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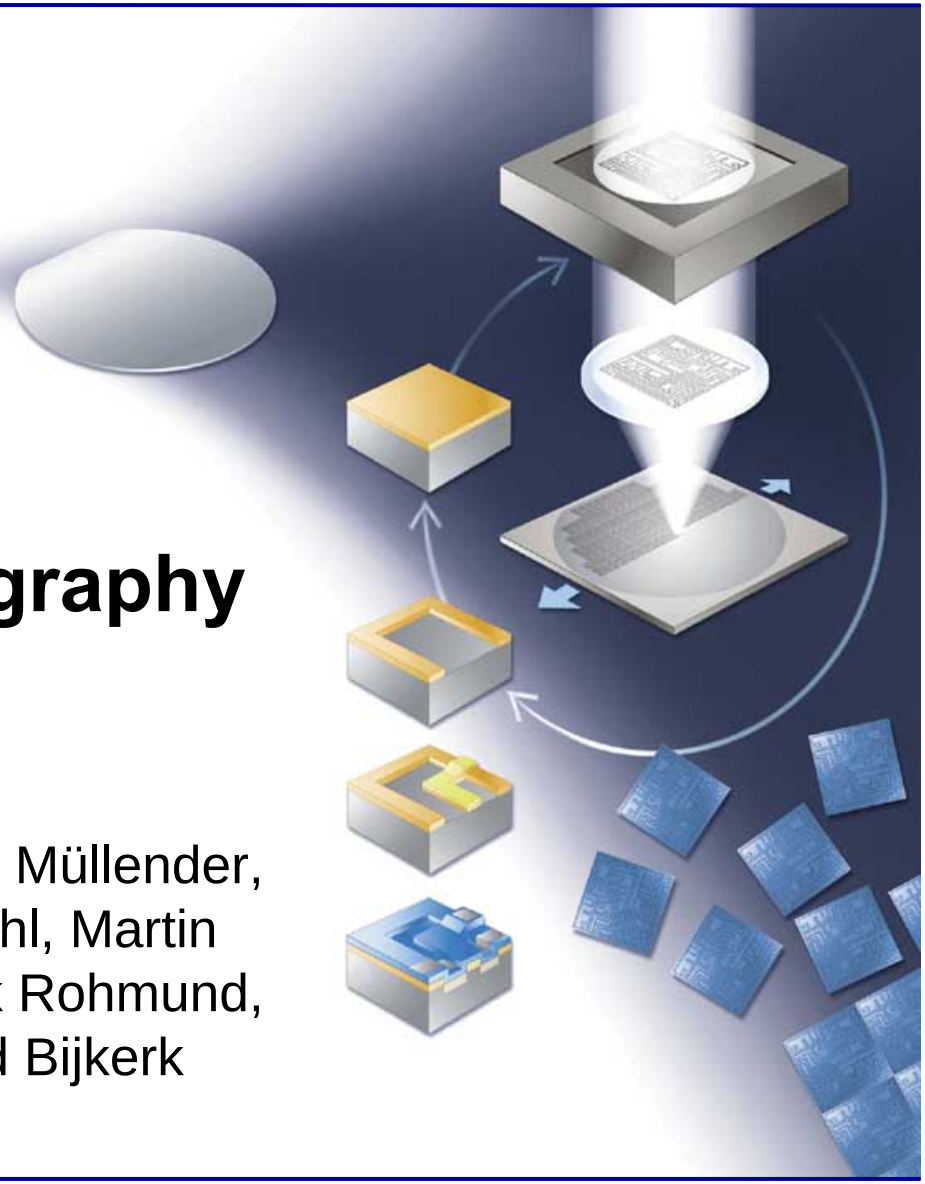
Lithography Optics Division



Optics for EUV Lithography

Peter Kürz, Thure Böhm, Stephan Müllender, Wolfgang Bollinger, Manfred Dahl, Martin Lowisch, Christian Münster, Frank Rohmund, Thomas Stein, Erik Louis, Fred Bijkerk

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EUV alpha demo tool: Status at Zeiss

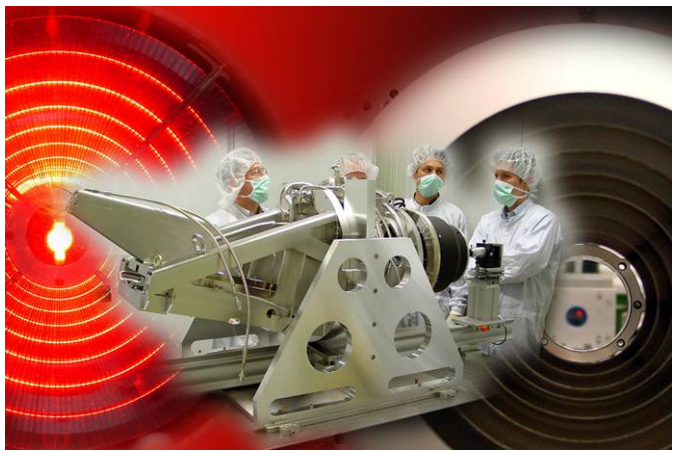
Key specifications

λ	13.5 nm
NA	0.25
Resolution	50 nm
field	26x33 mm²
Magnification	4x

One illuminator has been qualified and the second is in process

Design example

The early projection optics is in the qualification phase



A collector module has been qualifed and is used to test the illuminator at wavelength.

