High NA EUV optics: a big step in lithographic resolution

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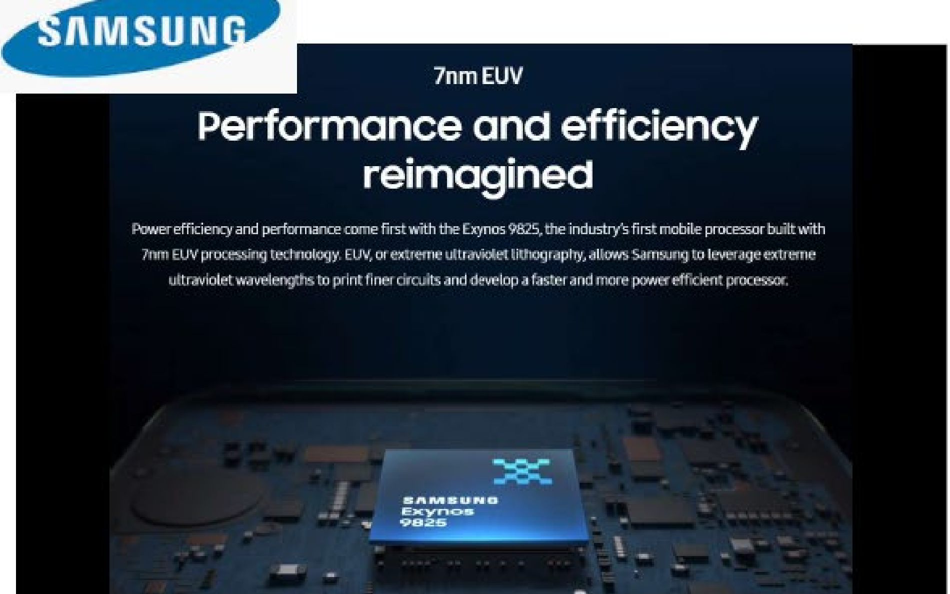
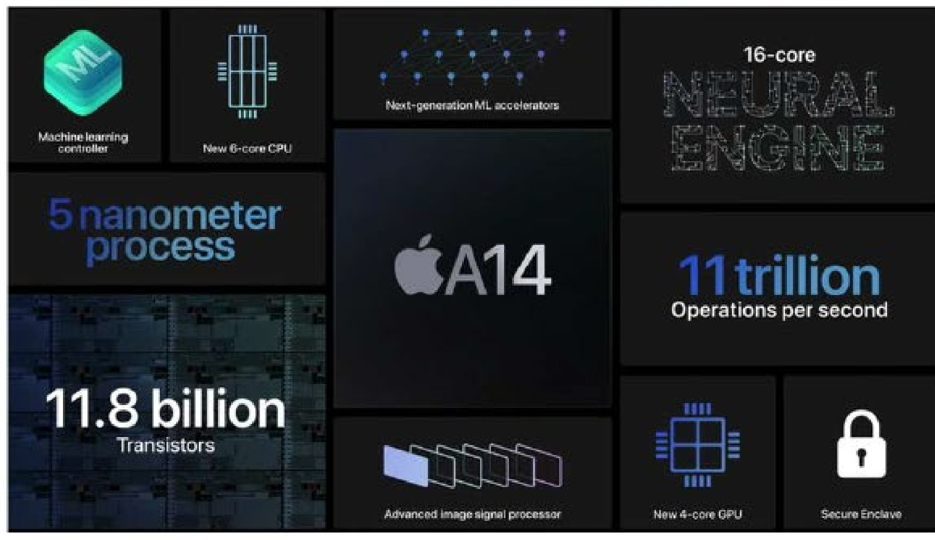
[1]ZEISS, [2]ASML

EUVL Workshop 2021

Customer flagship products are powered with 7nm+ EUV





Source: https://www.samsung.com/semiconductor/minisite/exynos/products/mobileprocessor/exynos-9825/ , https://consumer.huawei.com/en/campaign/kirin-990-series/

