ZEISS EUV Optics
Past, Present and Future

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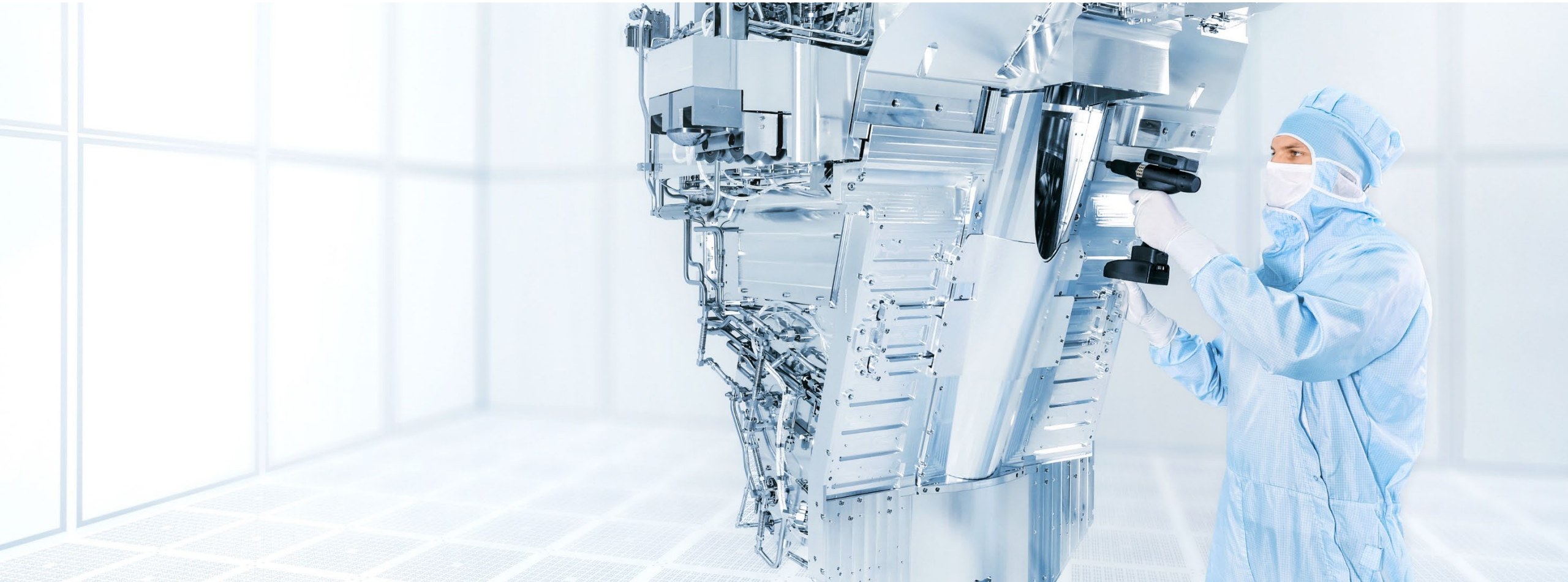
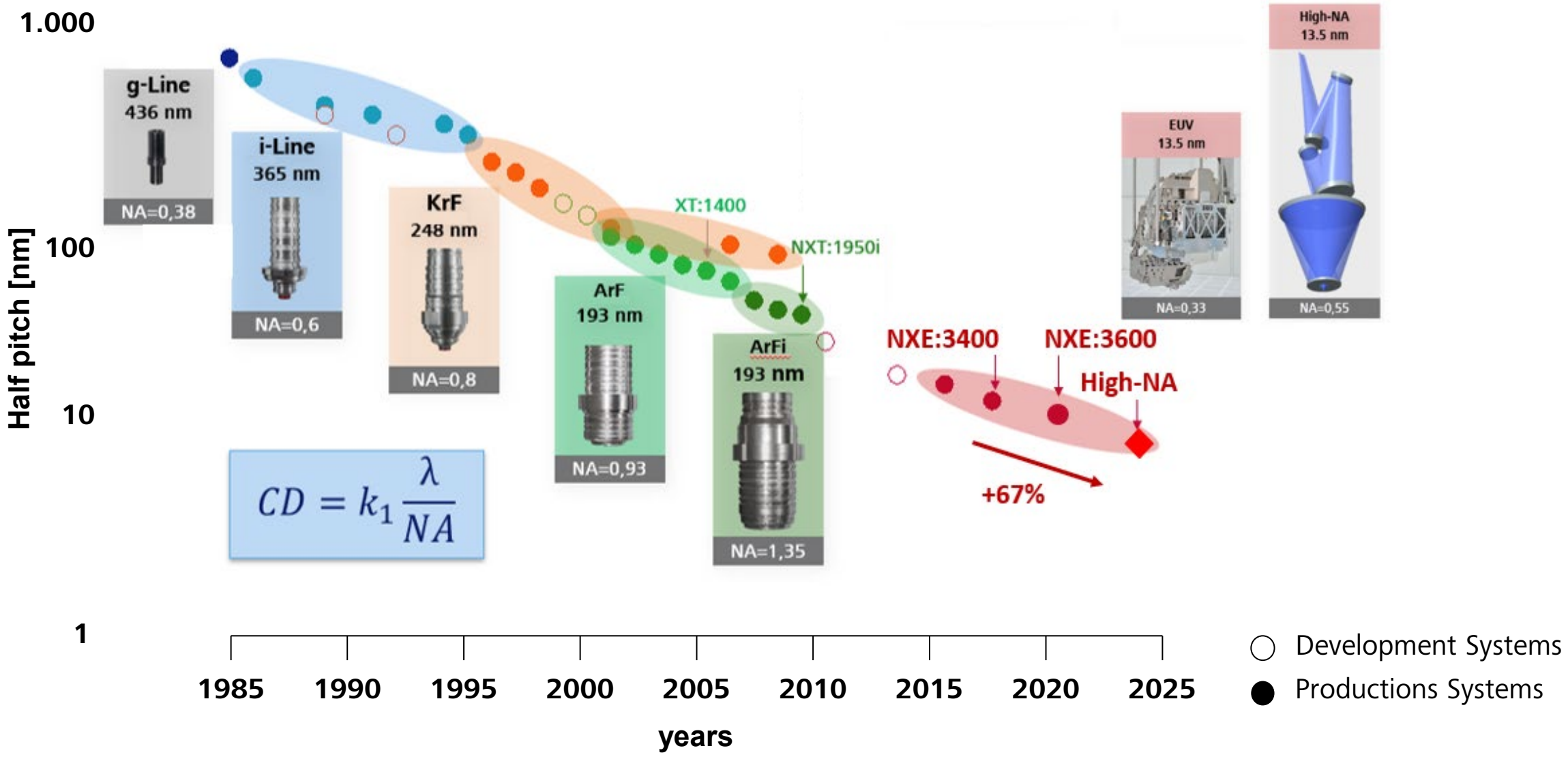


