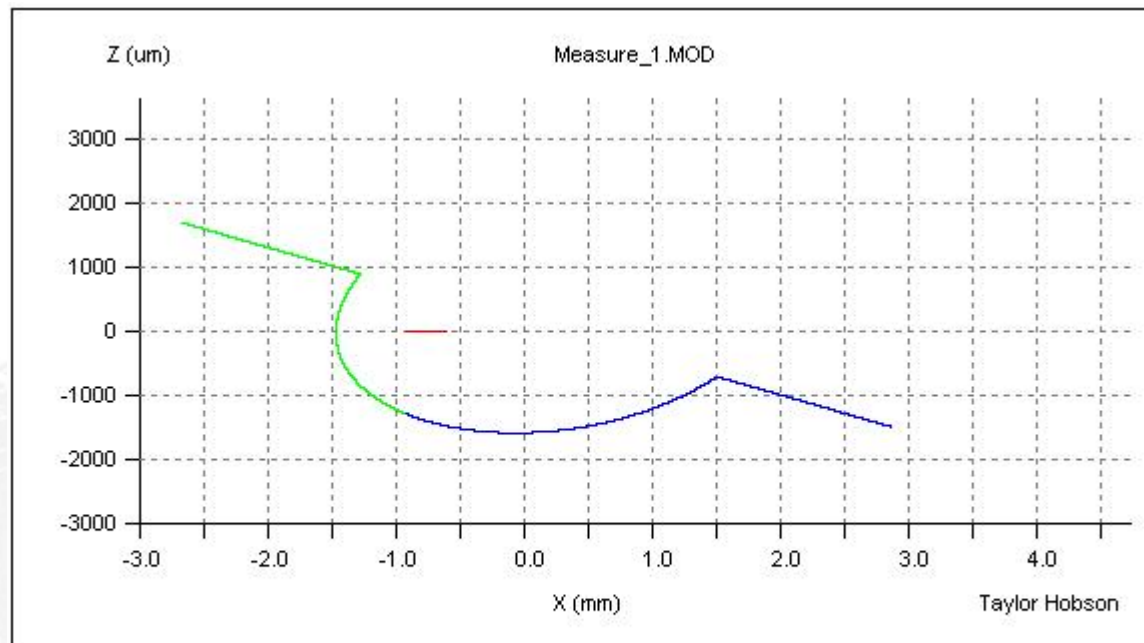
Profiles are Aligned (profile looks re-entrant due to scale)

- Radially opposing profiles are fused
 - Automatic (production user does not see this)



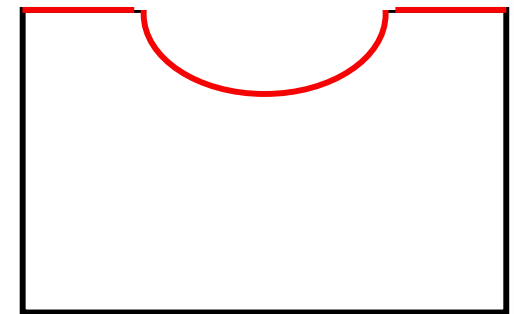
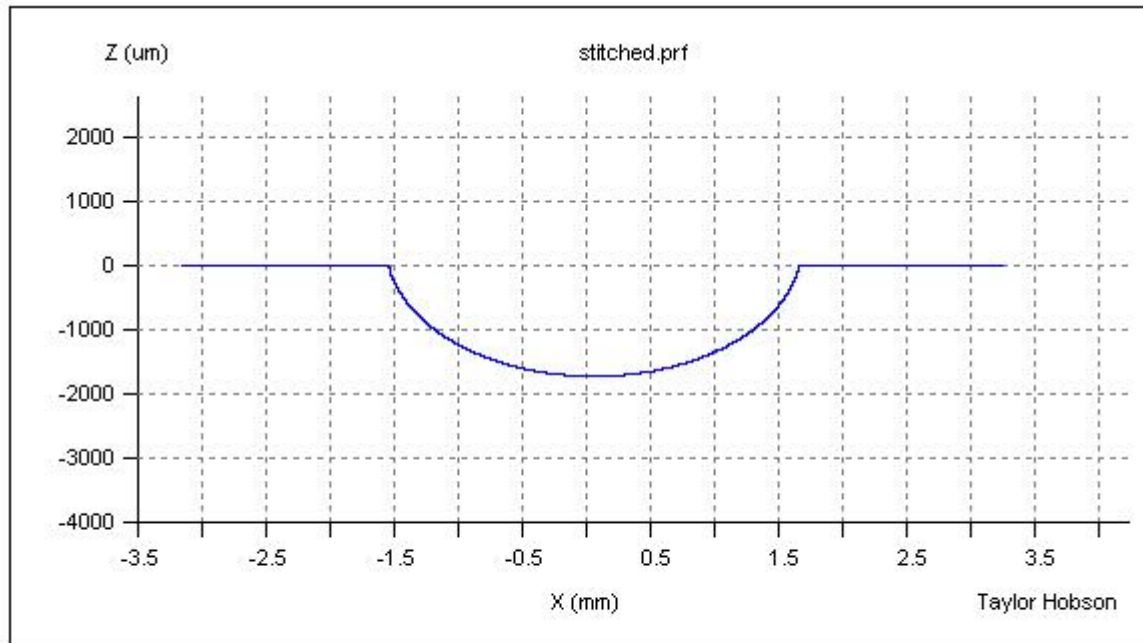
Opposing Profile (Measurement 1) is Imported