Next logical step on lithography roadmap is a High-NA EUV system

Resolution, nm

1,000
100
10
1

1985 1990 1995 2000 2005 2010 2015 2020 2025

g-Line
436 nm
NA=0,38

i-Line
365 nm
NA=0,6

KrF
248 nm
NA=0,8

ArF
193 nm
NA=0,93

ArFi
193 nm
NA=1,35

XT:1400

NXT:1950i

NXE:3400

NXE:3600

High-NA

+67%

EUV
13.5 nm
NA=0,33

High-NA
13.5 nm
NA=0,55

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

○ Development systems
● Production systems

Outline

1. New 0.33NA EUV optics
2. Design features of High-NA EUV optics
3. Manufacturing of High-NA EUV mirrors and frames

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Starlith 3600®: Extending the Roadmap for 0.33NA
EUV aberration roadmap continues at higher source power

3600 Illuminator

Key features:
- Support of higher EUV power
- Improved transmission

3600 Projection Optics

Key features:
- Support of higher EUV power
- Improved Wavefront Performance
- Improved Disto

Wavefront rms [nm]

0,4
0,2
0,0
3300
3400
3600
-30%

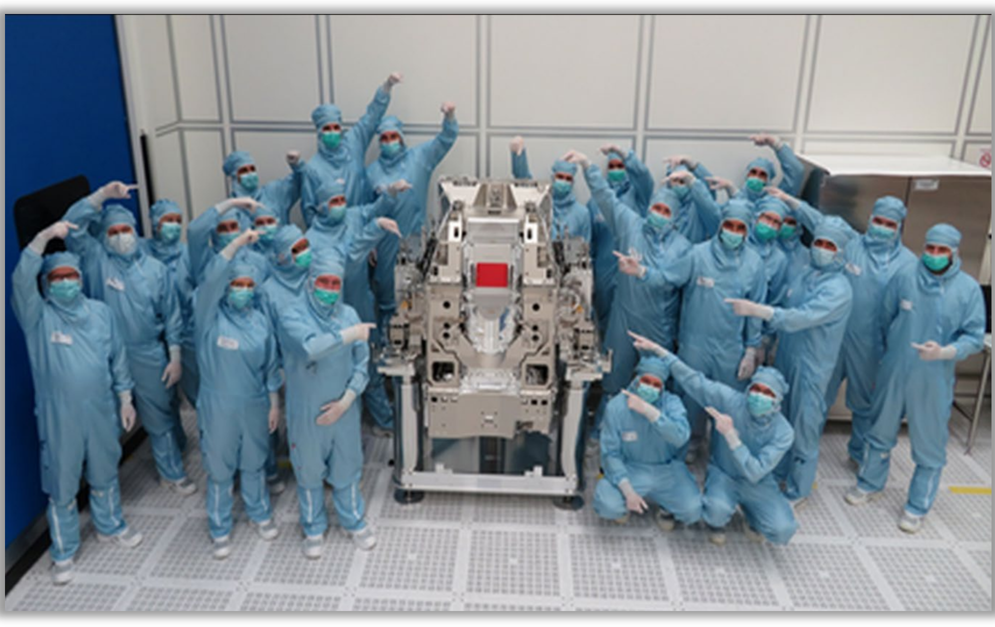
Distortion [nm]

1,0
0,5
0,0
3300
3400
3600
-30%

Starlith 3600®: First delivery in August 2020

First Starlith 3600® Illuminator delivery

First Starlith 3600® POB delivery



- Delivery of more than 140 EUV systems with 0.33 NA at high and robust performance.
- More to come due to strong market pull.

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High-NA EUV
The optical system for the ultimate printing machine with NA = 0.55

IR Laser

plasma

collector

intermediate focus

illuminator

mask (reticle)

projection optics

wafer

design scheme

Crash-course / reminder on High-NA design features

Obscuration can be used for new illumination feature that can improve process window

Structured reticle

+1st order
0th order
-1st order

pupil rays from illuminator

waver level

exposure latitude [%]

25
20
15
10
5
0

0 10 20 30 40 50

depth of focus [nm]