N. Harned et al: this conference

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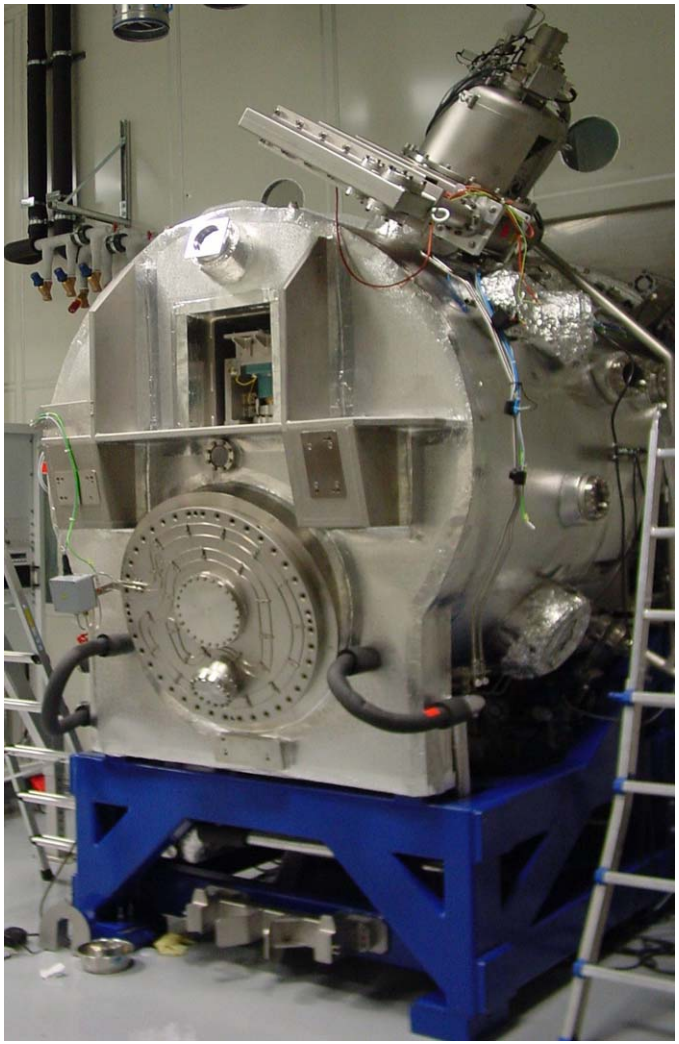
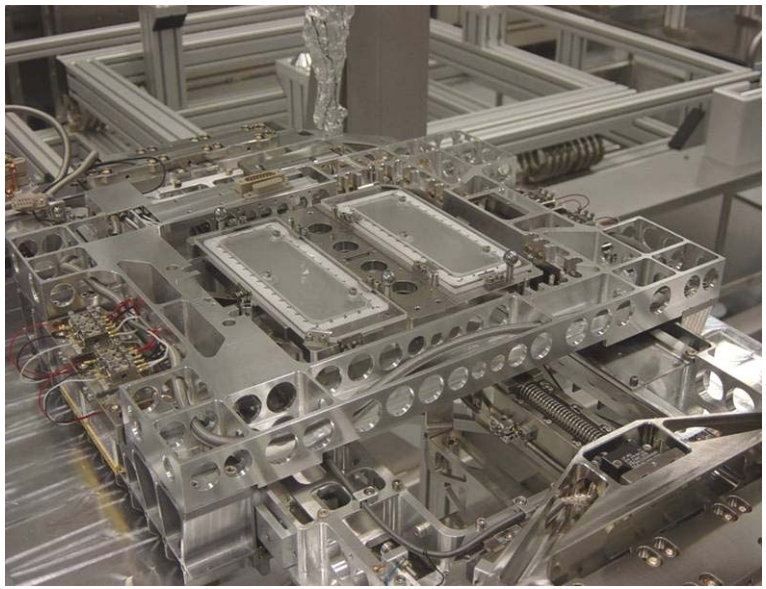
Illuminator

