Carl Zeiss SMT AG

Enabling the Nano-Age World

EUV Symposium 2003

The EUV optics development program at Carl Zeiss SMT AG

Peter Kürz

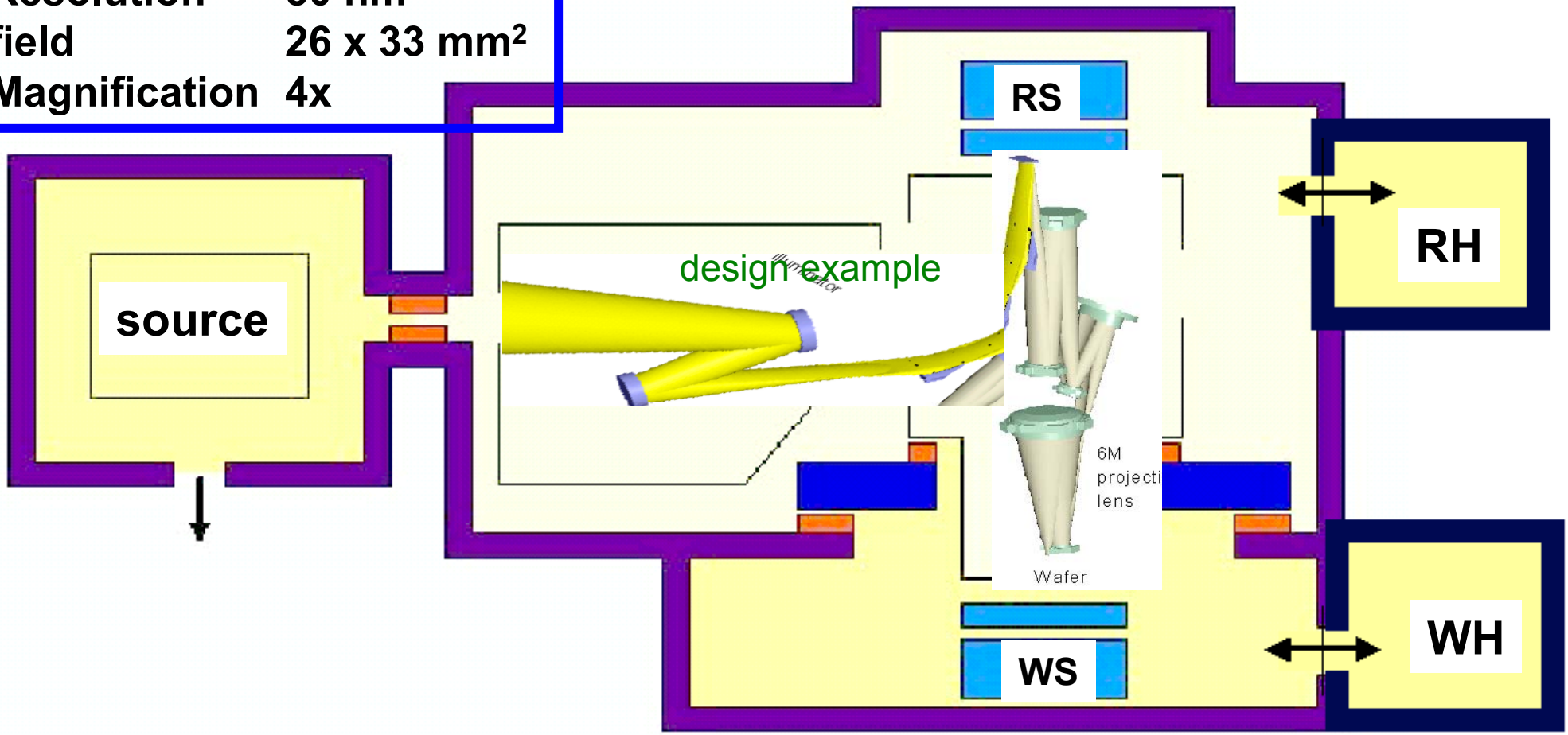
Outline

- EUV Program at Zeiss
- Source Collector Module and Illuminator
- Optics Fabrication and Metrology
- Coatings
- Contamination Control
- System Metrology
- Summary

EUVL Optics

- λ 13.5 nm
- NA 0.25
- Resolution 50 nm
- field 26 x 33 mm²
- Magnification 4x

N. Harned et al.: this conference



Goal: build full-field optical system for EUV production tool

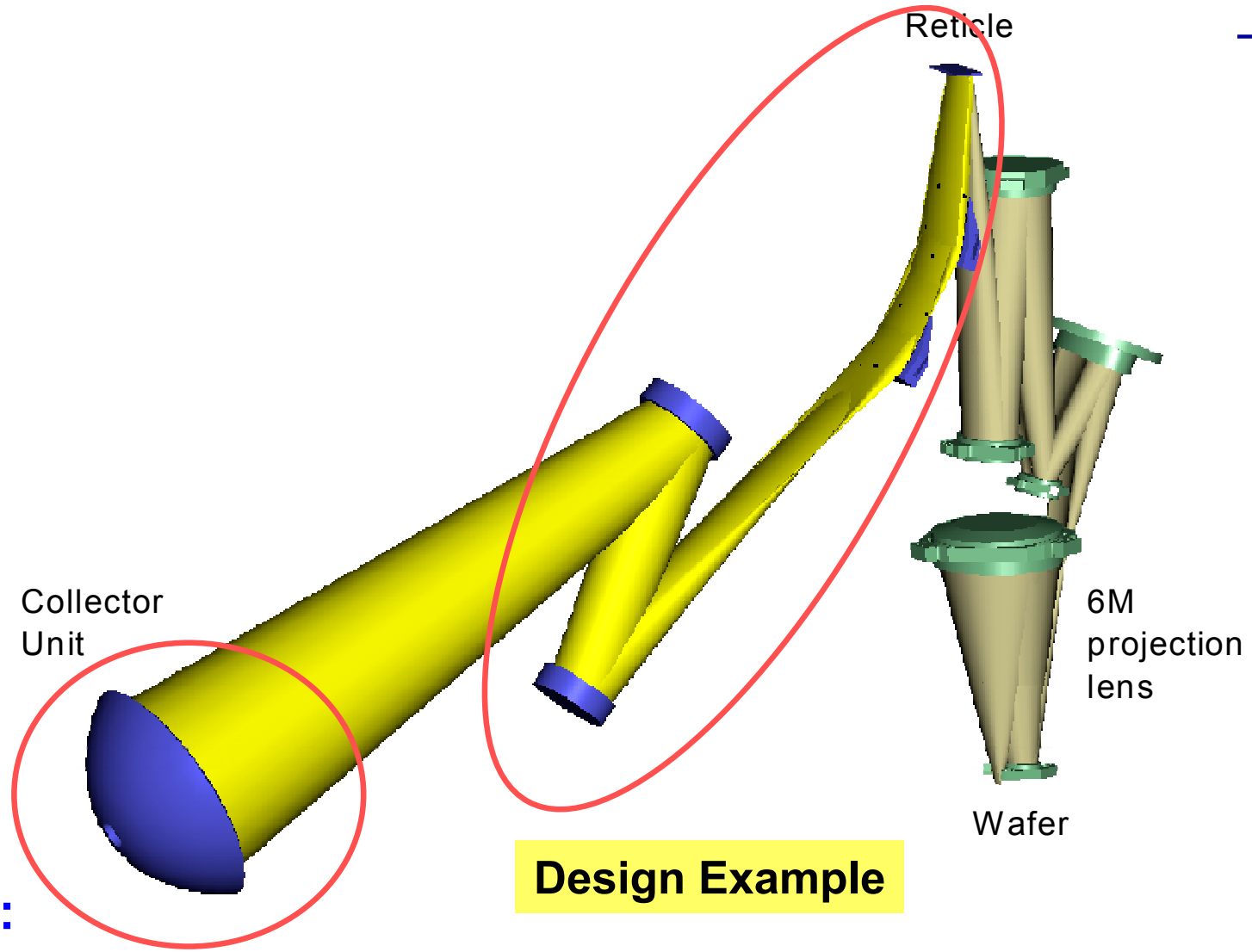
Current focus: build alpha demo tool

EUV Optics Program at Zeiss: Current Status

- Optical Design ✔
- Mechanical Concept ✔
- Development of Micro Exposure Tool as technology pathfinder ✔
- Start of mirror fabrication ✔
- Coating Technology ✔
- Lifetime Strategy ✔
- Assembly and Alignment Concept ✔
- Building of EUV infrastructure ✔

