

LPP collector mirrors – coating, metrology and refurbishment

2013 International Workshop on EUV and soft X-Ray Sources

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Outline

- Introduction to optiX fab
- History of LPP collector mirror coating at IOF / optiX fab
- NXE:3100 LPP collector lifetime
- Refurbishment of EUV collector mirrors
 - top layer refurbishment
 - multilayer stripping and recoating
- Summary and acknowledgement

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Team and organization

- Organization: GmbH (limited liability company)
- Mission: Fabrication of customized optics and optical components for EUV lithography @ 13.5 nm, synchrotron and FEL beamlines, metrology, R&D applications, etc.
- Team: Torsten Feigl, Marco Perske, Hagen Pauer, Tobias Fiedler



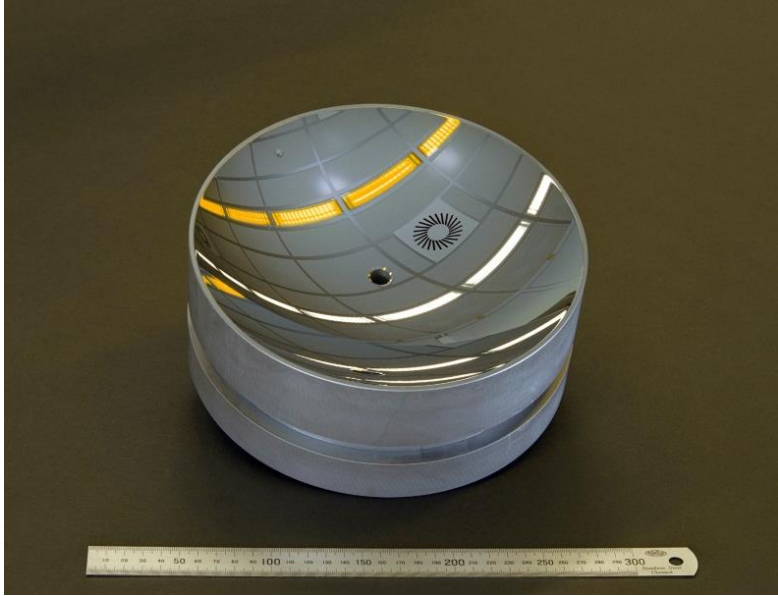
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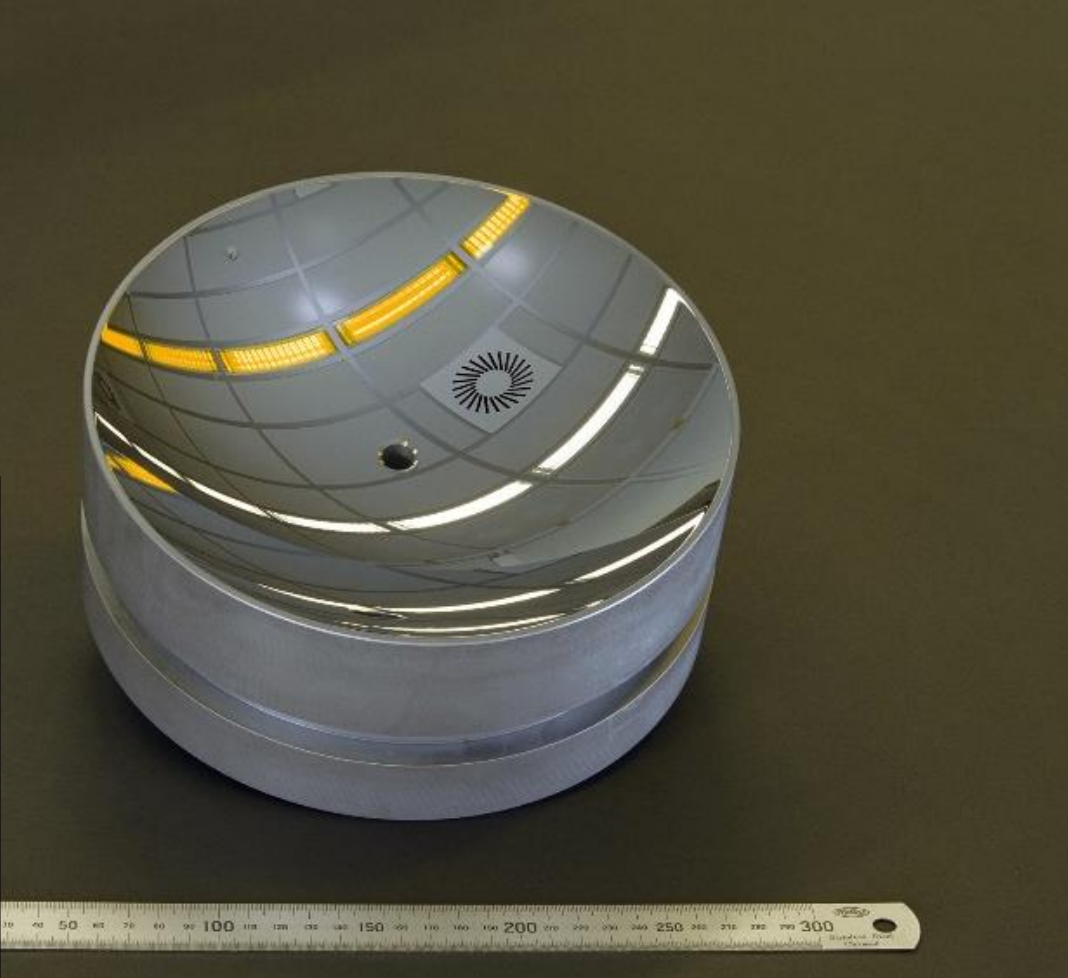
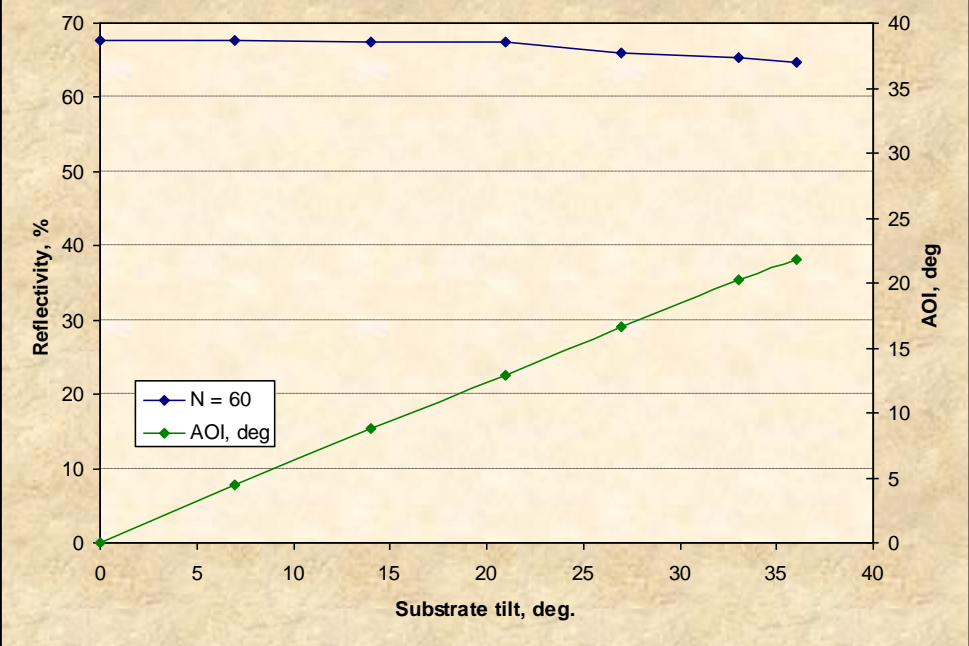
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Multilayer coated collector optics for LPP sources



