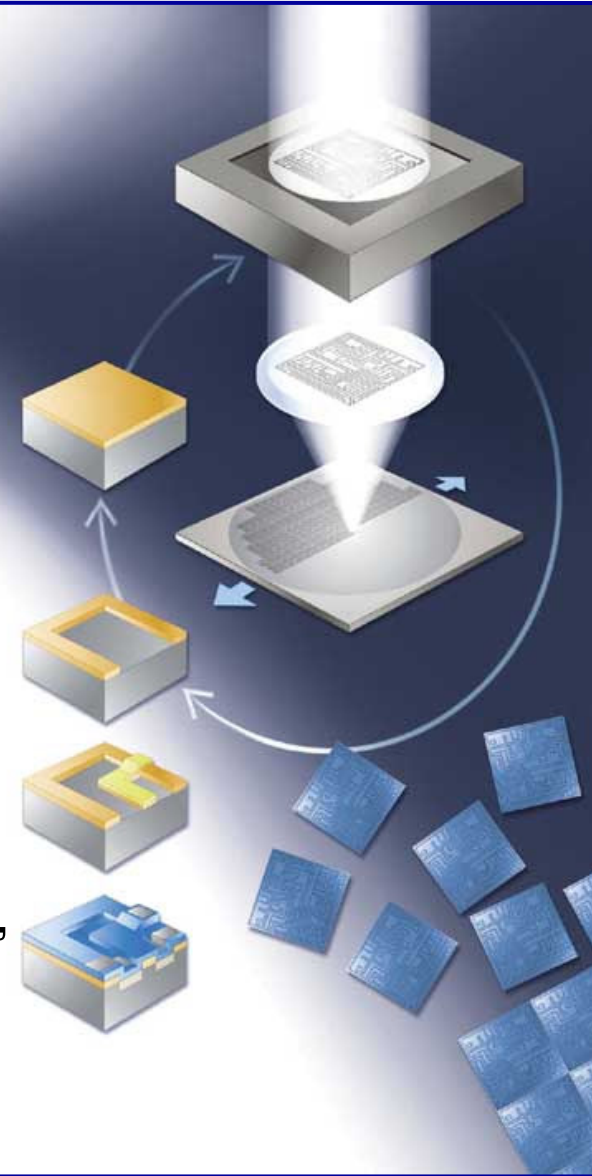


Carl Zeiss SMT AG

The EUV alpha demo tool program at Carl Zeiss SMT AG

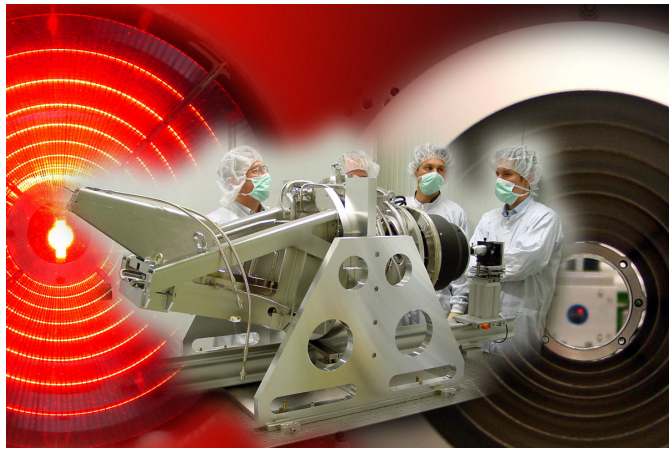
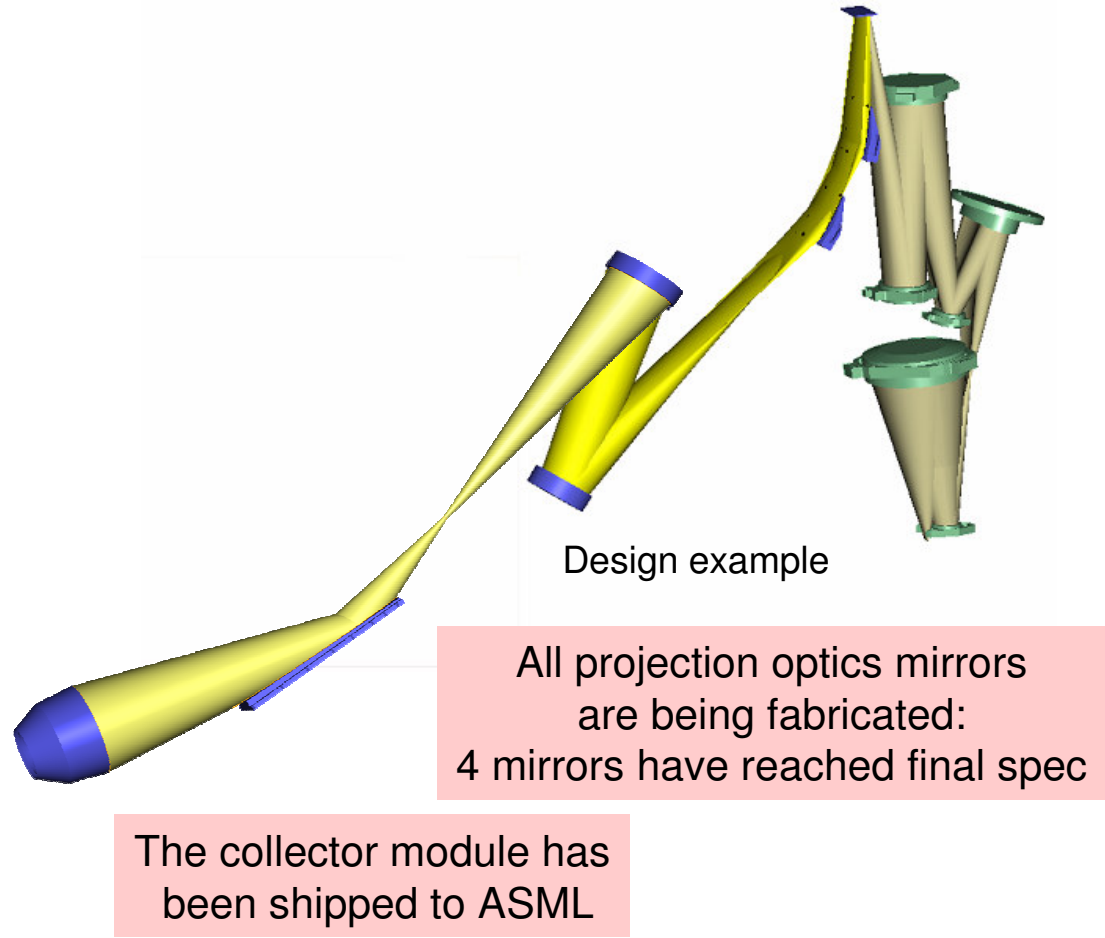
Peter Kürz, Wolfgang Bollinger, Manfred Dahl,
Martin Lowisch, Christian Münster, Frank Rohmund,
Thomas Stein, Thomas Neidhardt, Piotr Marczuk

