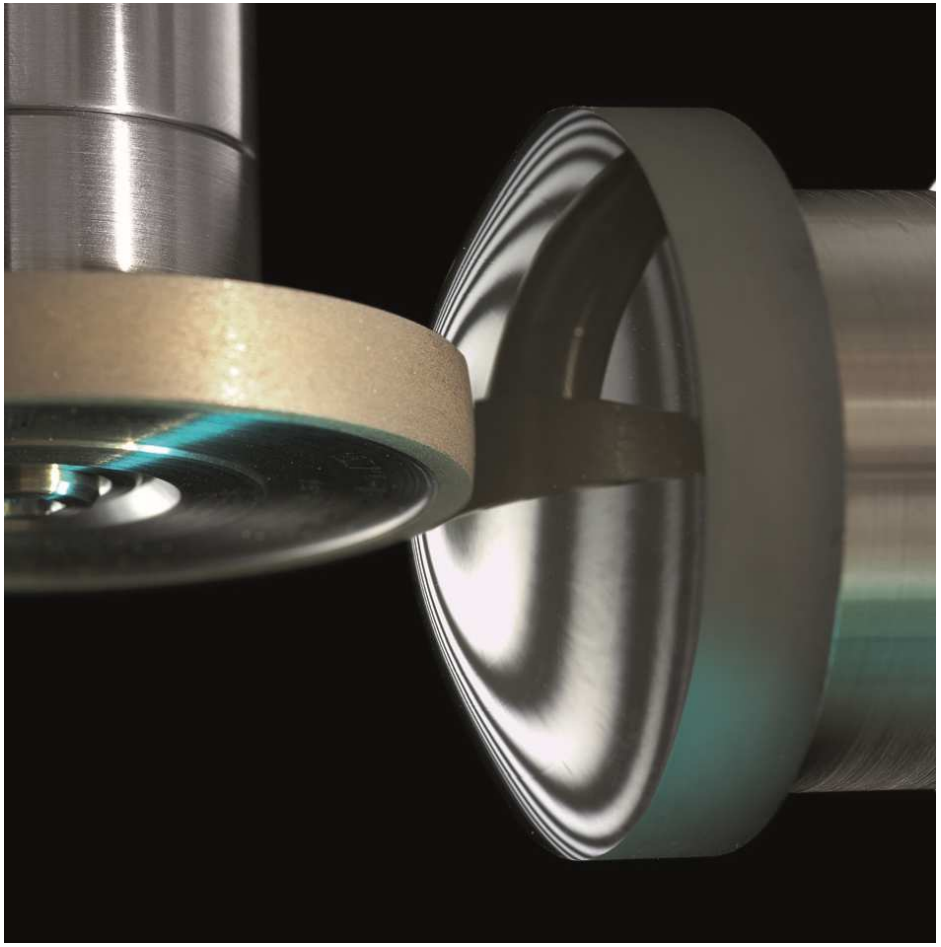

Optics Manufacturing

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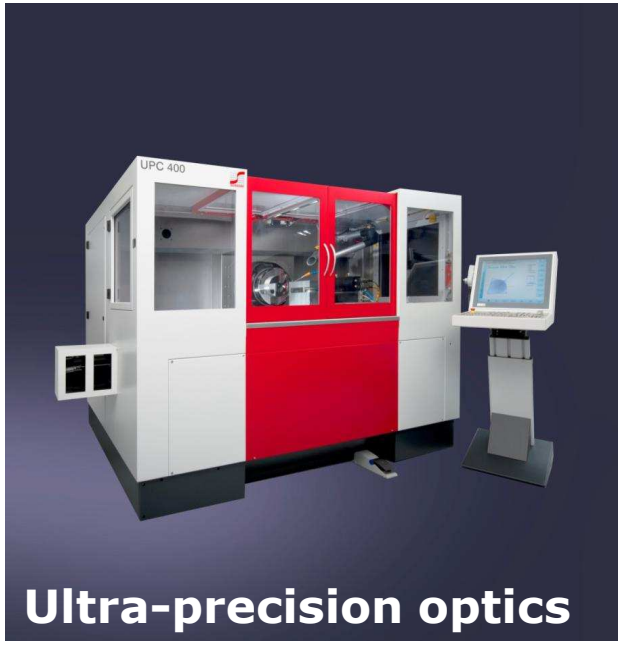
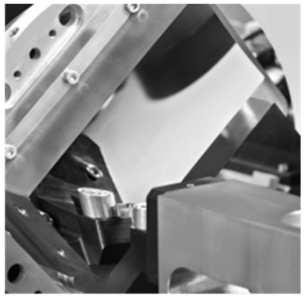
SCHNEIDER product families

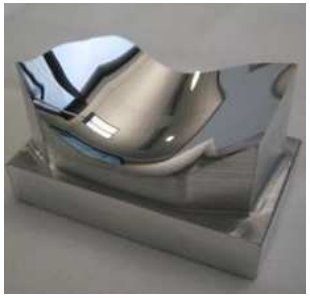

Ophthalmics

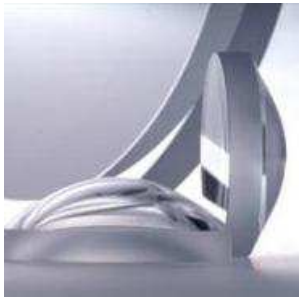


Ultra-precision optics

Precision optics







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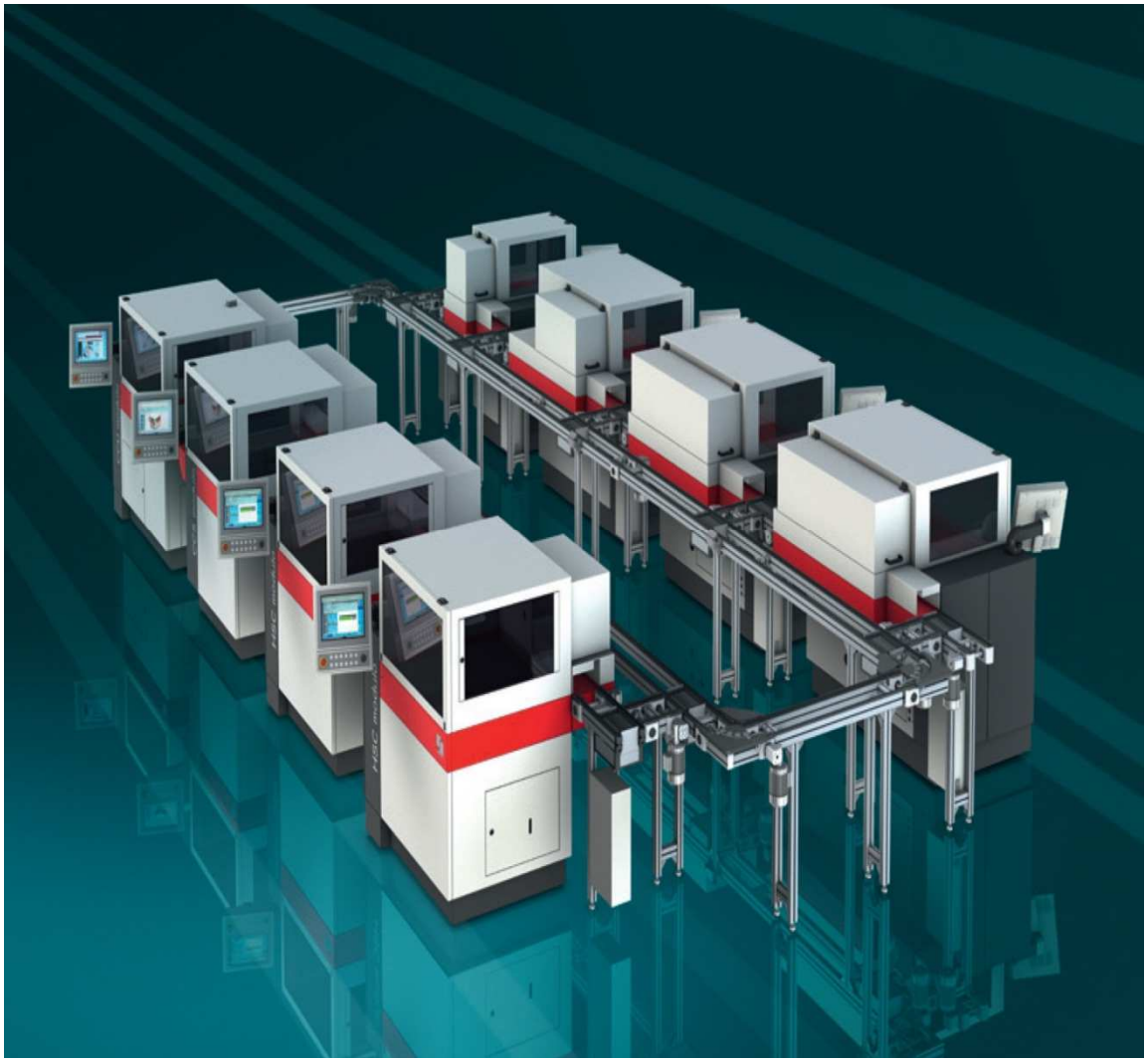
The Modulo system
First integrated production system