Core technologies (e.g. optics fabrication)
are approaching EUV (30) (and EUV (80)) requirements

Collector Module and Illuminator

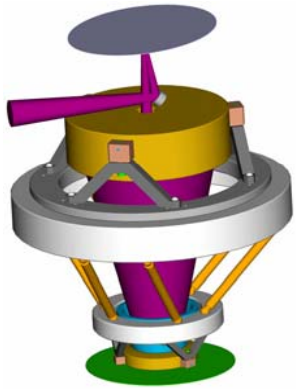


Current status:

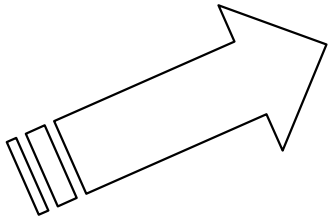
- alignment of collector module started
- fabrication of illuminator mirrors + mechanical parts ongoing
- fabrication of illuminator mirrors and alignment test stand in progress

Technology Development: The Micro Exposure Tool is a Path Finder

Developed by:
Lawrence Livermore National Labs and Zeiss



Micro Exposure Tool



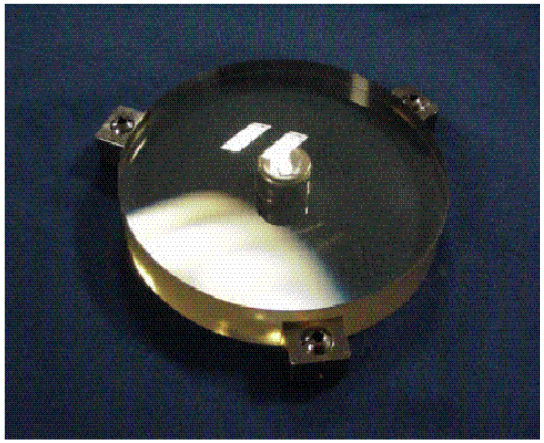
design example

alpha demo

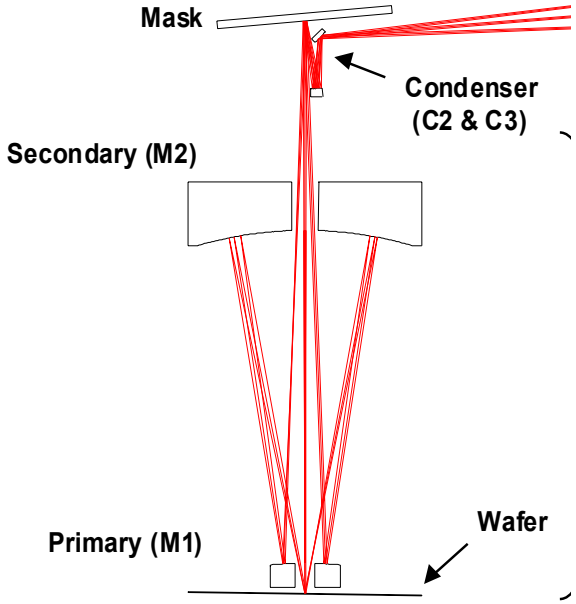
1. Technology development using the MET
2. Know-How transfer + further development for the realization of 6 mirror systems (alpha demo, EUV (30), EUV (80))