EUV qualification: hardware



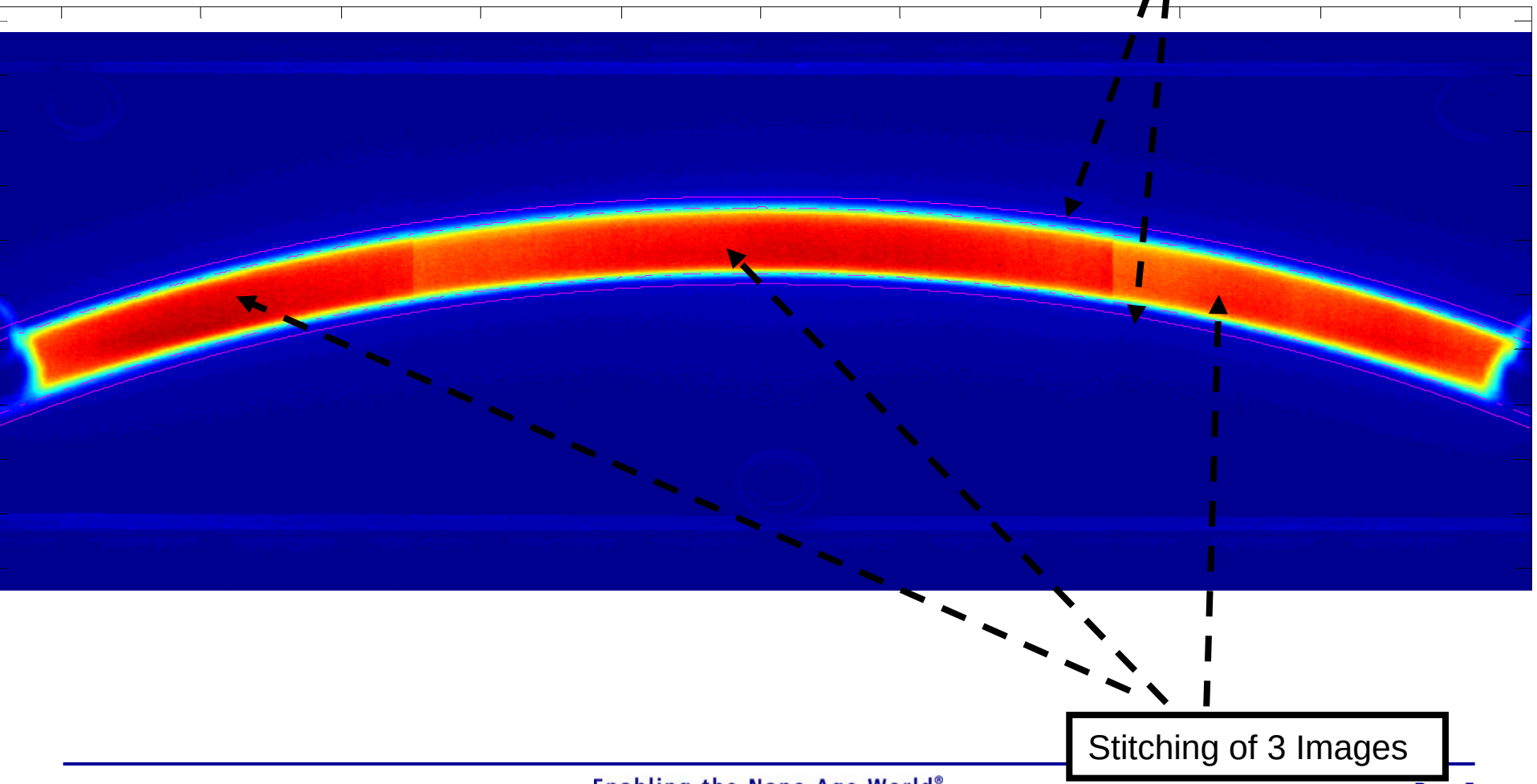
@ λ illuminator metrology tool



„reticle stage“ for metrology

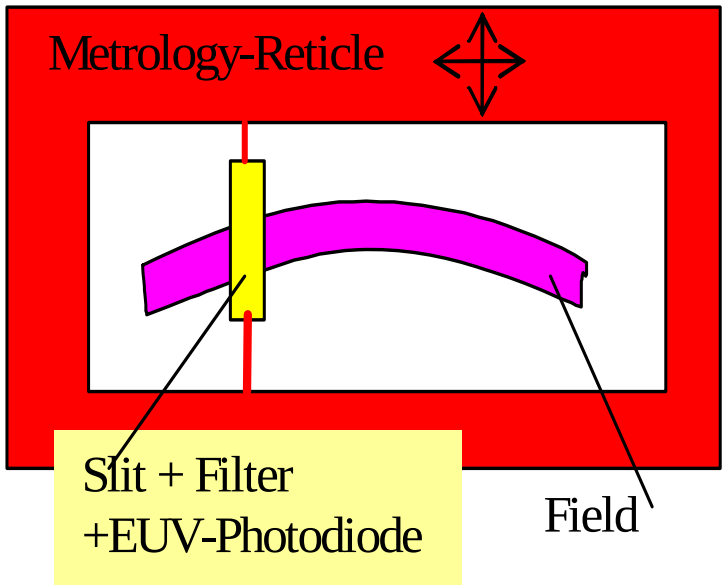
EUV qualification: Results (1)

Ring field measurement Metrology



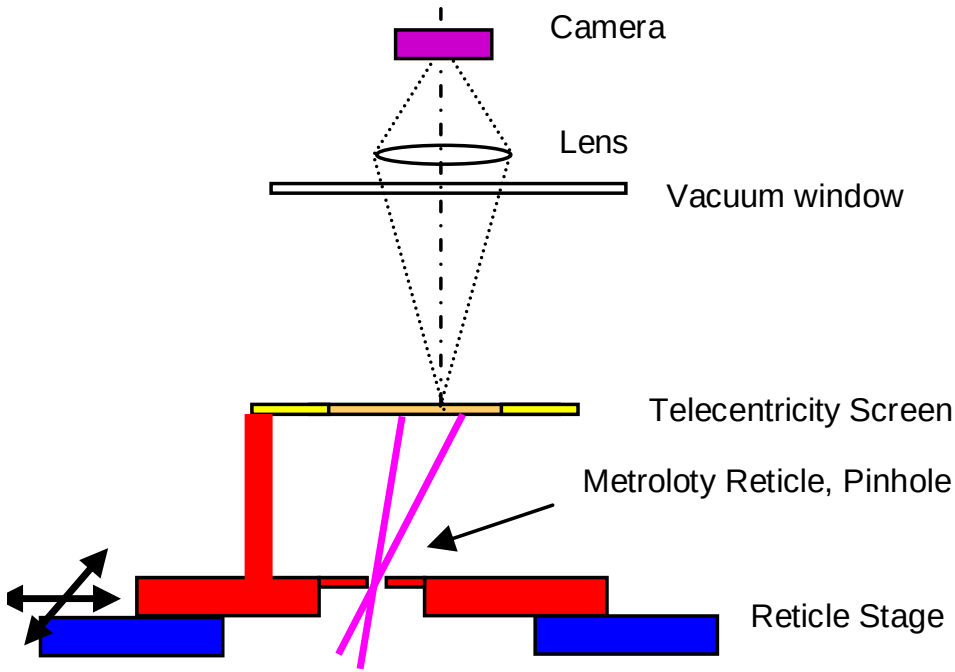
EUV qualification: concept for field and pupil qualification

Setup for Field Qualification



Scanning field with slit EUV photodiode. Integration in y-direction.