SMO full
SMO avoid obscuration

pitch = 28 nm
CD = 14 nm

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

High-NA NA=0.55 w/o obscuration

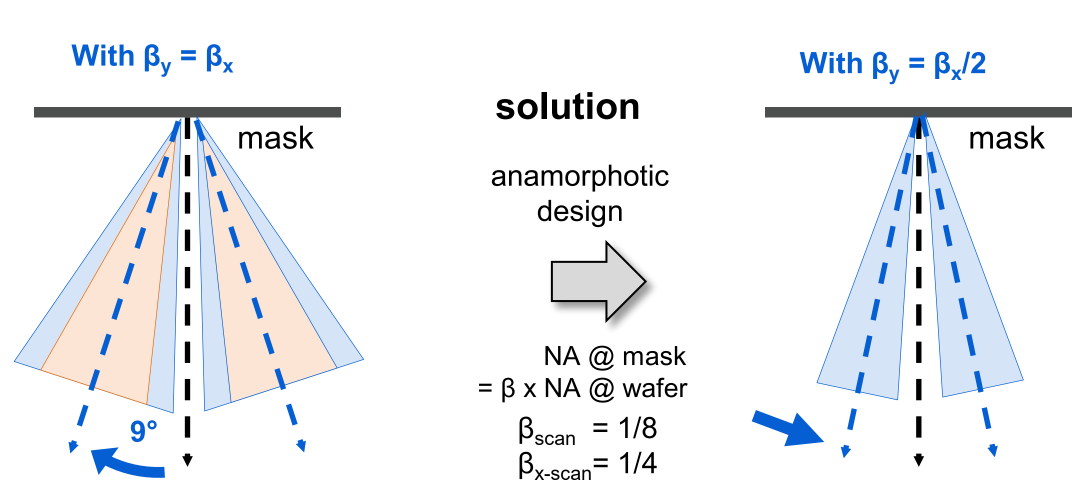
High-NA NA=0.55 with obscuration

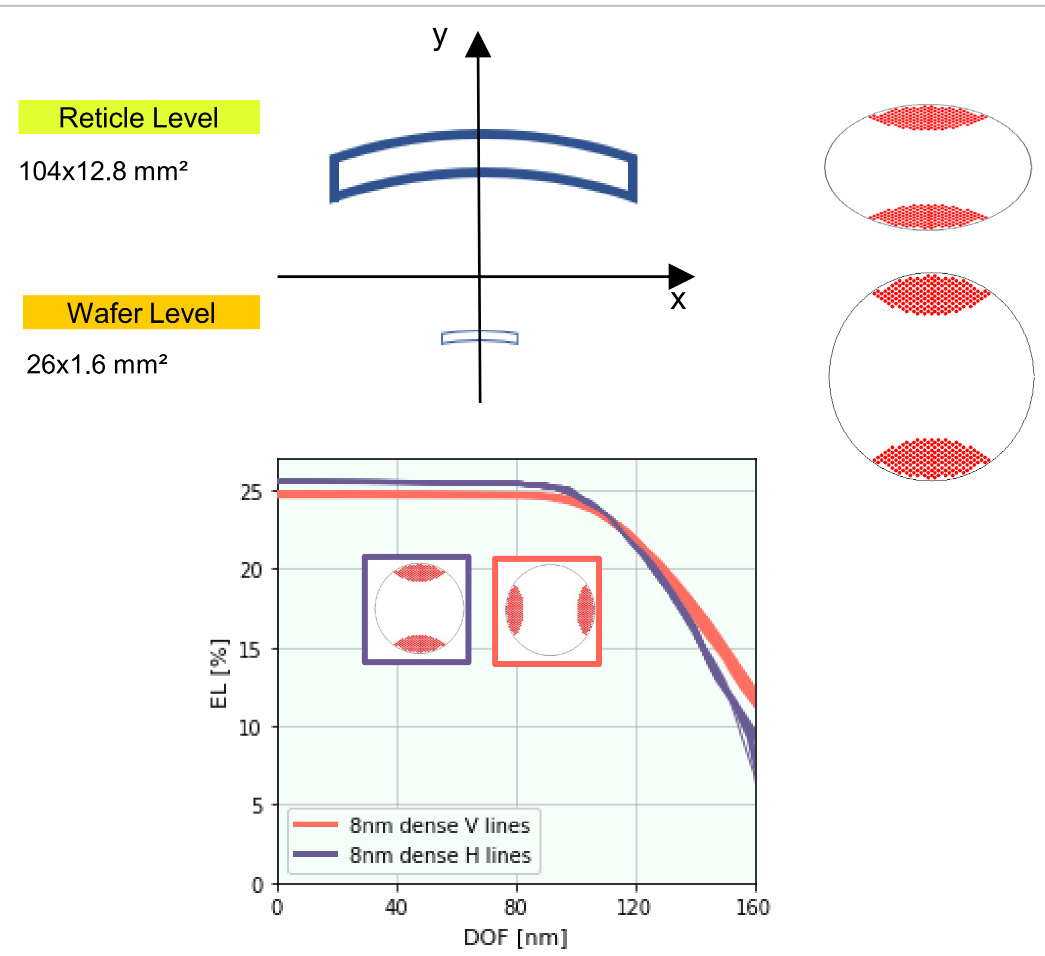
wafer

wafer

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

Crash course angles at reticle and anamorphic design





Bartosz Bilski, Photomask Japan 2021

- absorber shadowing at mask is angular dependent
- Inacceptable contrast loss for system with β_{scan}= 1/4

