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

Ulf Hinze[a], Torsten Feigl[b], Max-Christian Schürmann[c], and Boris N. Chichkov[a]

[a] Laser Zentrum Hannover e.V., Hollerithallee 8, D-30419 Hannover, Germany, e-mail: u.hinze@LZH.de
[b] Fraunhofer IOF Jena, Albert-Einstein-Straße 7, D-07745 Jena, Germany
[c] XTREME technologies GmbH, Hans-Adolf-Krebs-Weg 1, D-37077 Göttingen

Outline

The lifetime and the efficiency of EUV source collector optics will have direct impact on the cost effectiveness of the EUV lithography semiconductor production. Therefore the collector optics was identified as a critical issue in EUVL. To continually improve and optimize the source collector optics precise measurements of the optics characteristics are required as well as life time studies.

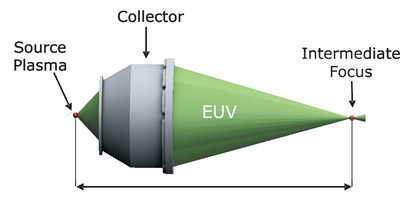
Adequate measuring equipment must be designed to perform these measurements on-site, at-wavelength and under realistic conditions. Moreover, the measurement accuracy must be sufficient to allow the detection of small changes in reflectivity and homogeneity of the EUV source collector optics. This makes it possible to predict the lifetime of an EUV source collector operated with a high power EUV source after a fraction of the specified pulse number, e.g. after a couple of hours.

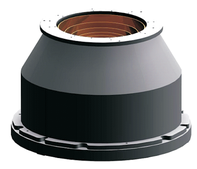
A reflectometer for the investigation of full EUV source collectors was developed, designed and set up. As an EUV source a commercial microfocus EUV tube was used. This source is particularly suitable for application in metrology, as it is very stable in its output parameters (namely power, spectrum, spot size, spot position), and it does not emit debris.
The radiation cone emitted by the EUV source is tailored with a Schwarzschildobjective to the spectral and geometrical requirements of the Wolter-shell EUV source collector optics

At the time of this contribution the measurement system presented here is in operation since 18 months, and a large number of collector measurements was performed. It is used for the quality control of factory-new EUV source collectors as well as for repeated measurements within the context of lifetime tests. With this device the efficiency of debris filters, which prevent the EUV source collector optics from contamination, could be determined and improved.

EUV Source Collector Optics

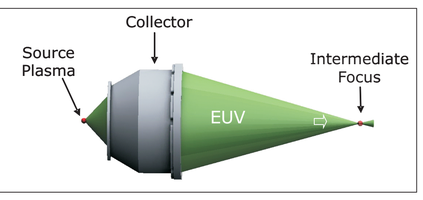
- Wolter-Shell Type 1 nested reflecting mirrors
- Source side: collection angle up to 2 sr (up to NA 0.73 = 47°)
- Intermediate focus side: up to 0.24 sr (up to NA 0.28 = 16°)





Reflectometer Concept

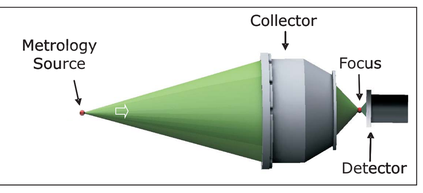
Orientation in high power Xenon source



Little space for spectral filtering, beam shaping etc.

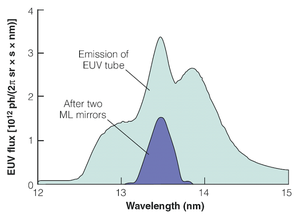
➔ Inverse orientation in metrology stand

suggested by XTREME



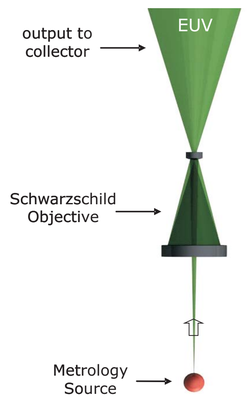
Metrology Source

- EUV-tube: 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



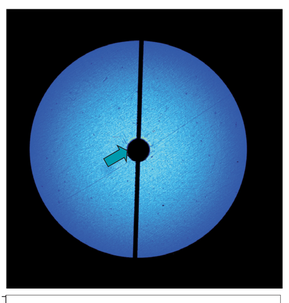
Schwarzschild Objective
for beam shaping and spectral filtering