Setup for Pupil Qualification



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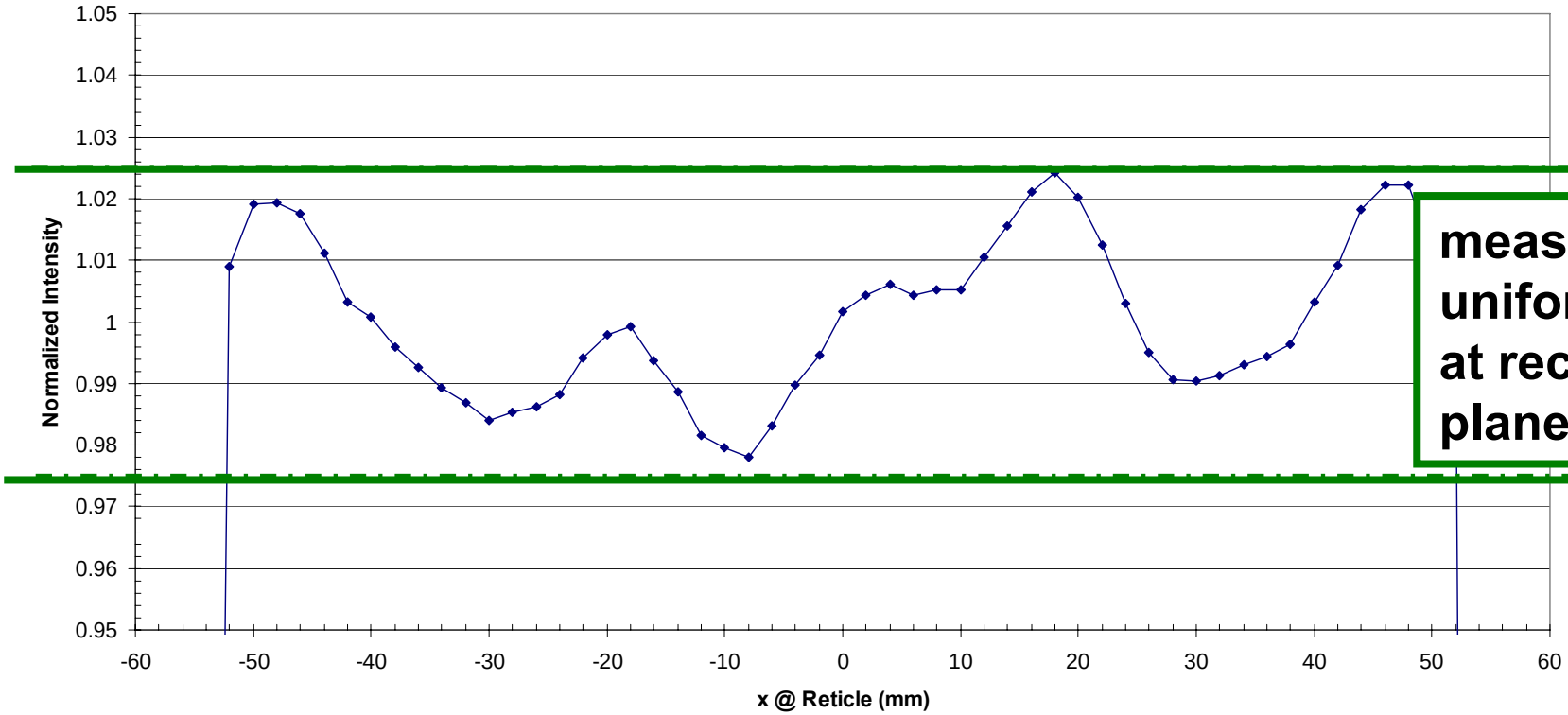
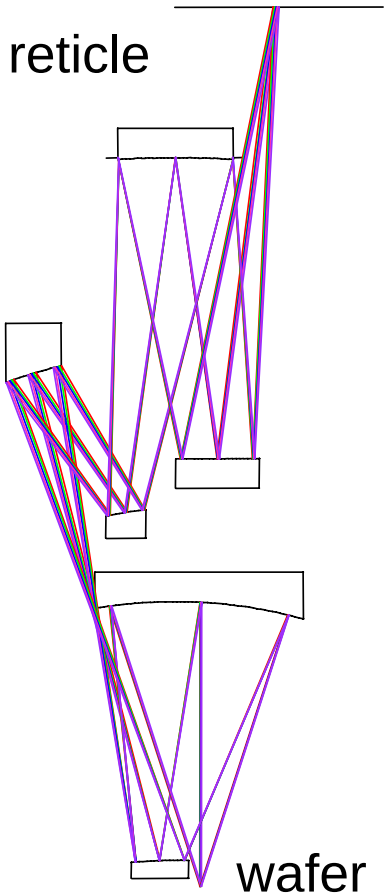
EUV qualification: Results (2)



measured uniformity at recticle plane < 2.5 %

Pupil: Telecentricity < 0.5%
Ellipticity < 10% (calculated value for Sn source)