Fabrication of Aspheres: The Micro Exposure Tool

MET primary

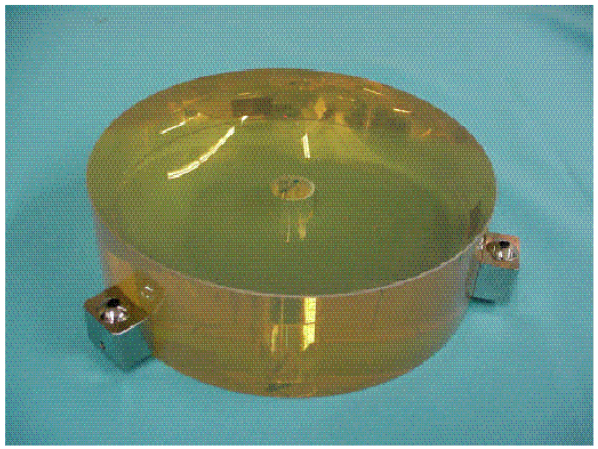


100mm



MET

MET secondary

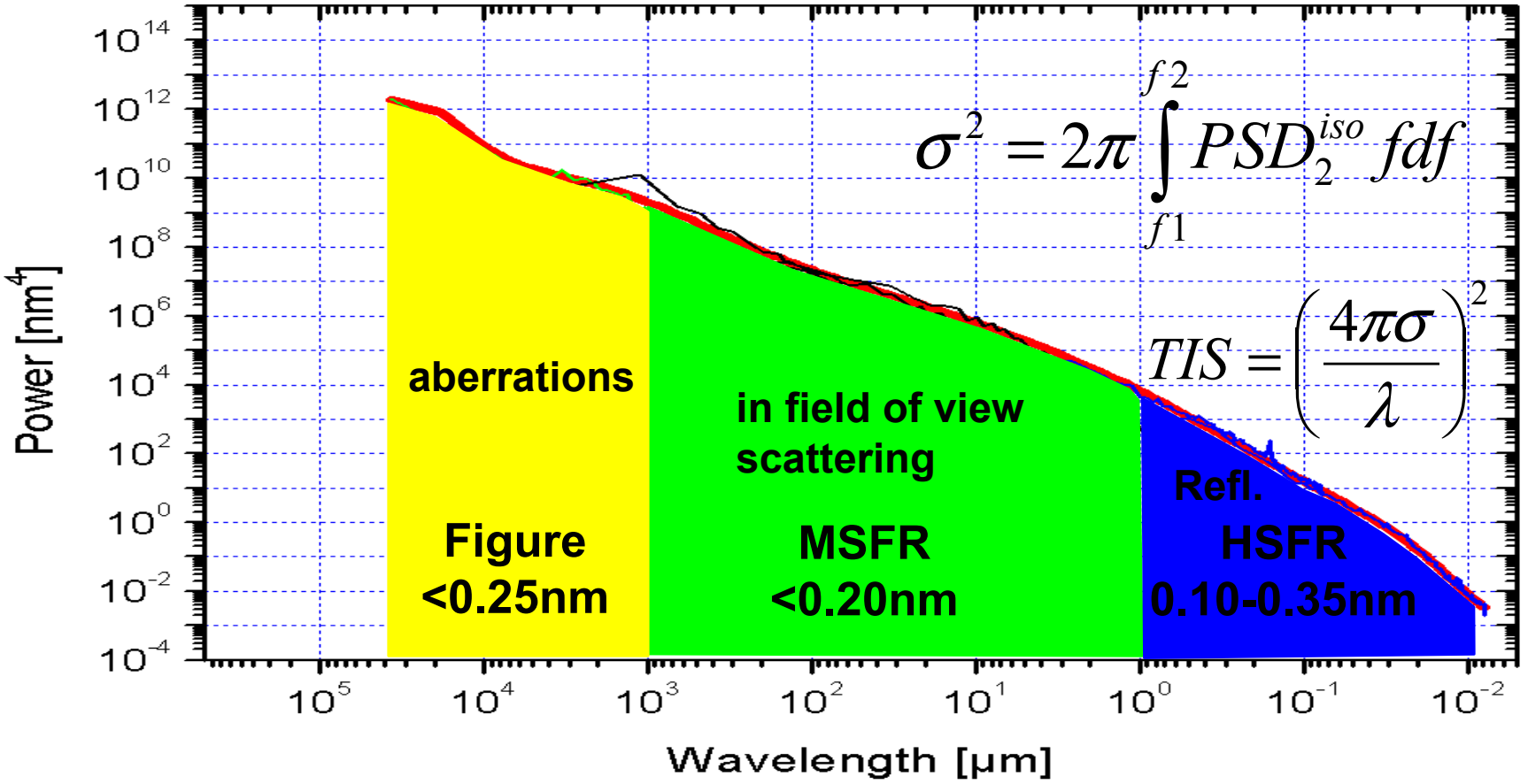


220mm

Collaboration with Lawrence Livermore National Lab
partially funded by ISMT

- λ 13.4 nm
- NA 0.3
- Resolution 30 nm
- Field 0.2 x 0.6 mm²
- Magnification 5x

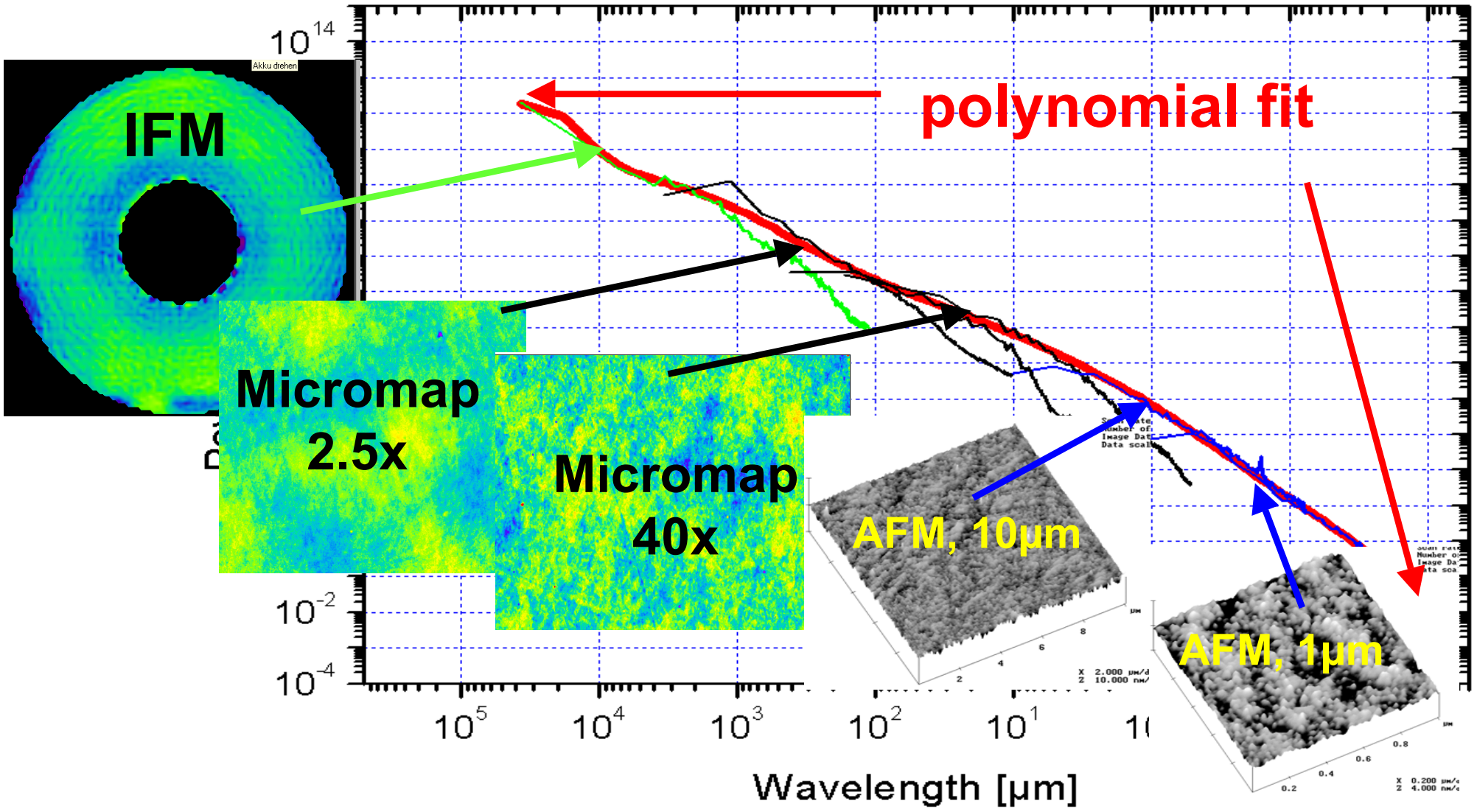
Specs for EUVL optics (MET): Power Spectral Density



The rms-roughness/figure is related to the integral of the PSD

Topography control on atomic scales

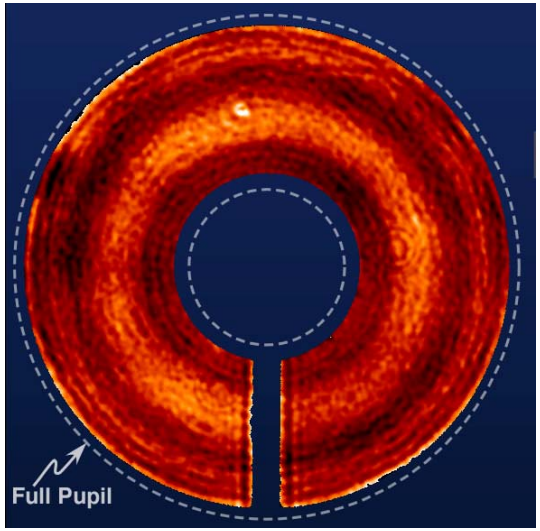
Mirror metrology: instruments cover full PSD



Status mirror production for MET

	frequency band	figure	MSFR	HSFR	extended MSFR,
M1	Set 1				
	Set 2				
	in process data				
M2	Set 1				
	Set 2	0,21	0,28	0,31	0,20
	in process data	0,20	0,20	0,20	0,15