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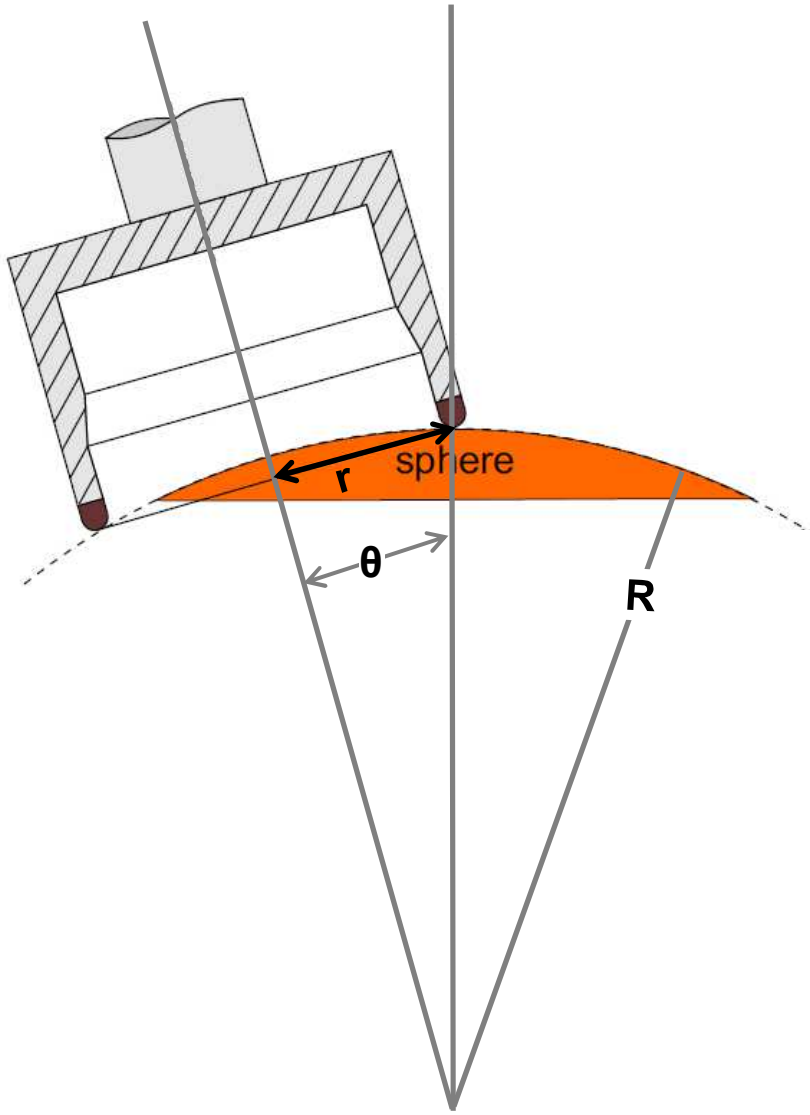
Basics of Cup Wheel Grinding for Spherical Lenses



- Angle of the cup wheel is determined by: $\Theta = \sin^{-1} r/R$.
- **R** is the radius of the optic.
- **r** is the distance from the point of contact to the axis of rotation of the cup wheel.
- For concave optics, the setup is the same although the angle is negative.

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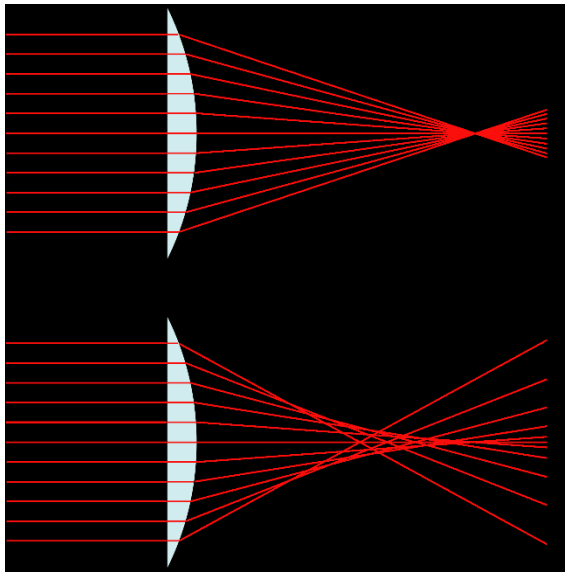
Spherical Lens



Spherical Aberration

Correction Method

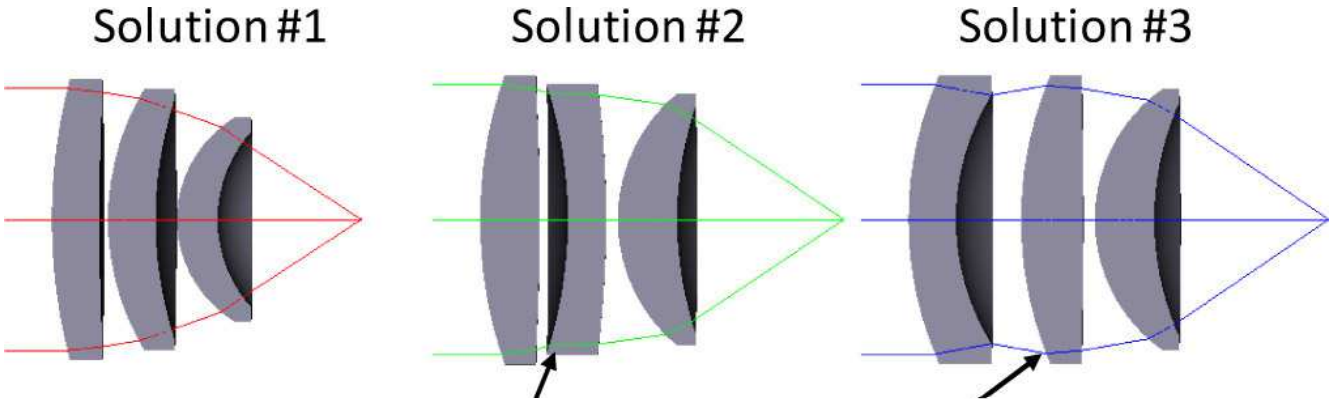


Image courtesy of Craig Olson, Julie Bentley and Richard Youngworth

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Aspherical Grinding with Cup Wheel Single Point Cutting

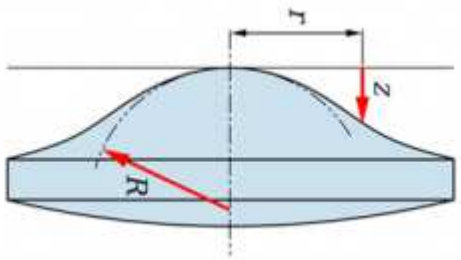
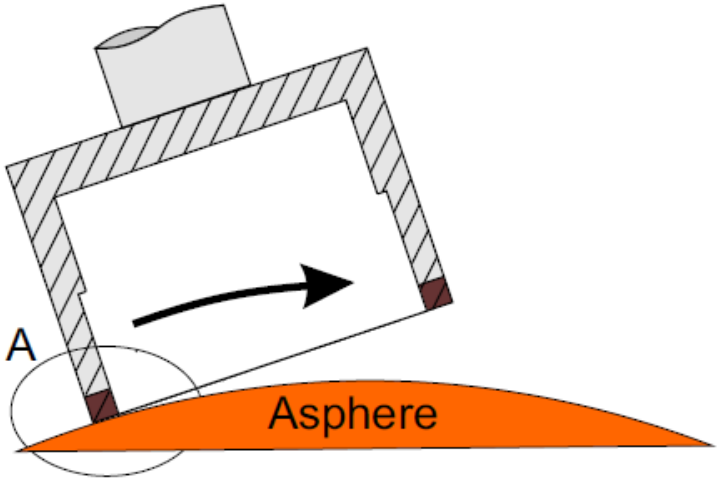
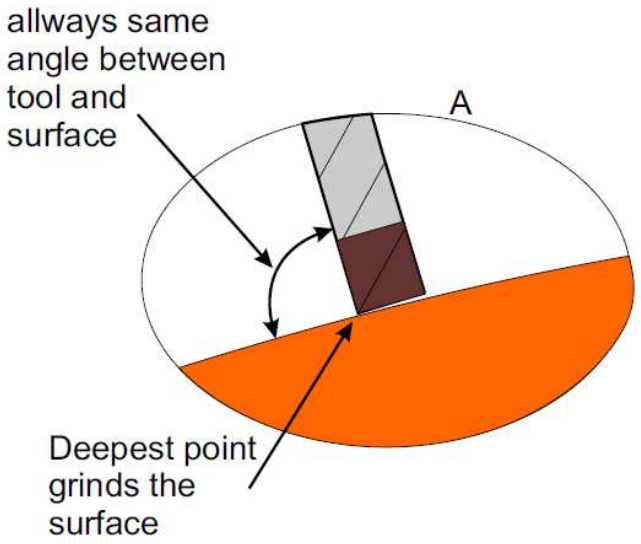