November 2004



Overview

Key specifications	
λ	13.5 nm
NA	0.25
Resolution	50 nm
field	26x33 mm ²
Magnification	4x

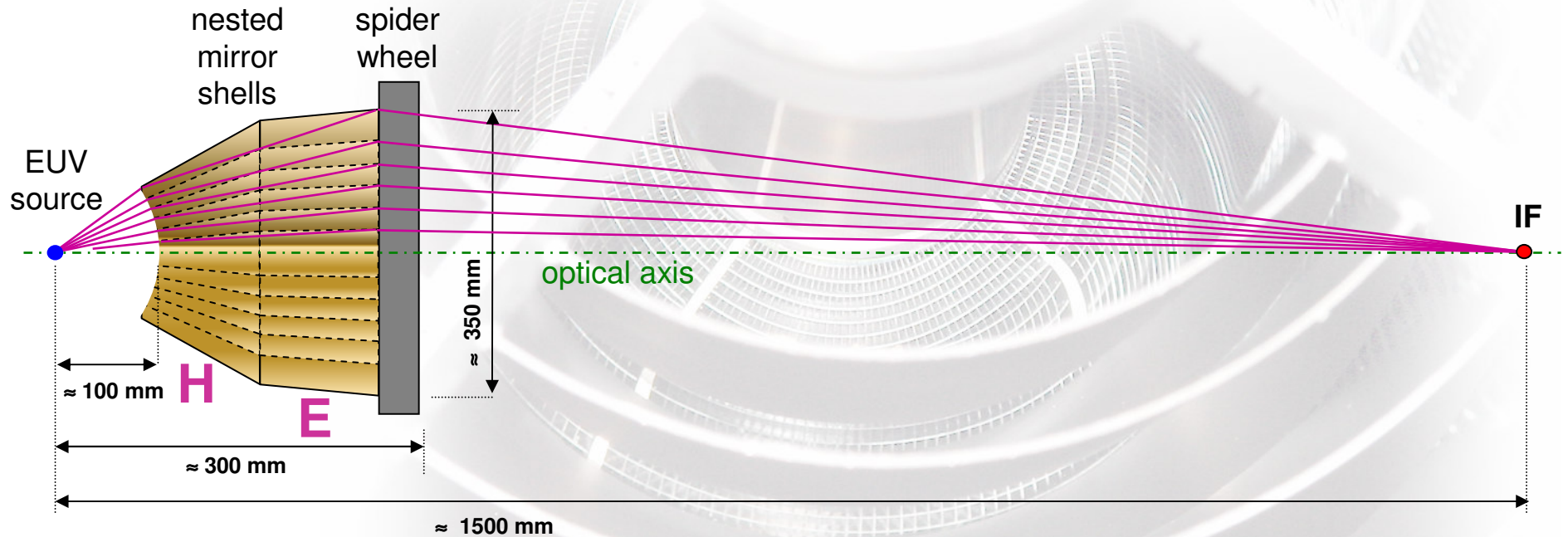


Life time strategy: 230 h of exposure w/o reflection loss have been demonstrated at the PTB BESSY synchrotron, pulsed source experiments are ongoing

Zeiss is building the optical train for ASML's alpha demo tool

Collector

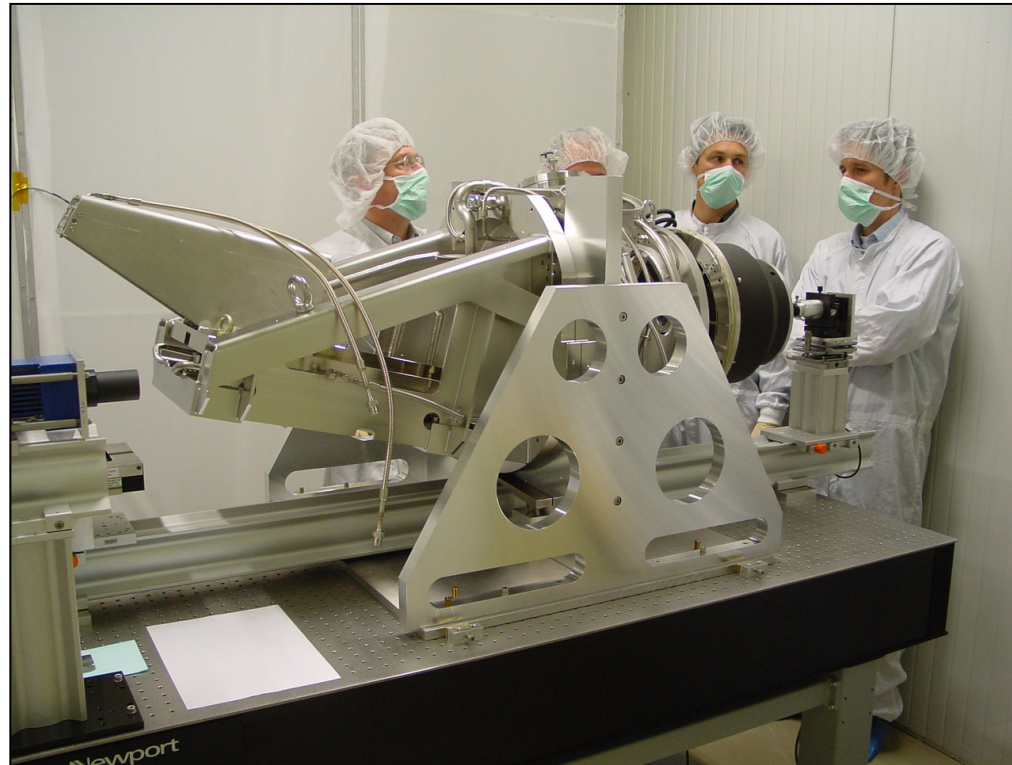
- Nested Wolter Type-1 Optics



- several nested metal shells coated with highly reflective coatings
 - Fabrication technology: replication by electro forming
- collecting solid angle of approx. 1.8 sr (± 45 deg; 0.7 max NA)
- mounted into a stainless steel spider wheel