Projection Optics Box



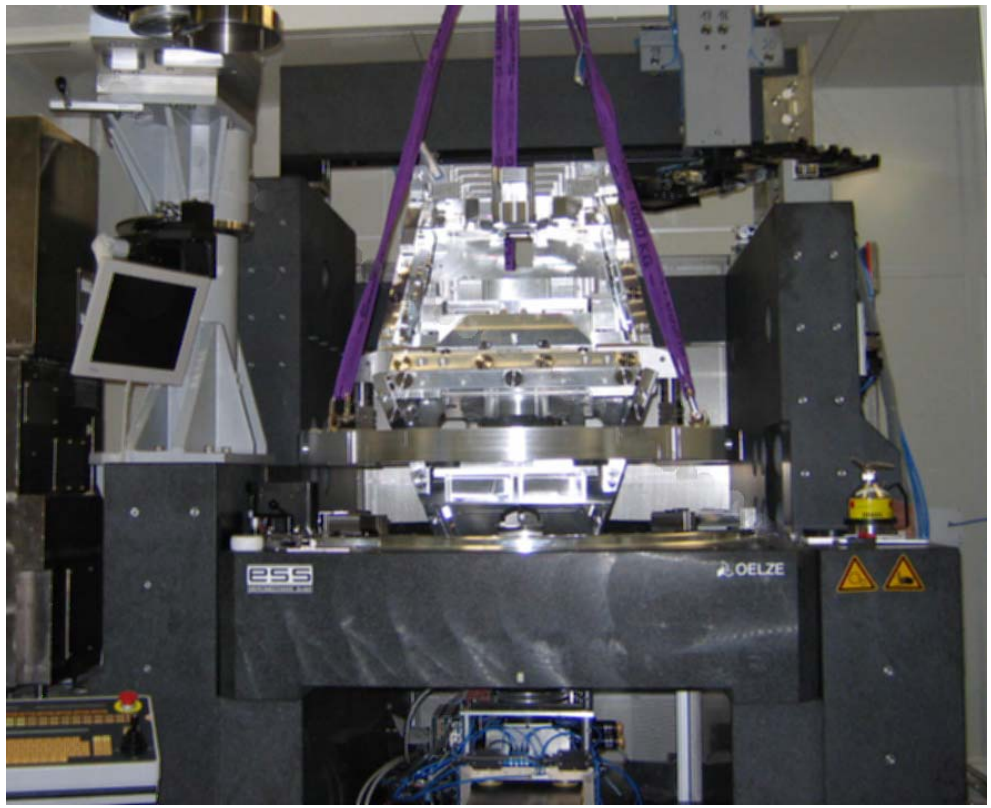
Status:

- all mirrors fabricated and coated
- assembly complete
- system metrology has been set up
- the POBox is in the qualification phase

Design example

Status POBox: System Metrology

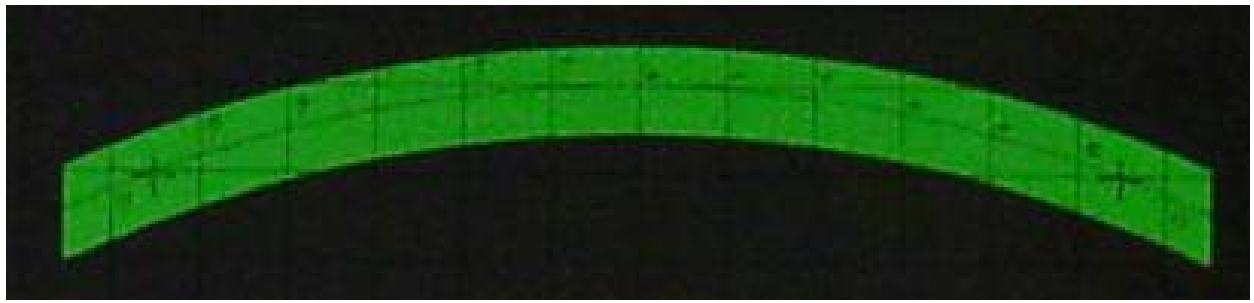
System Metrology for POBox alignment/qualification has been set up



POBox test lens on system inteferometer

Early POBox: Alignment Status

July 22: first light



248nm illumination (*converted by phosphor screen):
image of the reticle mask in the wafer plane

Status today:

- **POBox is in the final qualification phase**

Performance prediction:

- **50 nm dense lines can be printed with the early POBox**

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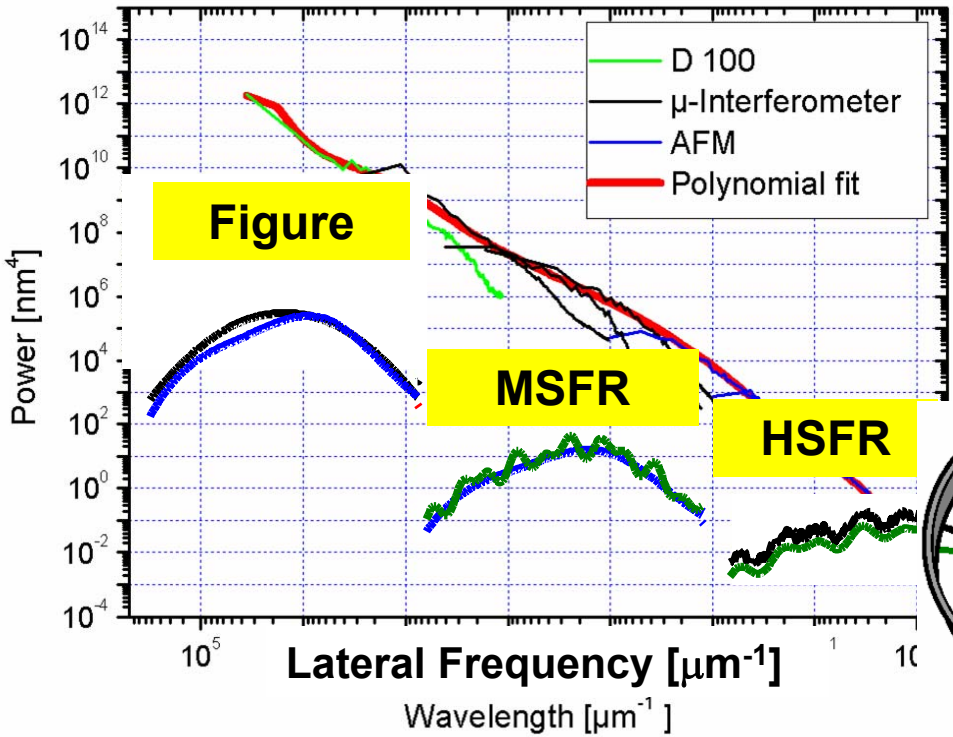
Optics Technology (1): Fabrication of EUV mirrors

