EUV Symposium 2010

Optics for EUV Production

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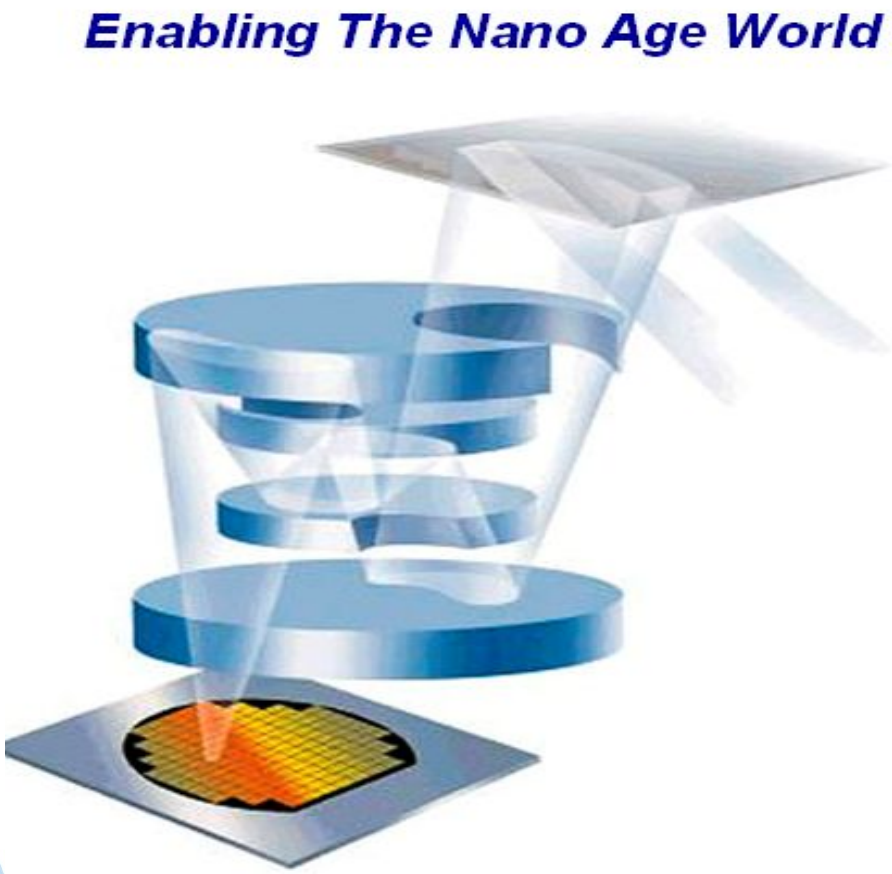


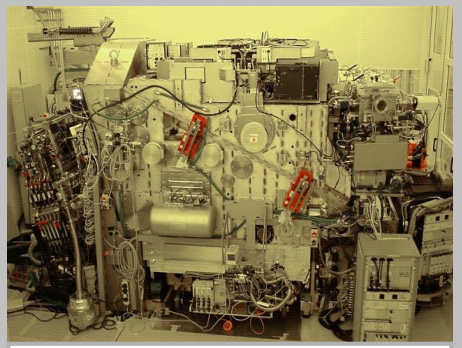
Agenda

1. **Starlith 3100**
2. Starlith 3300
3. Outlook to higher NA

From the Alpha Demo Tool to Starlith 3100

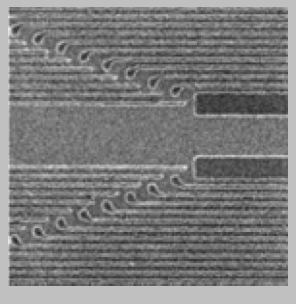
Alpha Demo Tool

Installed at
Albany Nanotech + IMEC



EUV Alpha Demo Tool

26 nm Flash



Starlith 3100™

Improved Alpha Demo Tool POBox

- flare < 8%
  (ADT: 16%)
- WFE < 0.7 nm
  (ADT: 1.2 nm)

+

New Illuminator

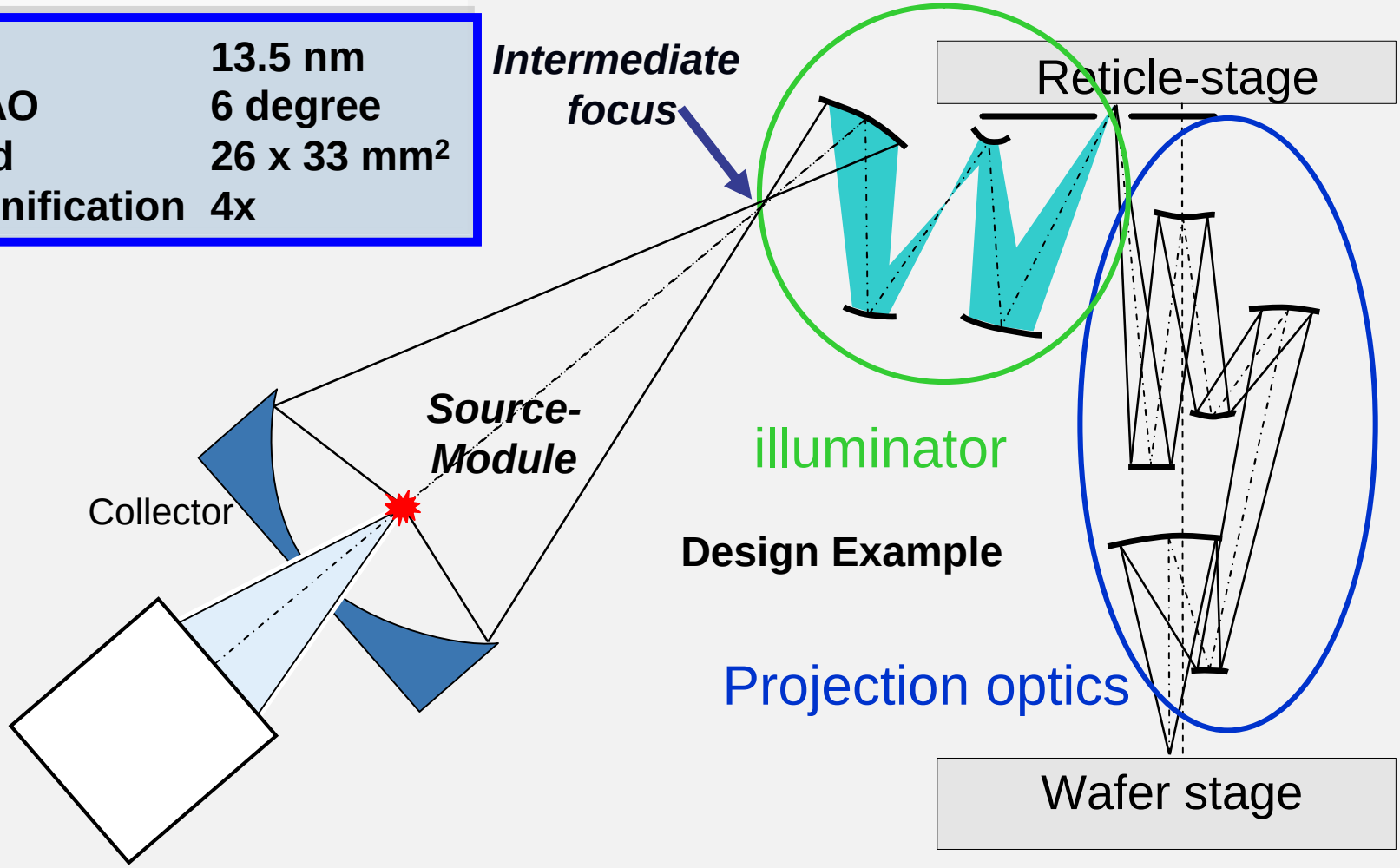
- variable sigma (0.3...0.8, annular, dipole, etc.)
  (ADT: 0.5 fixed)

Starlith 3100:

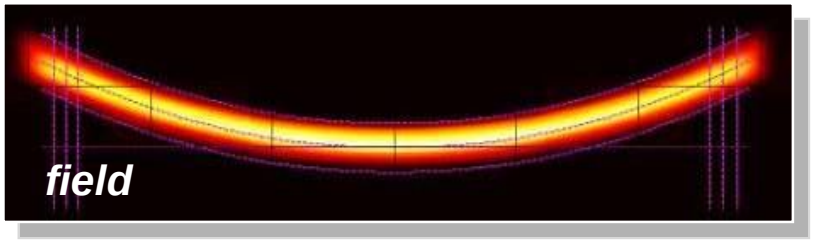
- fulfills production requirements of the 27nm node
- enables R+D for the 22 nm node