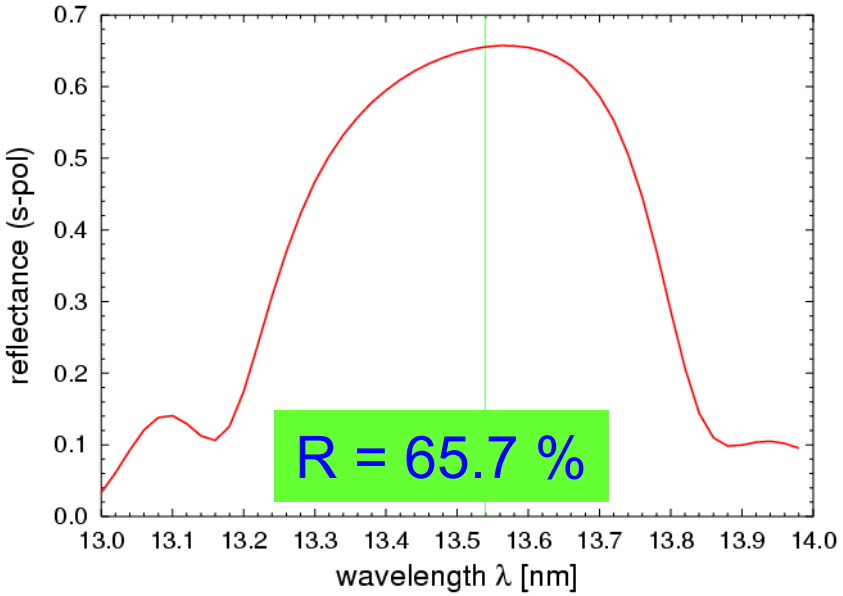
Zeiss lens @ PTB/BESSY
Sematech lens @ Lawrence Berkeley
customer lenses



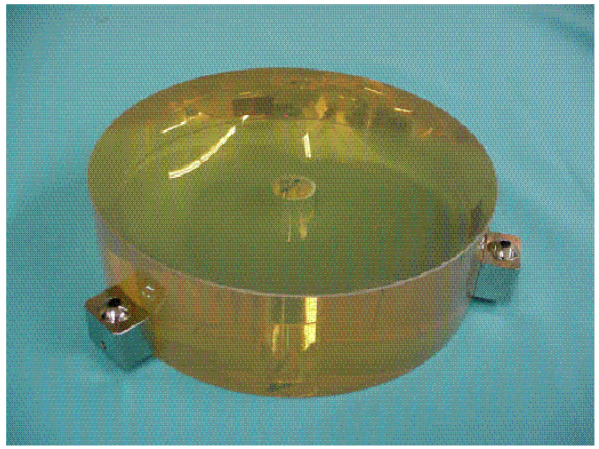
J.S. Taylor et al.
K. Goldberg et al.:
this conference

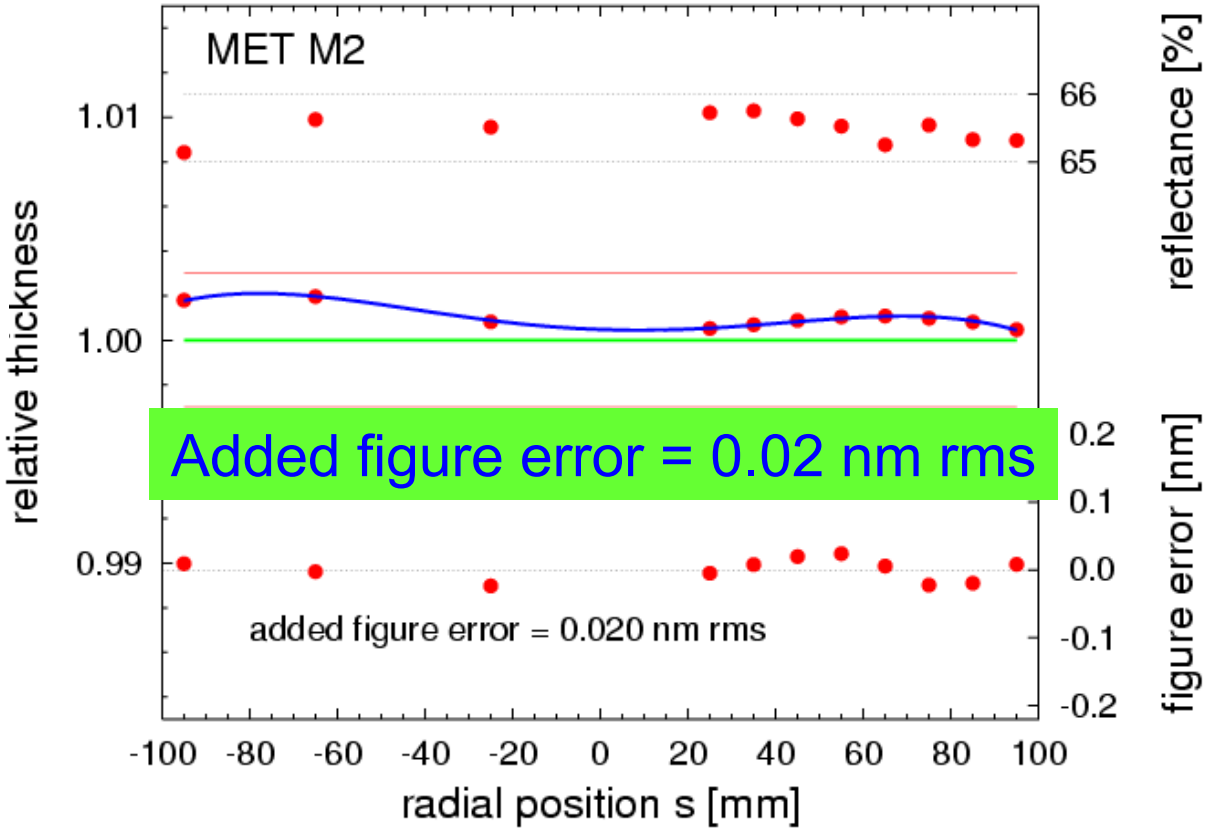
Measured WFE validates single mirror metrology

Coating Technology: MET M2 (FOM Rijnhuizen)