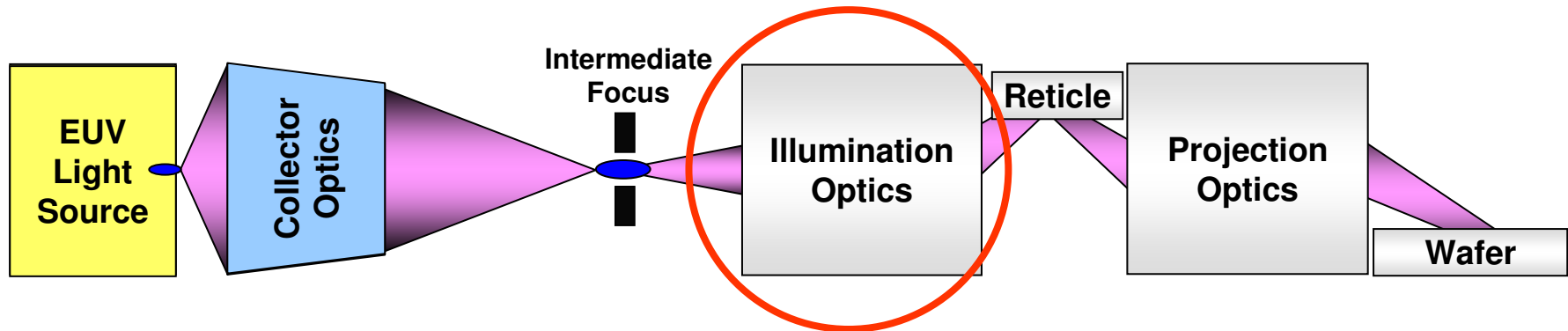
P. Marczuk et al: this conference

Collector Module



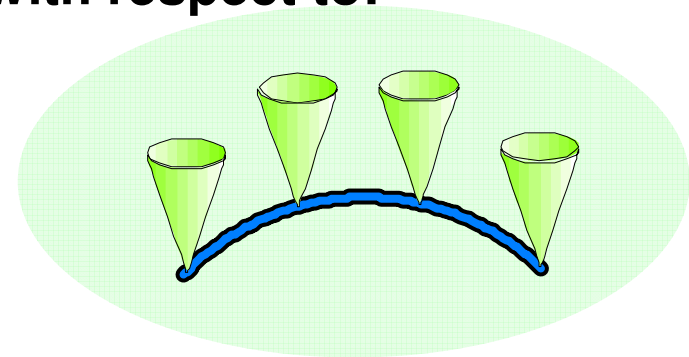
- First alpha demo tool compatible collector shipped to ASML in 12/2003

Illuminator



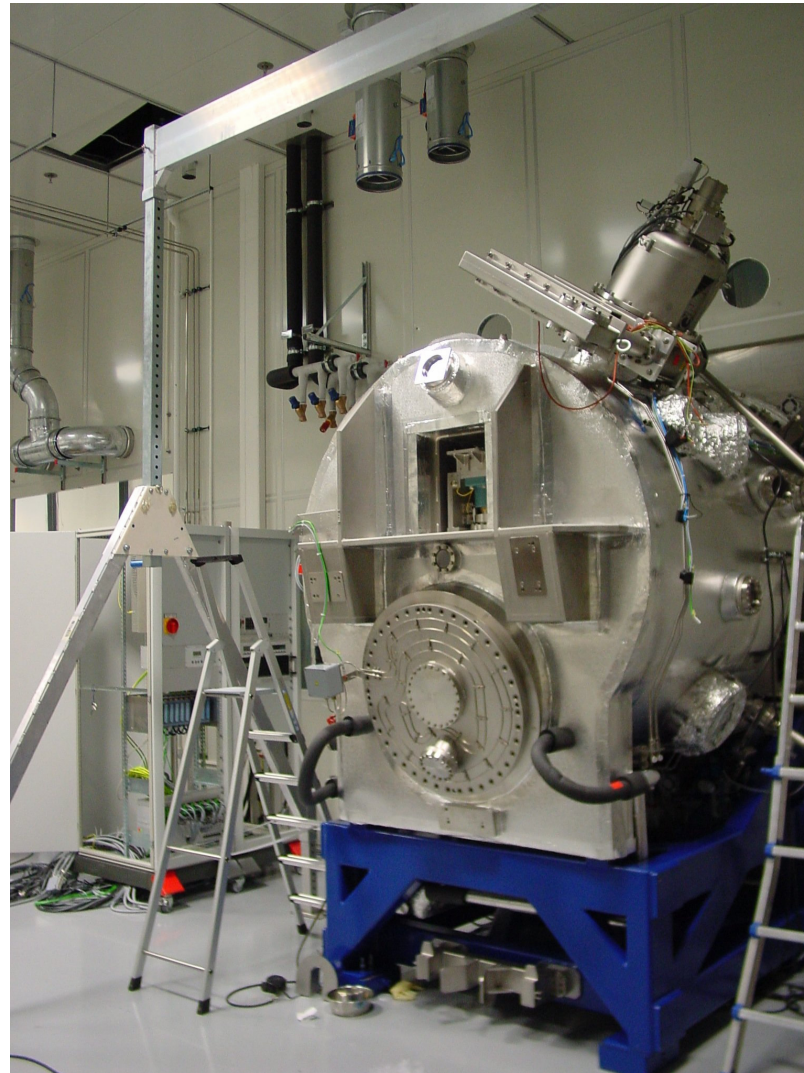
our illumination concept is optimized with respect to:

- uniform ring field fill
- uniform pupil fill



we have developed

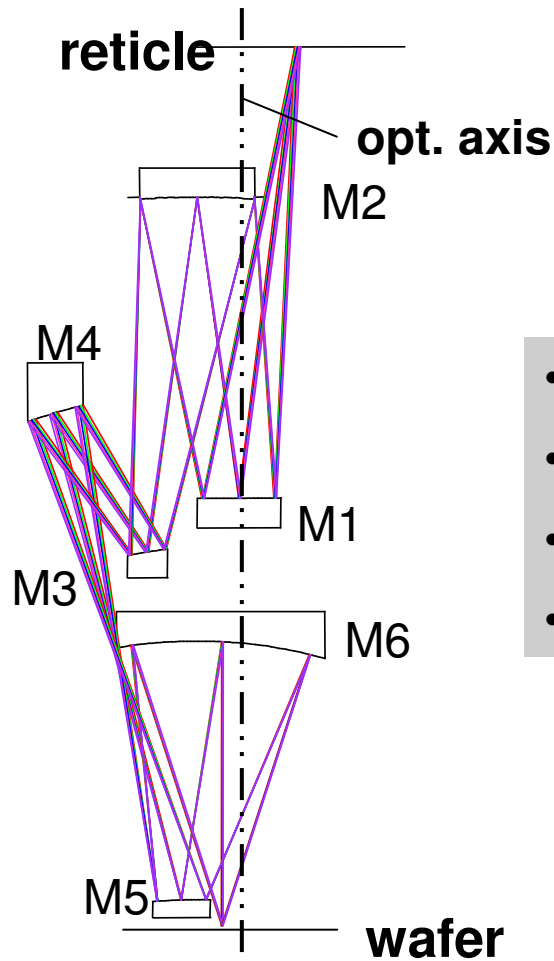
a „flexible“ design solution which can be adapted to different source types



