Investigations on the performance of autocollimator-based slope measuring profiler
Outline:

- Introduction
- Latest results on metrology
- Performance test by use of a periodic and chirped sample
Mirror quality and beamline performance

\[ \varphi = \frac{2 \Delta h \sin \theta}{\lambda} \]

* See also: VDI/VDE-Richtlinie Röntgenoptik
IWXM 6. July 2012

small angle scatter

wide angle scatter

Frank Siewert, INT / Optical Metrology
Mirror quality and beamline performance

Thanks to Franz Schäfeers and Silvio Kuenstner

Si
124 eV
θ=5°

specular reflection
small angle scatter
wide angle scatter

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Scanning Penta Prism – Set up

Moving double mirror (45°)

Reticle image \( \alpha = 0 \)

Autocollimator

Collimator objective

Beam splitter

Illumination + reticle

CCD line

Surface under test

diaphragm
Moving double mirror (45°)

\[ d = f \tan(2\alpha) \]

Reticle image
SUT angle \( \alpha \)

Reticle image \( \alpha = 0 \)

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Thermal isolation of the NOM by a double walled and thermal-bridge free housing - thermal stability is excellent.

In addition - low influence of air turbulence on the measurement

- max scan length: \( x = 1200 \text{ mm} \)
- \( y = 298 \text{ mm} \)

- Accuracy:
  - \(< 20 \text{ nrad rms plane optics}\)
  - \(0.1 \mu\text{rad rms curved optics}\)

- Spatial resolution: 1 – 1200 mm

- Min Radius:
  - R=1m (LTP)
  - R=5m (AC)
A plane elliptical focussing mirror for LCLS / CXI-Endstation
– inspecting the mirror clamping

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>$370 \times 50 \times 50 \text{ mm}^3$</td>
</tr>
<tr>
<td>Source dist.</td>
<td>420 000 mm</td>
</tr>
<tr>
<td>Image dist.</td>
<td>8 300 mm</td>
</tr>
<tr>
<td>Incidence angle</td>
<td>3.59 mrad</td>
</tr>
<tr>
<td>Slope err. (mer)</td>
<td>0.061 \text{ } \mu \text{rad rms}</td>
</tr>
<tr>
<td>Fig. error</td>
<td>0.89 nm rms / 3.5 nm PV</td>
</tr>
<tr>
<td>Roughness</td>
<td>$\leq 0.2 \text{ nm rms}$</td>
</tr>
</tbody>
</table>

F. Siewert et al, *Optics Express Volume: 20 Issue: 4, 2012*
IWXM 6. July 2012
An Angstrom mirror for beamline P06 at PETRA-III

Size: $100 \times 50 \times 20$ mm$^3$

Source dist.: 93 595 mm

Image dist.: 355 mm

Incidence angle: 4.715 mrad

Slope err. (mer): 40 nrad rms

Fig. error: $< 0.1$ nm rms / 0.8 nm PV

Roughness: $\leq 0.2$ nm rms

Towards „picometry“

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Residual slope / figure error – mirror optimization by IBF

Graphs showing the comparison between initial and final states:
- Slope [μrad] vs. x-position [mm]
- Height [nm] vs. x-position [mm]
Maypping + IBF enables shape optimization of optical elements

(Focusing mirror for UE48 at BESSY-II)

Res. slopes:
- It. 3: 0.82 µrad rms
- It. 4: 0.56 µrad rms

Height:
- It. 3: 63 nm pv
- It. 4: 30 nm pv


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Characterization of AC-Sensor – Apertur Size Variation

Simulation – spatial resolution

HZB-TXM resolved lines and spaces: 14 nm


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Sample with periodic and chirp profiles

1. Plasma Jet Machining

Tool: RF Plasmajet Rate ~ 80 nm/s, FWHM ~ 0.37 mm

Chirp-Struktur:

$$Amp=2.5;$$
$$P=0.3+(0.04375.*sqrt(50*y));$$
$$z=Amp*cos(2*pi./P.*y)+Amp;$$
Sample with periodic and chirp profiles

Be6arb2v63.wve PV: 91.0 nm RMS: 25.1 nm
482 x 482 Pi / 0.2° gedreht

Be6untergr.wve PV: 37.1 nm RMS: 8.0 nm
482 x 482 Pi
Sample with periodic and chirp profiles

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Sample with periodic and chirp profiles

Be6arb2g3.wve PV: 95.4 nm RMS: 33.8 nm
2442 x 228 Pi \rightarrow 79.4 x 7.4 mm²

Be6arb2v63z.wve PV: 88.4 nm RMS: 25.0 nm
482 x 482 Pi

Chirp-profile with underground
Microroughness after etching on the chirped section

10mm from left edge, $R_q = 0.26$ nm

20mm from right edge, $R_q = 0.17$ nm
Section with 2mm period

- 1.8mm
- 2.0mm
- 2.5mm diaphragm
- 3.0mm
- 5.0mm

dx = 0.2mm

NOM: 0.9 nm rms
ZYGO: 1.3 nm rms
Section with 1mm and 0.5mm period

1mm - period

NOM: 0.3 nm rms
ZYGO: 2.3 nm rms

0.5mm - period

dx = 0.2mm

dx = 0.05mm
PSD for 1.8mm Diaphragm

- 2mm period
- 1mm period
- 0.5 mm period

One Dimensional PSD [mm x μrad²]

Tangential Spatial Frequency [mm⁻¹]
Summary

- ultra precise mirrors with nm and sub-nm accuracy are available

- Ultra precise metrology is a key-technology to verify these achievements

- Dedicated mechanics and clamping strategy is essential for a shape preserving mount of optics

- Spatial periods of 1mm can be identified – but not with precise height resolution

- Special care is required to define the right combination of autocollimator and diaphragm-diameter: 2 - 2.5mm in case of BESSY-NOM depending on curvature of SUT

- This method can be applied in principle to all kind of slope measuring profiler
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Thank you for your attention