NXE:3100 – System overview

- λ 13.5 nm
- CRAO 6 degree
- Field 26 x 33 mm²
- Magnification 4x

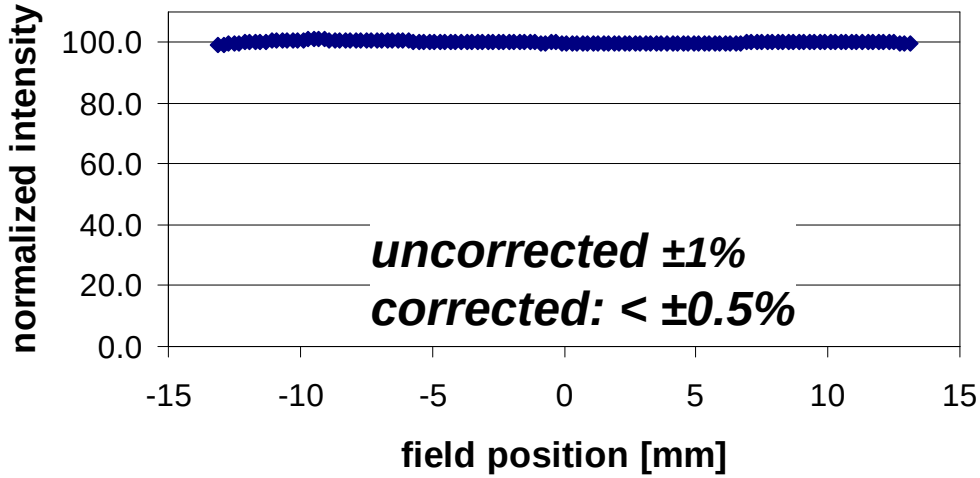


Six 3100 illumination systems qualified and delivered



Transmission	✓
Uniformity	✓
Telecentricity	✓
Ellipticity	✓

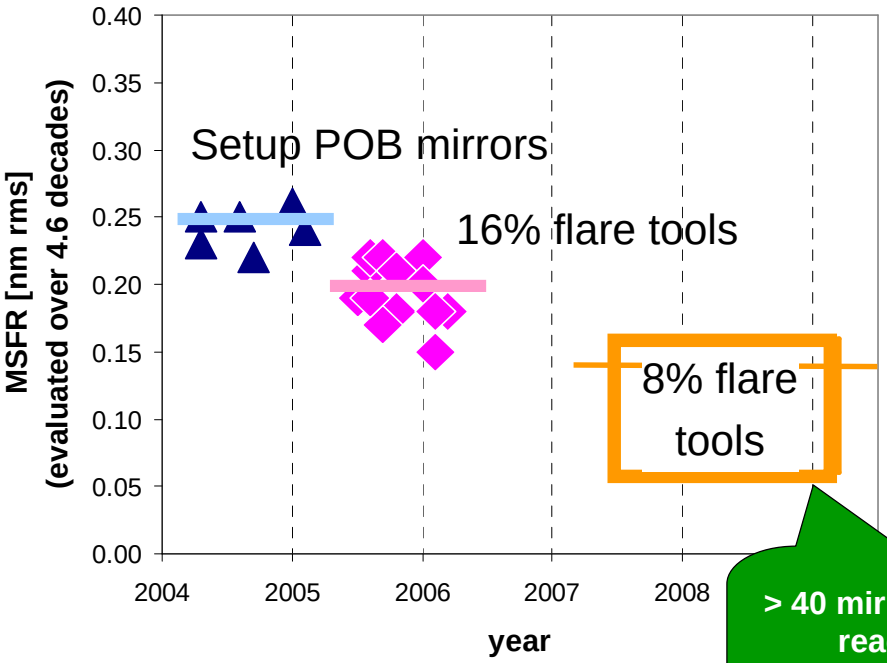
Example: Uniformity (uncorrected)

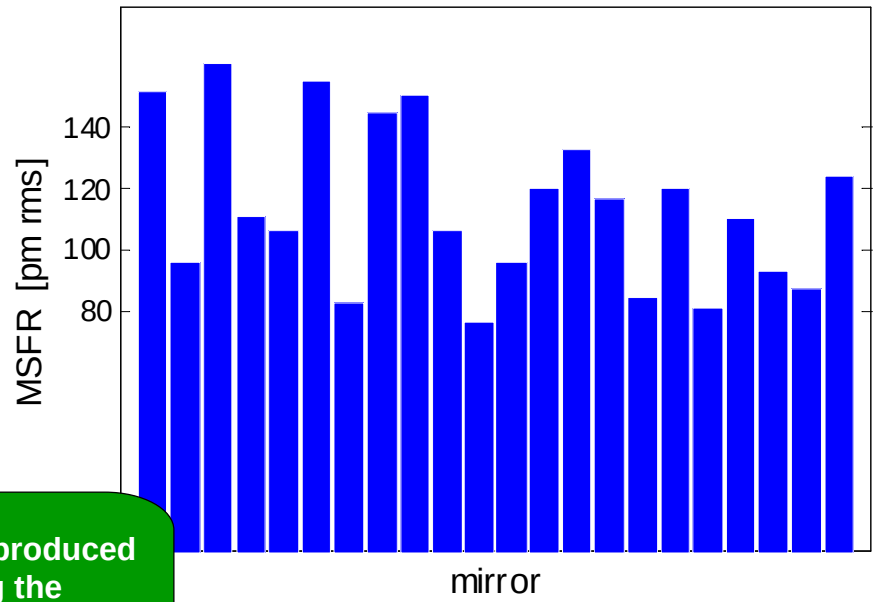


.. let‘s have a look at the projection optics

NXE:3100 – Significant surface RMS reduction achieved

$$Flare \propto n_{mirrors} \cdot (\mathrm{MSFR}/\lambda)^2$$

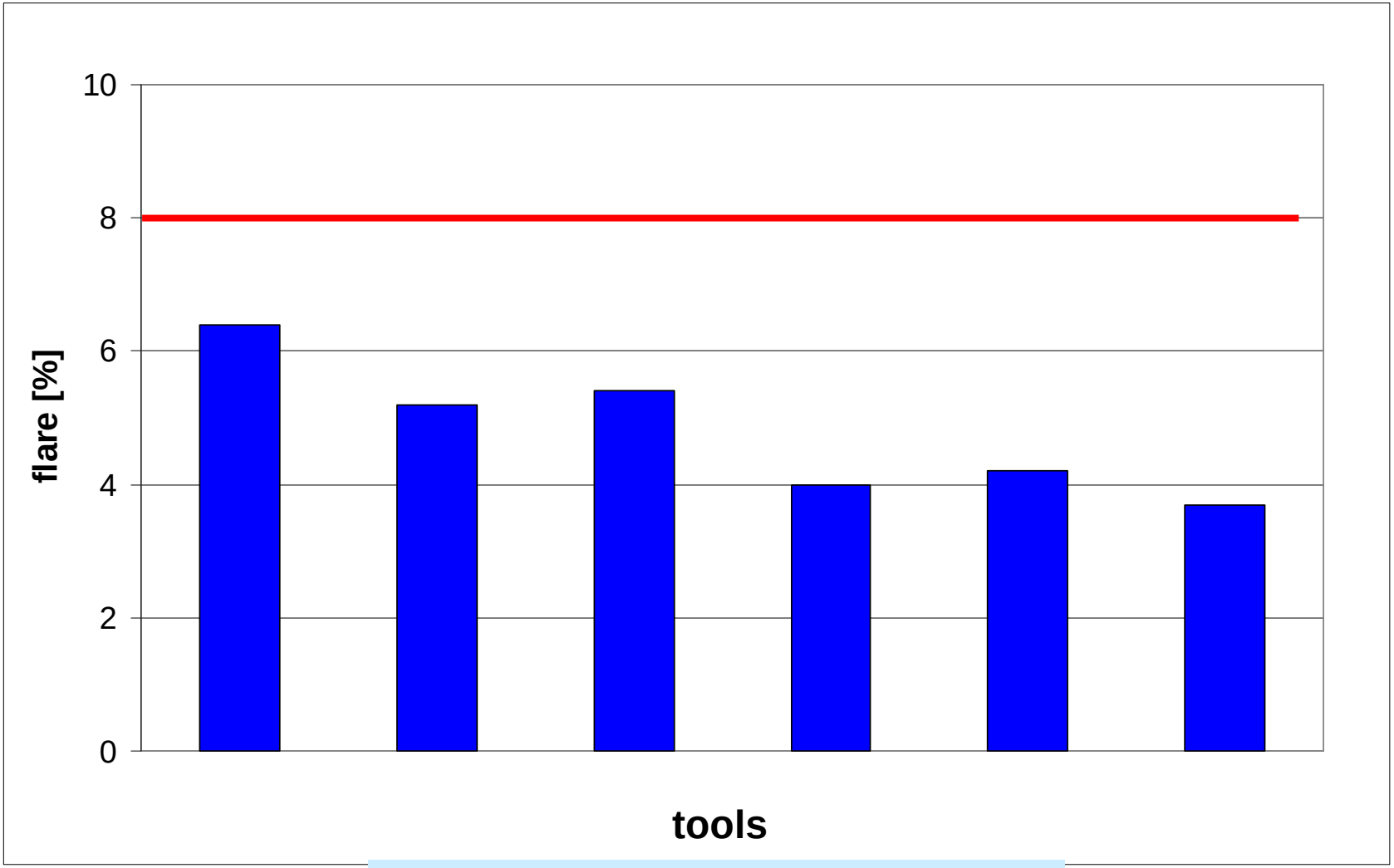




> 40 mirrors produced reaching the specifications for 3100 generation

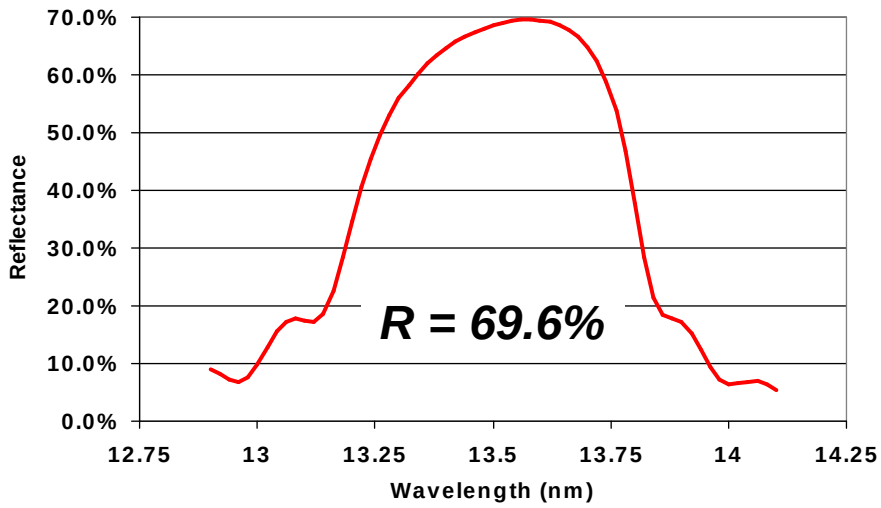
Continuous process improvements in production processes lead to mirror quality well within requirements