Image courtesy Apre Instruments



$$z(r) = \frac{r^2}{R\left(1+\sqrt{1-(1+\kappa)\frac{r^2}{R^2}}\right)} + \alpha_4 r^4 + \alpha_6 r^6 + \cdots,$$



- Corrects aberration
- Reduces number of elements required

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Spherical and Aspherical polishing

Tool correction

_ Integrated tool correction spindle system for fast and flawless adjustment of the polishing tool

_ Cut polish pad to desired diameter and profile

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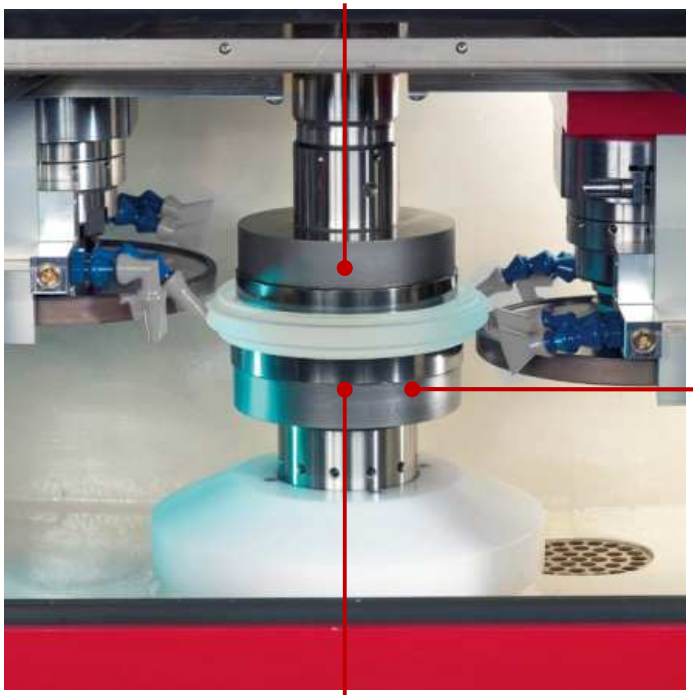
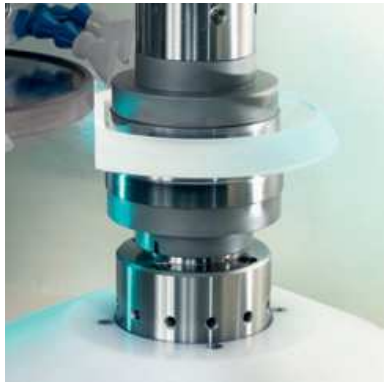
Edging and Centering

Clamping-Control

_ CNC-controlled bell clamping technology





Truncation-Control

_ CNC-controlled contour processing of non-rotationally symmetric edge geometries

SCT

_ Geometry- and Technology Software

Align-Control

_ Interactive laser measuring system to measure and control the centering error

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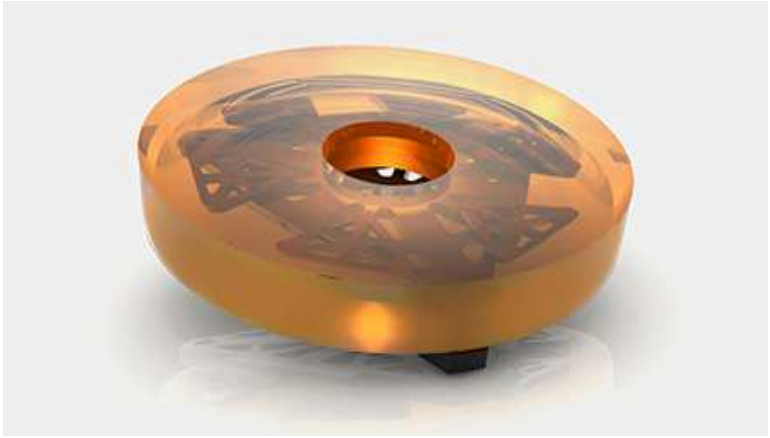
Sample Workpieces



On-,Off Axis-Aspheres

On-,Off Axis-Spheres

Cylindrical Lenses

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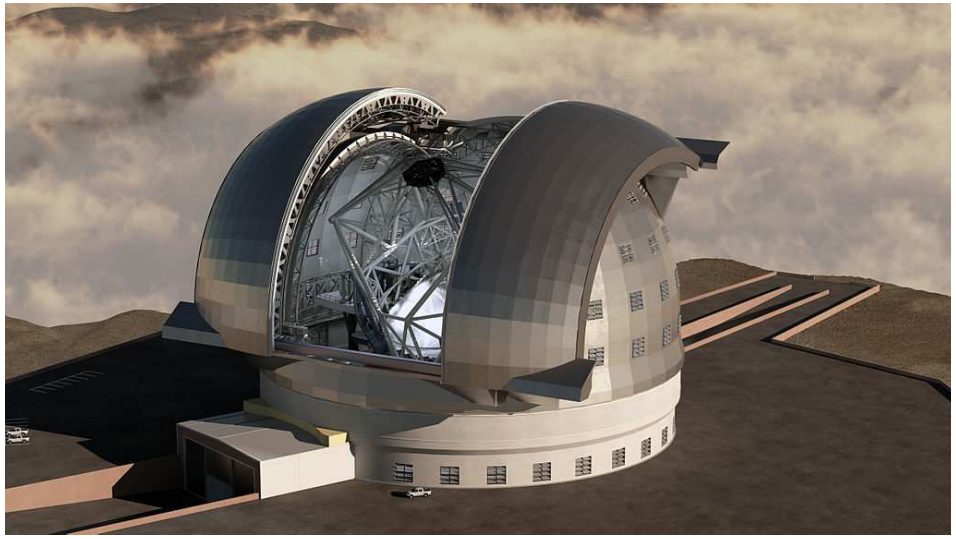
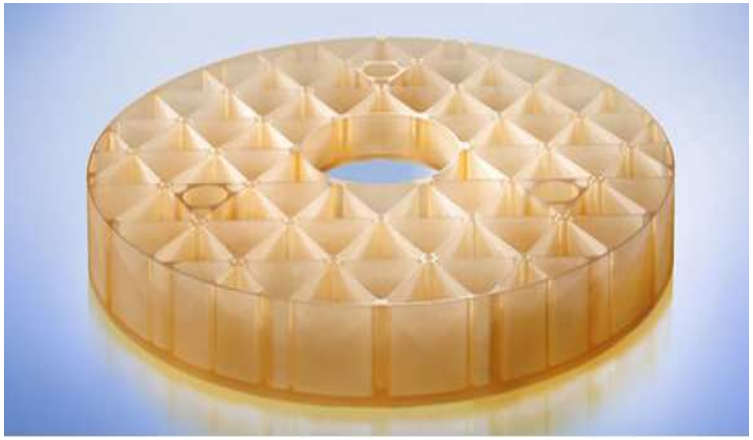
Large Workpieces



European Southern Observatory



Shott

Lightweight Structures

www.cranfield.ac.uk

Edge Processing

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Applications of Freeform Optics
Illumination and Imaging

Illumination

Streetlights

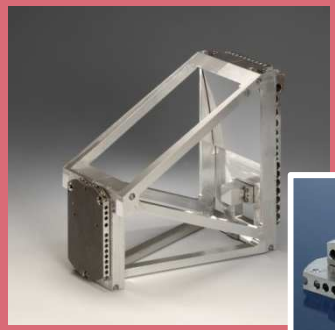
Buildings

Automotive

HUD

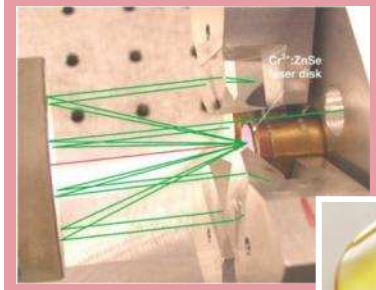
LED headlights

Space



Tele-scopes

Laser



ZnSe Optics

Courtesy: Automotive Lighting, Mercedes Benz, Philips, BMW, OEC, II-VI, Fraunhofer IOF