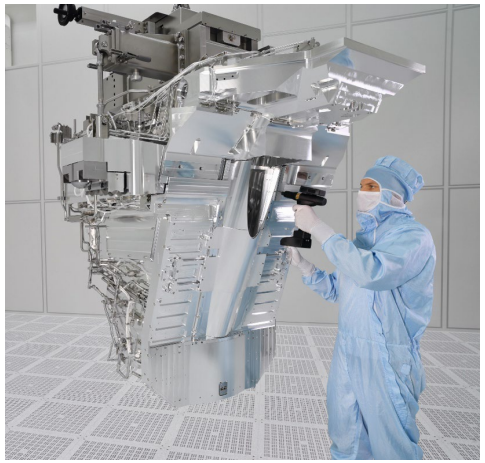
Evolution of ZEISS products



0.33NA EUV optics

Starlith® 3600: Newest Member of the 0.33NA Family

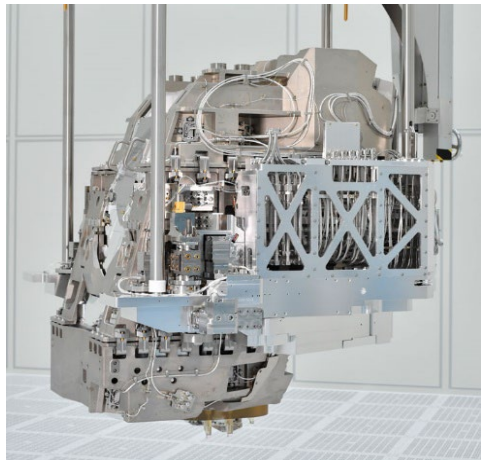
EUV aberration roadmap continues at higher source power



3600 Illuminator

Key Features:

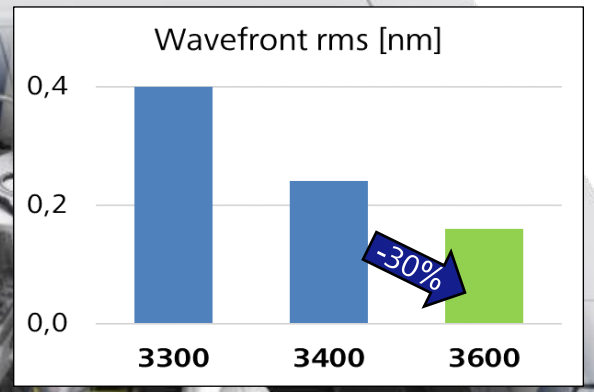
- Support of higher EUV power

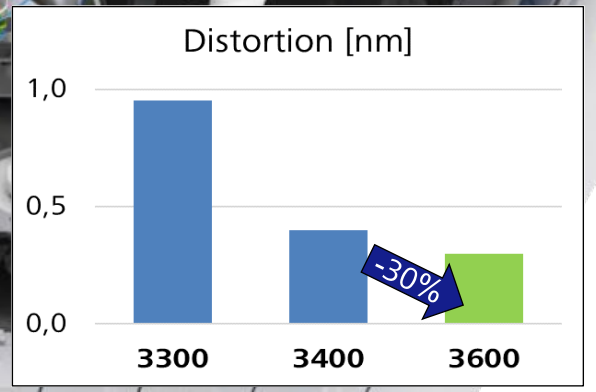


3600 Projection Optics

Key Features:

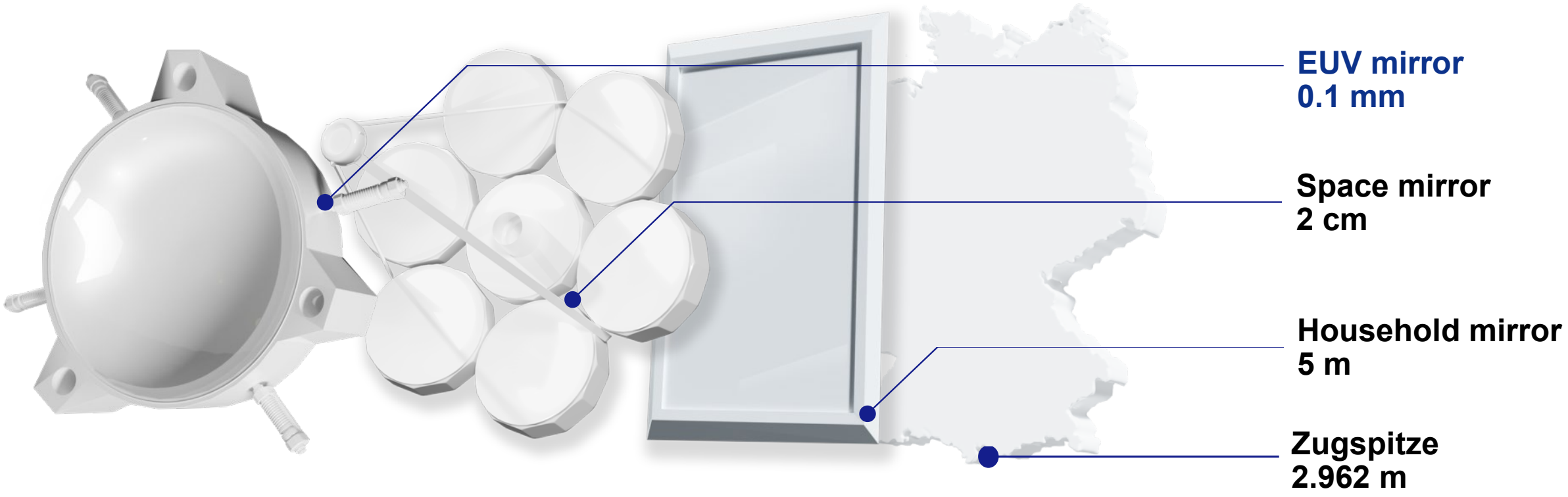
- Support of higher EUV power
- Improved wave front performance
- Improved distortion





How Does ZEISS Achieve That?