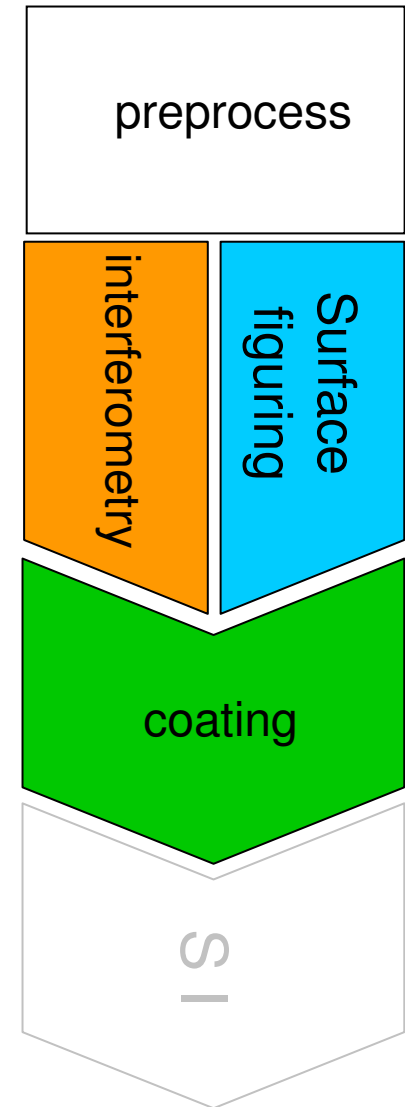
@ λ illuminator metrology tool

Enabling the Nano-Age World®

Projection Optics Box: Optics Fabrication



- 6 off axis asph. mirrors
- material: low CTE material
- coating: 50 bi-layer Mo-Si; R < 70%
- operation environment: vacuum

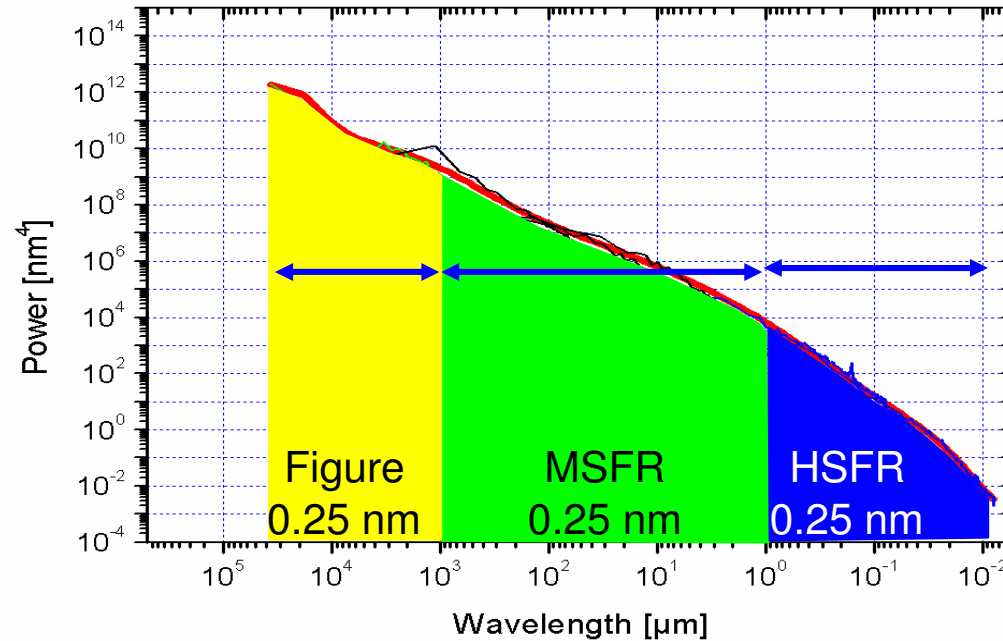


LIT-S4/Peter Kürz

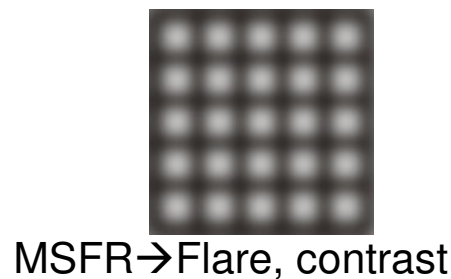
Design example

Optics fabrication: requirements

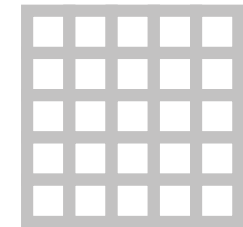
2D-isotropic PSD



Errors ... causes



in field of view scattering



HSFR → reflectivity

Challenge: reach Spec for Figure, MSFR and HSFR simultaneously

Optics fabrication: General approach

Key technologies:

- **Metrology**
 - interferometry
 - **Surface roughness metrology (MSFR + HSFR)**
- **Fabrication technology (surface figuring)**
 - **Controlling MSFR**
- **Coatings**

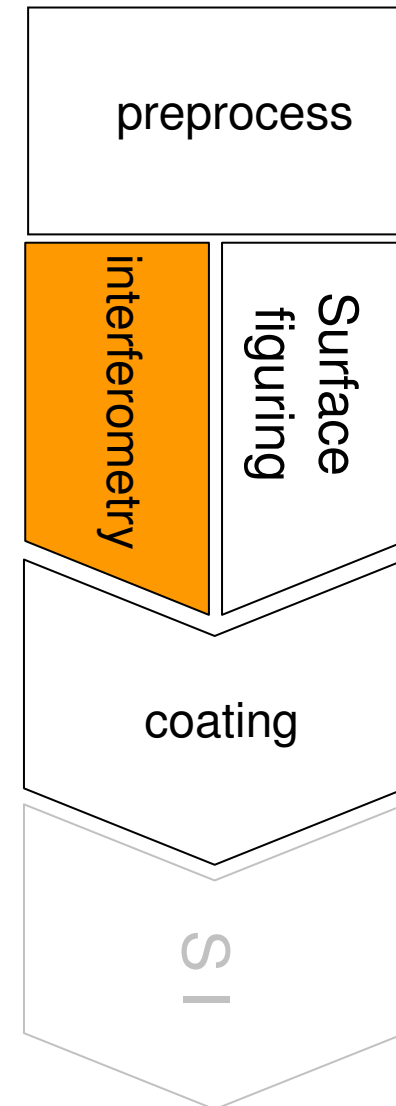
Alpha demo tool specs have been reached !