Limitations in Freeform Manufacturing

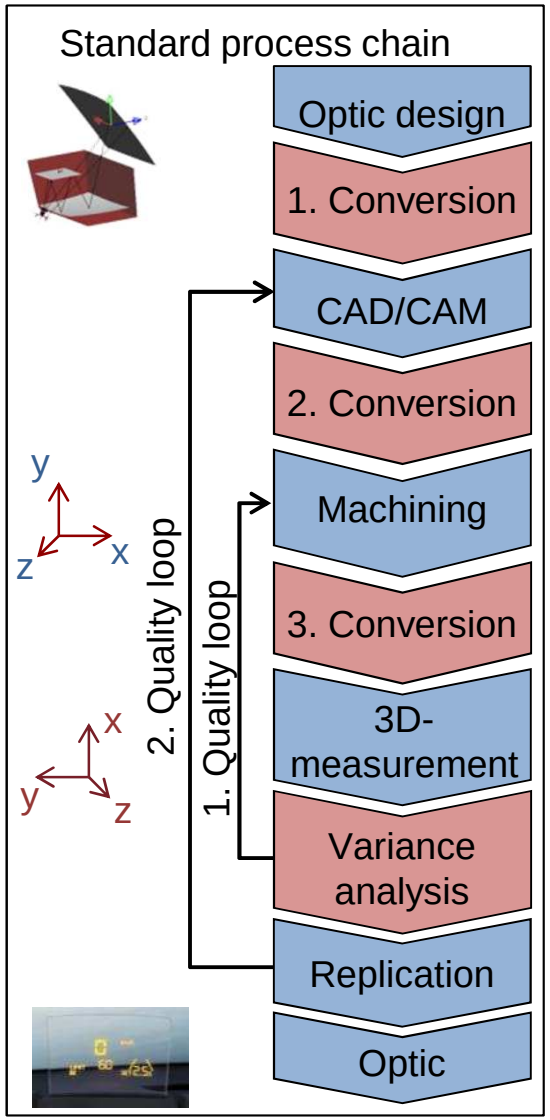
Data Handling

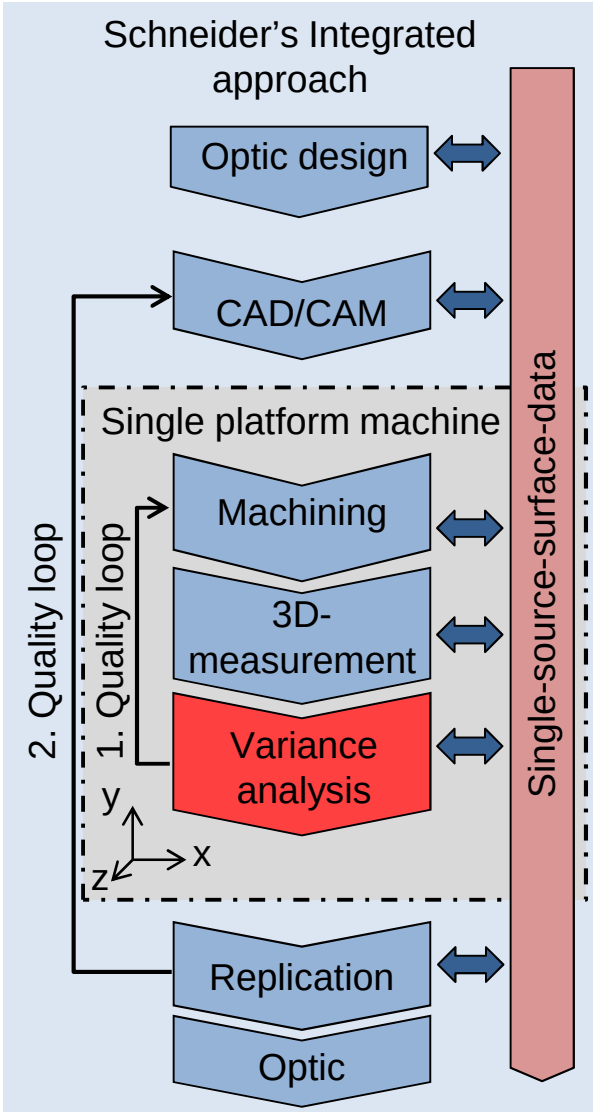
Current state of the art
_ Wide variety of surface descriptions
_ Different coordinate systems
_ Conversion errors

Solution
_ Integrated approach with single-source-surface-data
_ No conversion required for different processes

Import interfaces
_ NURBS in Step-Files
_ Polynomials
_ Point clouds
_ ...

Courtesy: Peugeot, OEC





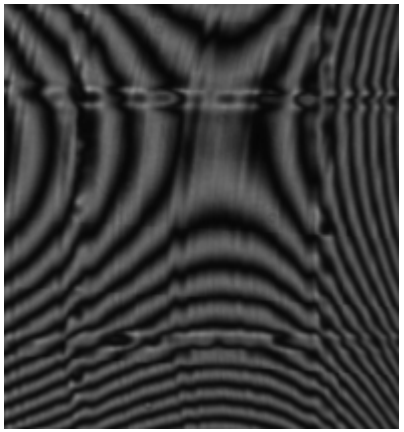
CAM Capabilities

Generating Surface of High Density Point Cloud

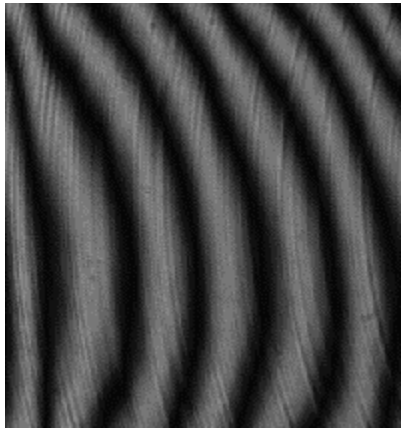
Surface evenness

Reproducing details

Commercial software



SOM software



Initial point cloud

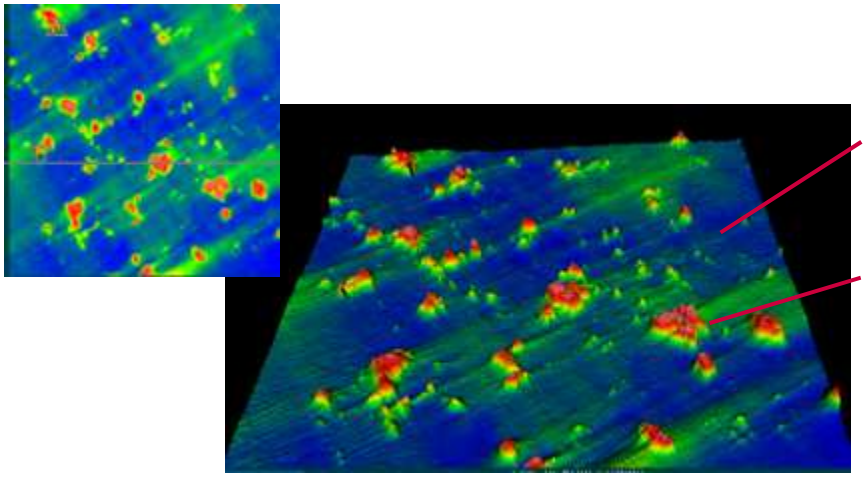
_ Freeform geometry
_ Diameter: < 100 mm
_ 18 million data points (x,y,z)

Limitation of commercial software

_ Unable to handle large data files
_ Visible Raster (10 x 10 mm², deviation < 200 nm)
_ Strong undulation at surface details like radius transitions

Surface Roughness
Influence of Material

Aluminum (Al 7075)



Aluminum base material

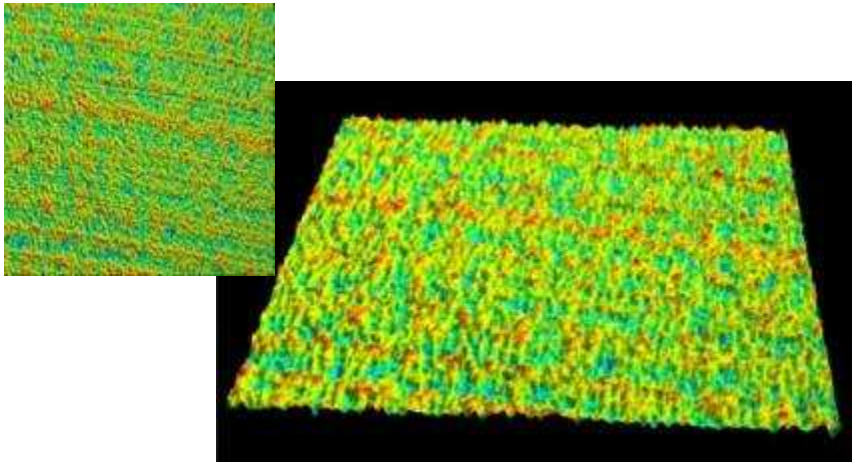
Intermetallic, hard phases (Spring-back-effect)

Sa 7.36 nm

Material
- Aluminum: Al 7075
- Nickel-Phosphorous Coating

Result
- Surface roughness:
  - Aluminum: Sa 7.36 nm
  - Nickel: Sa 0.97 nm

Nickel-Phosphorous Coating (gNiP)