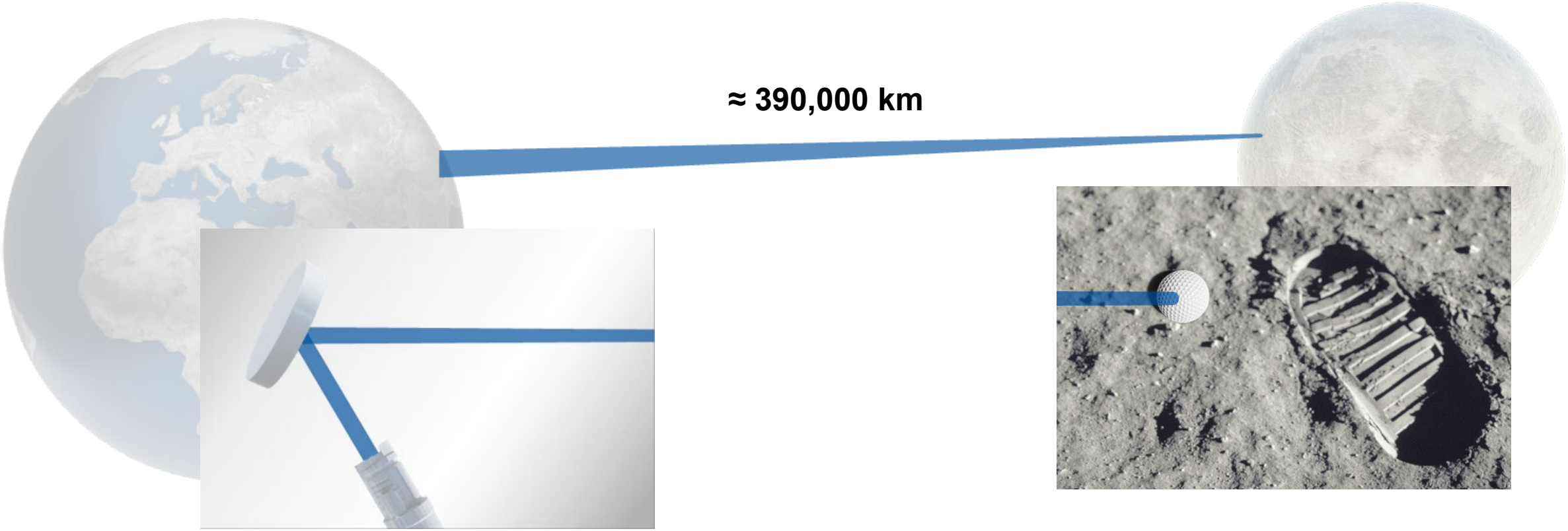
Mirror surfaces are controlled over orders of magnitude



The most precise mirror in the world: If we were to enlarge an EUV mirror to the size of Germany, the largest deviation from the nominal shape would be just 0.1 millimeters.

How Does ZEISS Achieve That?

Mirror tilts controlled with **sub nrad** accuracy for sub nm image placement



Perfection in reflection: Sensors and actuators in ZEISS projection optics work so precisely that you would hit a golf ball on the **surface of the moon** with the deflected laser beam.

Starlith® 3600: More than 40 Systems Delivered

First Starlith® 3600 Illuminator delivery

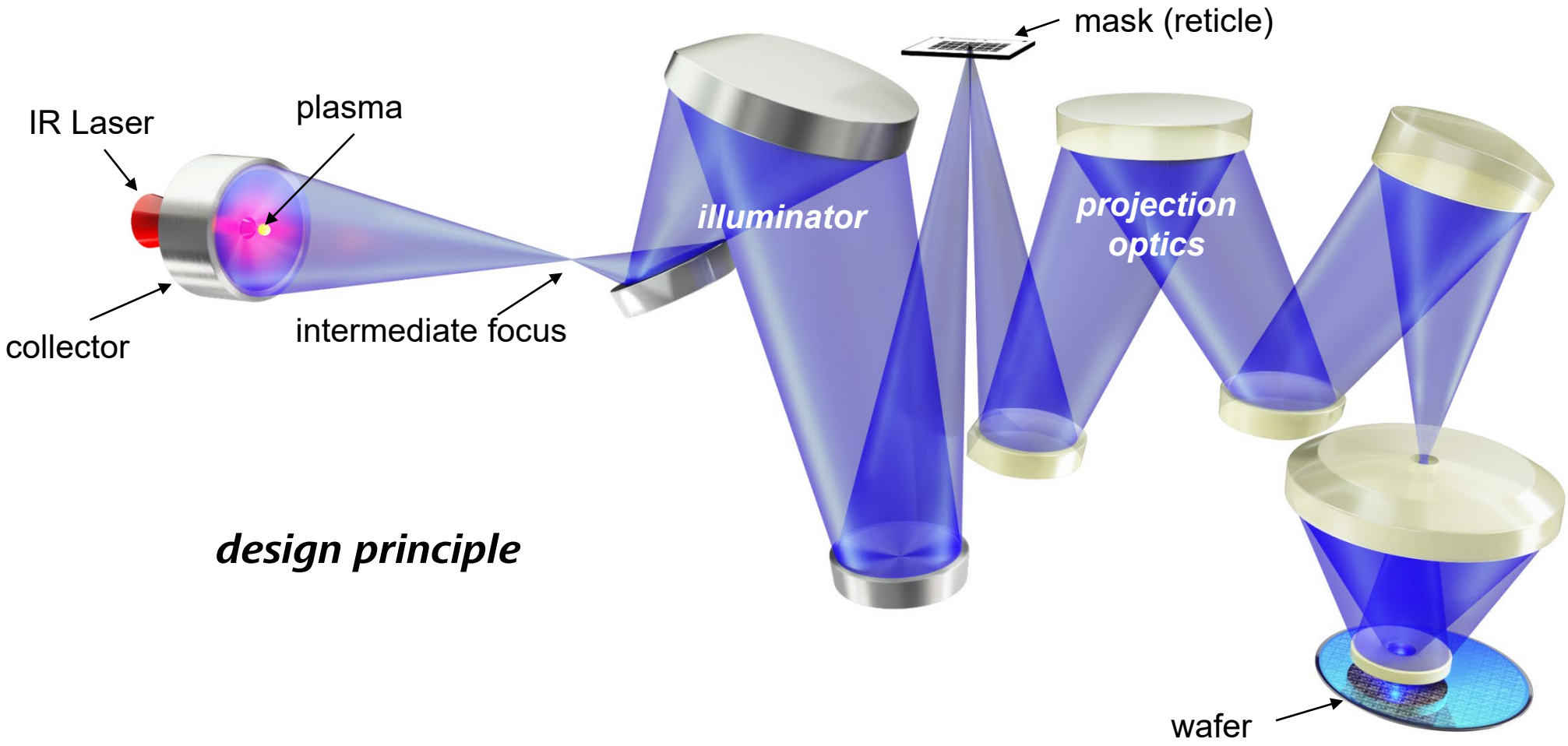
First Starlith® 3600 POB delivery

- Overall, more than **180 Starlith** 3xyz EUV systems with 0.33 NA at high and robust performance delivered.
- More to come due to strong market pull.