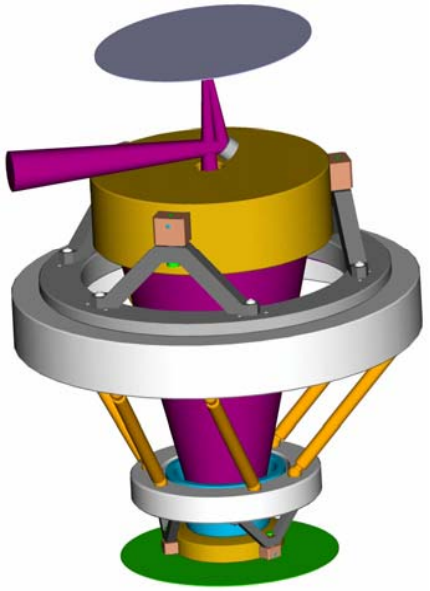
MET secondary





The challenge of large field systems

2 mirrors → $MSFR \propto \sqrt{\frac{1}{N_{mirror}}}$ ← 6 mirrors

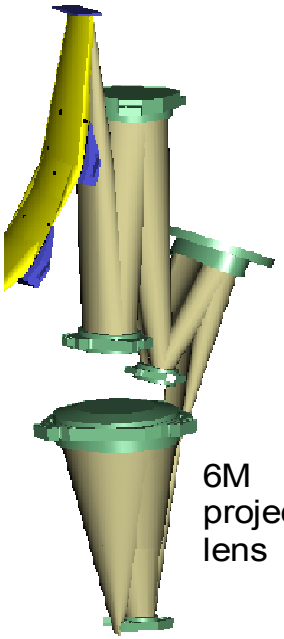


Field of view

0.2 x 0.6mm² → 26 x 2mm²

3 decades → 4.7 decades

MSFR-bandwidth



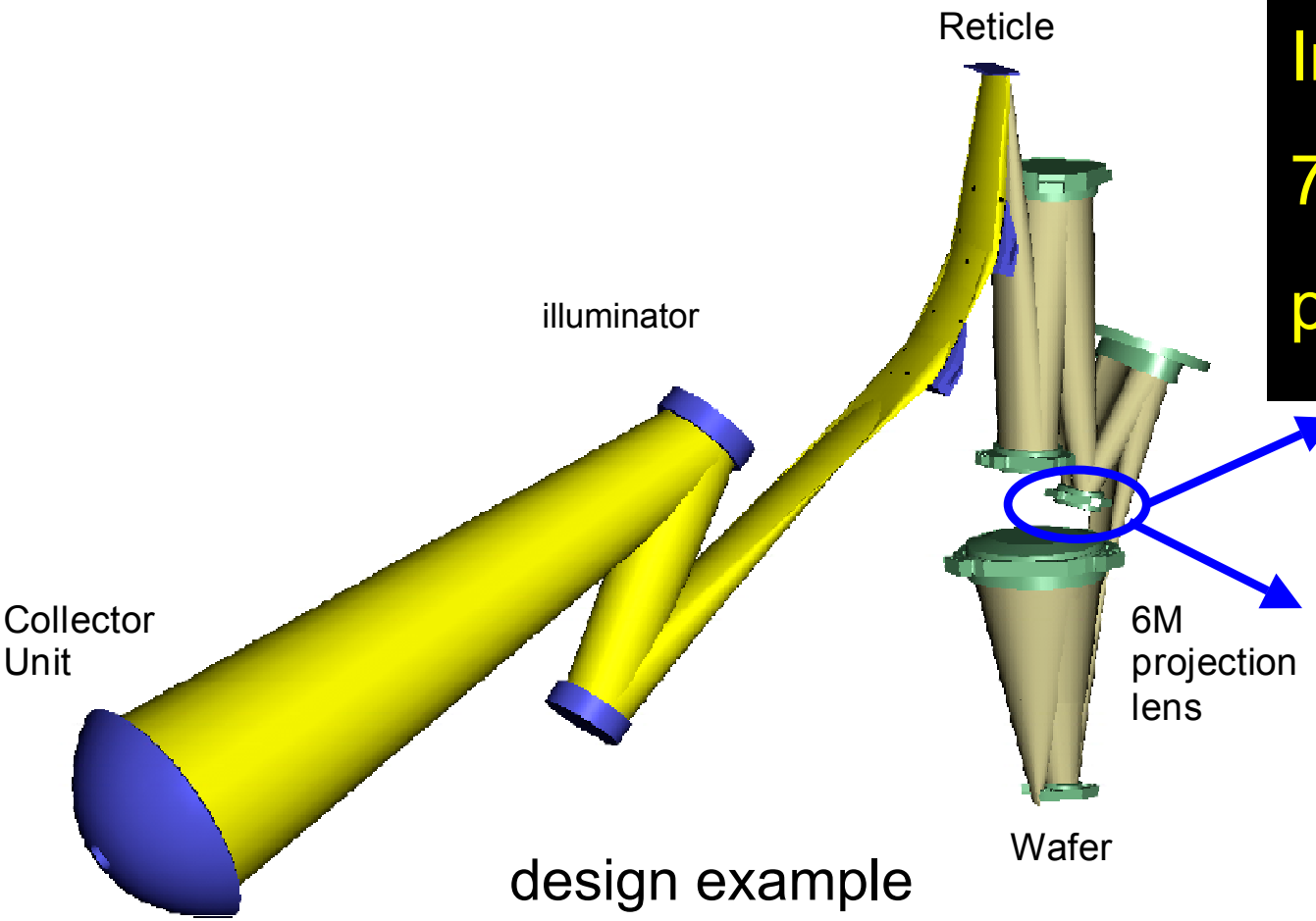
design example

MSFR for 6-Mirror large field (26 x 2mm²) systems within 4.7 decades:

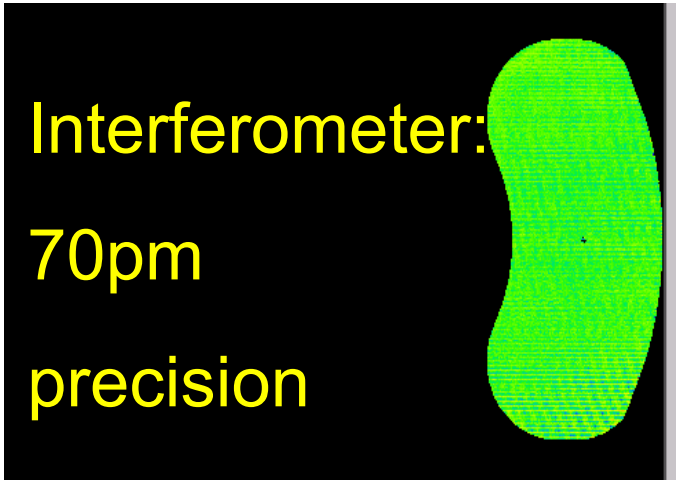
today (Set 3)	→	α-tool	→	γ-tool	
0.27		0.25		0.14	[nm rms]