First π sr multilayer collector realized in 2004

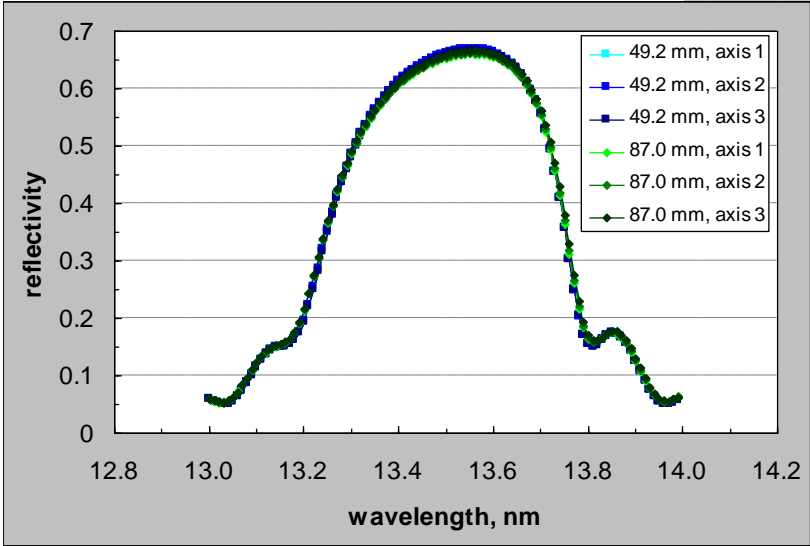
Measured EUV reflection and angle of incidence on EUV collector mirror (R-measurement: PTB Berlin).



First 300 mm multilayer collector realized in 2006

$R_{CA} > 66.5 \% \text{ (s-pol)}$
 $\lambda = 13.500 \text{ nm}$
 $\text{FWHM} > 0.510 \text{ nm}$
 $\sigma_{\lambda} = 0.001 \text{ nm}$