→ First four POB-Mirrors ready !

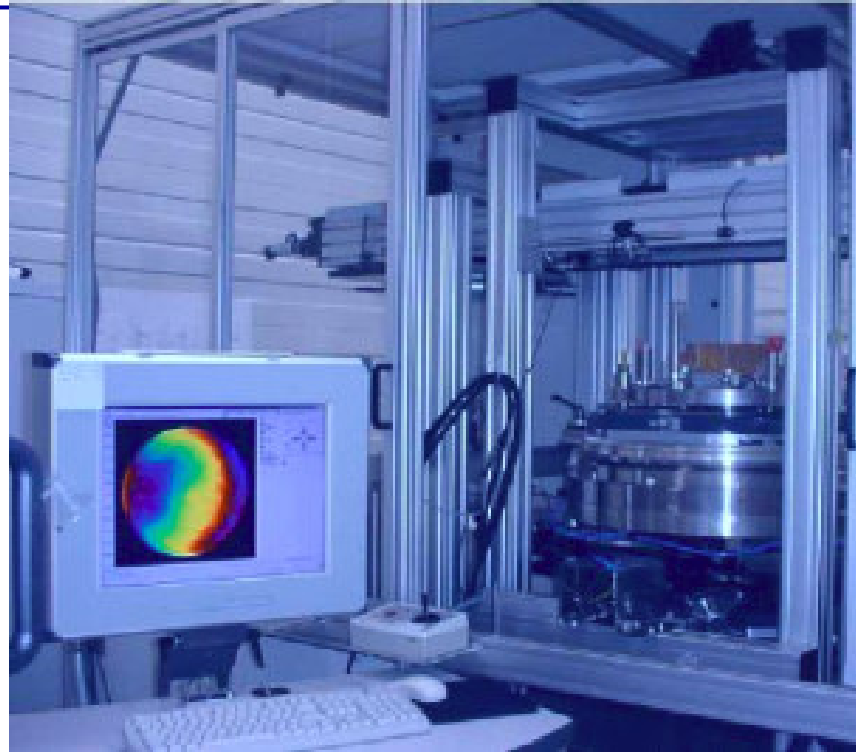
→ First POB-Mirror and all ILLU-Mirrors coated !

Optical Value Chain

interferometry



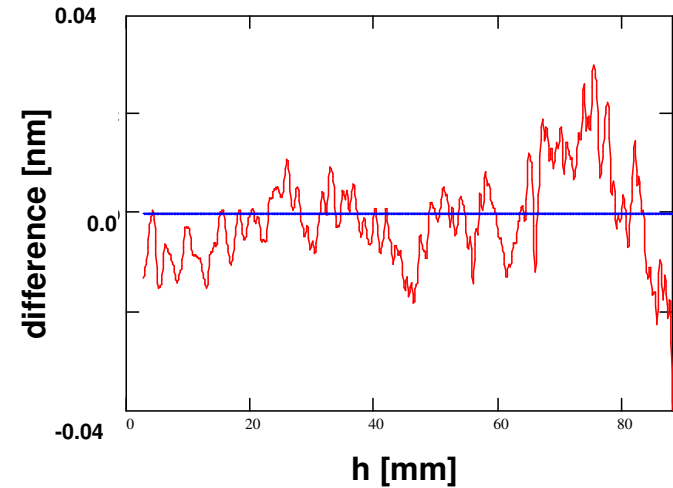
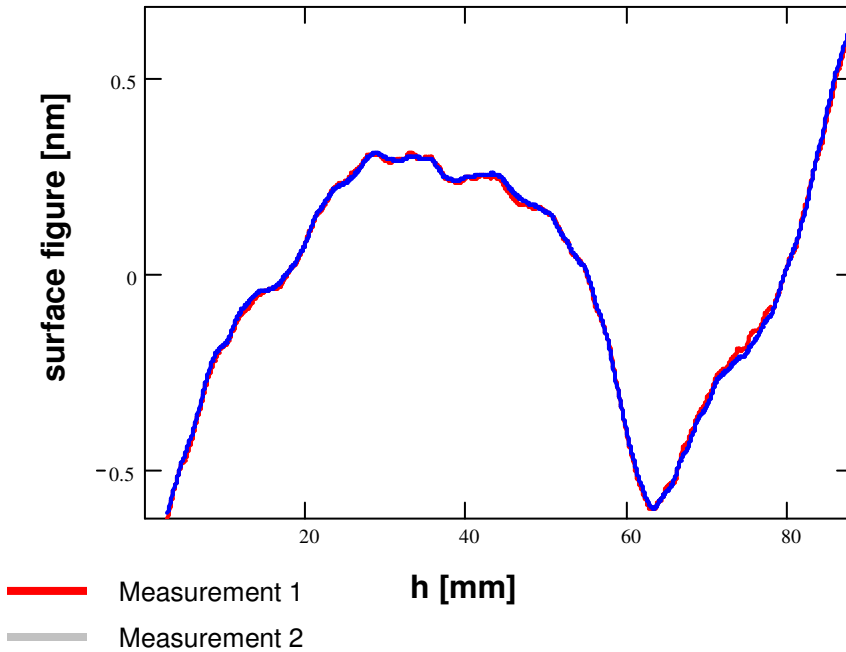
metrology



- statistical errors (repeatability): $E_S = 27$ pm rms surface figure !!!
- adjustment errors (reproducibility): $E_J = 46$ pm rms surface figure !!!
- All 5 interferometers in Oberkochen and 1 interferometer in Richmond have been set up
- Reproducibility: 40-60 pm

Measurement accuracy (where is the limit?)