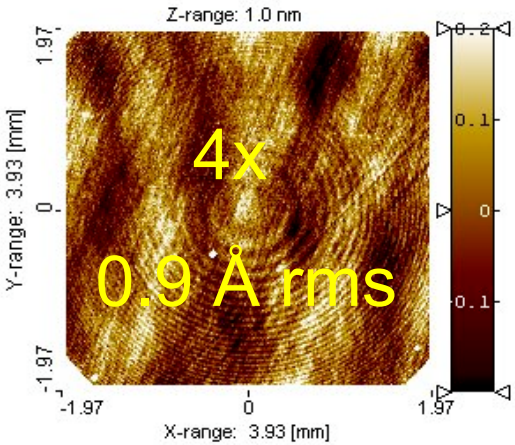
Large off-axis mirrors

Alpha-tool: first interferometers operational and mirror fabrication started

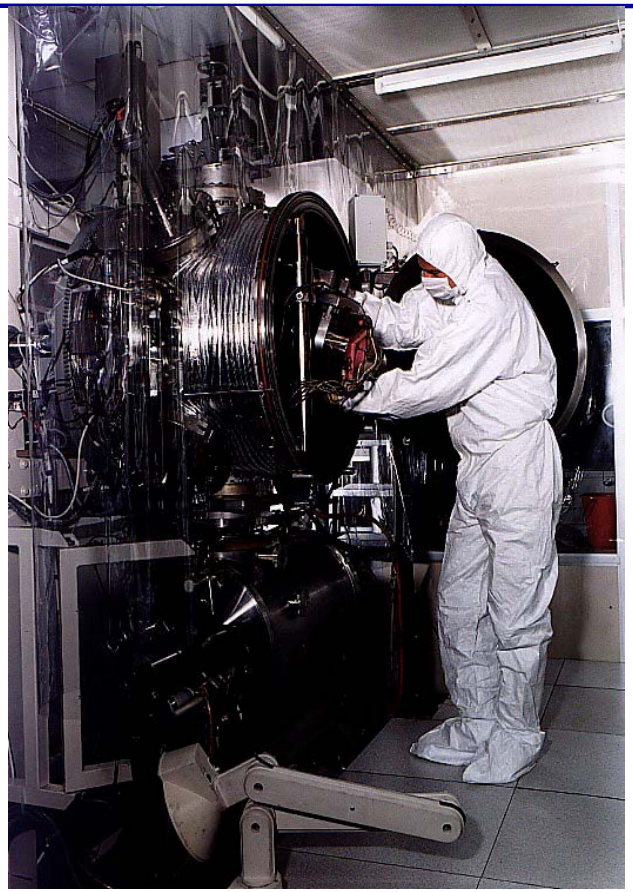


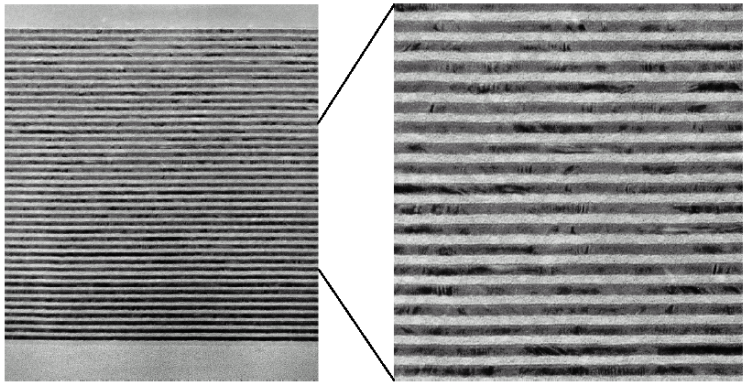
design example



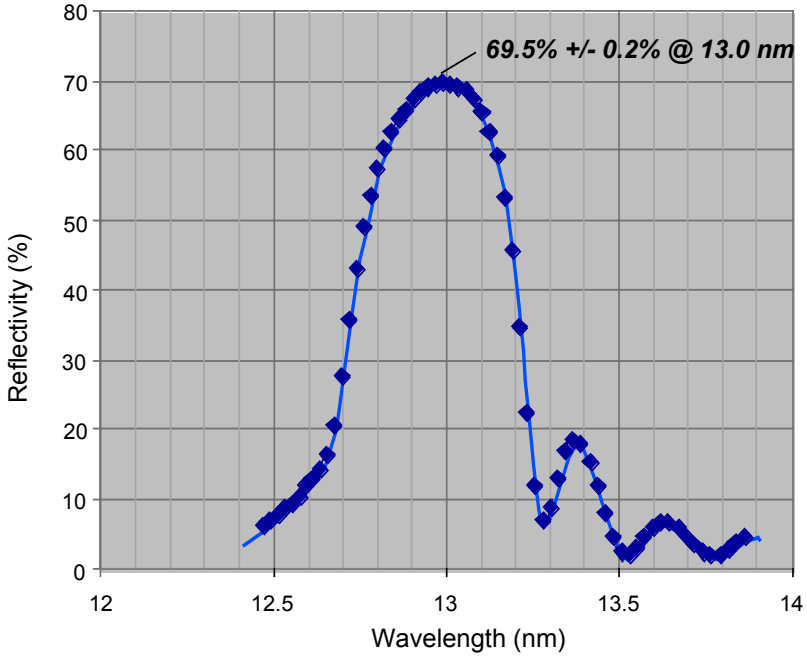


Coating Technology





reflectivity ~ 70 %



Technology:
ion-beam assisted
electron beam evaporation

Collaboration with FOM Rijnhuizen

R. v. d. Kruijs et al.:
this conference

Partners in the contamination control effort

ML c
samp

FOM

Coater,

ZEISS

ASML

Photo
tests

PTB

contamina
Reflectom

PHILIPS

Electron contamination tests and surface analysis

E-beam, SEM, Auger, SIMS, XPS
...

new:

ASML

Pulsed source contamination experiments

Xe discharge source

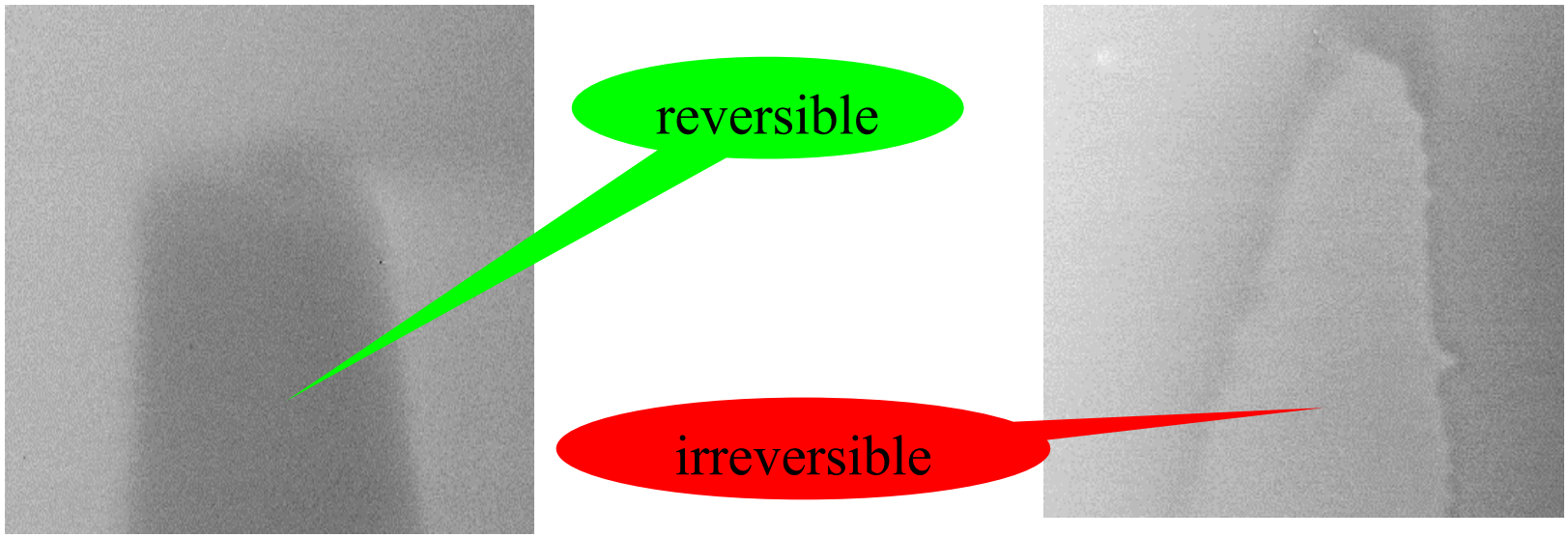
Lifetime: Contamination and reflection loss

Carbon growth:

1% loss per nm Carbon

Oxidation:

3% loss per nm additional oxide



Optics Lifetime endangered by

- Carbon build-up -> reflectivity loss
- Oxidation of multilayer -> reflectivity loss
- sputter damage by source related ions and debris