High NA (0.55NA)

High-NA (NA = 0.55)

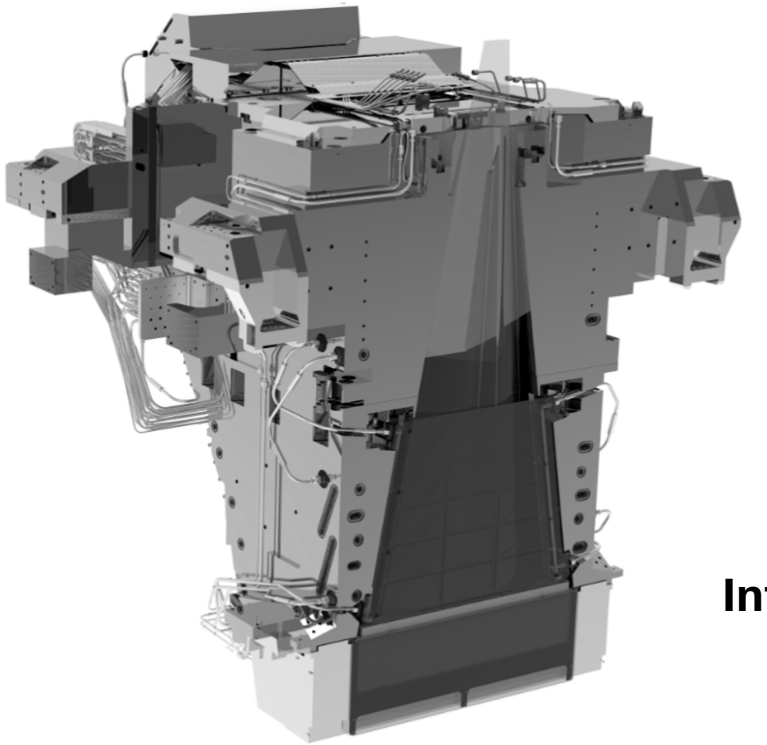
The optical system for the next generation lithography scanner

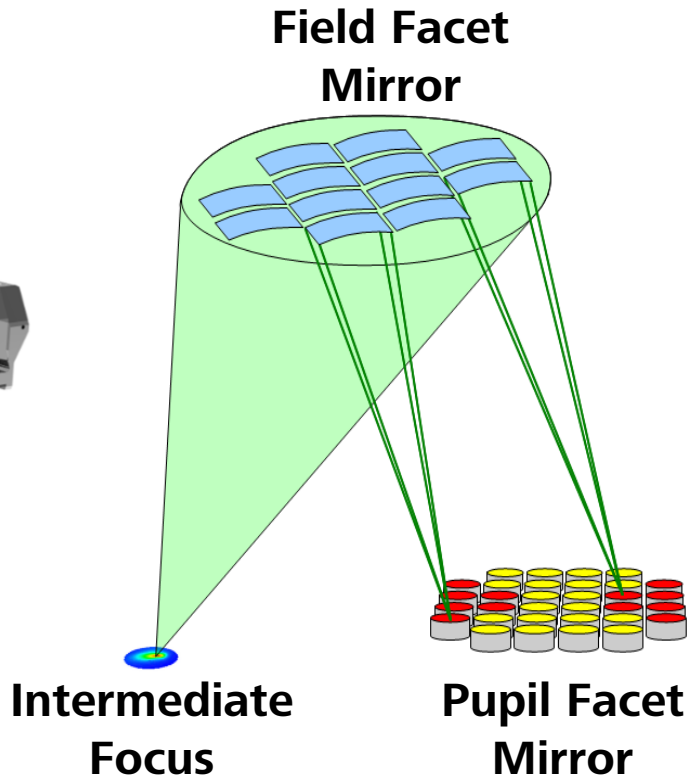


design principle

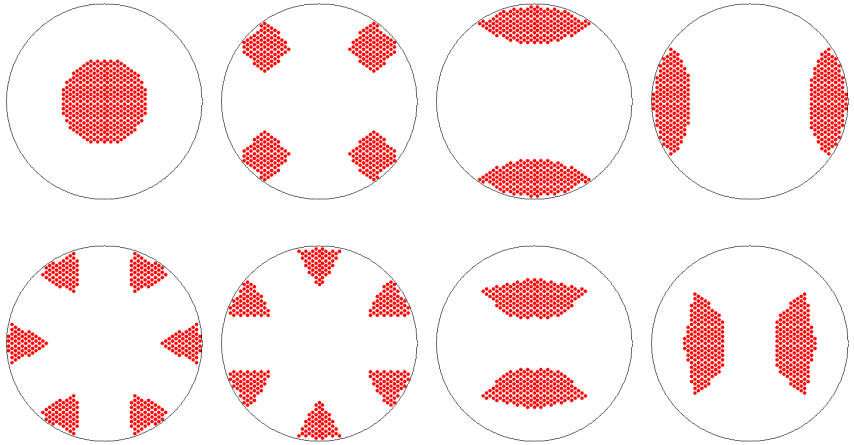
High-NA illuminator

will utilize 0.33NA technology with actuated facet mirrors

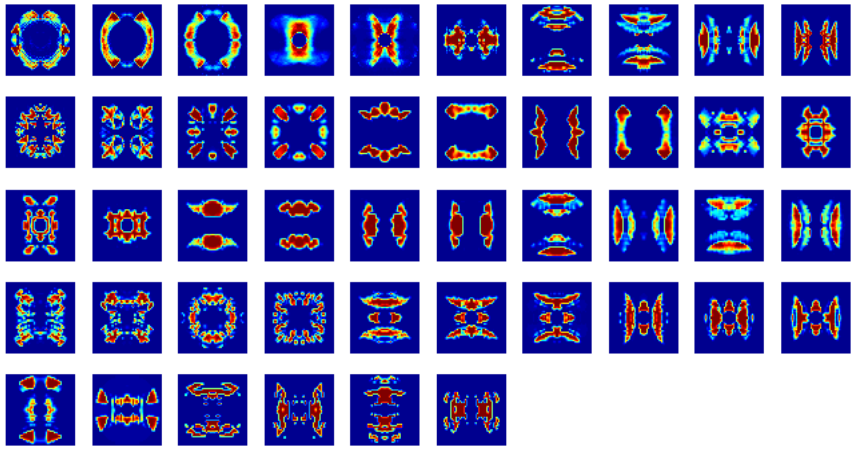




Standard Illumination Settings



Tachyon SMO pupils



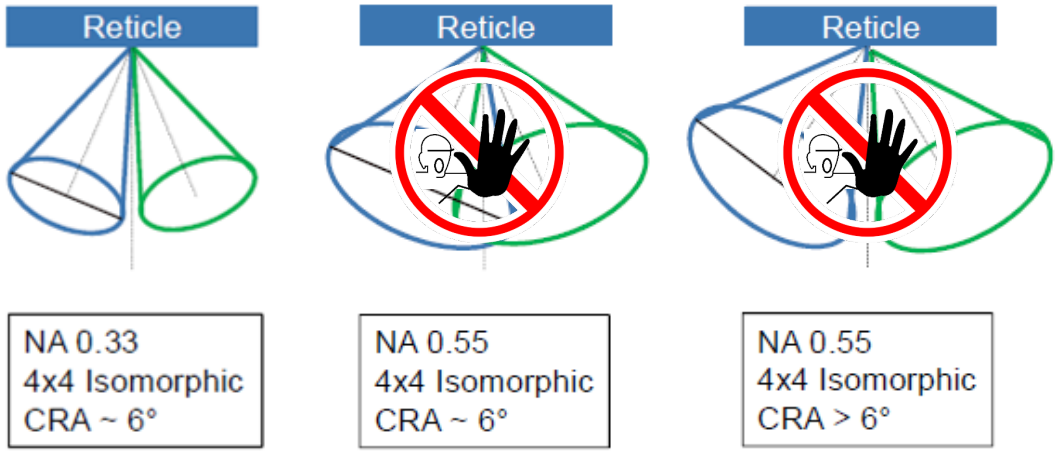
→ High-NA illuminator provides 20% pupil fill ratio

