Characterization of Performance and Lifetime of EUV Source Collectors with a Full Size EUV Collector Reflectometer


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Outline

• Introduction

• Concept of EUV source collector reflectometer
• EUV metrology source
• Schwarzchild objective
• Reflectometer hardware & results

• Conclusion
EUV Source Collector Optics

- Wolter-Shell Type 1 nested reflecting mirrors

- Source side: collection angle up to 2 sr (up to NA 0.73 = 47°)

- Intermediate focus side: up to 0.24 sr (up to NA 0.28 = 16°)
Reflectometer Concept

Orientation in high power Xenon source

Little space for spectral filtering, beam shaping etc.

Inverse orientation in metrology stand suggested by XTREME
Metrology Source

- EUV-tube (sem|20): modified μ-focus X-Ray tube
- Uses Si L$_{2,3}$ emission at 13.5 nm
- compact, stable, debris-free

- EUV power 30µW 2πsr
- spot size down to 20µm dia. possible
Mo/Si multilayer mirrors
Input numerical aperture up to NA 0.01 (0.57°, 3·10⁻⁴ sr)
Output numerical aperture up to NA 0.28 (16°, 0.24sr)
Focus on mirror surface
Demagnification × 28
**$I_0$-Measurement Behind Objective**  
*(in Front of Collector)*

- CCD camera about 20 mm behind focus
- Total power in image after objective and filters: 30-50 pW (EUV, in band)

**Diagram:**
- EUV source
- Schwarzschild Objective
- CCD camera (thinned)
- Stopper for direct light, $r=300\mu$m
- EUV image
  - Counts per pixel: 0 to 20,000
  - X (pixel): 0 to 900
  - Y (mm): 13 mm
Before Collector Measurement: Adjustment Verification

- CCD-camera behind collector

- adjustment verification: collector focus + direct light on CCD
Focal Images

-800 µm
-400 µm
-200 µm
0 µm
+200 µm
+600 µm
Test Collector Images: Focus to „Extra Focus“

- Point-like source, inverse configuration
- High spatial resolution of the reflectometer enables accurate metrology
Collection Efficiency

• collection efficiency = \( \frac{I}{I_0} \cdot c \)

\( c = \) correction factor considers:

- angular intensity distribution
- CCD camera angular sensitivity (measured at synchrotron Bessy II, PTB)
- numerical aperture correction
- inverse geometry (ray tracing calculations)

• reflectometer accuracy better than 1.5%'
### Collection Efficiency

<table>
<thead>
<tr>
<th>Collector</th>
<th>Coating</th>
<th>Calculated</th>
<th>Measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-shell</td>
<td>Gold</td>
<td>2.34%</td>
<td>2.37%</td>
</tr>
<tr>
<td>Dual-shell</td>
<td>PVD Ru</td>
<td>9.0%</td>
<td>7.8-8.1%</td>
</tr>
<tr>
<td>Full-configuration</td>
<td>PVD Ru</td>
<td>17.1%</td>
<td>16.4-17%</td>
</tr>
</tbody>
</table>
Summary

• First full-size laboratory EUV collector reflectometer
• >20 different collectors tested
• >50 Collector measurements
• Metrology source: EUV-tube
• Measurement of focal spot size, collection efficiency, optical quality, lifetime and ageing,…

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