Reproducibility of surface figure measurement → Sphere

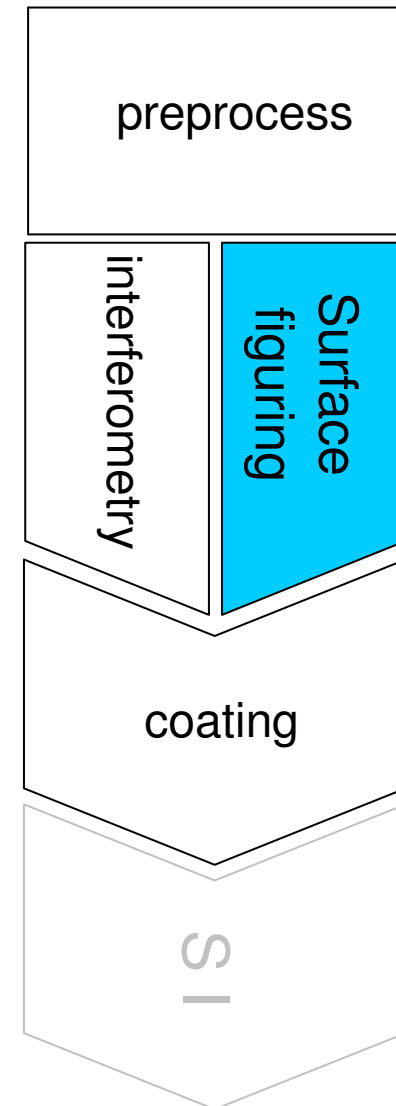


difference: 10 pm rms !!

 **reproducibility of surface figure measurement: 10 pm rms !!!!**

Optical Value Chain

Surface figuring



4 alpha tool mirrors have been fabricated: Example M6

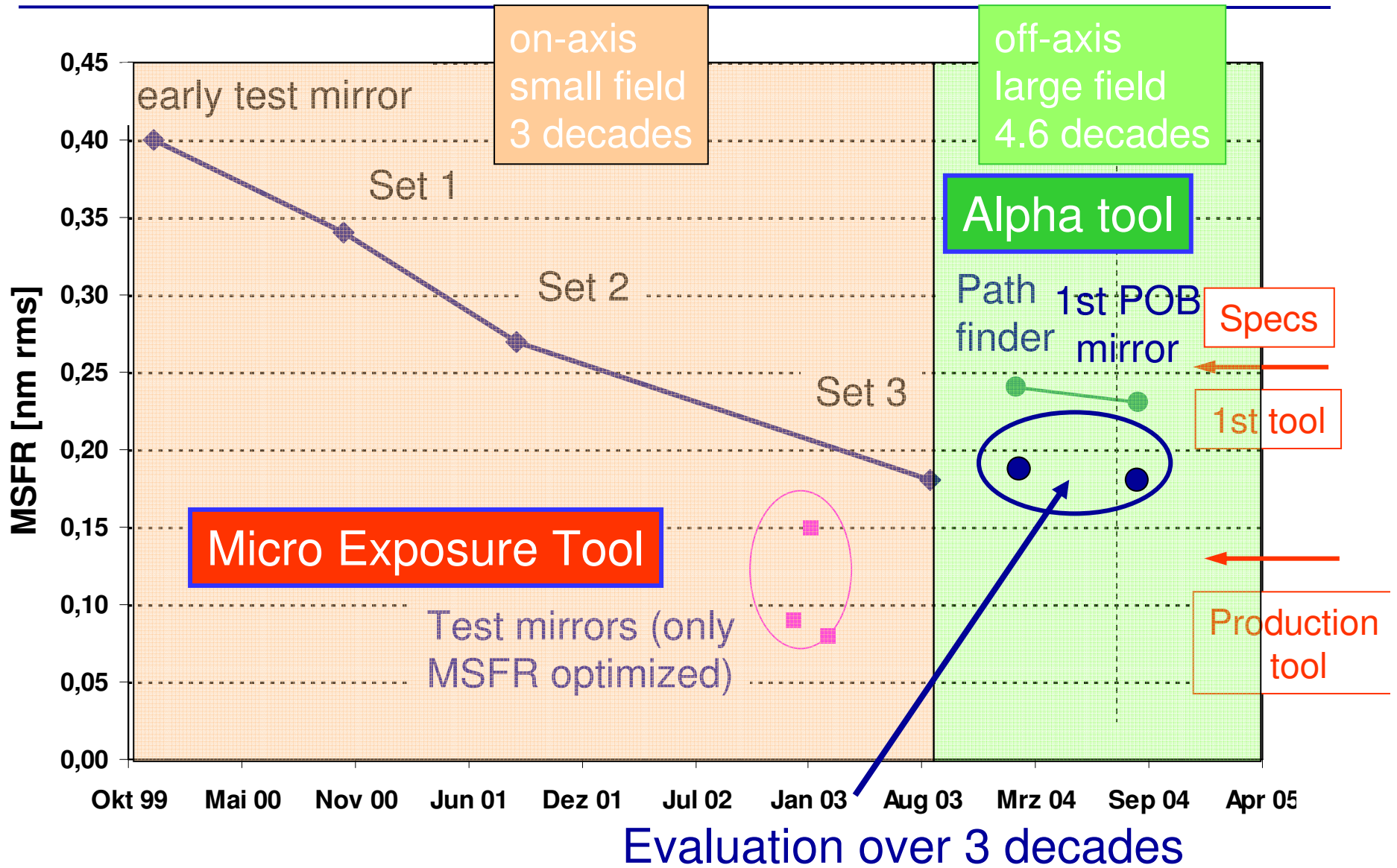
<u>Property</u>	<u>Results</u> <u>M6</u>	<u>Specifications</u> <u>alpha demo tool</u>
figure [nm rms]	0.10	0.25*
MSFR [nm rms] /flare	0.23	0.25 /26%
HSFR [nm rms]	0.28	0.25

* incl coating

Current status

- Excellent figure data achieved
- Low roughness capability demonstrated (4 mirrors with MSFR < 0.25 nm rms)