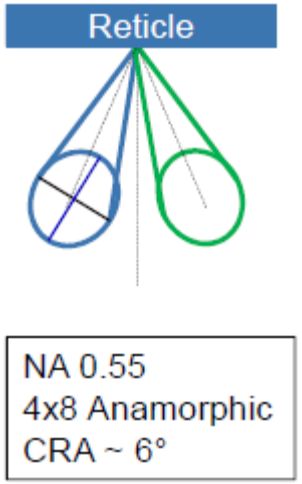
High-NA Projection

Crash course angles at reticle and anamorphic design

Reflection Angles must be kept small < ~10deg,

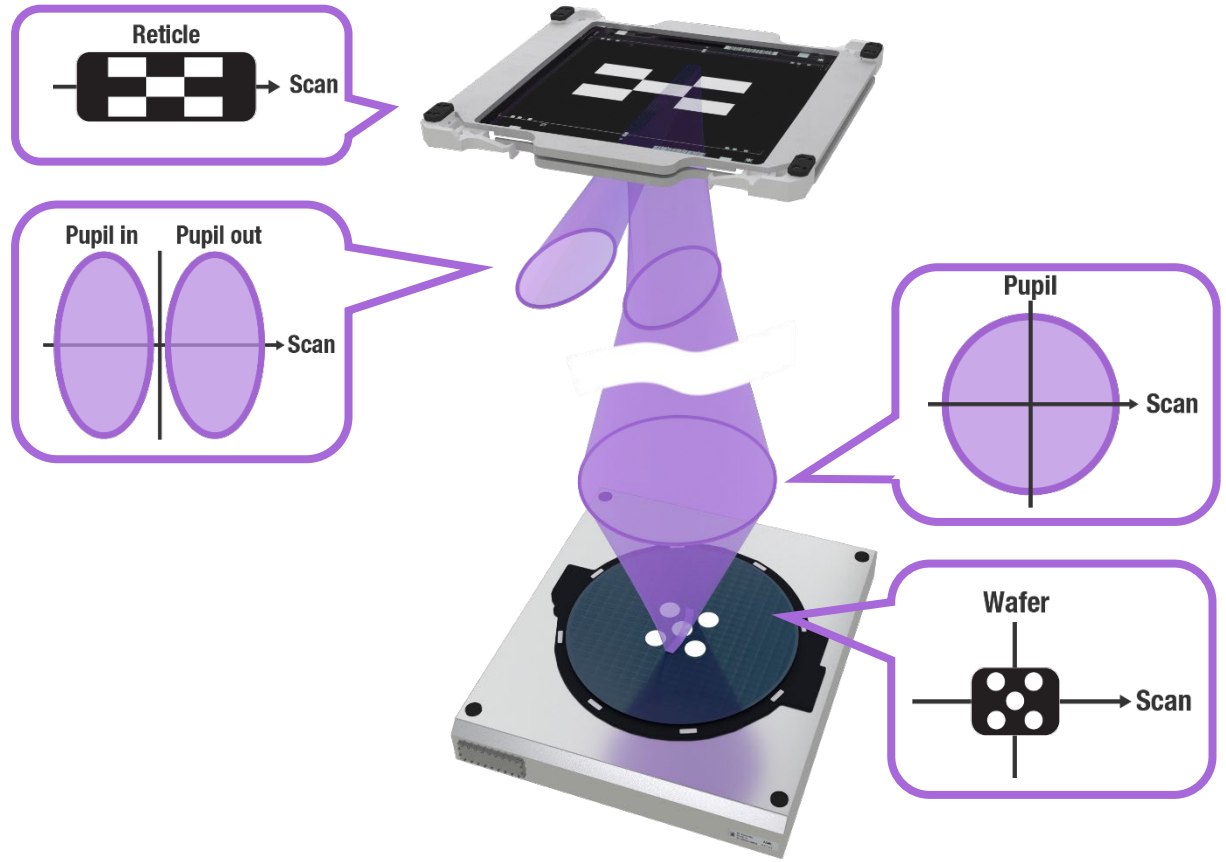
Otherwise, large shadowing effects and lower reflectivity





→ Solution: Anamorphic design
4x magnification in x
8x magnification in y

Mask design needs to be stretched by 2x in scan direction

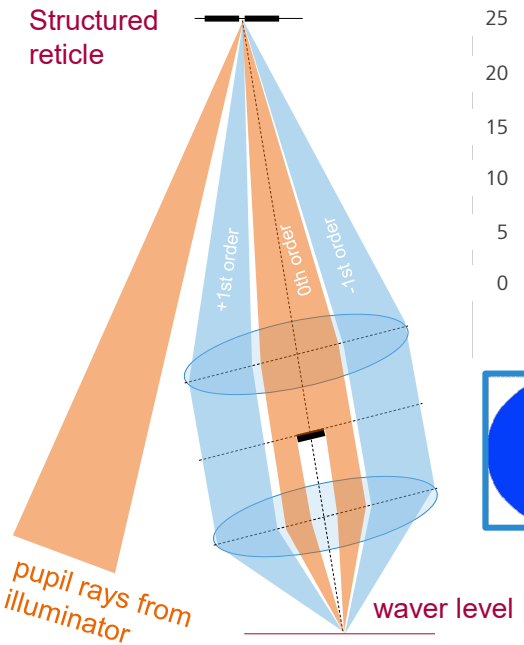


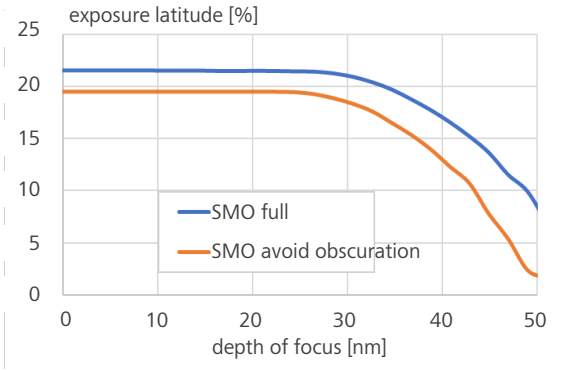
Resolving power at wafer is isotropic
resolution$_x$ = resolution$_y$