- Radially opposing profiles are fused
 - Automatic (production user does not see this)



Profiles are aligned using central overlap

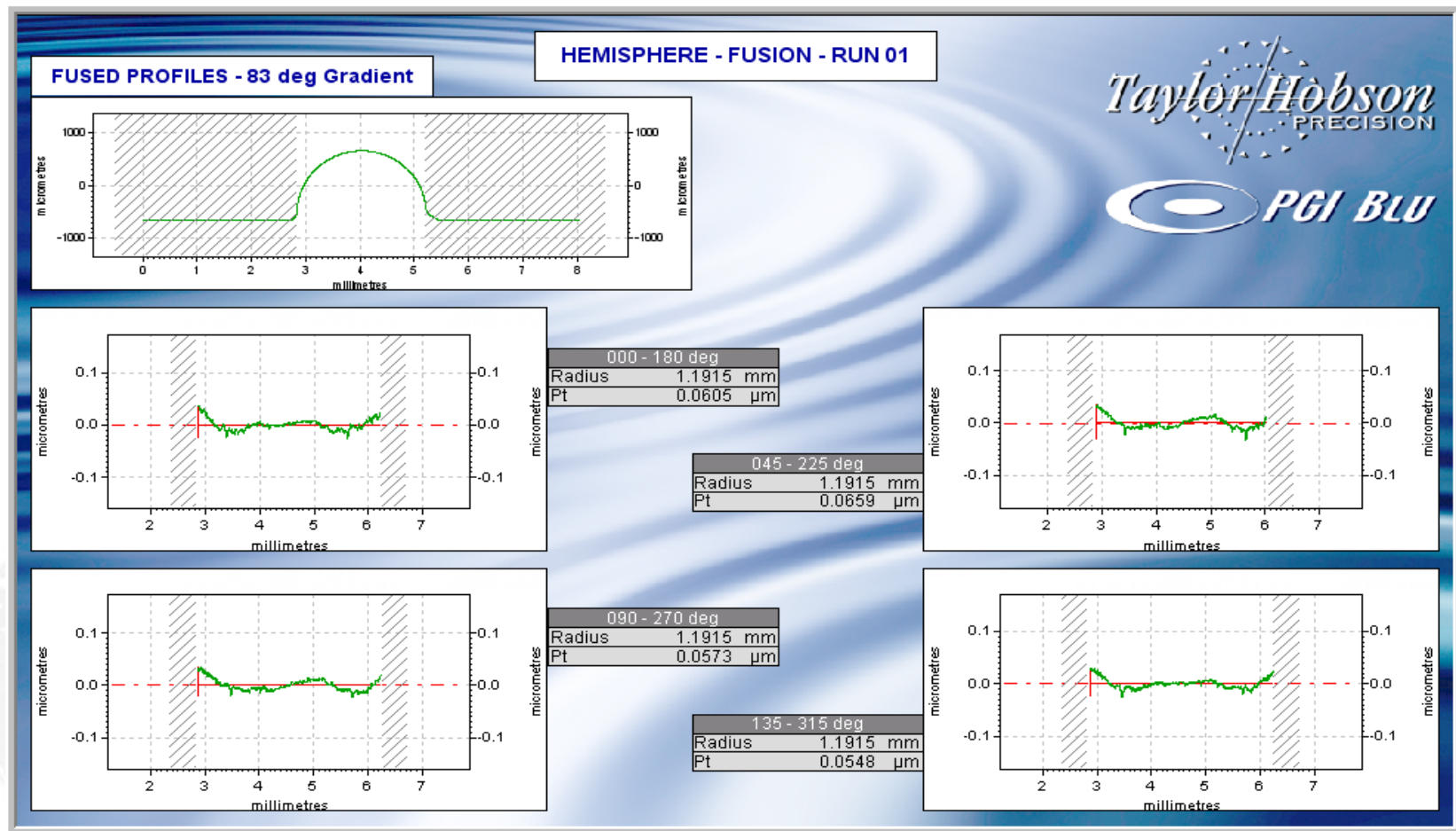
- Radially opposing profiles are fused
 - Automatic (production user does not see this)