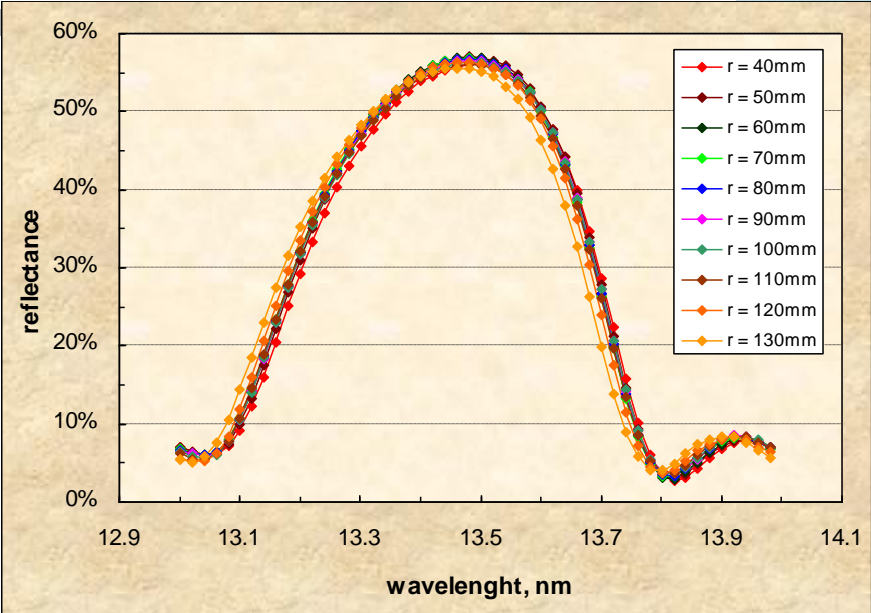
Measurements: PTB Berlin



High-temperature multilayer collectors realized in 2008

$R_{CA} > 58\%$ (s-pol)

New Mo/X/Si/X coating with superior thermal stability up to 600 °C



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LPP collector coating challenges

$R > 50 \%$ (uncapped ML)

$\lambda = (13.50 \pm 0.03) \text{ nm}$

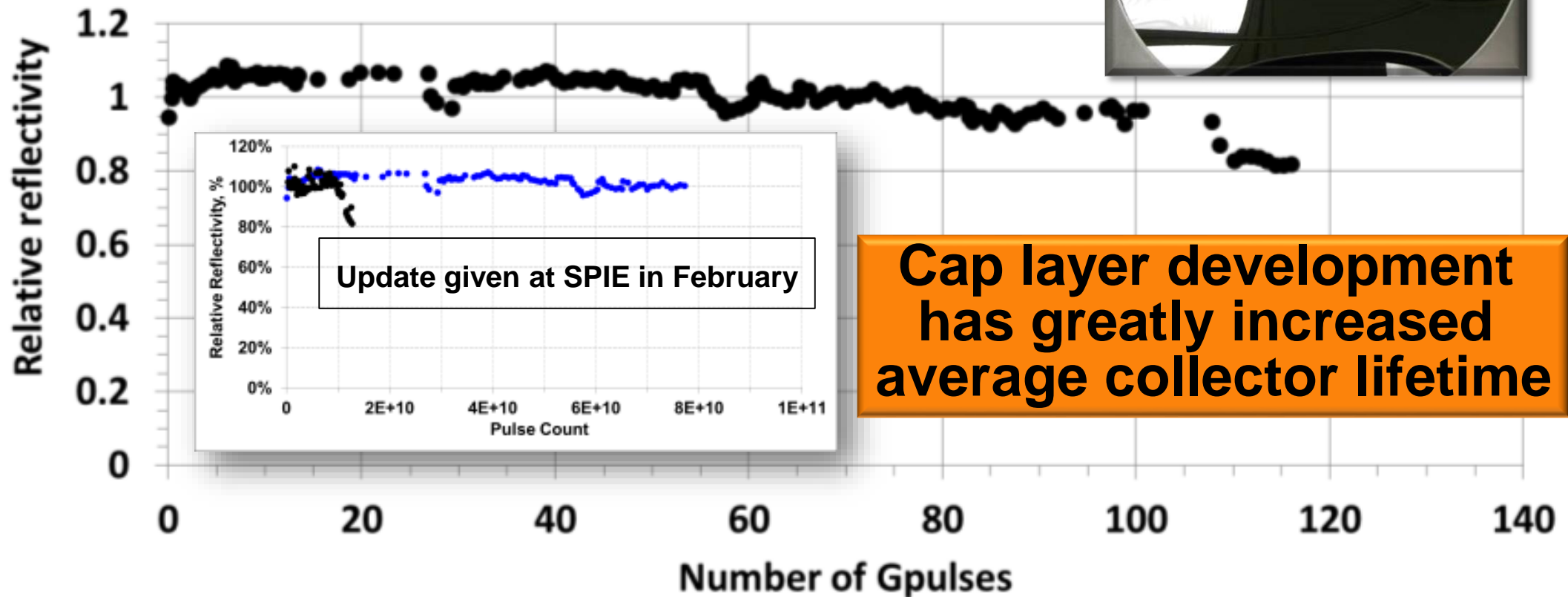
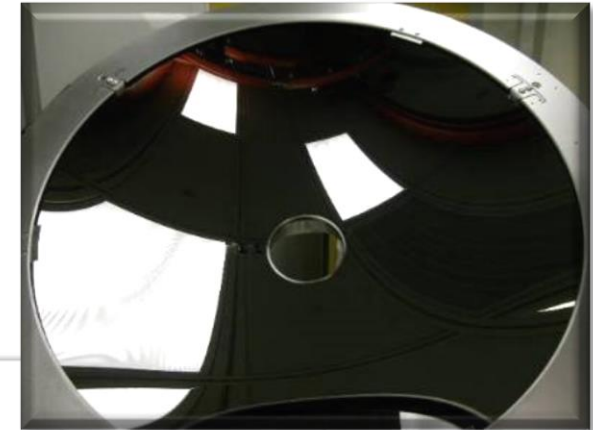
$\rightarrow \Delta d = 0.015 \text{ nm} = 15 \text{ pm}$