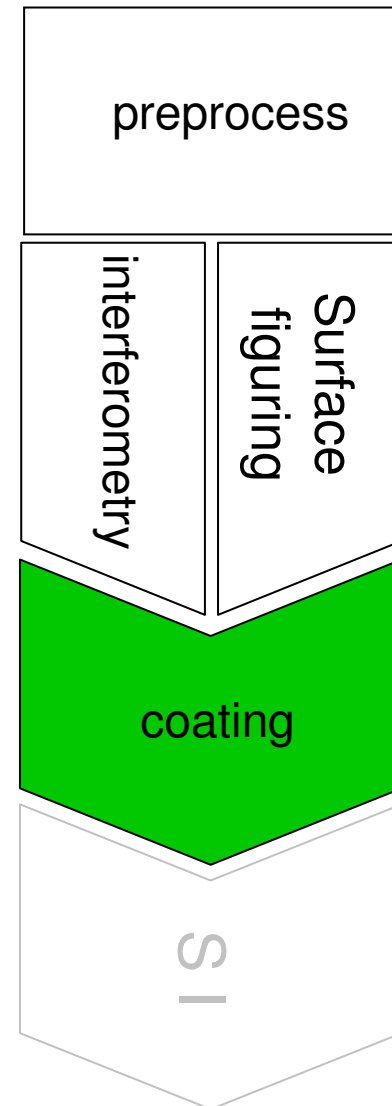
MSFR evolution



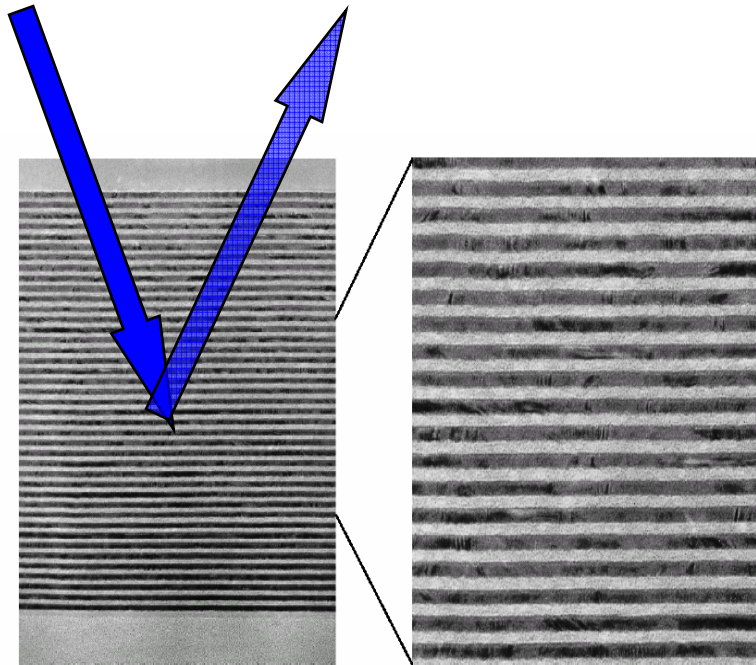
LIT-S4/Peter Kürz

Optical Value Chain

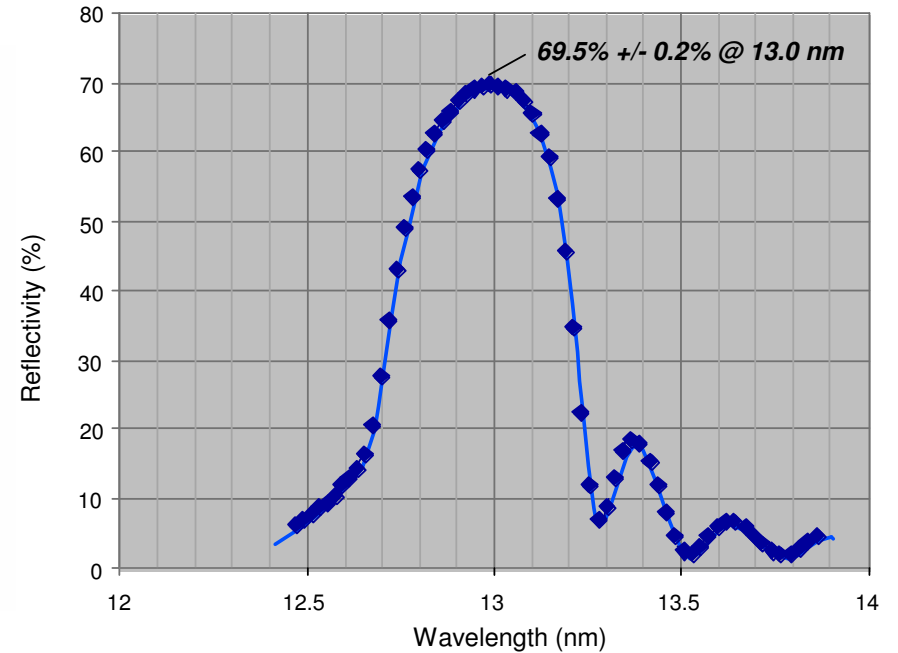
coatings



EUV coatings



reflectivity reaches up to 70 %



- layer thickness Mo/Si pair: only a few nm's
- total thickness of coating has to be controlled within a fraction of a %!

LIT-S4/Peter Kürz

Coating technology has been developed together with FOM Rijnhuizen (Netherlands)