2D-isotropic PSD



Errors … causes …

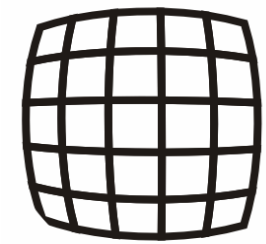
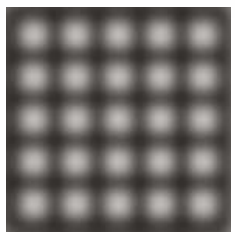
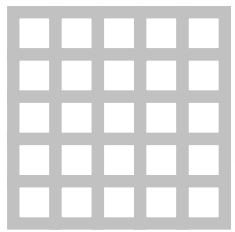


figure →aberrations



MSFR→Flare, contrast

in field of view scattering



HSFR→reflectivity

Challenge:

reach about 0.2 nm rms for Figure, MSFR and HSFR simultaneously

Main challenge: flare reduction

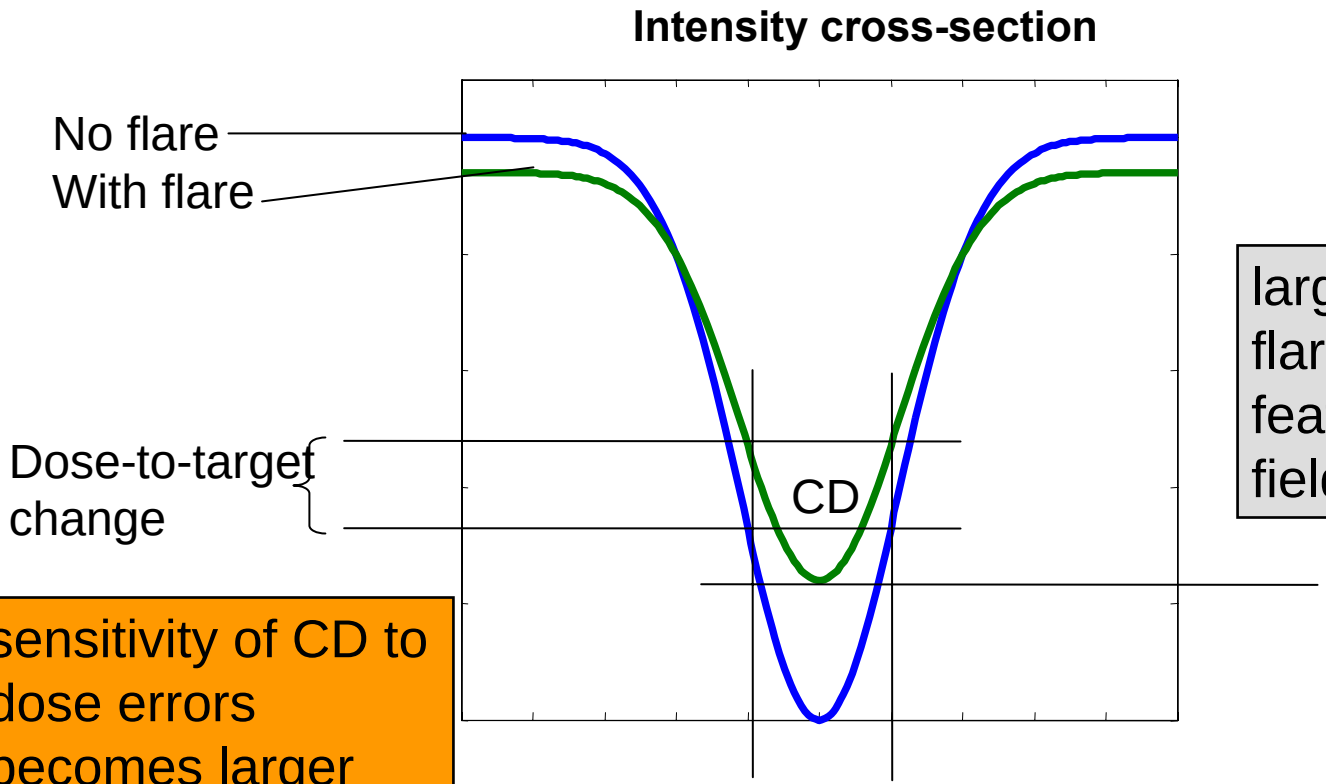
Total integrated scatter $$TIS = (4\pi)^2 \left(\frac{rms_{surface}}{\lambda} \right)^2$$

Due to the very small wavelength EUV imaging is sensitive to scatter !!!