Resolving power at wafer is isotropic
$resolution_x = resolution_y$

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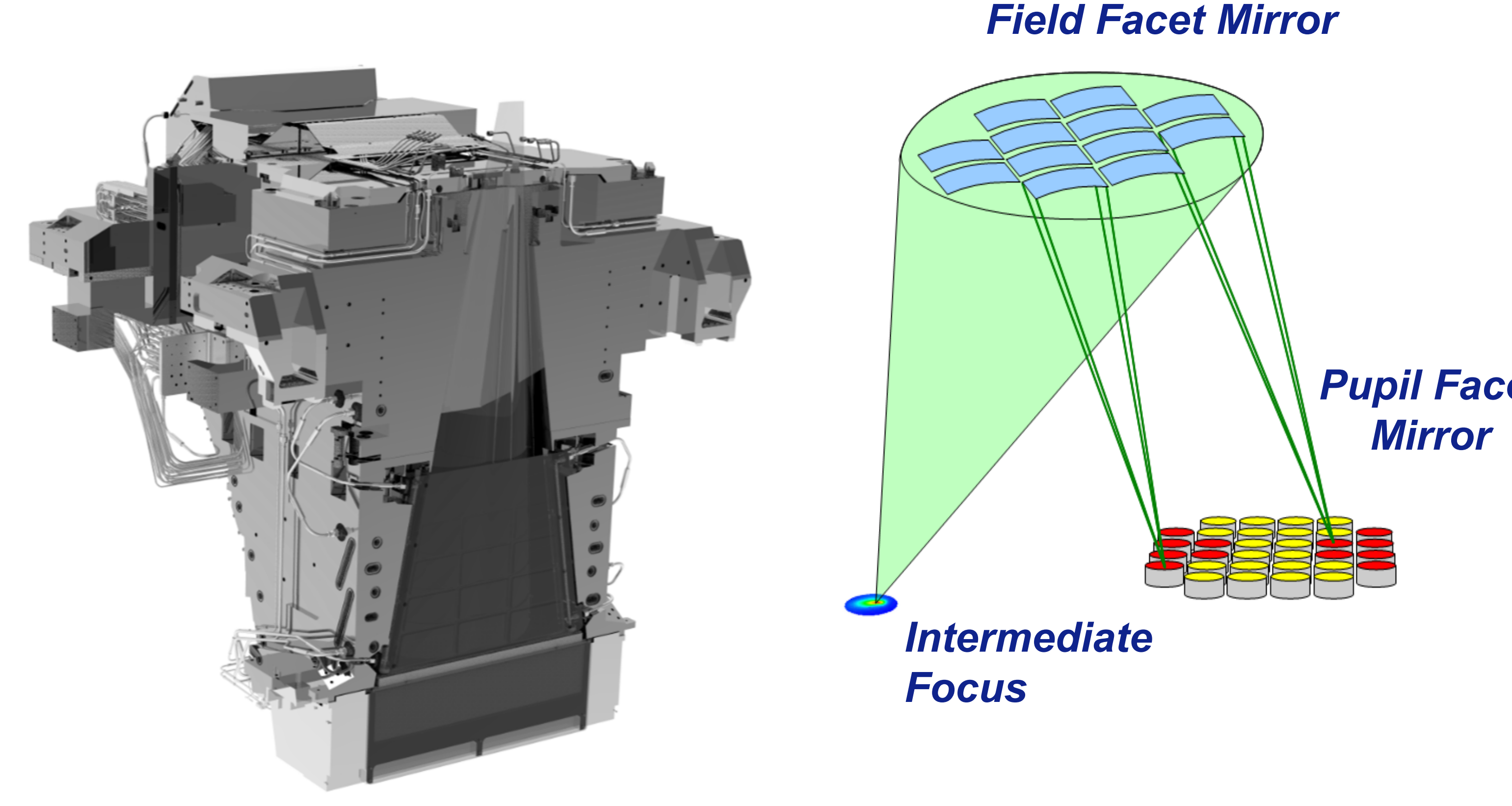