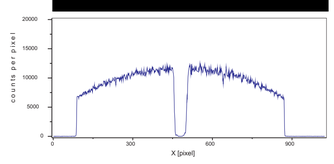
- Mo/Si multilayer mirrors
- Input numerical aperture up to NA 0.01 (0.57°, $3 \cdot 10^{-4}$ sr)
- Output numerical aperture up to NA 0.27 (15.7°, 0.23sr)
- Focus on mirror surface
- Demagnification x 28



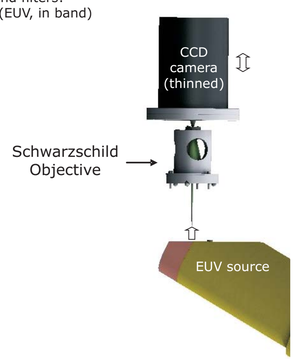
Fraunhofer Institut Angewandte Optik und Feinmechanik

I_0-Measurement Behind Objective
(in Front of Collector)



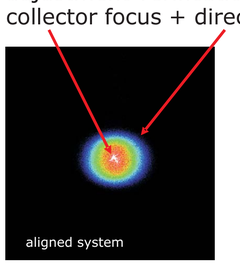


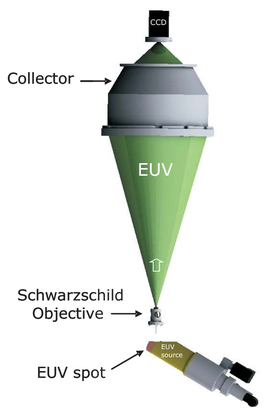
- CCD camera about 20 mm behind focus
- total power in image after objective and filters: 30-50 pW (EUV, in band)



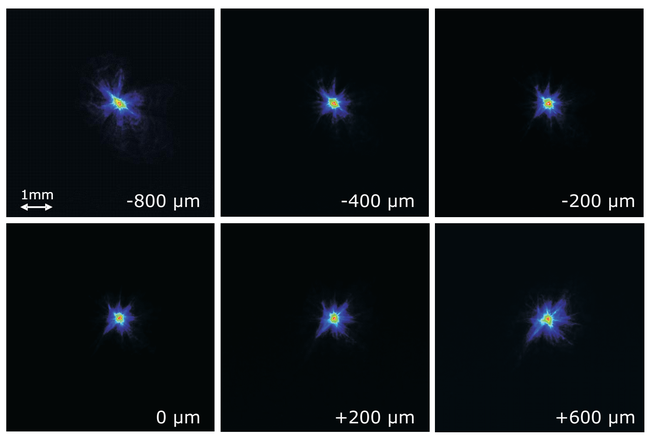
Before Collector Measurement: Adjustment Verification

- CCD-camera behind collector
- adjustment verification: collector focus + direct light on CCD



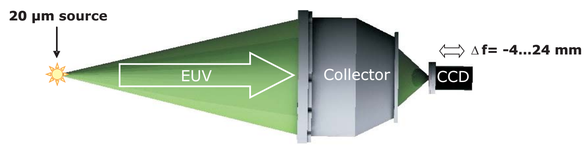


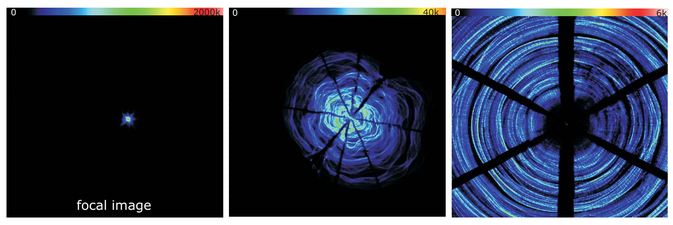
Focal Images



Test Collector Images: Focus to „Extra Focus"

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



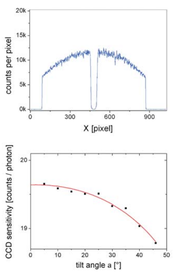


Collection Efficiency

- collection efficiency = I / I0 · 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

Collector	Coating	Calculated	Measured
Single-shell	Gold	2.34%	2.37%
Dual-shell	PVD Ru	9.0%	7.8-8.1%
Full-configuration	PVD Ru	17.1%	16.4-17%

Summary

- First full-size laboratory EUV collector reflectometer
- lots of different collectors tested
- >50 Collector measurements
- Computer controlled measurement
- Based on EUV-tube
- Measurement of focal spot size, collection efficiency, optical quality, lifetime and ageing,…

Acknowledgements

- Antonio Ritucci
- Gianluca Cassol
- Michel Fokoua
- André Egbert
- Thomas Mißalla

LASER ZENTRUM HANNOVER e.V.

EUVL International Symposium on Extreme Ultraviolet Lithography Praha 2009