- Diameter: $> 660 \text{ mm}$
- Lens sag: $> 150 \text{ mm}$
- Tilt: $> 45 \text{ deg}$
- Weight: $> 40 \text{ kg}$



NXE:3100 - Improved collector lifetime in the field

**Champion lifetime in the field ~11 months
(~120 billion pulses)
Six collectors with >6 months lifetime**



Collector damage and degradation mechanisms

- Impact of particles, ions, radiation onto the collector
- Degradation mechanisms on the surface: tin accumulation, ion damage, oxidation, blistering,...
- Tin deposition is the dominant mechanism
- Damage occurs only at the top section of the coating
- With additional coating protection, the collector field performance has become much more mature
- Huge lifetime improvements were achieved by the introduction of new and improved cap layers

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EUV reflectance mapping after coating

Measurement of s-polarized EUV reflectance at 13.500 nm over full collector CA

(3360 measurement points)

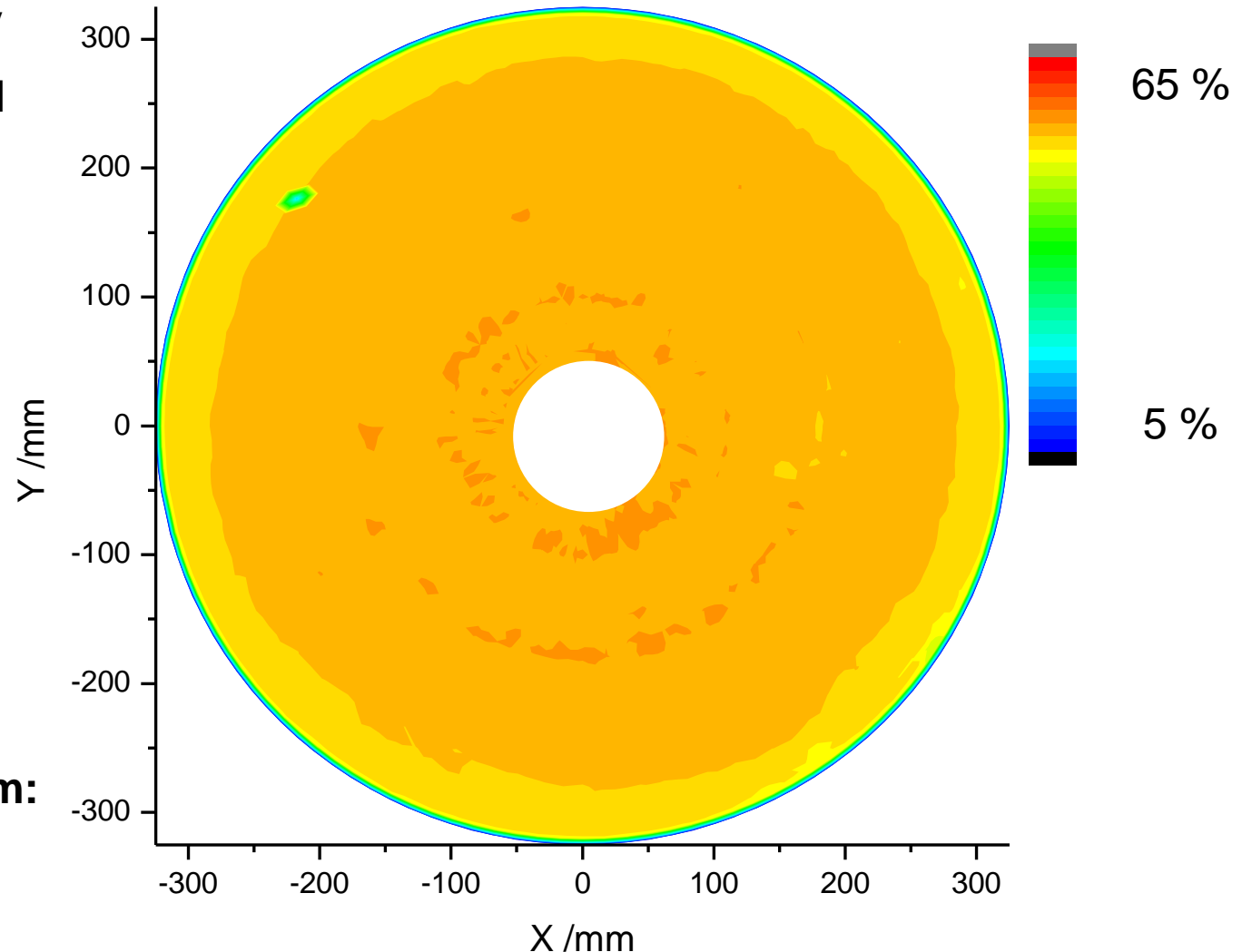
Average reflectance

$$\langle R_{s-pol} \rangle = 53.5 \%$$

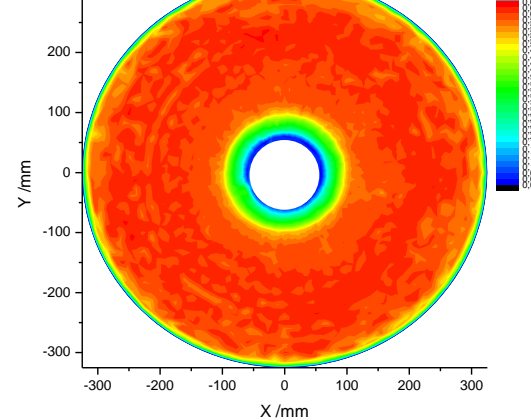
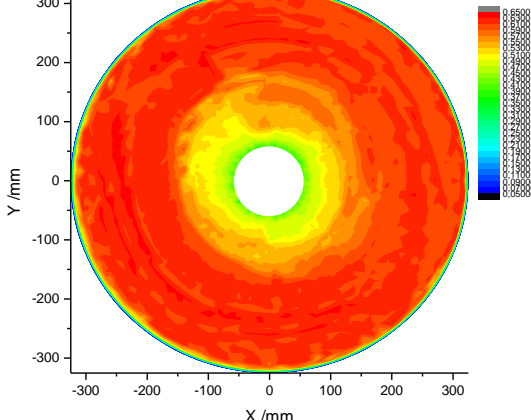
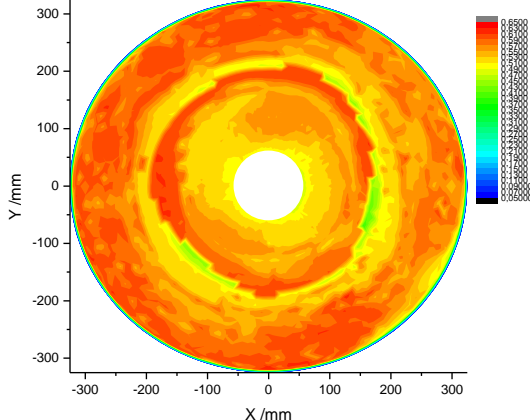
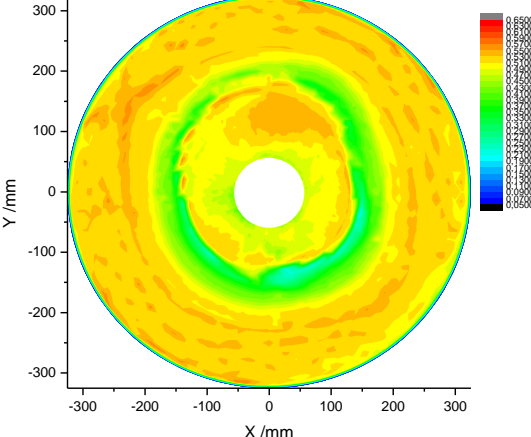
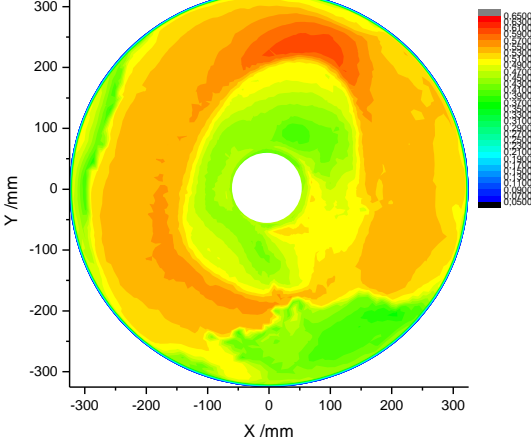
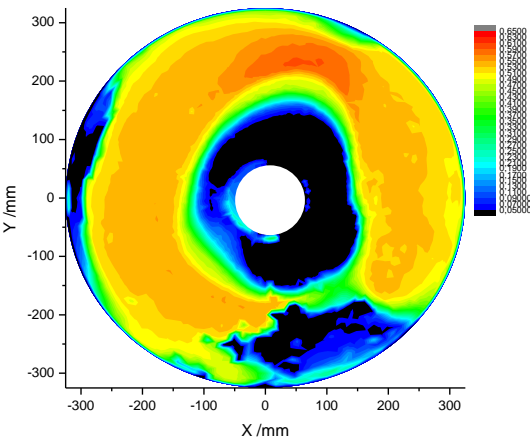
$$\langle R_{upol} \rangle = 44.7 \%$$

EUV reflectance map @ 13.5 nm:

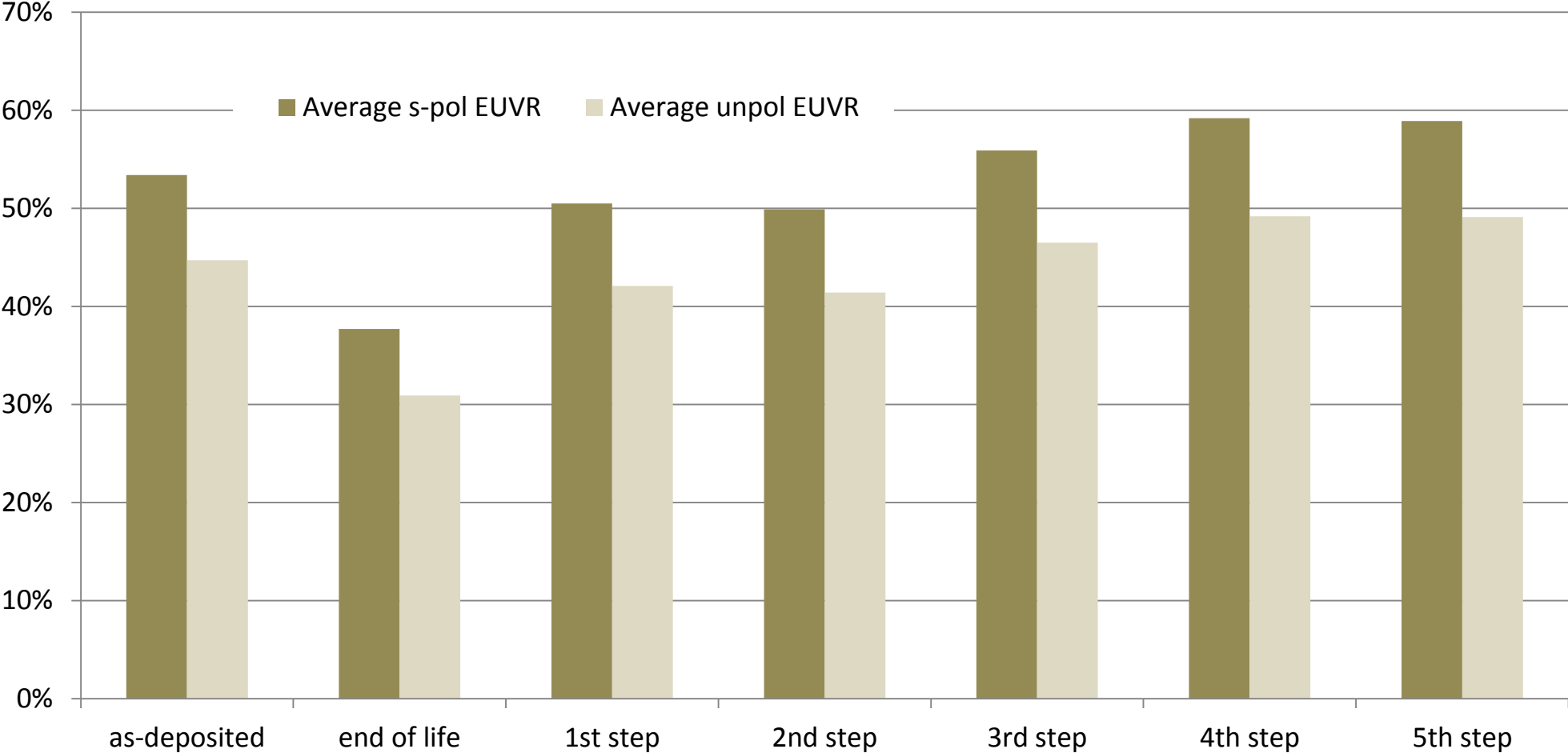
Measurements: PTB Berlin



EUV reflectance mappings at different stages of refurbishment



Averaged EUV reflectance at different stages of refurbishment



BB04: EUV reflectance after coating of capping layer

Measurement of s-polarized EUV reflectance at 13.500 nm over full collector CA

(3360 measurement points)