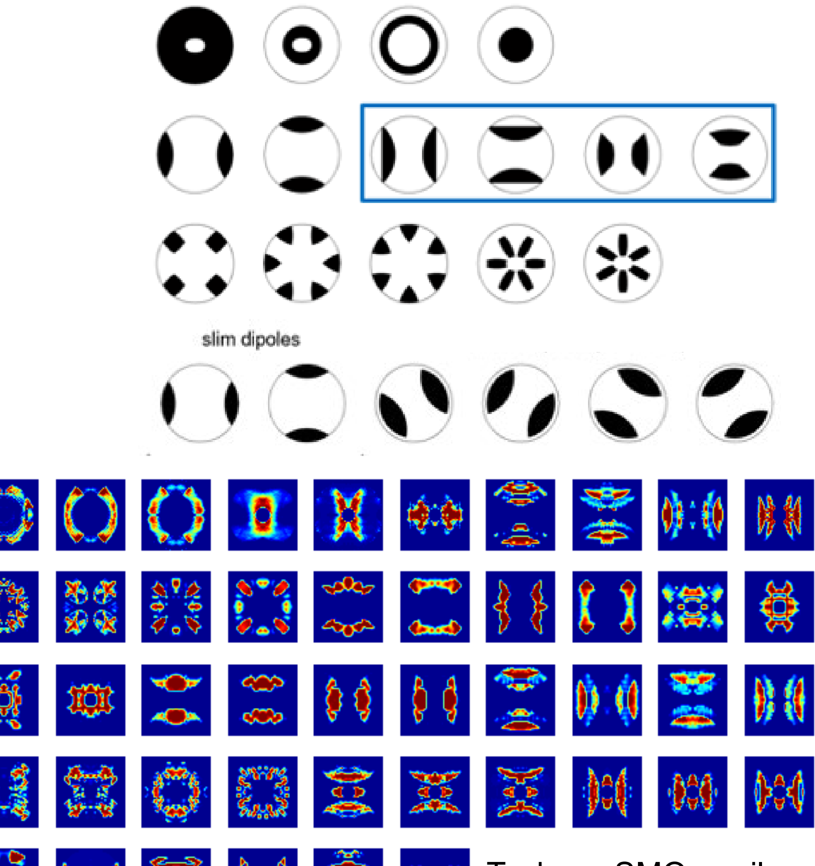
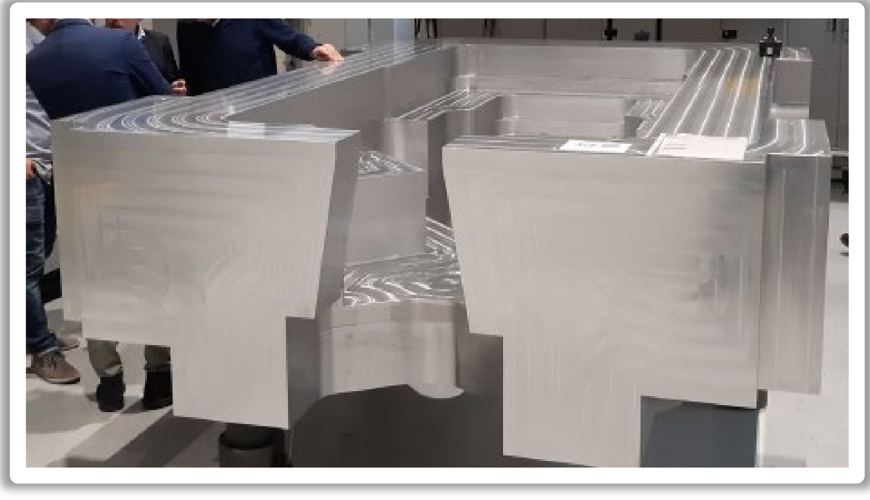
High-NA illuminator will utilize 0.33NA technology with actuated facet mirrors