Sa 0.97 nm

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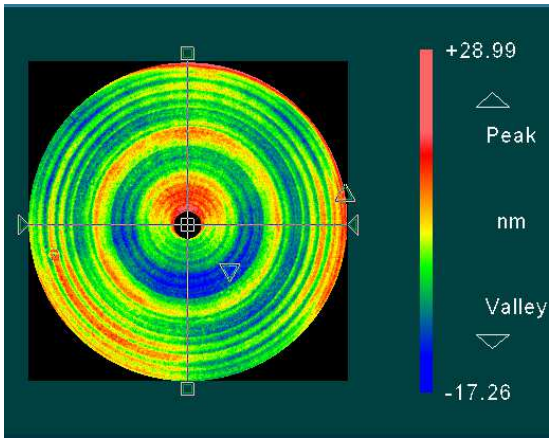
Form Accuracy
Planar Surface

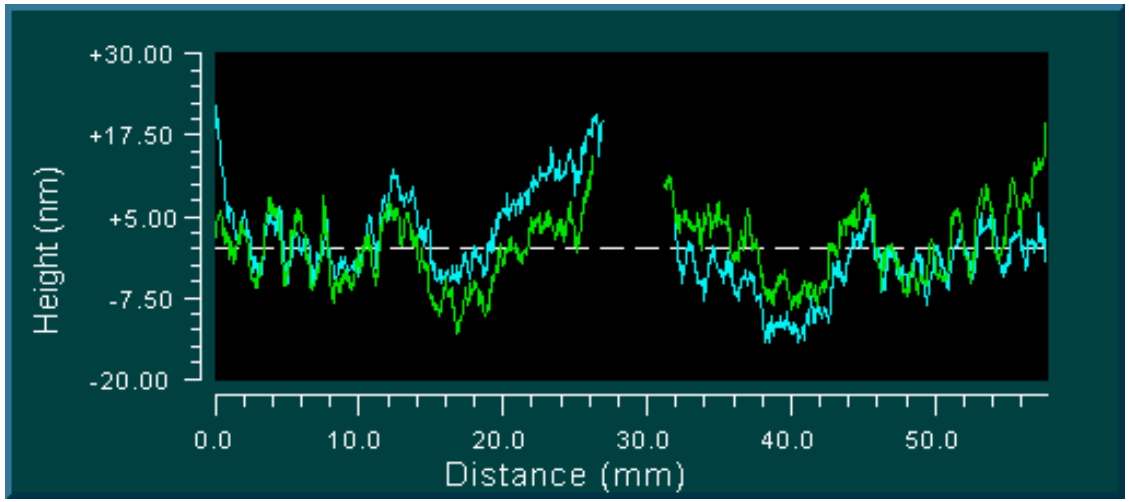
Planar surface



Top view

Workpiece
_ Material: Al 7075
_ Diameter: 60 mm

Result
_ Form accuracy:
< 40 nm @ D < 55 mm



Cross section (without filtering, 95% of surface)

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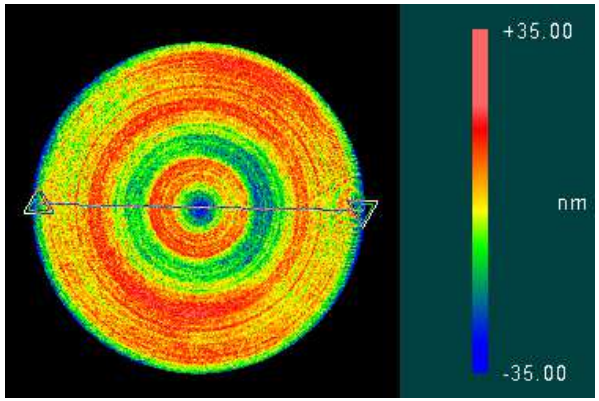
Form Accuracy

Spherical Surface with Radius 100 mm

Spherical surface



Top view (PST, TLT & PWR filtered)

Workpiece

_ Material: Al 7075

_ Diameter: 60 mm

_ Sphere: R = 100 mm

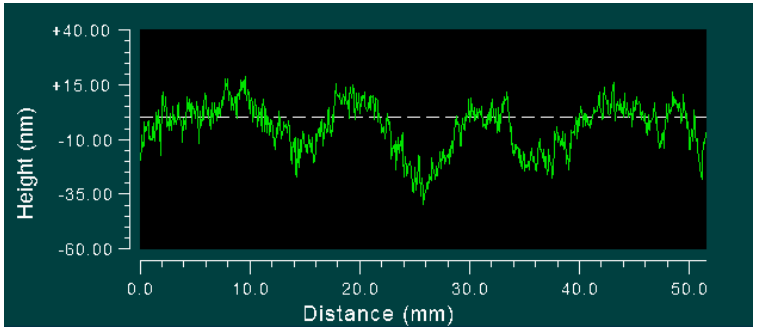
Result

_ Form accuracy

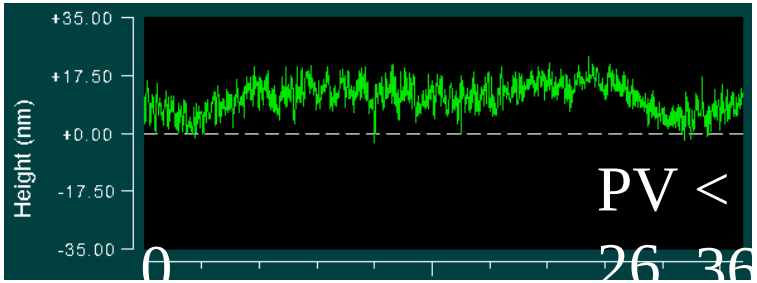
PV < 60 nm @ D = 50 mm

RMS 10 nm @ D = 50 mm

Linear
cross section



Circular analysis



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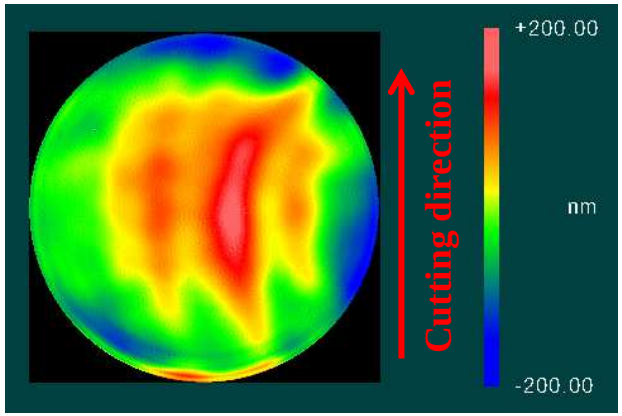
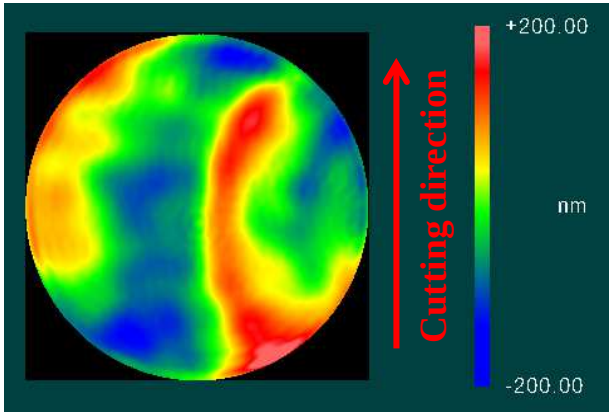
Freeform Accuracy

Slow Tool vs. Long Stroke Fast Tool

Off-Axis Spheres



Slow Tool



Fast Tool

Workpiece

_ Geometry
- _ 2x Sphere: R 100 mm
- _ Depth: 4 mm
- _ Aperture: 50 mm

_ Material: Al 6082

Results

(**without** compensation)