NXE:3100 – Flare is well in Specification for all delivered systems

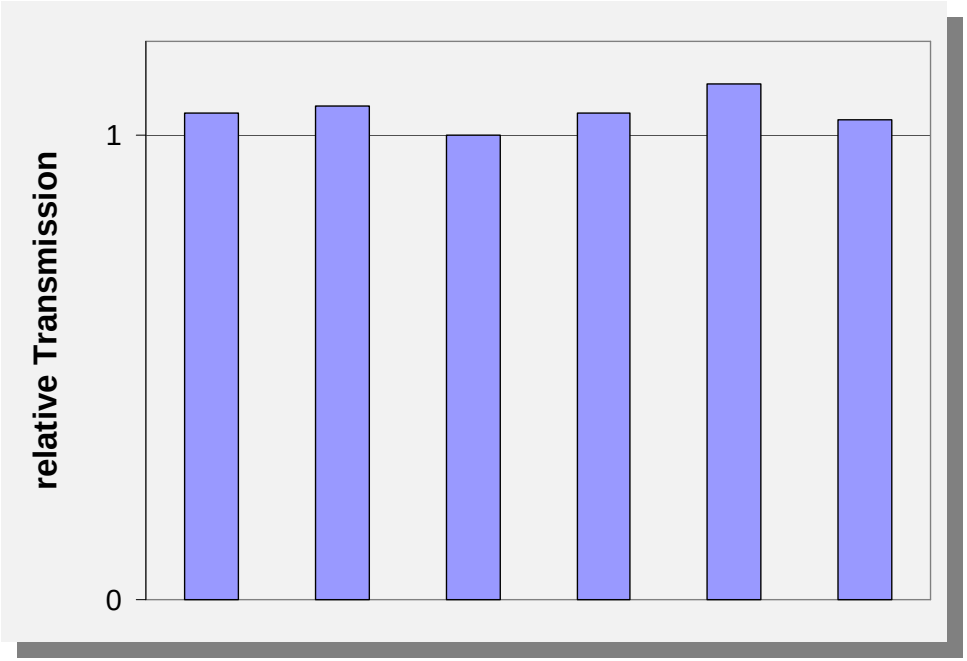


Flare is calculated for a 2 µm line in a bright field

NXE:3100 – Coating reflectivity significantly increased compared to ADT



Coated at FOM, measured at PTB
ADT: ~ 64% (typical achievements)

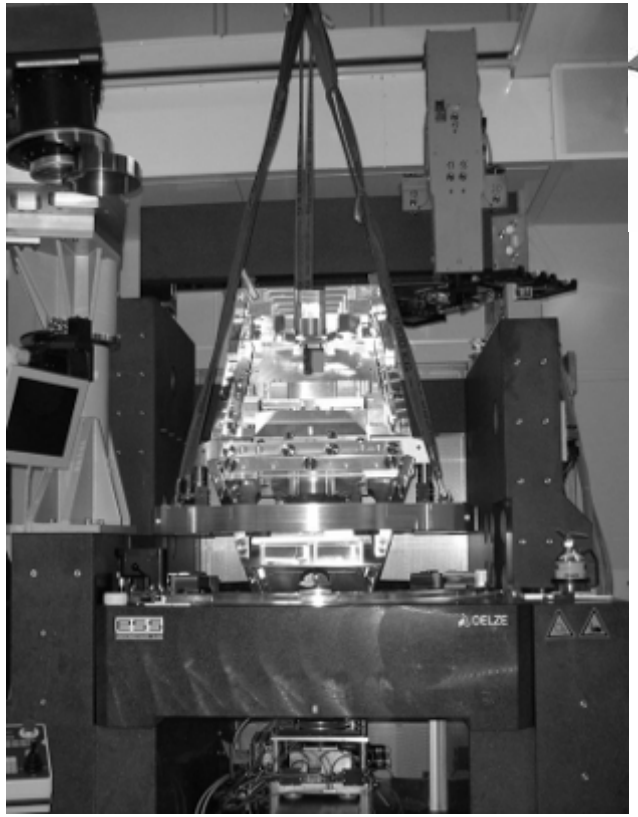


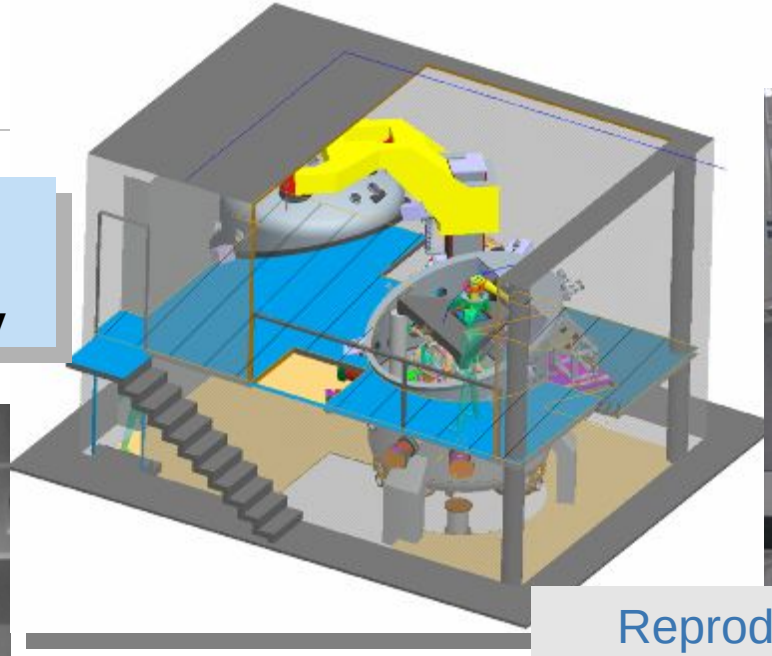
about 50% more transmission of 3100 projection optics

3100 Coating: Collaboration with FOM/Rijnhuizen, IWS/Dresden, and IOF/Jena

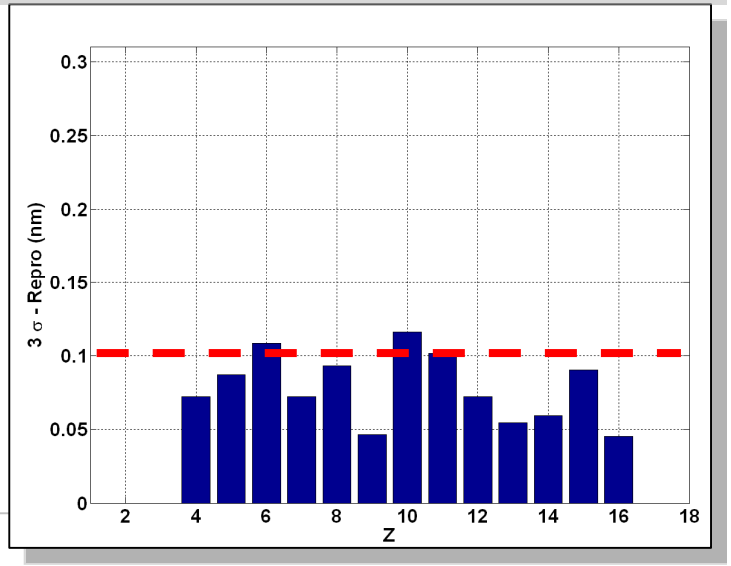
NXE:3100 – System metrology is fully operational