M. Weiss et al.
B. Mertens et al
R.v.d Kruijs.:
this conference

Contamination Control: Current Status

230 h exposure

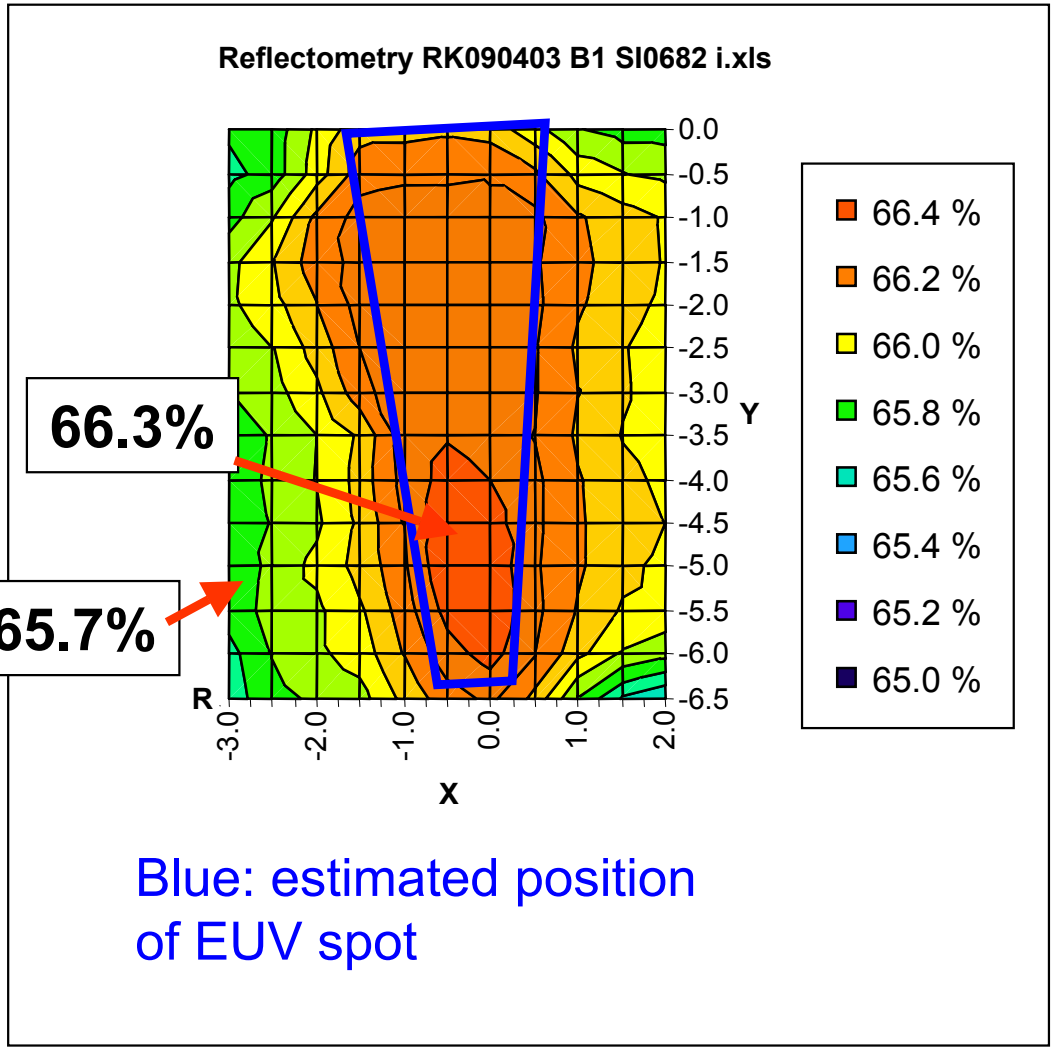
at PTB/BESSY

Gasses: C_xH_y, H_2O, O_2

Intensity: 30 mW/mm²

Initial reflectivity recovered

Surface analysis shows no oxidation or other damaging effect !