_ **Slow Tool @ 30 rpm**
- _ PV: < +/- 170 nm
- _ RMS: 63 nm

_ **Fast Tool @ 80 rpm**
- _ PV: < +/- 190 nm
- _ RMS: 70 nm

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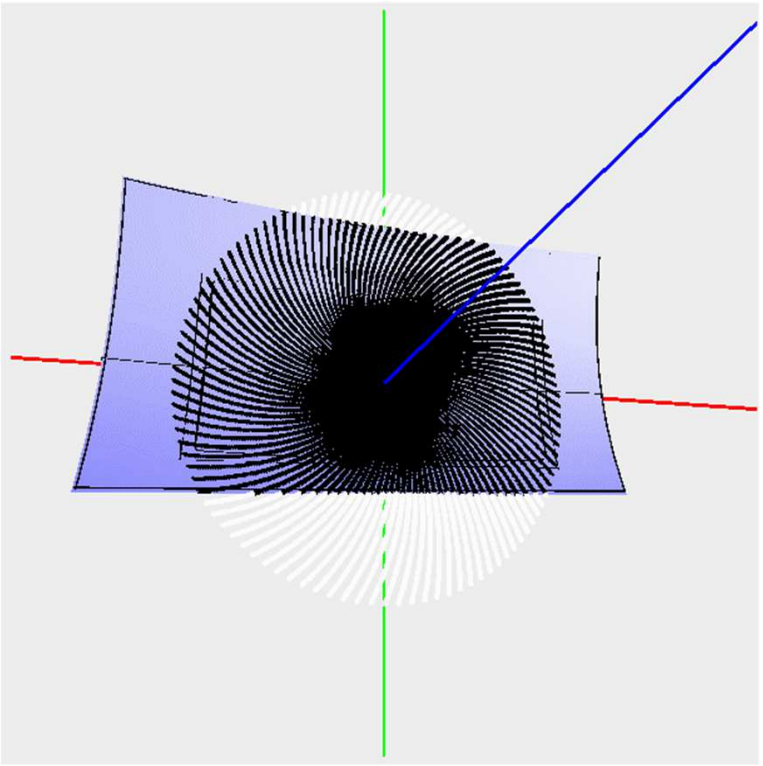
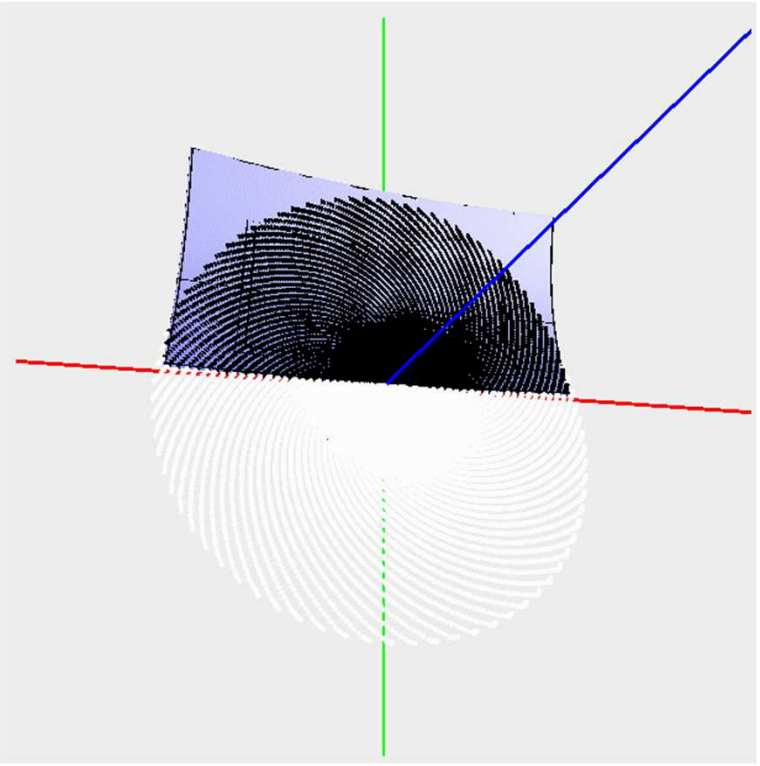
CAM Capabilities

Automatic Closing of Spiral Tool Path



On-Axis-Spiral



Off-Axis-Spiral

Spiral points:

_ Black: Defined by NURBS set-point surface

_ White: Interpolated by the software to close the spiral in order to achieve a smooth tool path for highest precision and rotational speed

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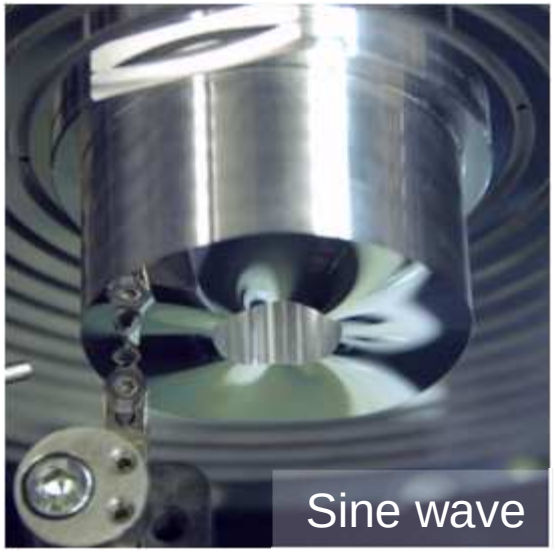
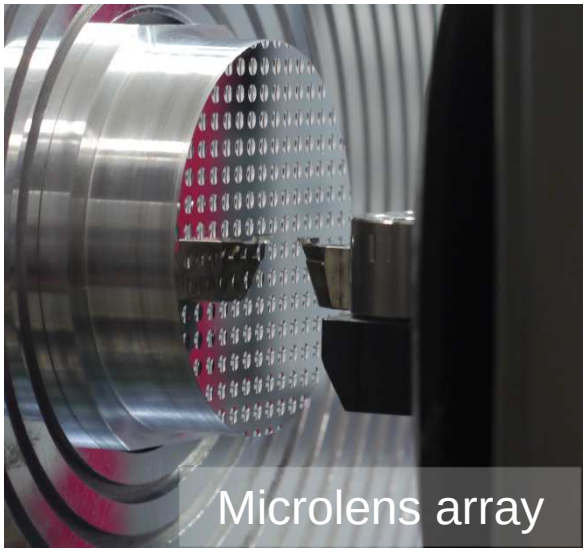
Wide Range of Freeform Geometries

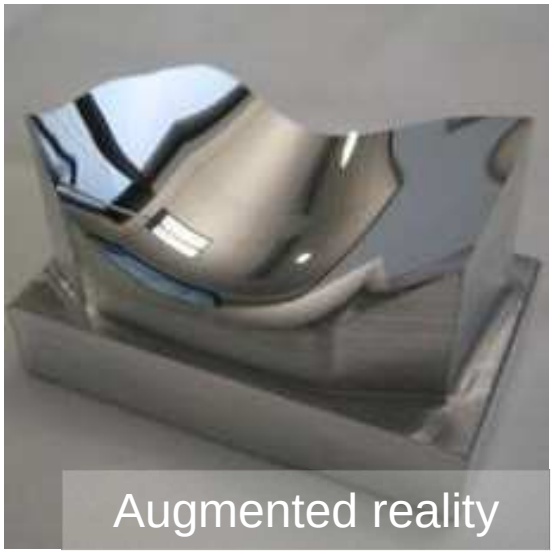
Machined on the »UPC 400«


Facet mirror


Sine wave


Microlens array


Molds


Augmented reality

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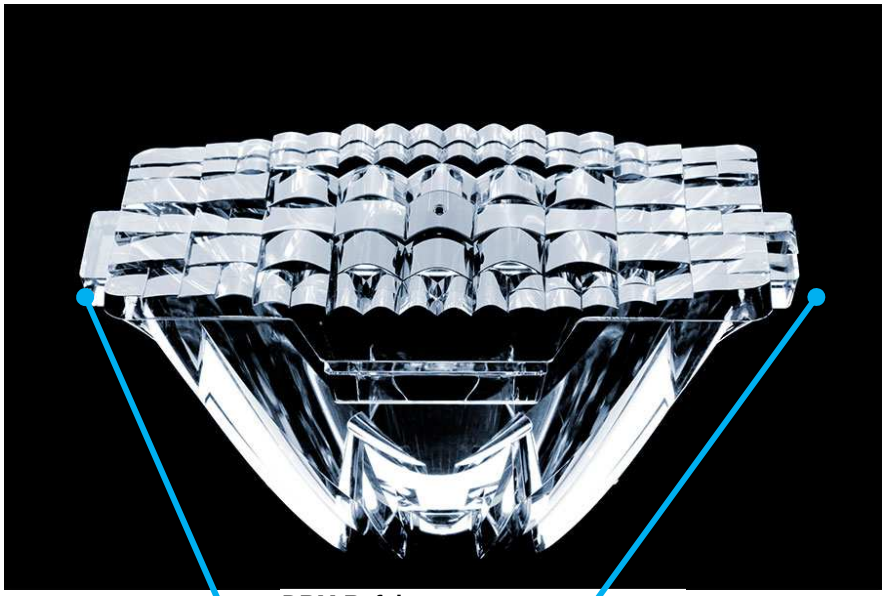
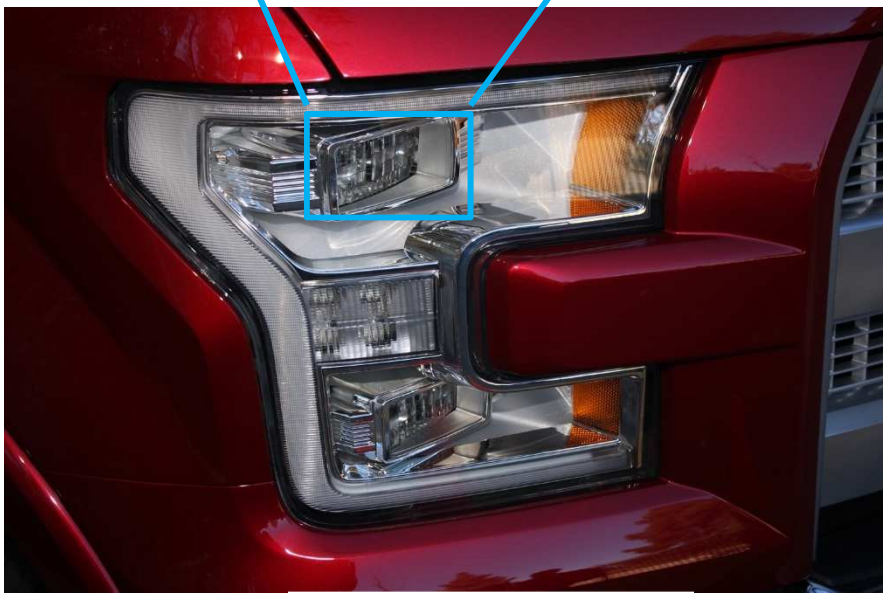
Automotive Lighting