3100 POBox Metrology
VOBIF: 248 nm metrology
EUV-BIF: 13.5 nm metrology

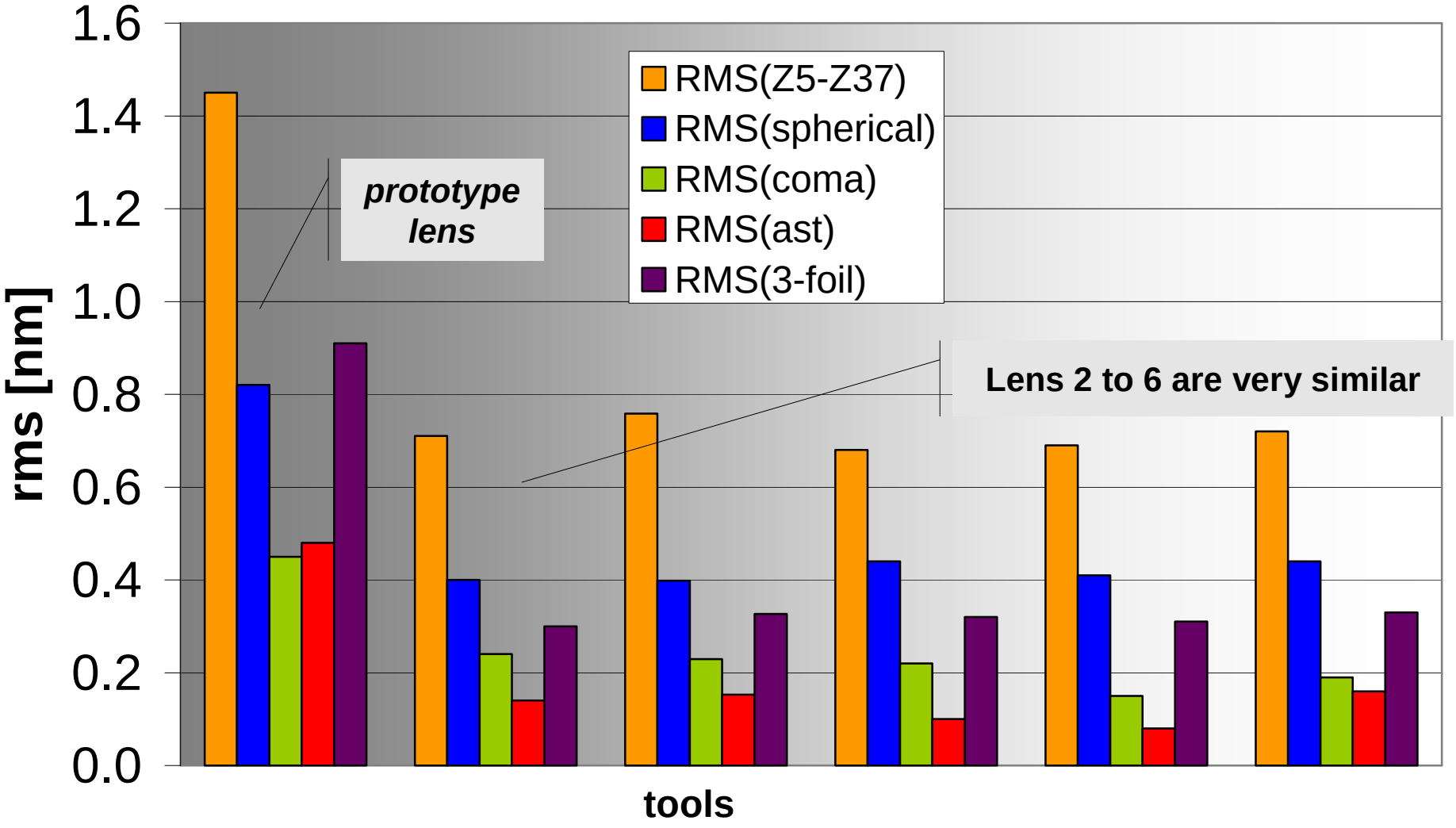




Reproducibility performance of metrology head



NXE:3100 – 6 POBs Shipped: Wavefront Aberrations in Specification



Agenda

1 Starlith 3100

2 **Starlith 3300**

3 Outlook to higher NA

The future - What are the basic optical requirements?

EUV is introduced as a high k1 technology…

NA →

hp ↓

k_1	0.25	0.3	0.35	0.4	0.45	0.5
27	0.50	0.60	0.70	0.80	0.90	1.00
24	0.44	0.53	0.62	0.71	0.80	0.89
22	0.41	0.49	0.57	0.65	0.73	0.81
18	0.33	0.40	0.47	0.53	0.60	0.67
16	0.30	0.36	0.41	0.47	0.53	0.59
13	0.24	0.29	0.34	0.39	0.43	0.48
11	0.20	0.24	0.29	0.33	0.37	0.41

$$Resolution = k_1 \cdot \frac{\lambda}{NA}$$

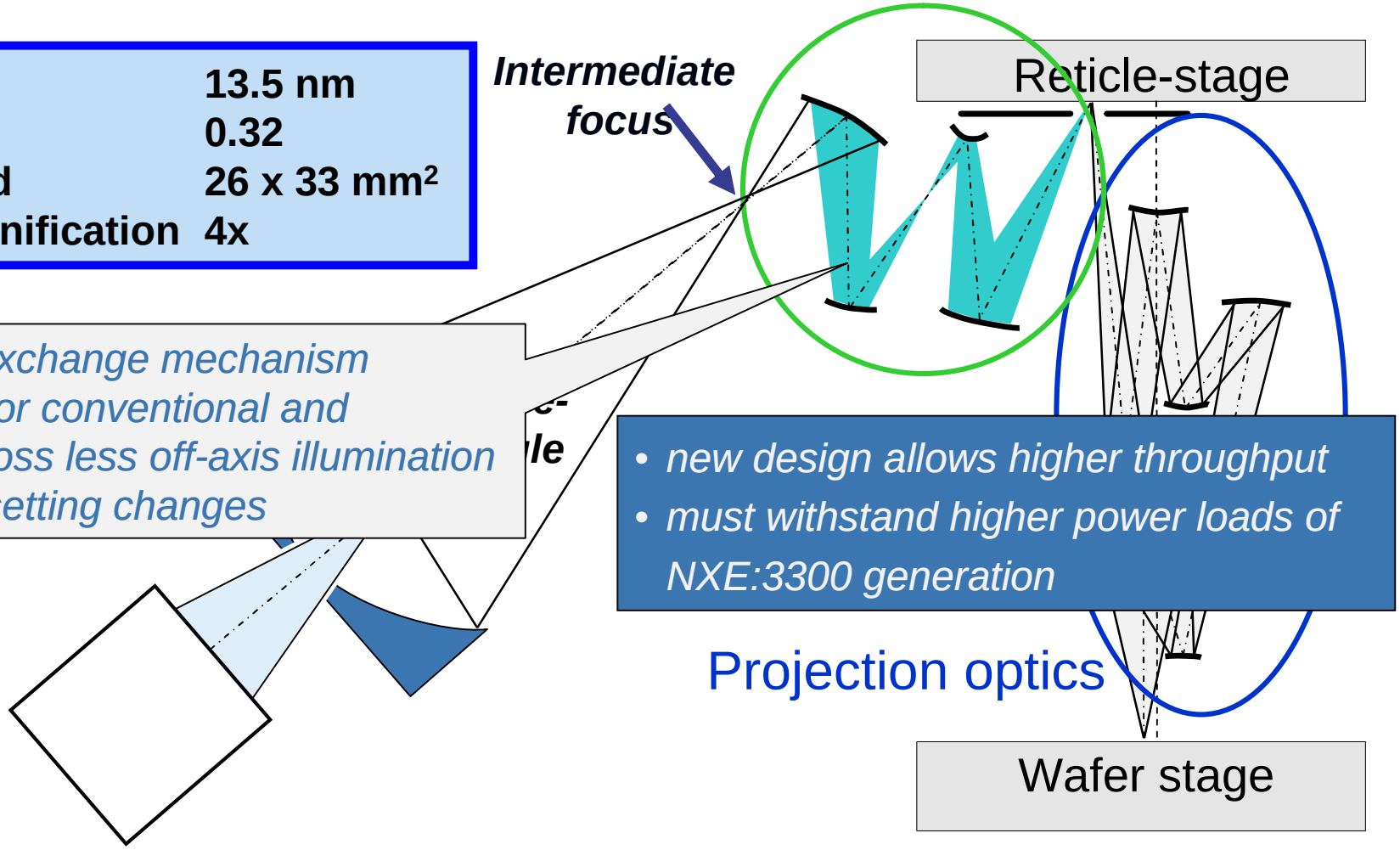
- conventional illumination possible
- off-axis illumination required
- NA too small, even with off-axis illumination

… and will at higher NA and lower k1 factors enable resolutions down to 11 nm … and beyond

3300 approach:
For high productivity, a 6 mirror solution is preferred.
A projections optics with NA $\gtrsim$0.3 is required for the **22 nm node**.
We need to provide off-axis illumination for the **18/16 nm node**.