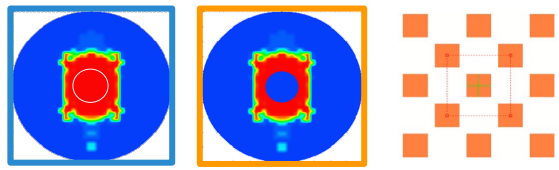
Status of High-NA EUV

Crash-course / reminder on High-NA design features

Obscuration can be used to obscure 0th order → improve process window

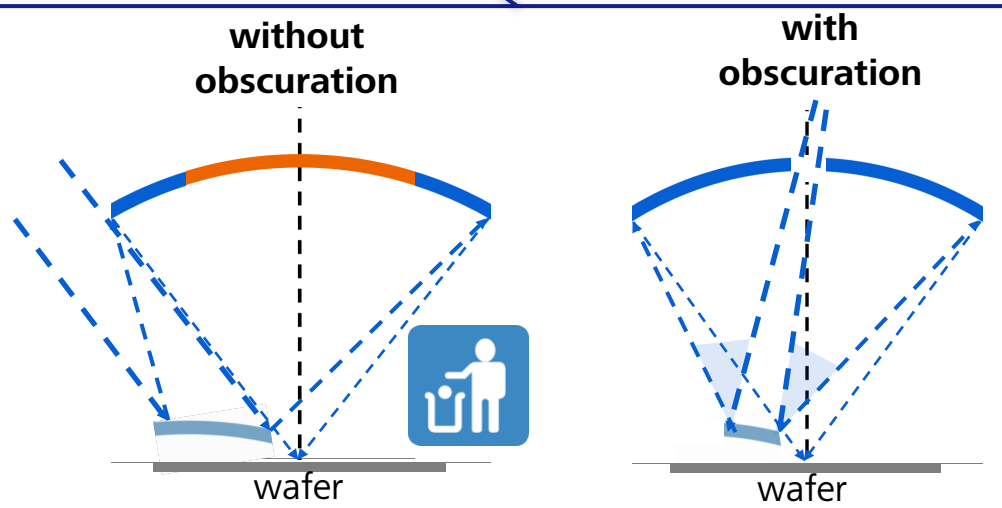






pitch = 28 nm
CD = 14 nm

[1] van Setten et al, Proc. SPIE 1095709

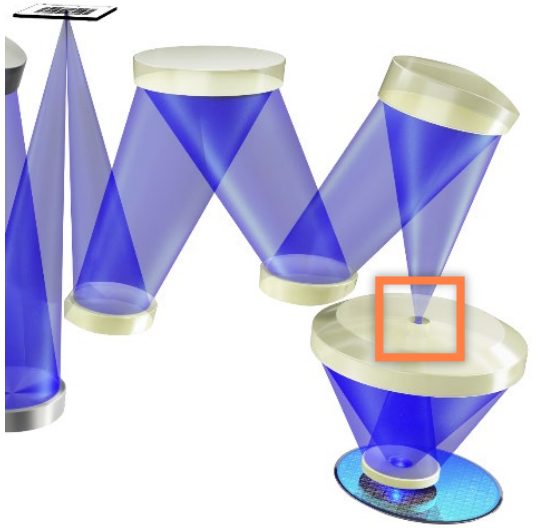


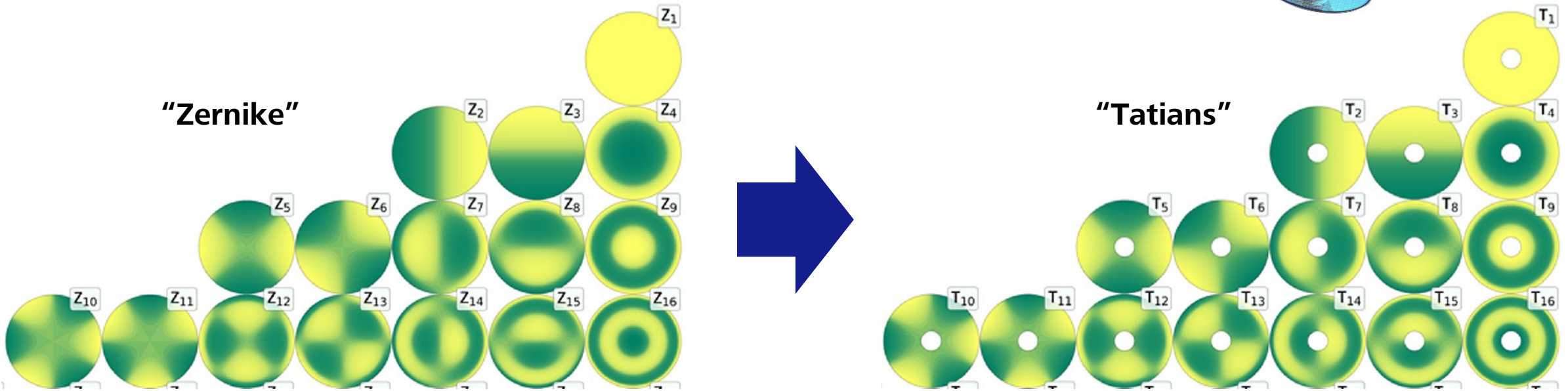
Obscuration reduces angular load and angle variation → High-transmission design solution.

Status of High-NA EUV

Zernike wave front description replaced by Tatians

- Central Obscuration in high-NA → ‘hole’ in wavefront → Zernike polynomial not orthogonal
- New Base to describe wavefronts at ASML & ZEISS for high-NA are fringe-Tatian polynomials
- Details: Laurens de Winter et al. “Extreme Ultraviolet scanner with high Numerical Aperture: obscuration and wavefront description”, JM3, 21 April 2022