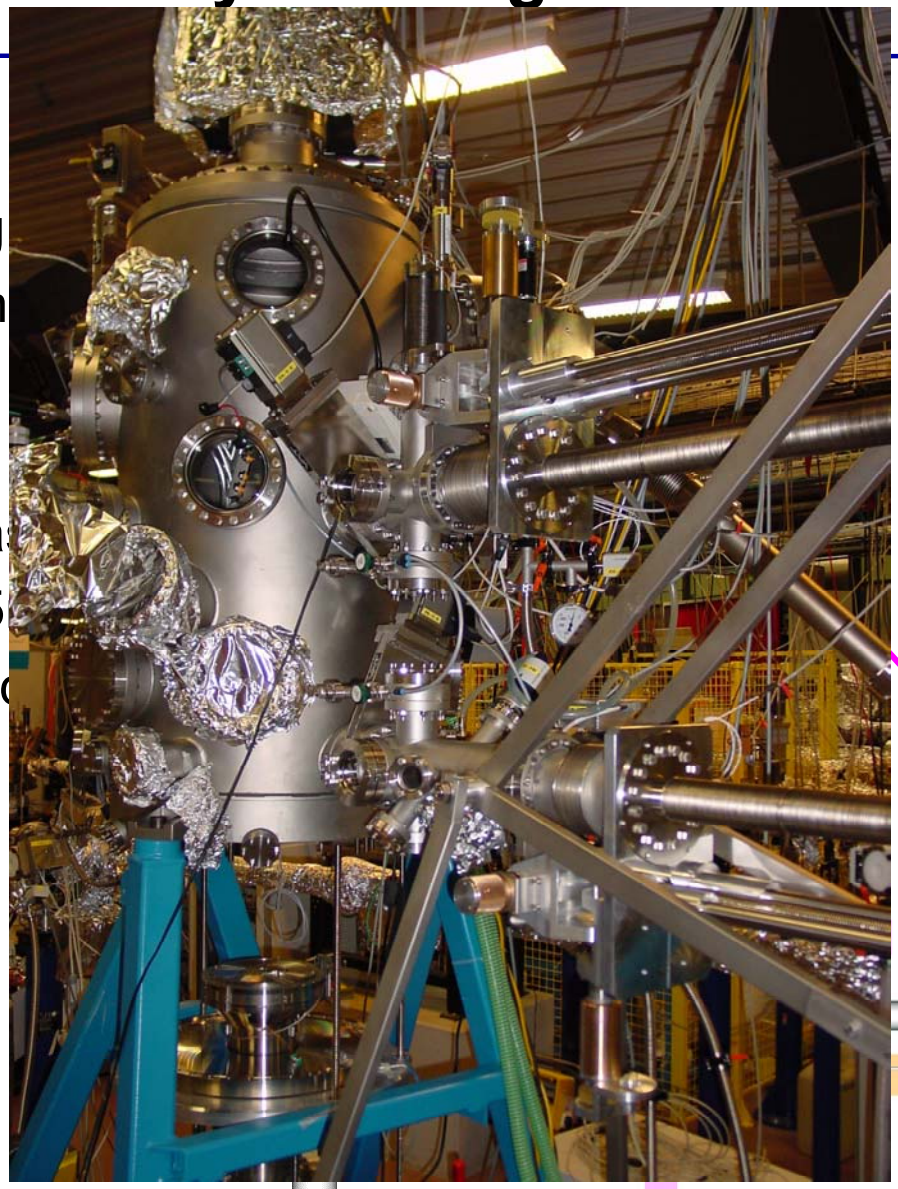


Next step: do experiment with pulsed source

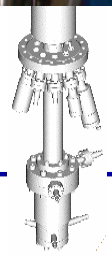
Assembly and Alignment

Ring
Illum
0.04

Ma
2.5
fiel



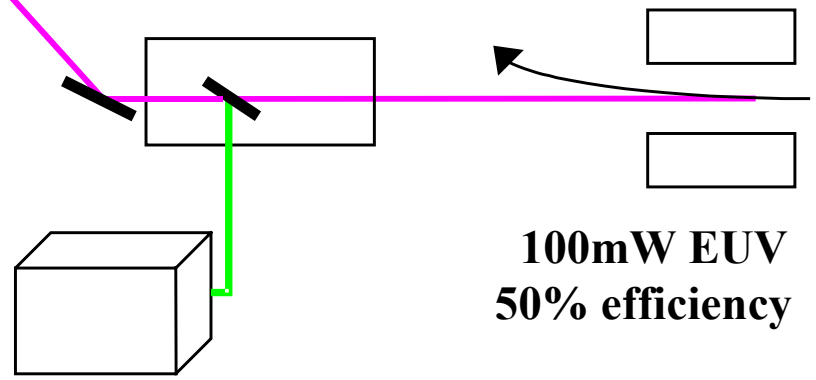
Focus sensor



wafer transfer system

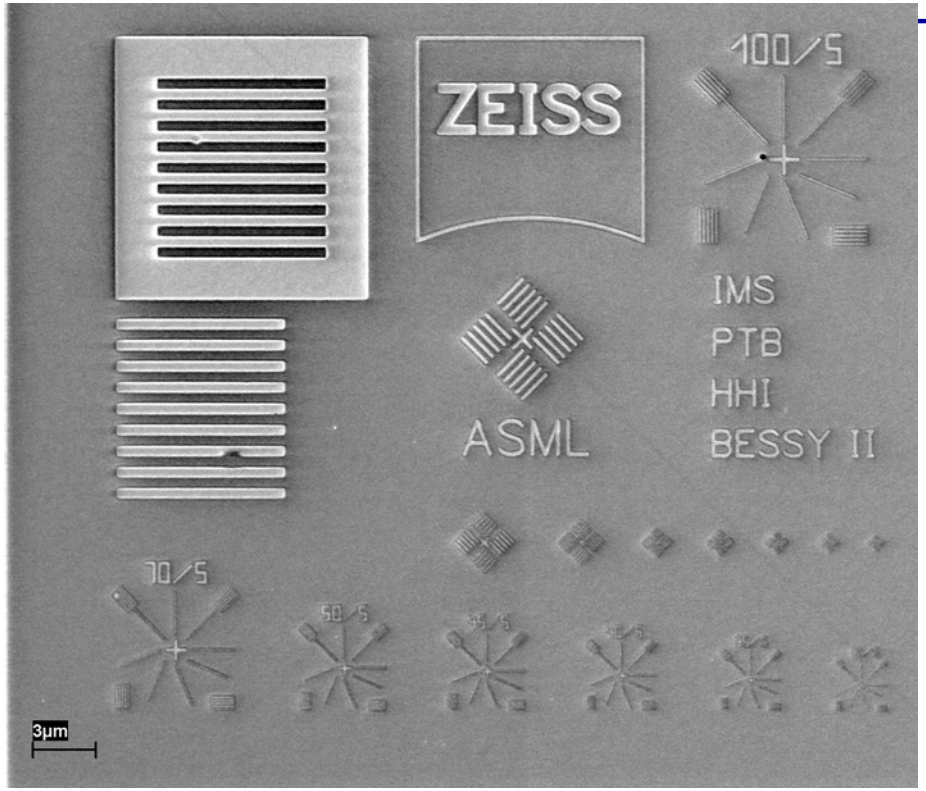
Goals:
- check single mirror metrology
- develop EUV system metrology
- **35 nm resist printing**

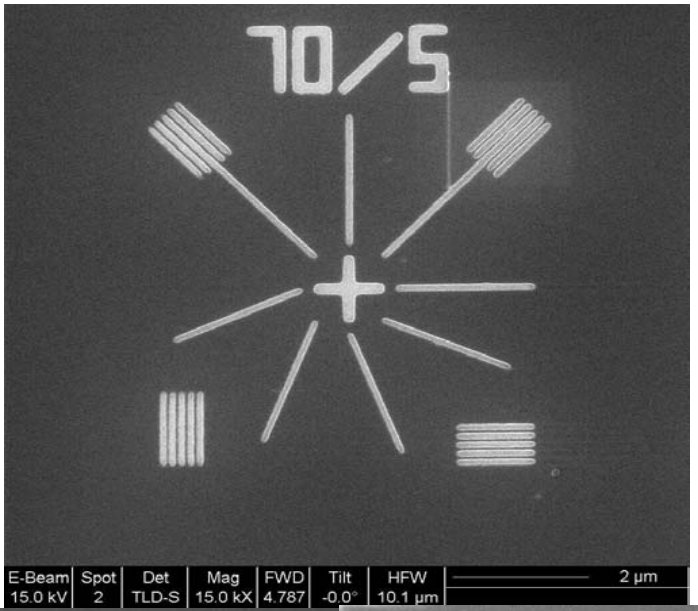
Undulator U180 at the PTB lab at the Synchrotron BESSY 2

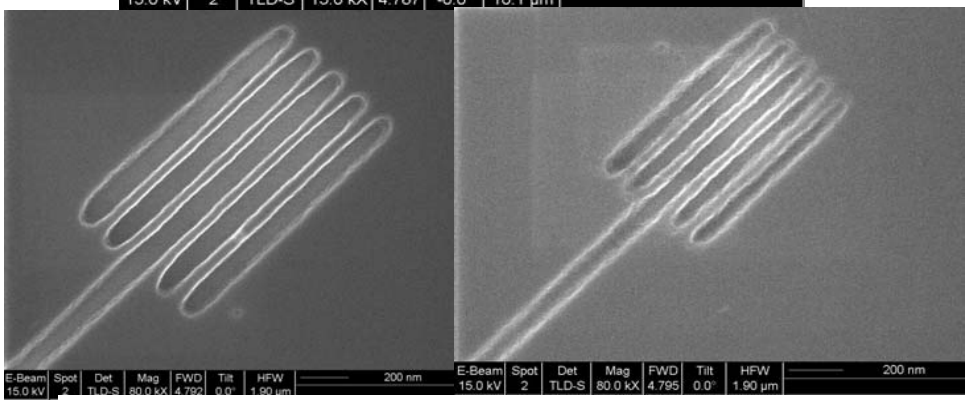


Laser 248nm

EUV-MET-Tool at PTB/BESSY: resist images

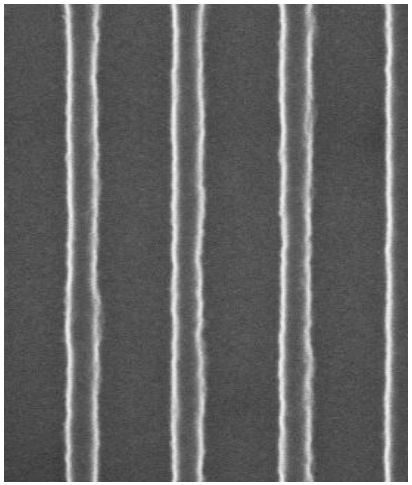






70 nm

50 nm



35 nm resolution !
(70 nm overexposed)

Summary

- a Micro Exposure Tool optics has been developed as a technology pathfinder
  - ➡ now the MET optics is commercialized (collaboration with Exitech)
- our alpha tool program is progressing:
  - the source collector module is in the assembly and alignment phase
  - fabrication of all illuminator parts nearing completion
  - the fabrication of the alpha tool POB mirrors has been started
  - alpha demo tool coating technology is available
  - Contamination Control Strategies have been identified and tested
  - system metrology is being developed
- an “EUV infrastructure” has been set up

EUV Optical Technology at Carl Zeiss SMT AG:

➡ has reached α-tool specs in key technology areas

➡ is progressing towards production tool capability

Acknowledgment

Thanks to a huge team effort at…

- FOM-Rijnhuizen
- TNO TPD
- PTB-BESSY
- Philips
- Lawrence Livermore National Labs (MET program)
- The teams at ASML and Zeiss
- …and many others

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