$$TIS \propto n_{mirrors} \cdot rms^2_{surface}$$

Reduction of mid spatial frequency rms is essential to reduce the flare level

Main challenge: flare reduction



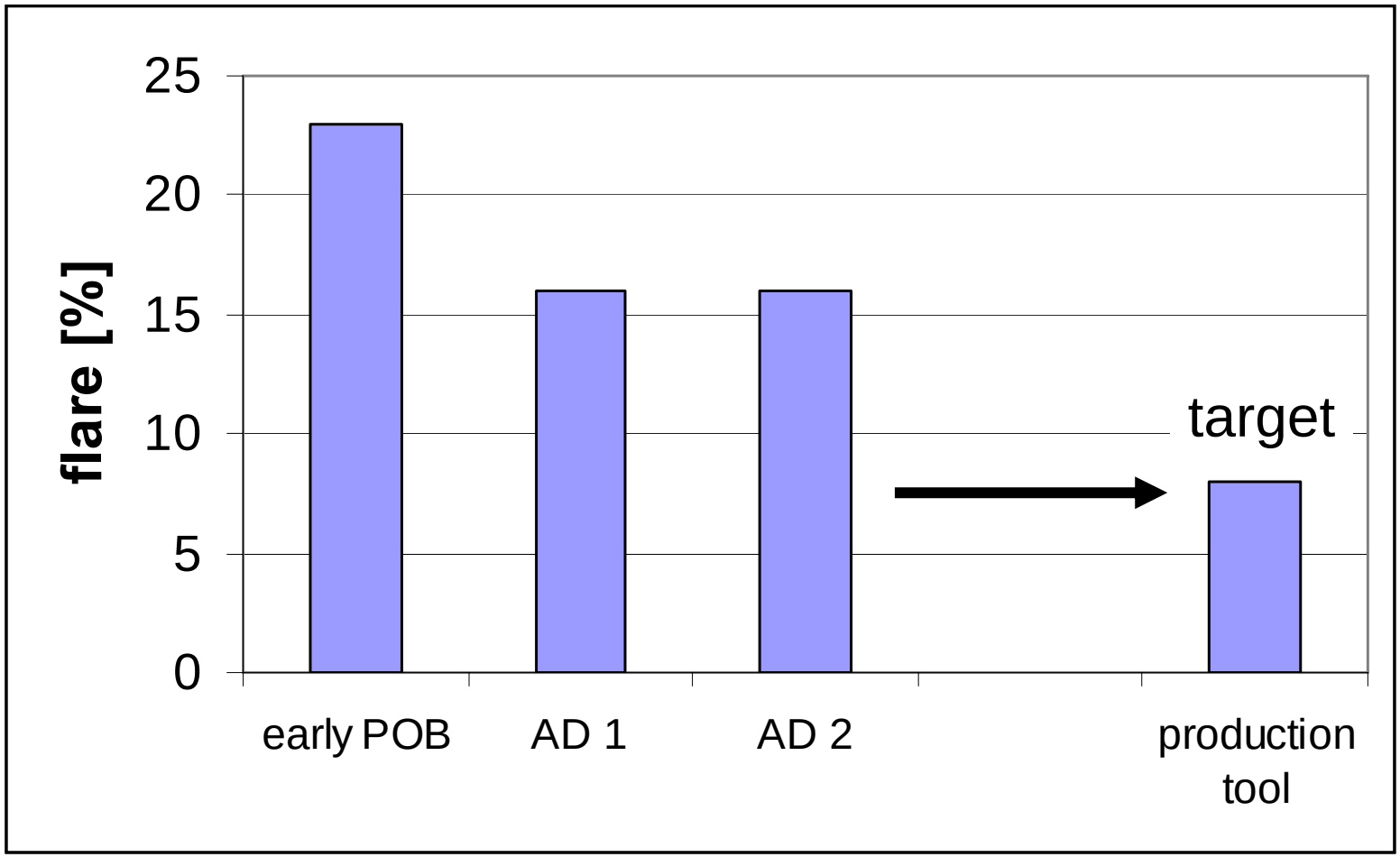
largest impact of flare on isolated features on bright-field masks

sensitivity of CD to dose errors becomes larger

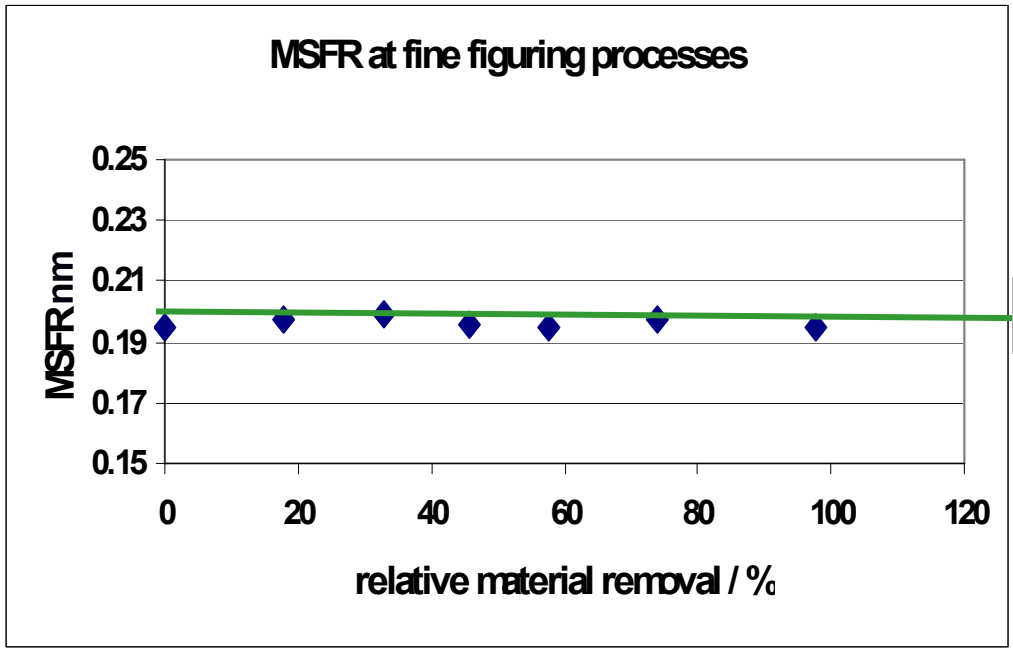
proximity effects in dependence of the local reticle transmission

flare reduces overlap of process windows due to dose offsets

Flare roadmap



EUV mirror fabrication: Process development



Critical process step: Fine Figuring

Relative material removal: 100% is representative for reaching figure spec on alpha demo tool mirror

➔ technology to reach MSFR of ≤ 0.2 nm rms on alpha tool mirrors has been established (16% flare tool)