Production at ZEISS SMT

Mechatronics modules integration at SMT in Oberkochen

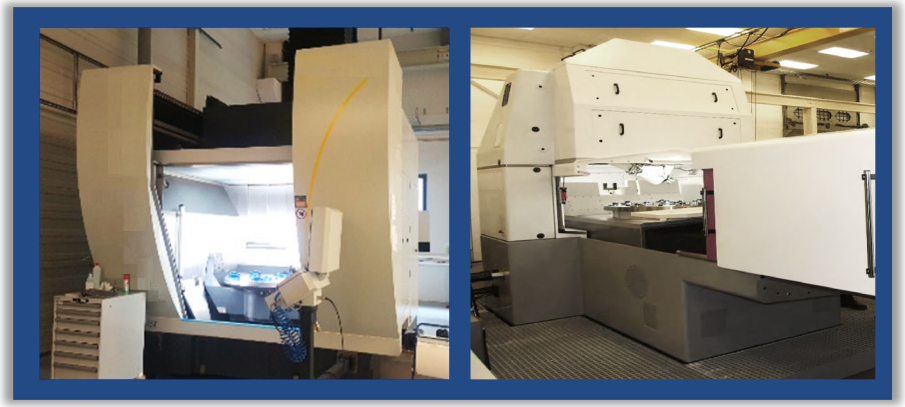
Illuminator frame

POB frames after integration test

Mirror modules with aluminum dummies

Mirror Manufacturing

Processing infrastructure is up and running



Roughness metrology

Grinding

Polishing

Ion beam Figuring

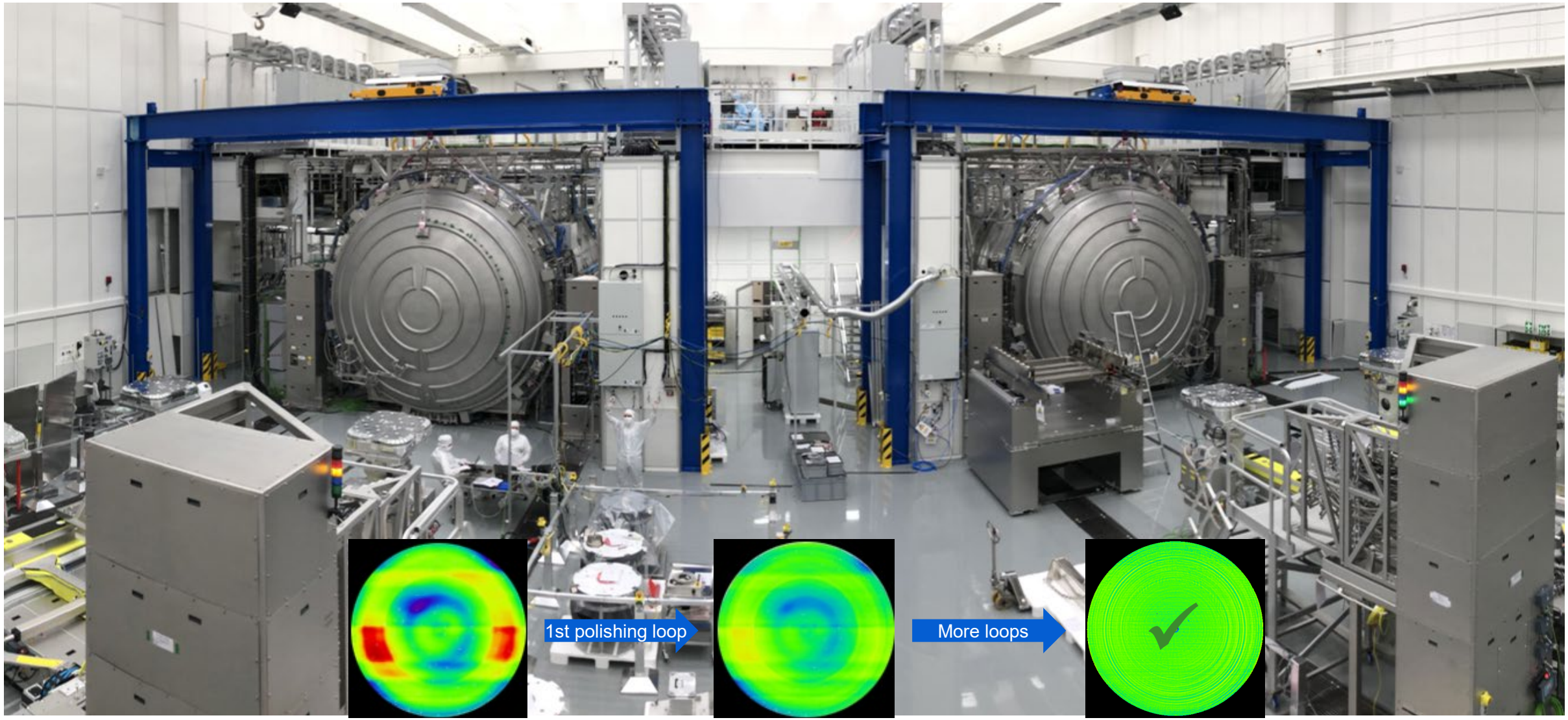
Coating

Surface Figure Metrology

Reflectivity metrology

Mirror metrology supports mirror manufacturing requirements

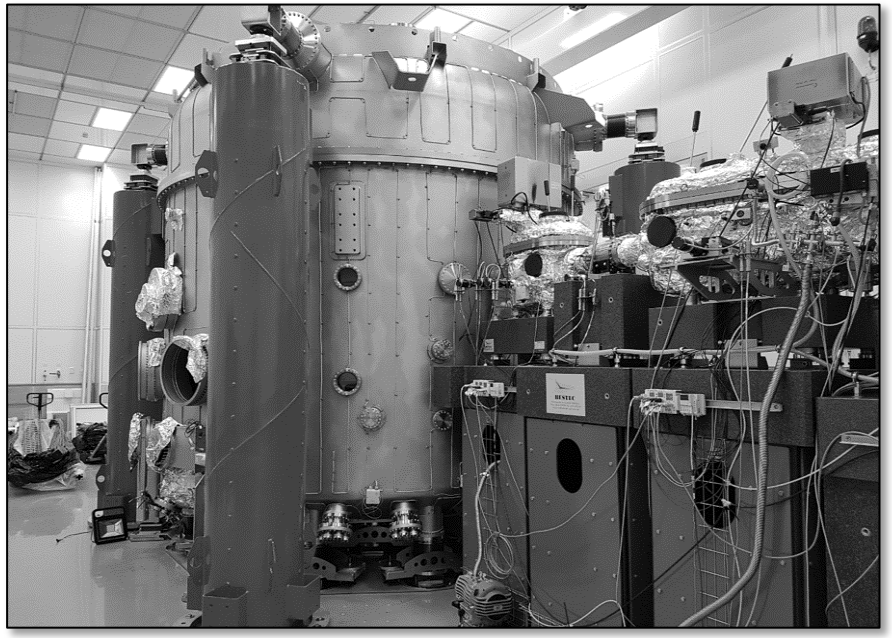
Final accuracy targets reached and first mirrors within final specification