DBM Refelx



Ford

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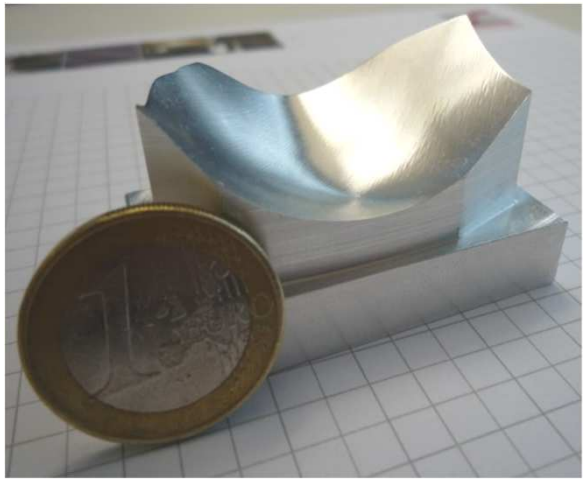
Off-Axis-Machining of Steep Freeform

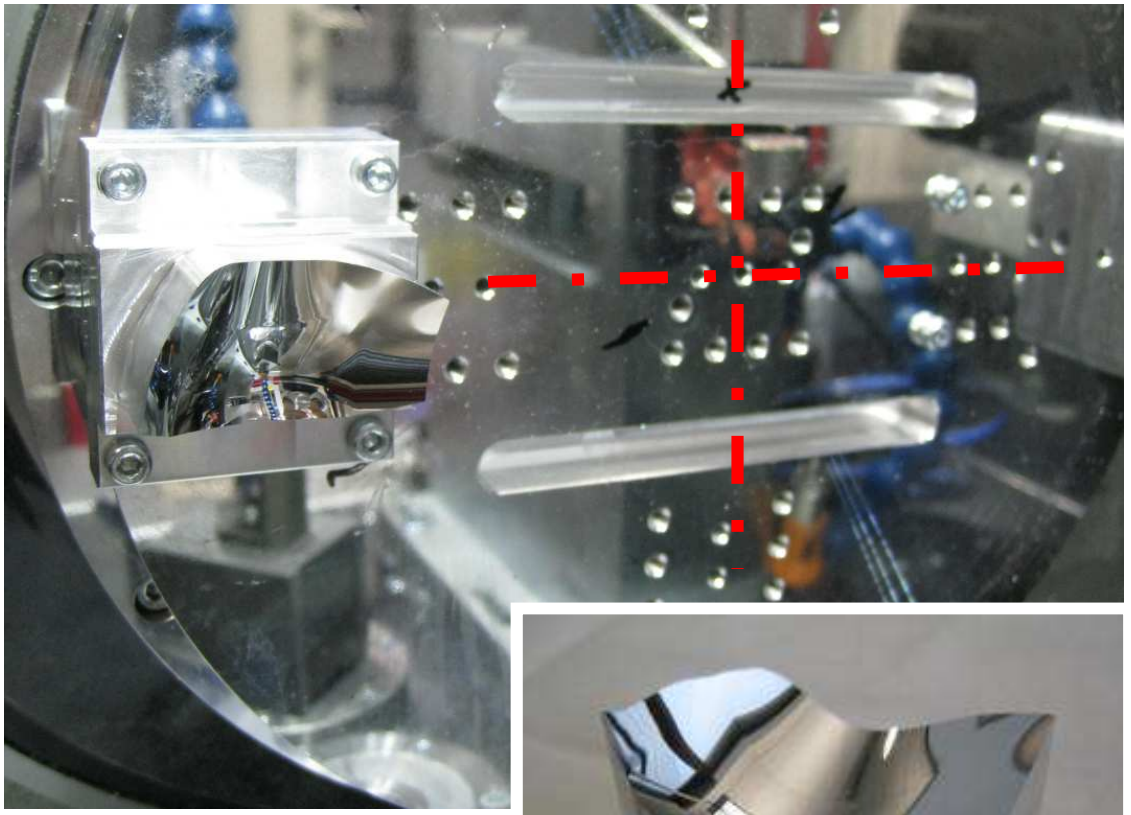
Demonstrator for Mold Insert



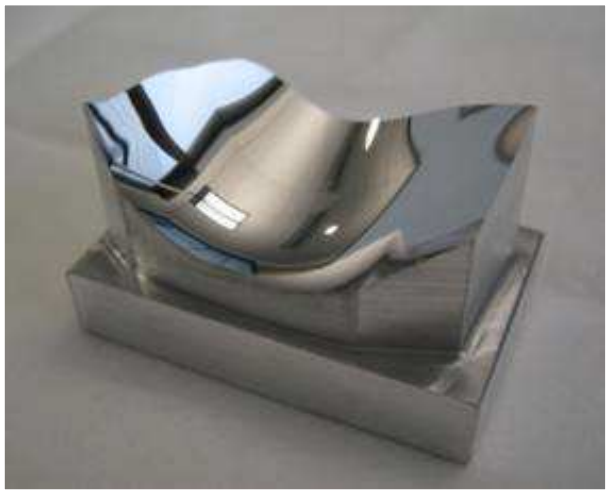
Pre-milled raw piece

Workpiece

_ Material: RSA 6061
_ Dimensions
  _ Width: 30 mm
  _ Length: 50 mm
_ Maximum slopes
  _ Cutting direction: 18°
  _ Horizontal: 40°



In-machine clamping



Finished work piece

Manufacturing of Head Up Display Mirror
Using Fast Tool Machining

Work piece

_ Material: cNiP
_ Geometry: Freeform
_ Area: 100 x 270 mm

Machining parameters

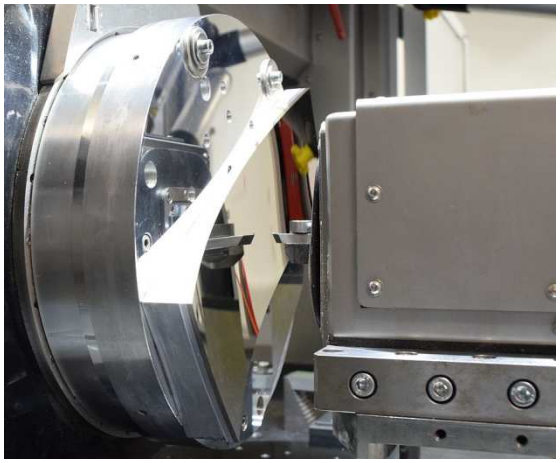
_ Tool radius: 0.5 mm
_ Rot. speed: 100 RPM
_ Machining time: <12 hours

Measurement parameters

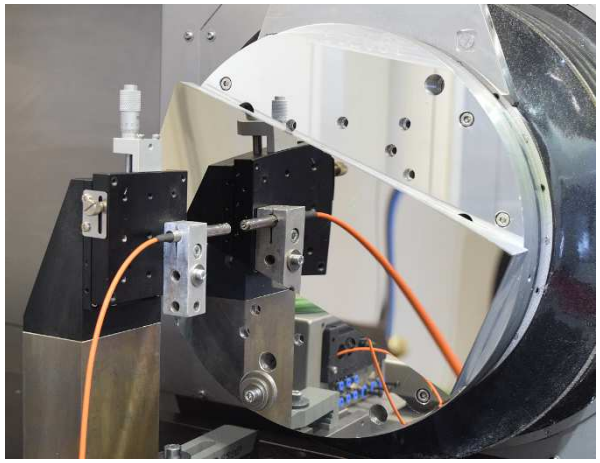
_ Rotational speed: 30 RPM
_ Measurement time:
less than 10 minutes

Results
(**without** compensation)