NXE:3300 – illuminator design provides lossless off-axis illumination under HVM conditions

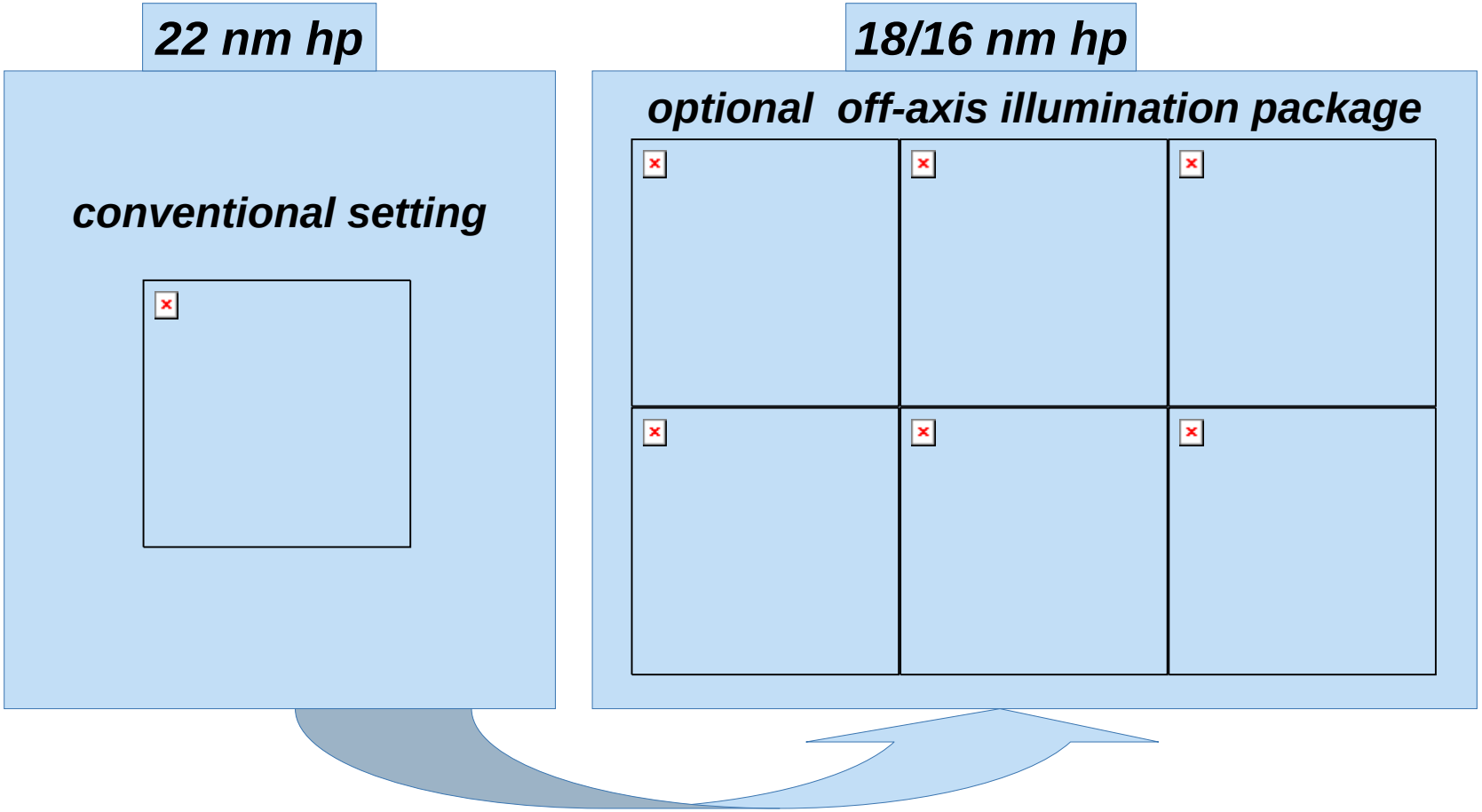
- λ 13.5 nm
- NA 0.32
- Field 26 x 33 mm²
- Magnification 4x



- *exchange mechanism for conventional and loss less off-axis illumination setting changes*

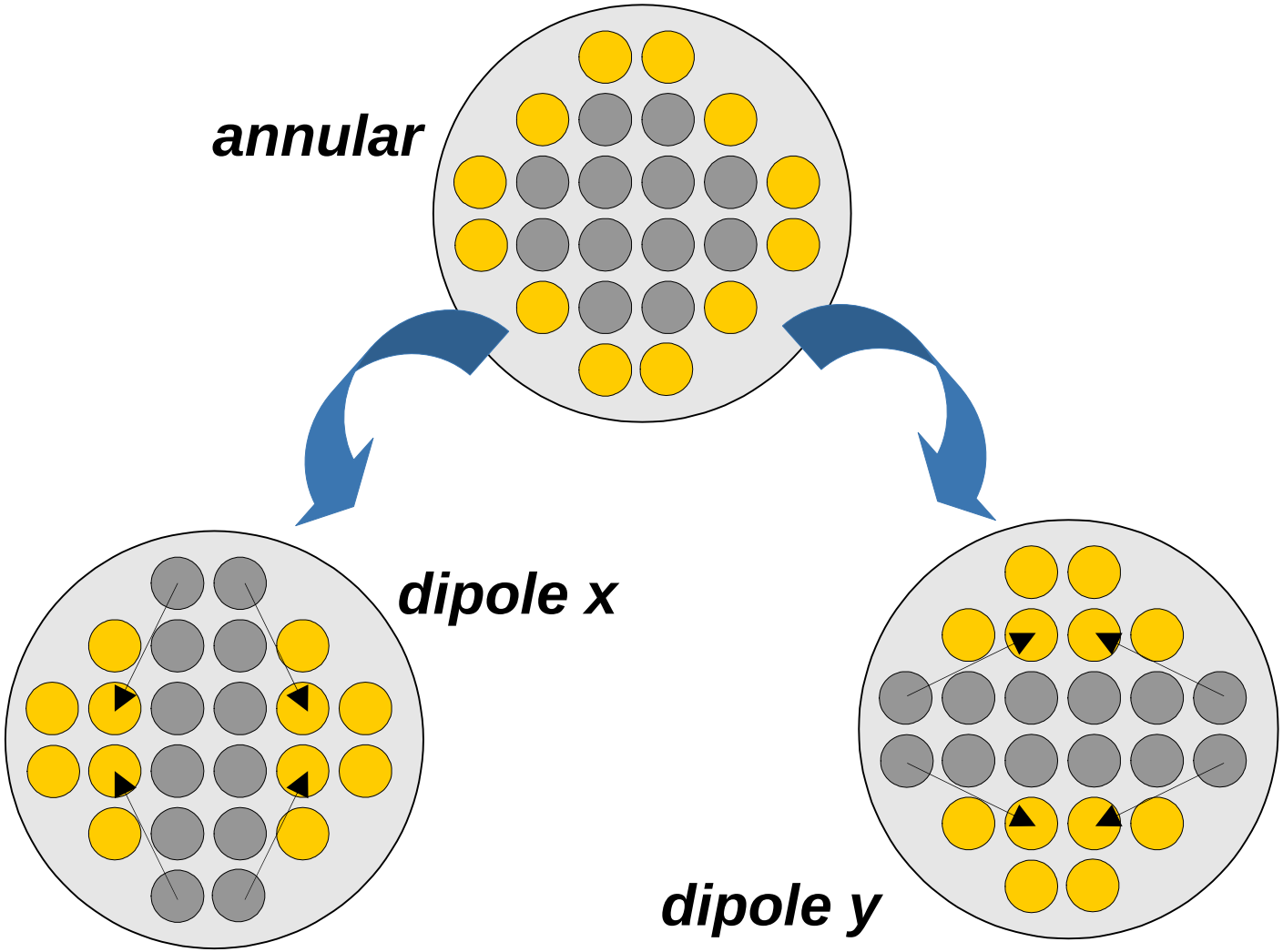
- *new design allows higher throughput*
- *must withstand higher power loads of NXE:3300 generation*

NXE:3300 – Flex illuminator enables 16 nm imaging

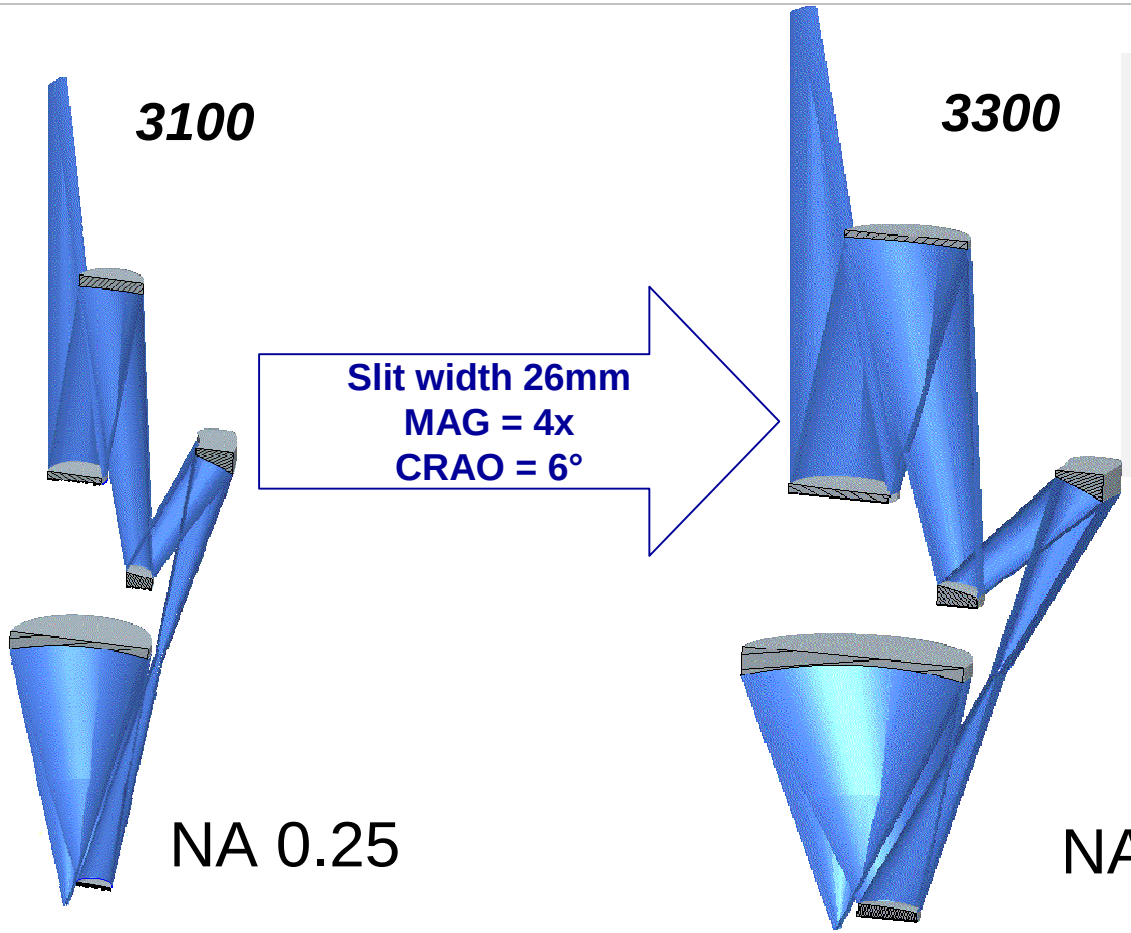


Setting change without energy loss!