EUV reflectometer for large mirrors is operational

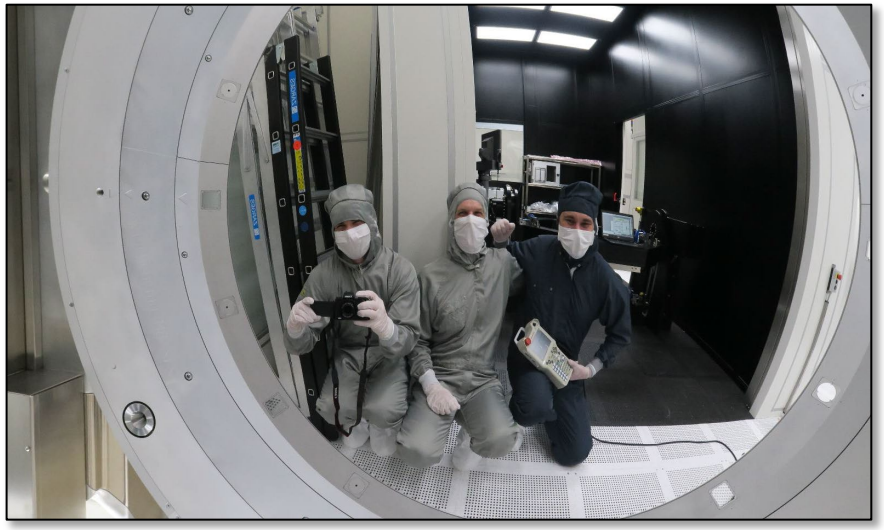
First mirrors coated within target performance

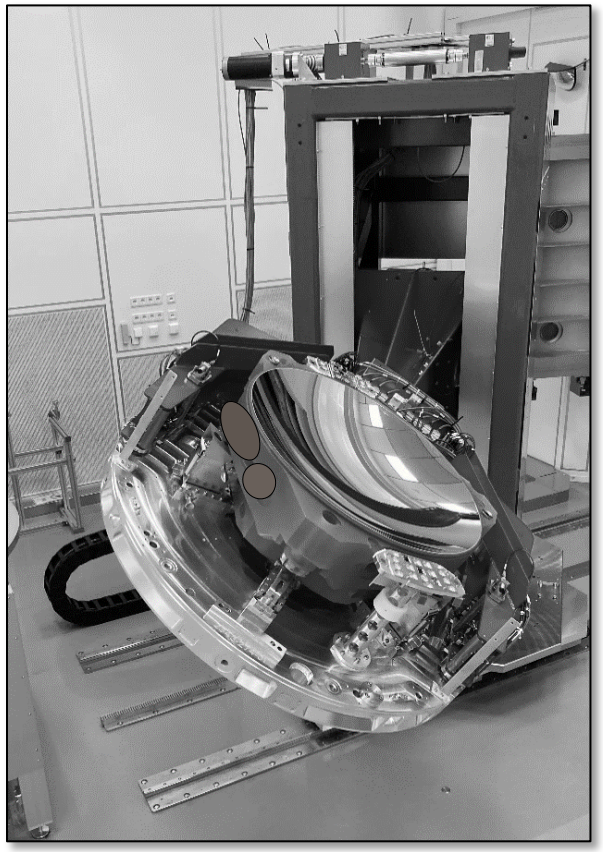
Reflectometer



Coating reflectivity supports system specification for both transmission and apodization ✓

Coated test mirror





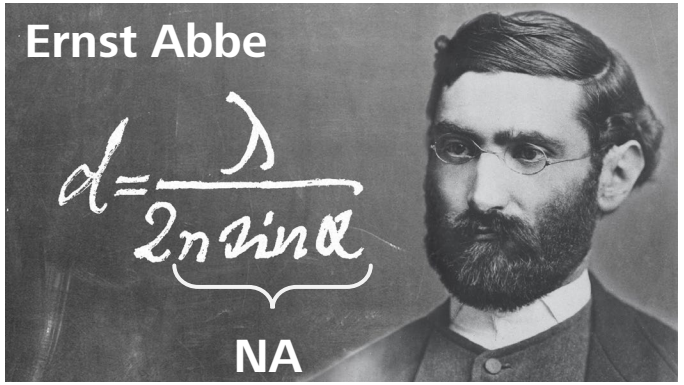
Ramp Up


2007


2021
High-NA Integration
High-NA coating
High-NA optics
High-NA Mirror Metrology

Outlook

Outlook: Ever decreasing resolution



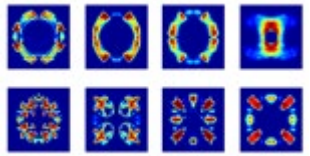
d = Resolution
λ = Wavelength
n = Refractive index of the medium
α = Half aperture angle

$$CD = k_1 \frac{\lambda}{NA}$$

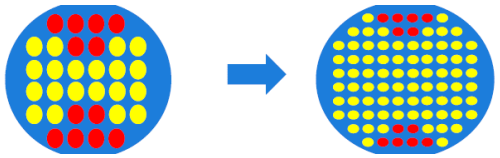
Lower k_1 or higher NA

Illuminator:

- **High-NA**
  High flexibility with 20% PFR



- **Future:**
  Lower PFR will enable lower k1

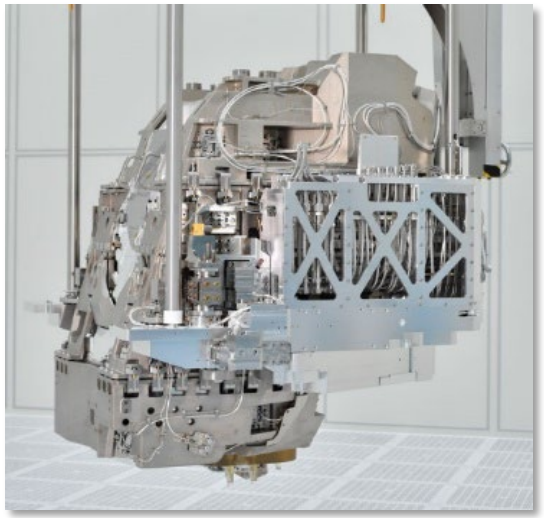


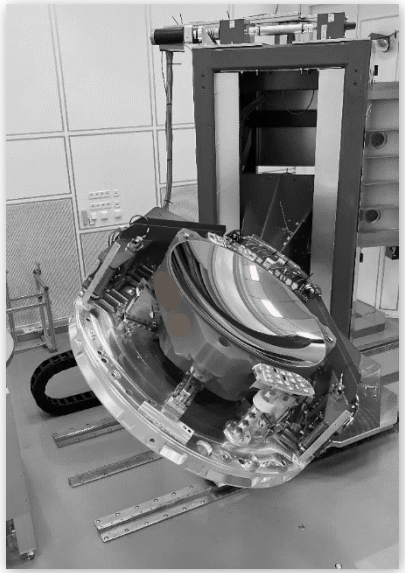
Higher NA:

- **Basic ideas exist**
- **Still many challenges**
- **The future will tell…**

Summary

- ✓ We are shipping 0.33NA optics in high volume to the customers.
- ✓ Mirrors and frames are produced at full speed for High-NA EUV optics.
- ✓ First mirrors have final coating and performance is within target.
- ✓ EUV roadmap extensions are visible.





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Seeing beyond