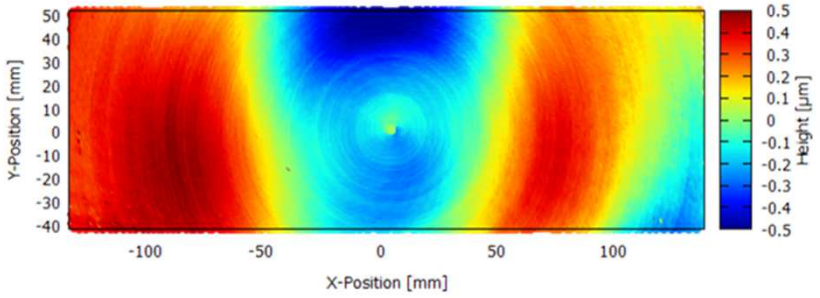
_ Form error: < ± 0.5 µm PV



Fast Tool machining



Optical freeform measurement



Measurement result without compensation
(strong influence of clamping fixture)

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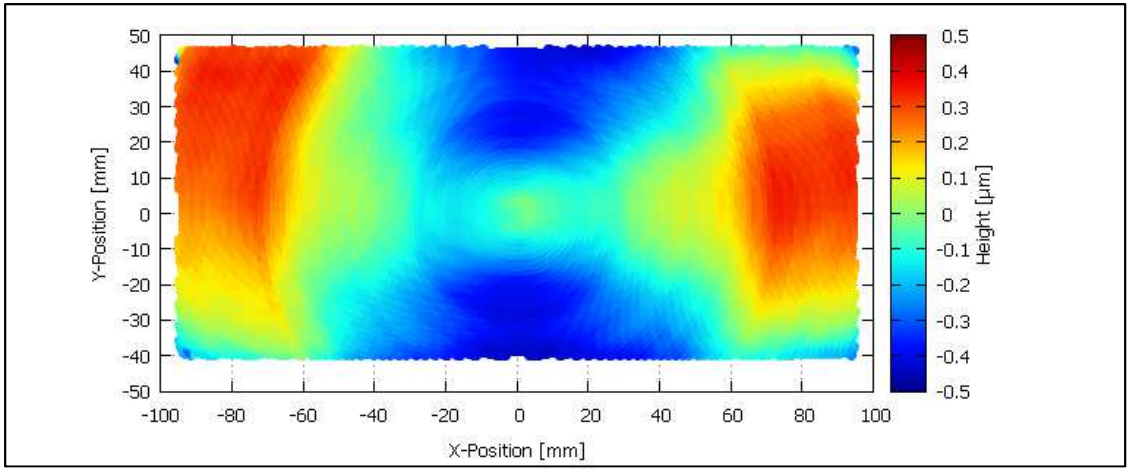
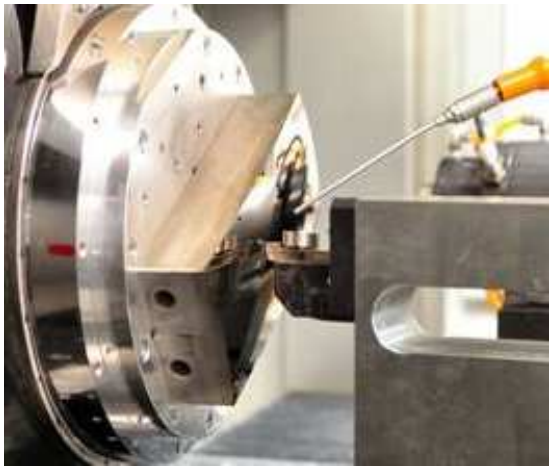
On-Axis Machining of Head Up Display Mold

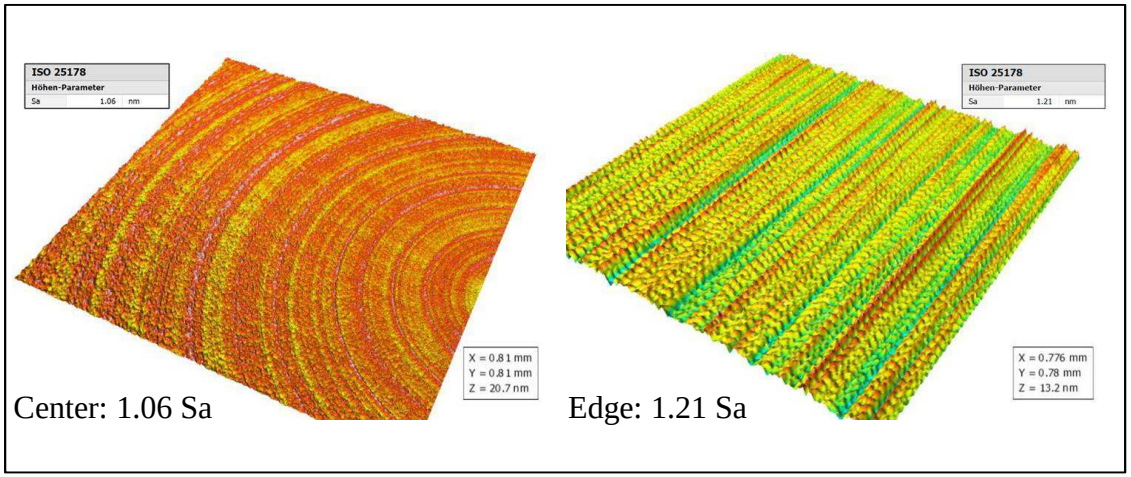
Form and Surface Accuracy



Internal form measurement: < **±0.5 µm PV**



Slow Tool machining NiP mold



Center: 1.06 Sa

Edge: 1.21 Sa

Surface roughness: < **1.25 nm Sa**

Mold with projected line pattern

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Corrective Machining of Freeform Mirror

Using Fast Tool Machining

Work piece

_ Material: Aluminum
_ Geometry: Freeform
_ Diameter: 130 mm

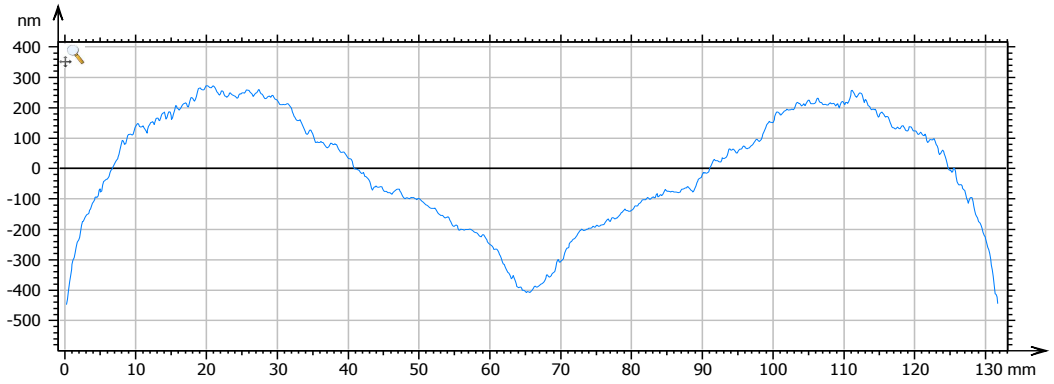
Parameters

_ Tool radius: 0.5 mm
_ Rot. speed: 180 RPM
_ Machining time: < 2.5 h

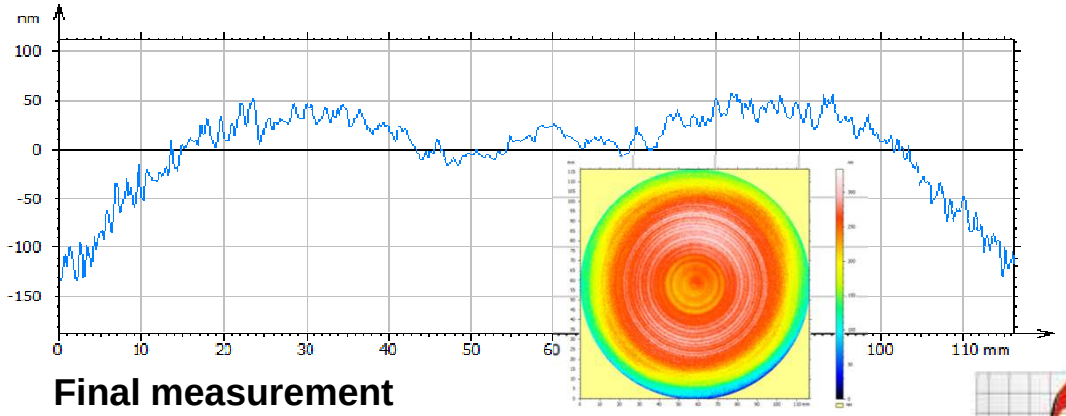
Results of machine integrated measurement

_ Rot. speed: 50 RPM
_ Measurement time less than 10 minutes

Correction reduced form error on relevant aperture by 700%



Initial measurement
700 nm PV over 100% aperture



Final measurement
< +/- 100 nm PV over 90% aperture
< 100 nm PV over Diameter = 100 mm

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