NXE:33X0 Off-axis illumination will allow for energy conservation



NXE:3300 – Projection optics design for NA 0.32



Enabling for higher NA:

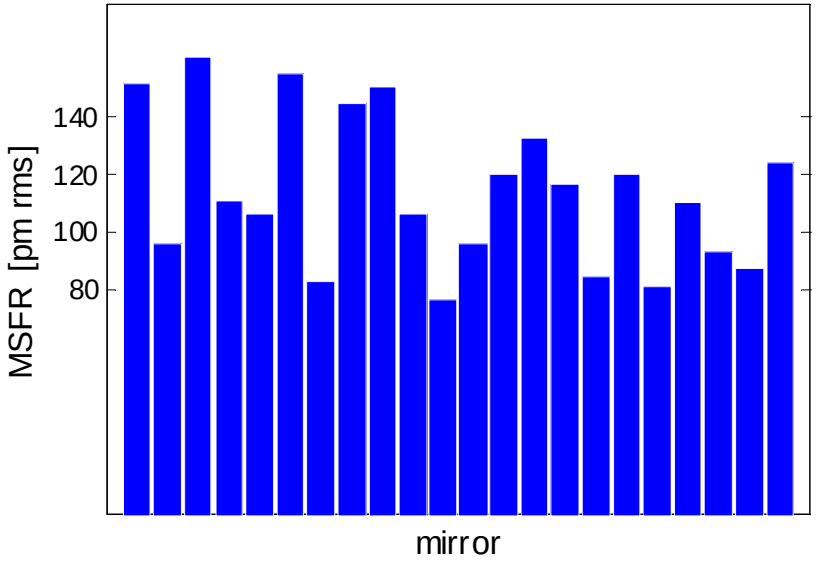
- **Larger mirror sizes**
- **Stronger aspheres**

Full field 6 mirror designs can be extended to NA 0.32

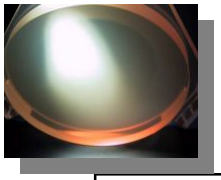
schematic designs – for illustration only.

NXE:3300 – Improvements in mirror polishing allow for reduced flare on larger and more complex mirrors

3100 status



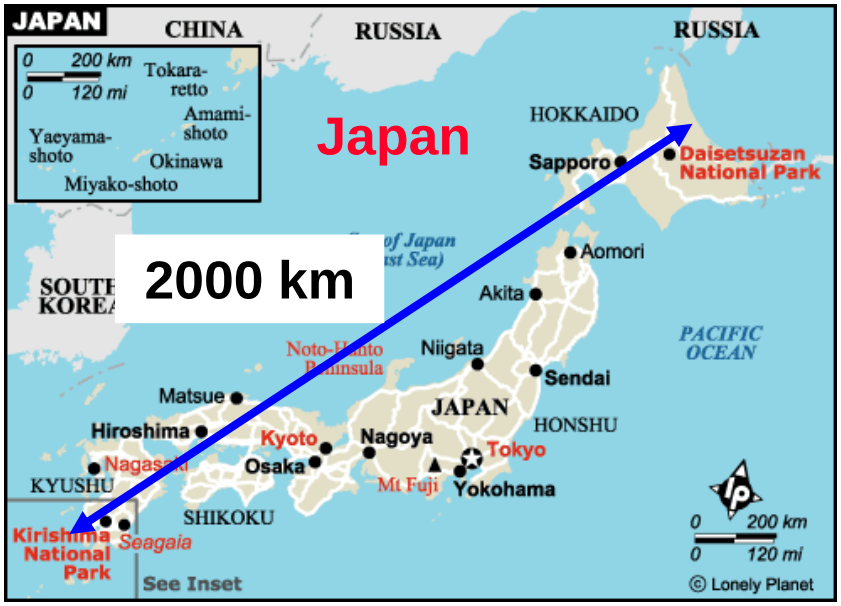
Improvement potential successfully demonstrated



	Champion 1	***Champion 2***
MSFR	68 pm	59 pm
Figure and HSFR are in spec. as well		
Figure	45 pm	30 pm
HSFR	70 pm	95 pm

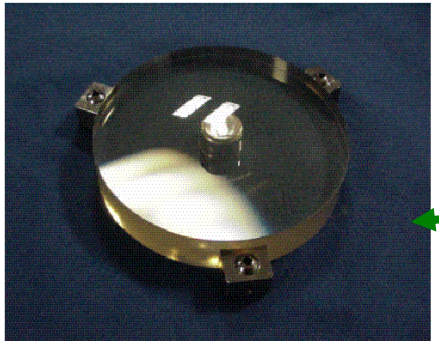
Further improvement potential for 3300 production demonstrated

Mirror Specs: compare to real world



3776 m

MET primary

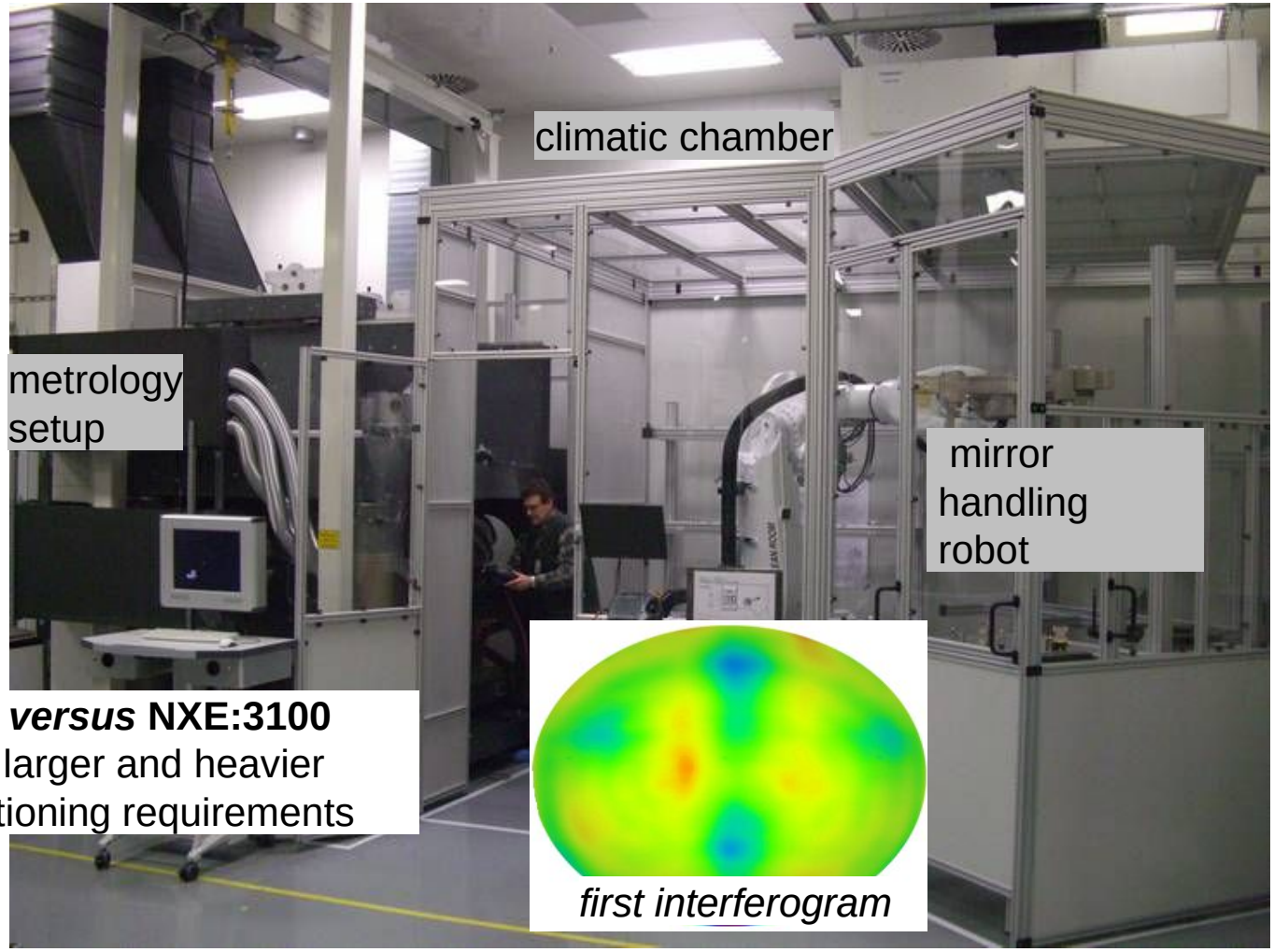


200 mm

Surface roughness corresponds to of 70 pm

peaks of 0.7 mm in the area of Japan

Infrastructure Build-up (1): The new high-end surface metrology setup for NXE:3300B is in the qualification phase