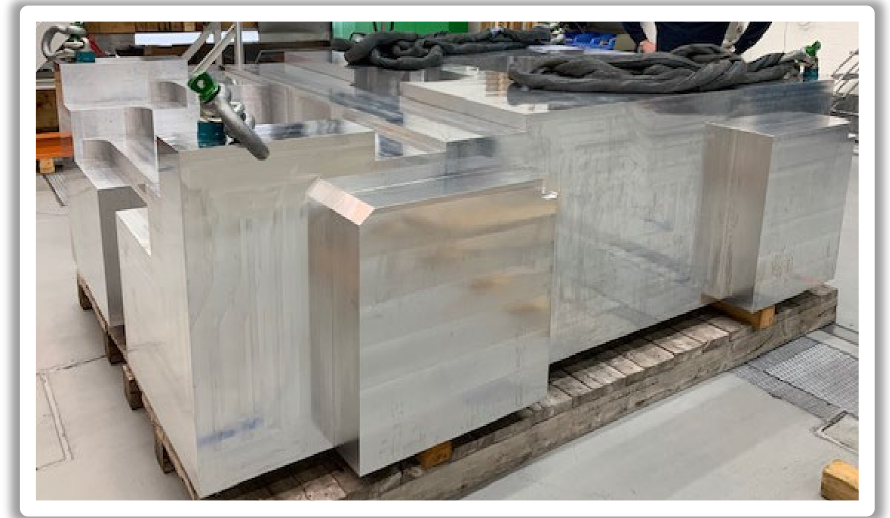




- High-NA illuminator provides 20% pupil fill ratio
- More focus on medium sigma dipoles (→ mask 3D effects)

First frames for illuminator and POB processed
Further sets already in production





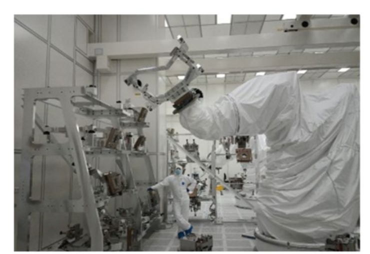
Build up of system integration tooling is progressing

>20.000 mechatronic parts & components

assembly & qualification on module level

mirror glueing

mirror module assembly



dynamic qualification

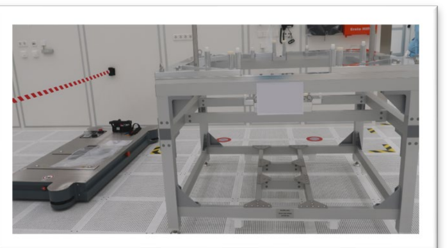
assembly & qualification on sensor frame level