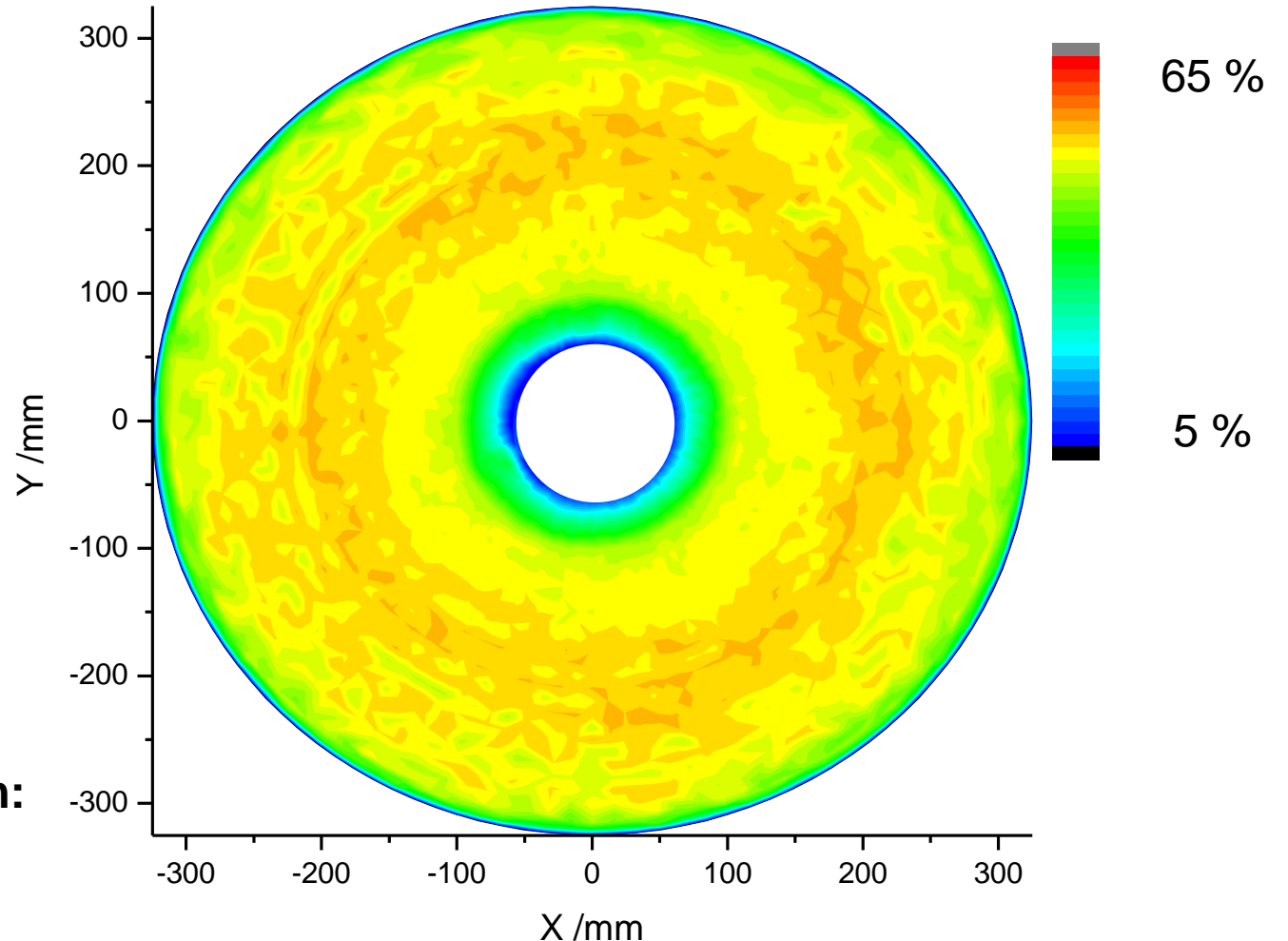
Average reflectance

$$\langle R_{s-pol} \rangle = 47.7 \%$$

$$\langle R_{upol} \rangle = 39.8 \%$$

EUV reflectance map @ 13.5 nm:

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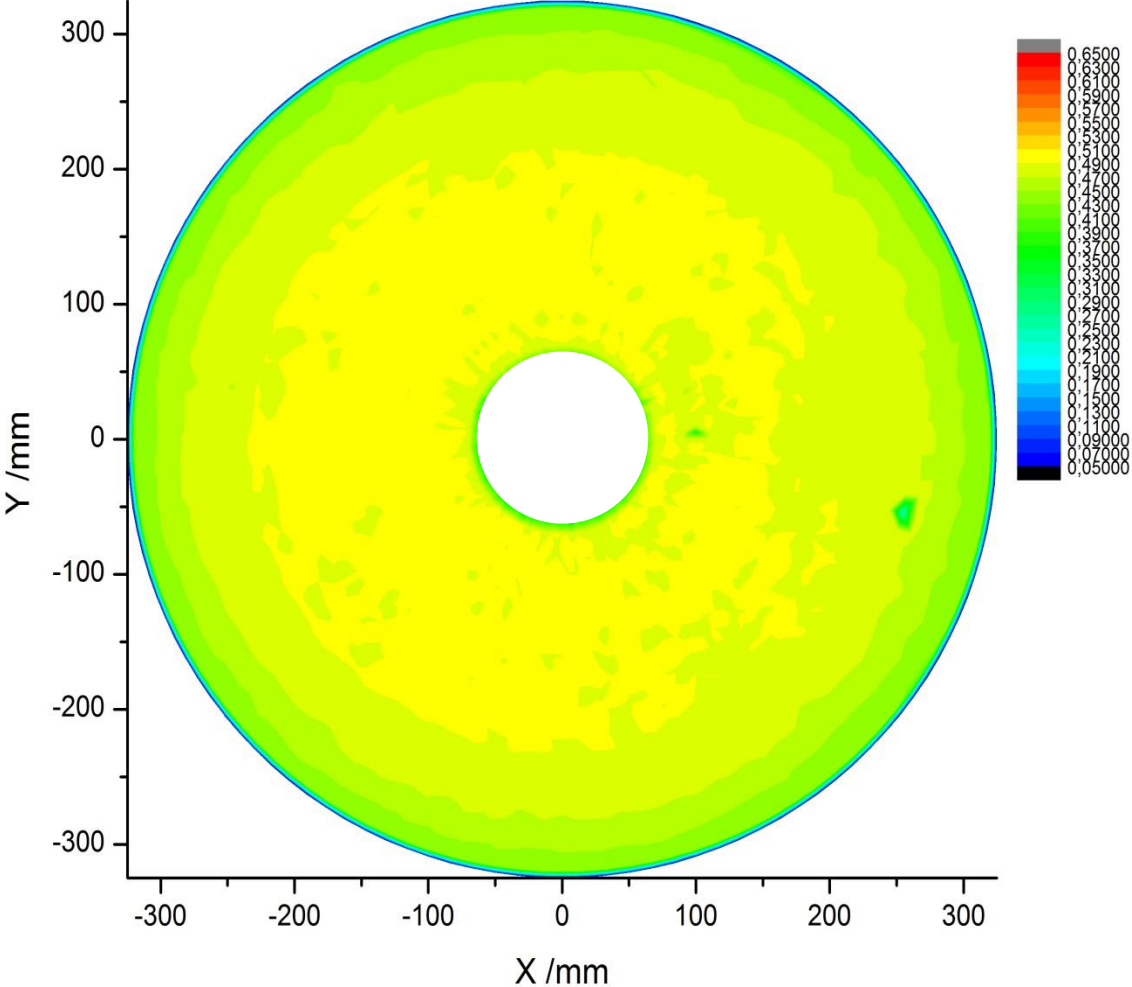
Complete multilayer stripping and recoating – initial reflectance