EUV coater at FOM



EUV coater at Zeiss



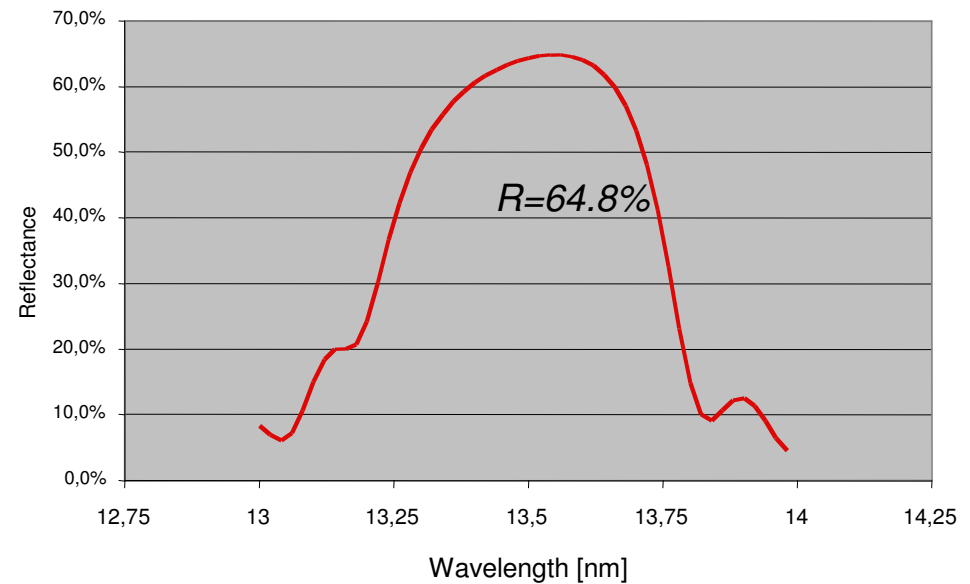
Technology

Ion-beam assisted electron beam evaporation

Projection optics mirror coated at FOM

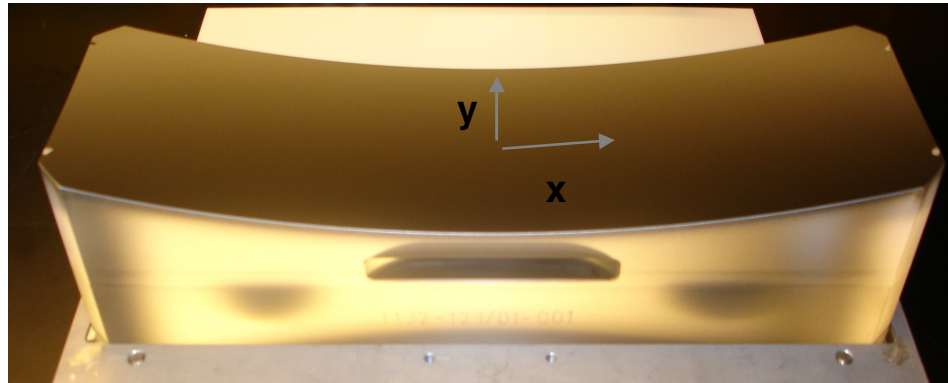
Requirements deposition 1e PO Box optic

- Stress 0 +/- 100 MPa
- Non-correctable added figure error 0.02% or 100 pm

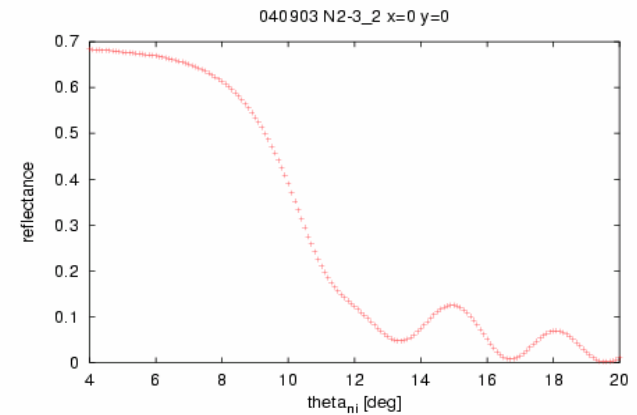


E. Louis et al: this conference

First Alpha demo tool mirror coated at Zeiss



← 480 mm →



Reflectivity = 67%

Largest EUV ML optic to date sucessfully coated !

- *First real EUV optic from new large area EUV coating facility @ Zeiss*
- *Several new coating technologies sucessfully incorporated*
- *Reflectivity 67% (EUVR characterized)*

Optics lifetime: extended exposure using contamination control strategy



230 h continuous exposure at synchrotron

Experimental conditions

- intensity: 0.05 - 30 mW/mm²
- 10x higher H₂O pressure than spec
- R₀=66.4 %

Observations

- Initial reflectivity recovered
- Surface analysis shows no oxidation or other damaging effect

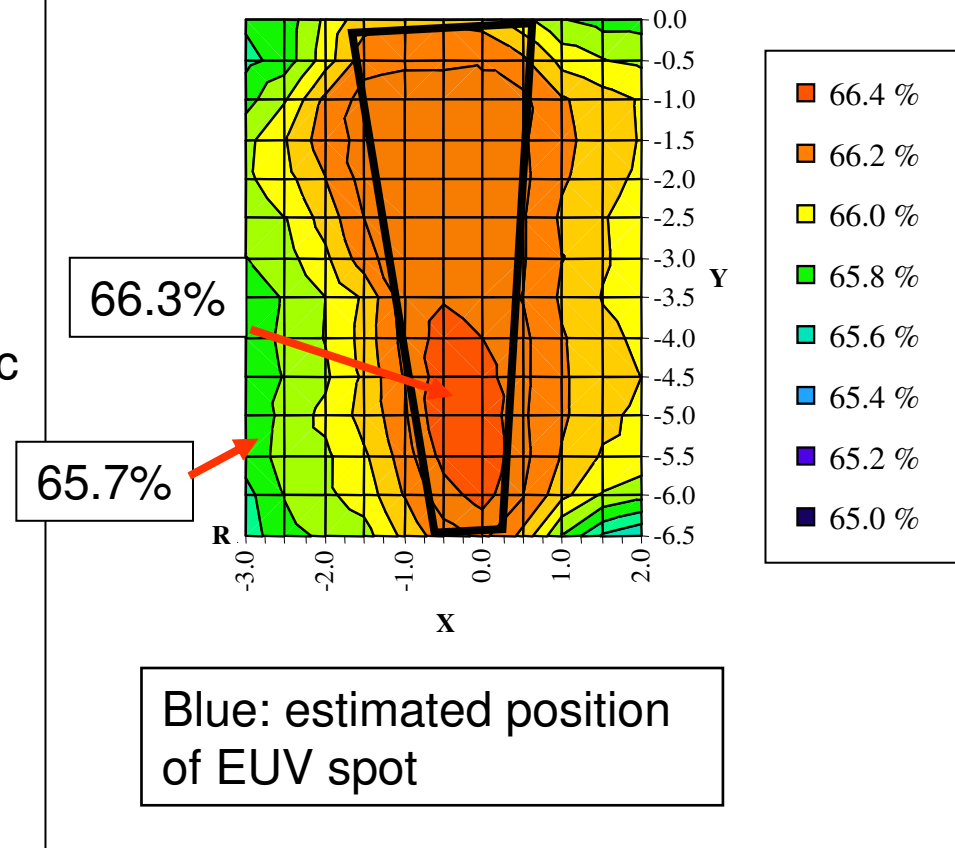
Conclusion

- with measurement error <0.25 %, the estimated lifetime is >1000h

Currently

- pulsed source experiments have been started, first results are very encouraging

Reflectometry Results



- alpha demo tool program is progressing:
 - the source collector module has been shipped to ASML
 - the illuminator is in the assembly phase
 - all interferometers for the POB are operational, four mirrors have reached final spec
 - 1st POB mirror has been coated
 - assembly of POB has started
 - a contamination Control Strategy has been identified and tested
- an “EUV infrastructure” has been set up

EUV Optical Technology at Carl Zeiss SMT AG:

➡ has reached α -tool specs

➡ is progressing towards production tool capability

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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