NXE:3300B *versus* NXE:3100

- mirrors are larger and heavier
- tighter positioning requirements

courtesy of Zeiss SMT AG

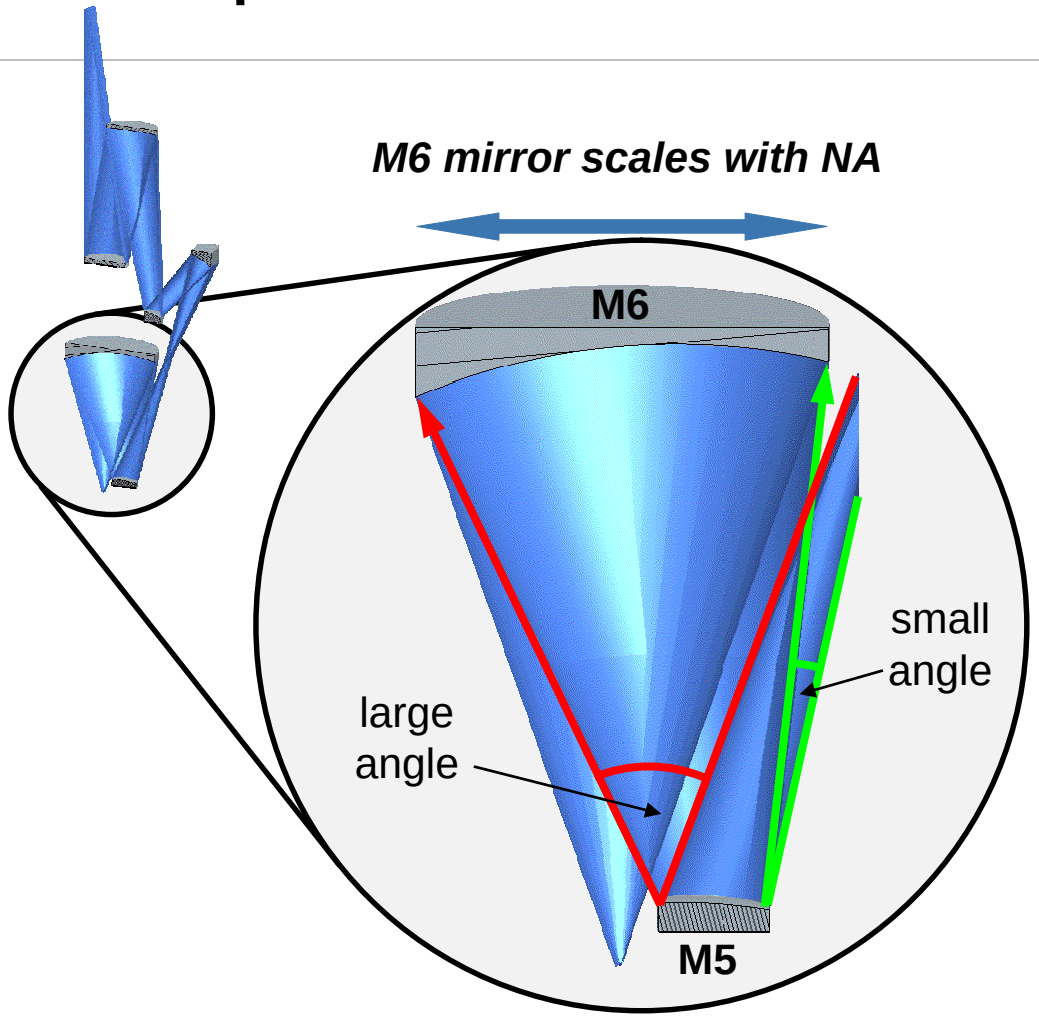
Agenda

1 Starlith 3100

2 Starlith 3300

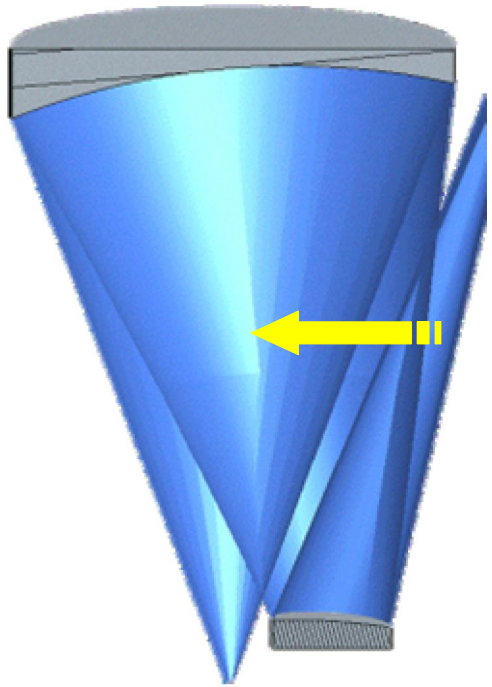
3 **Outlook to higher NA**

Angular spread is limiting unobscured designs
Option 1: 6 mirrors with Central obscuration



Possible way out:

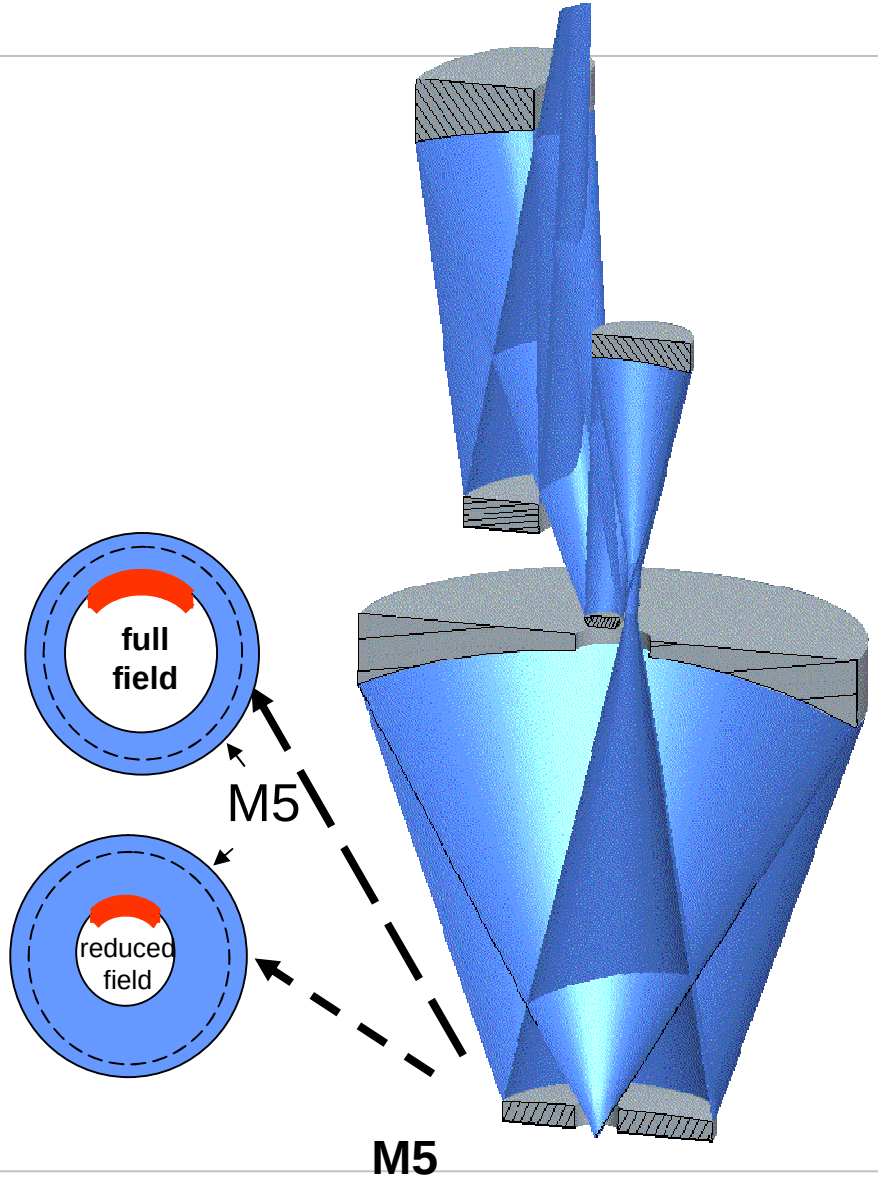
Make a hole into M5 and M6 and move the rays closer to the optical axis