Initial coating

Average reflectance

$\langle R_{\text{upol}} \rangle = 39.8 \%$

EUV reflectance map @ 13.5 nm:



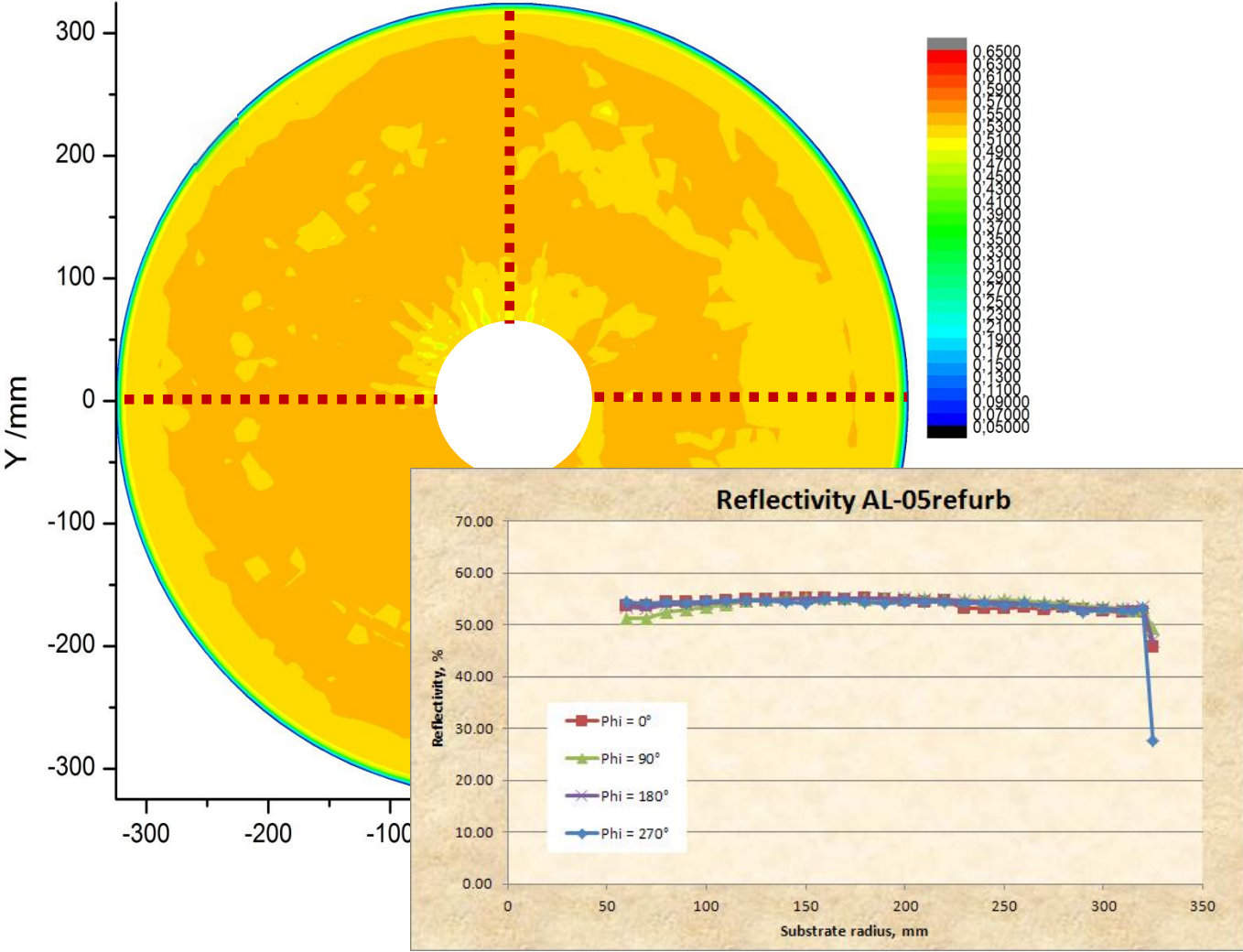
Complete multilayer stripping and recoating

Complete ML stripping + recoating

Average reflectance

$\langle R_{\text{upol}} \rangle = 43.8 \%$

EUV reflectance map @ 13.5 nm:



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Summary

- Collector lifetime: 120 Billion pulses with new collector coating
- It is possible to refurbish multilayer LPP collector mirrors!
- Collector refurbishment:
 - keeping initial ML coating: **90 % of initial EUVR**
 - stripping initial ML coating and ML recoating: **no EUVR loss**

Acknowledgements

- **EUV source development team @ Cymer and @ ASML**
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optiX fab.

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