➔Mirror for 16% flare tool: M1 - 0.19 nm

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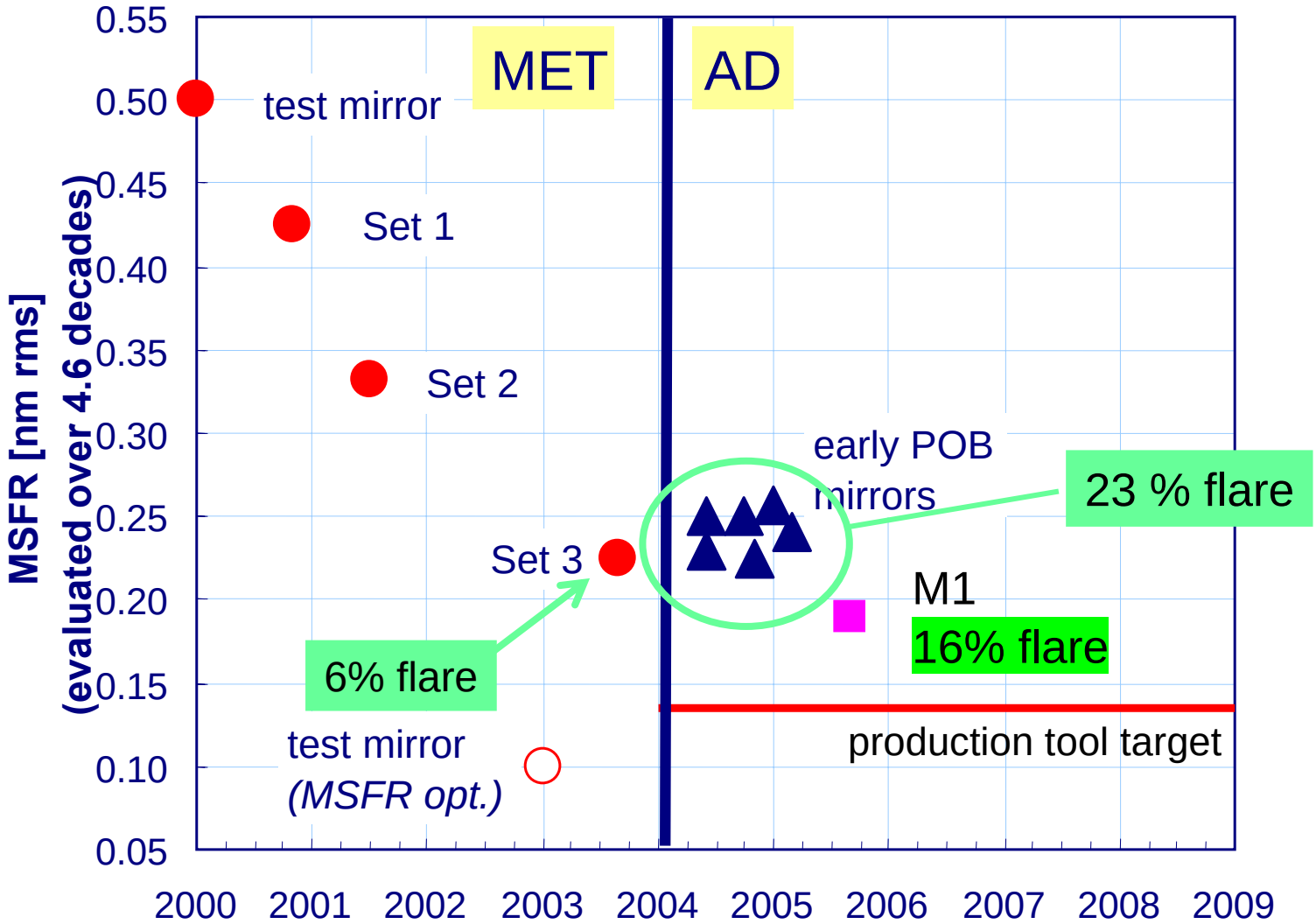
Learning curve – mid spatial frequency roughness



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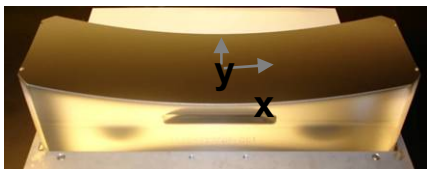
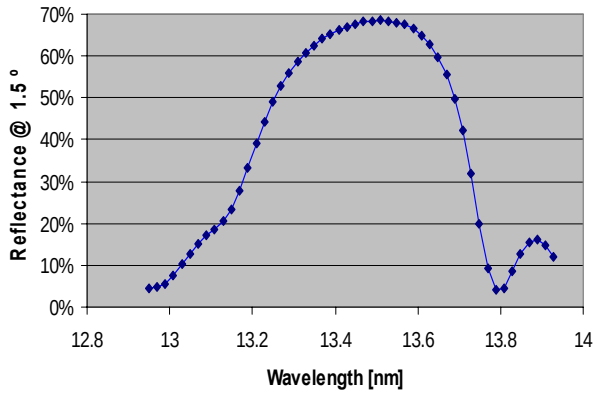
Optics Technoloy (2): Coatings

A complete set of alpha tool mirrors has been coated at FOM…

… and Zeiss



Recent development at FOM



New capping layer:

➔*reflectance 68.5% comparable to uncapped multilayer*

E. Louis et al: this conference

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Summary

- alpha tool program is progressing:
  - illuminator
    - alignment and EUV qualification has been finished
  - POBox
    - all mirrors have been fabricated and coated
    - system metrology for the POBox is operational
    - the POBox has been assembled and is in the qualification phase
  - technology development
    - 16% flare capability has been demonstrated on AD tool mirrors
    - new high reflectivity cap layer has been developed

EUV Optical Technology at Carl Zeiss SMT AG:

➔ has reached α-tool specs

➔ is progressing towards production tool capability

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Acknowledgment

Thanks to a huge team effort at…

- FOM-Rijnhuizen
- TNO TPD
- PTB-BESSY
- Philips
- The teams at ASML and Zeiss
- …and many others

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Thank you !!!