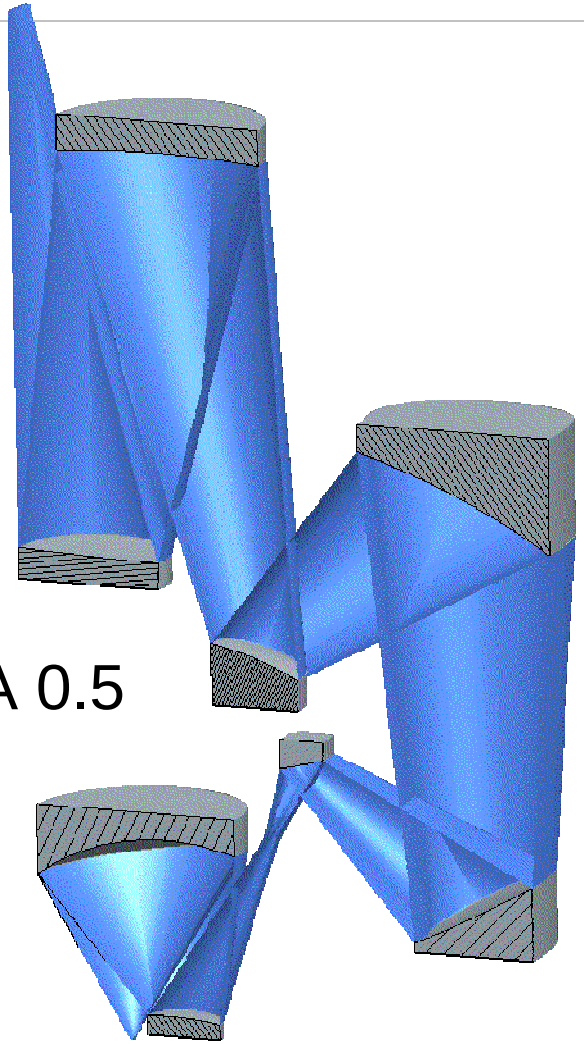
The larger NA introduces a high angular load on surfaces which exceeds the ML bandwidth

Angular spread is limiting unobscured designs
Option 1: 6 mirrors with Central obscuration

- *Central obscuration avoids apodisation but limits the field size.*
- *Full field designs show big central obscurations and tend to long track length.*
- *Stopping down increases the obscuration ratio.*

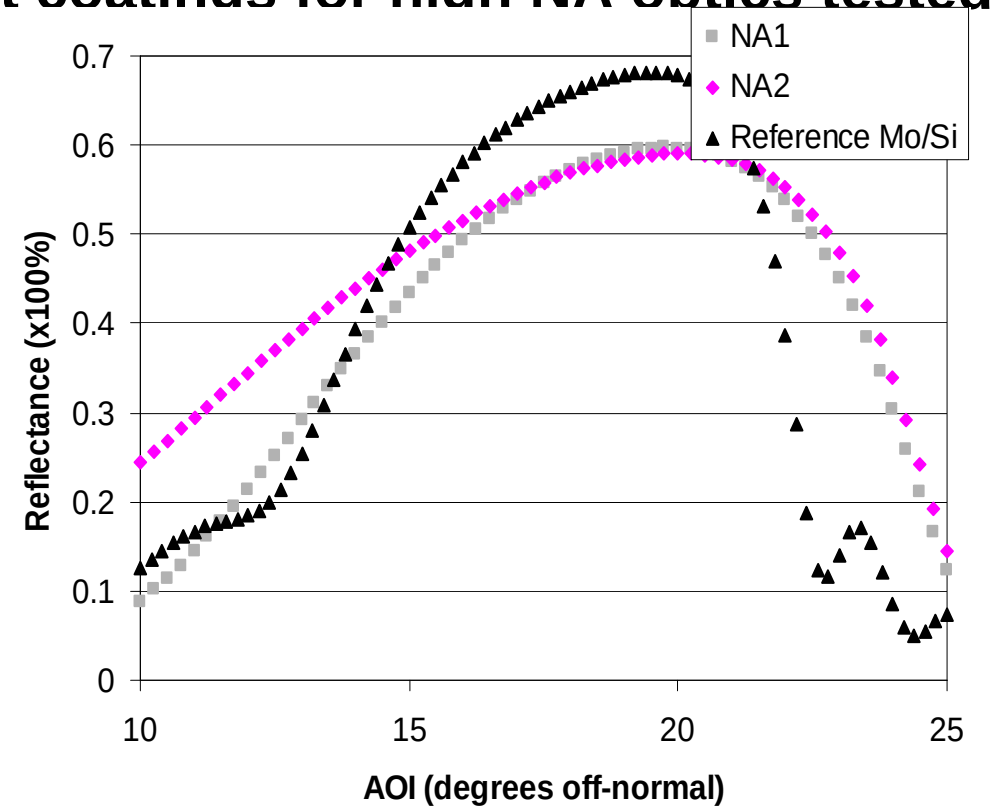


Option 2 : The 8-Mirror design



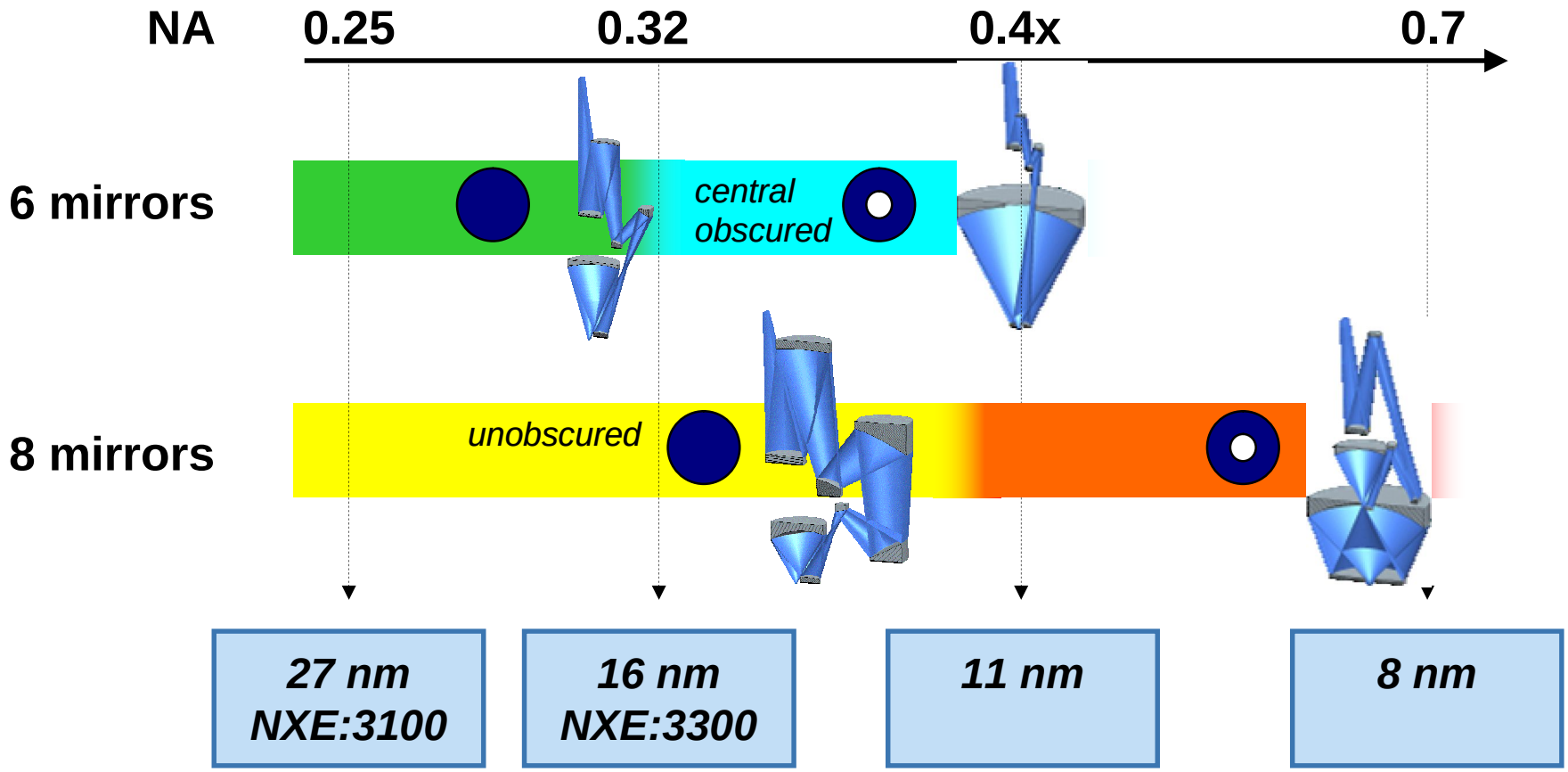
NA 0.5

First coatings for high NA optics tested



broadband coatings designed and succesfully tested (collaboration with FOM)

We see design solutions for high NA systems enabling 11 nm resolution and beyond



schematic designs – for illustration only.

W. Kaiser et al., SPIE 2008

Summary: EUV Optics is in the Production Phase!

- Shipment of 3100 series ongoing, 6th optical system shipped
  - Strong improvements in transmission and flare achieved
  - Actinic illuminator and PO system metrology are standard
- Design for 3300 optics finalized, optics production started
  - Fully Production worthy infrastructure in place
  - Further transmission and flare improvements prepared
- NA > 0.4 solutions are expected to be feasible and will enable 11nm hp SE printing
- Design extensions up to NA~0.7 for < 10nm hp on the horizon

ACKNOWLEDGEMENT

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ZEISS

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