Finally - Fused trace is rotated to account for traverse angle

Accuracy & Repeatability Test (example)

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- Arc-fit to 1.2mm (nominal radius) hemispherical standard
 - Repeat tests (25x) shows zero change in best fit radius (within 0.1 μm)
 - Pt ($\lambda\text{s} = 25\mu\text{m}$) varies by +/-15nm

- **Premium Configuration**

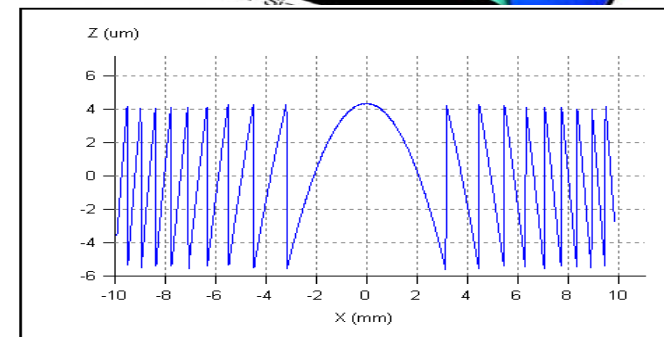
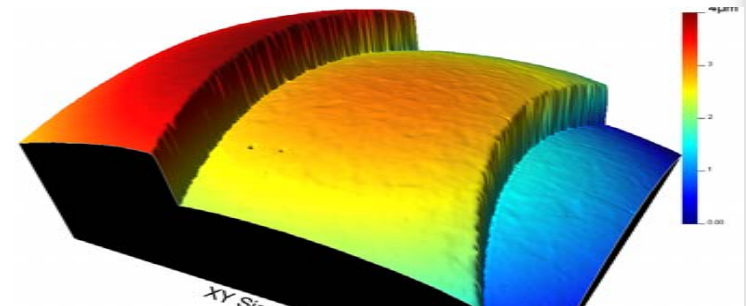
- Precision PGI Gauge and Traverse Unit
- Specialized Air-bearing Spindle with Centre & Levelling table
- Active Anti-vibration
- Dedicated User-interface with Automated Control

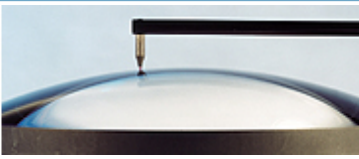
- **Unrivalled Performance**

- Form Measurement Capability < 50nm
- Ability to Measure Steep Angles (> 80 deg)
- Flexible Configuration for Small or Large Components (up to 50mm)
- Specialized Optical Analysis Package
- Seamless Operation for Production Use



- **Metrology for Production Facilities has many Challenges**
 - Manufacturing capabilities are continuously improving
 - Higher precision metrology is required
 - Production facilities are operating 24/7
 - Reliable, automated and easy to use instruments are essential
- **Taylor Hobson Metrology**
 - Responding to these needs
 - Building upon existing reputation and customer base
 - Developing solutions together with key industrial partners
 - Complete range of contact / non-contact instruments to suit most application needs





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Production Metrology for Steep-sided Aspheric Optics

Presented by
Mark Middleton

Thank you for Listening