sensor frame & interferometer assembly

alignment & qualification

transports

module transport

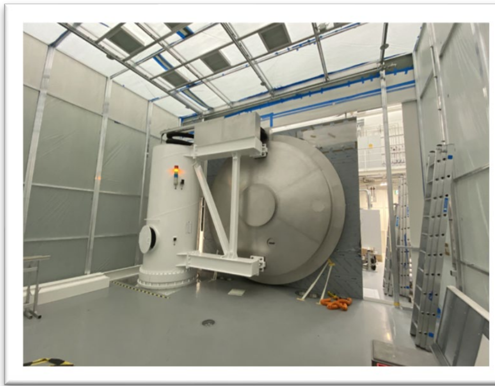


frame transport

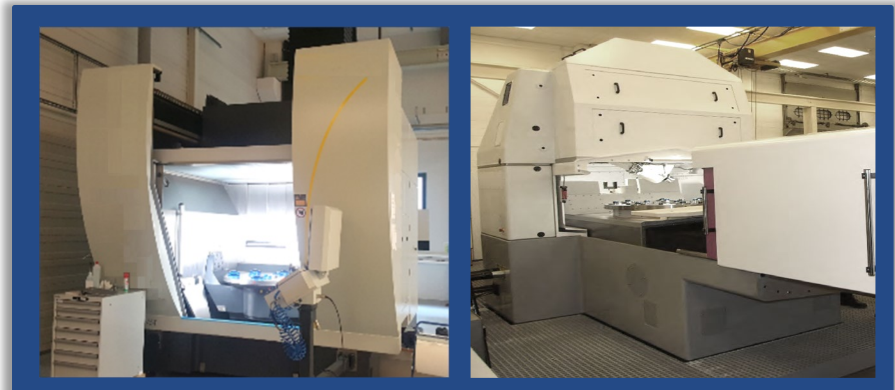
assembly & cleaning

force frame & module integration

cleaning & leak check



Optics manufacturing process



Roughness metrology

Grinding → Polishing → Ion beam Figuring → Coating

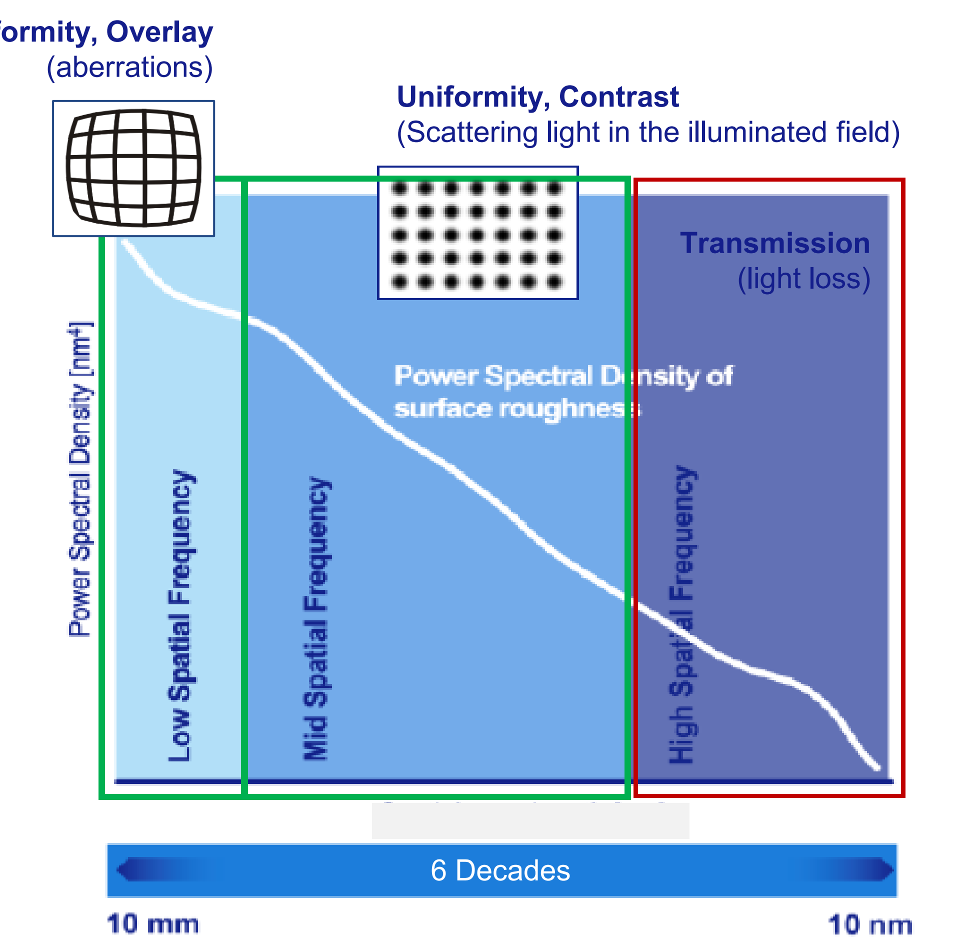
Surface Figure Metrology

Reflectivity metrology

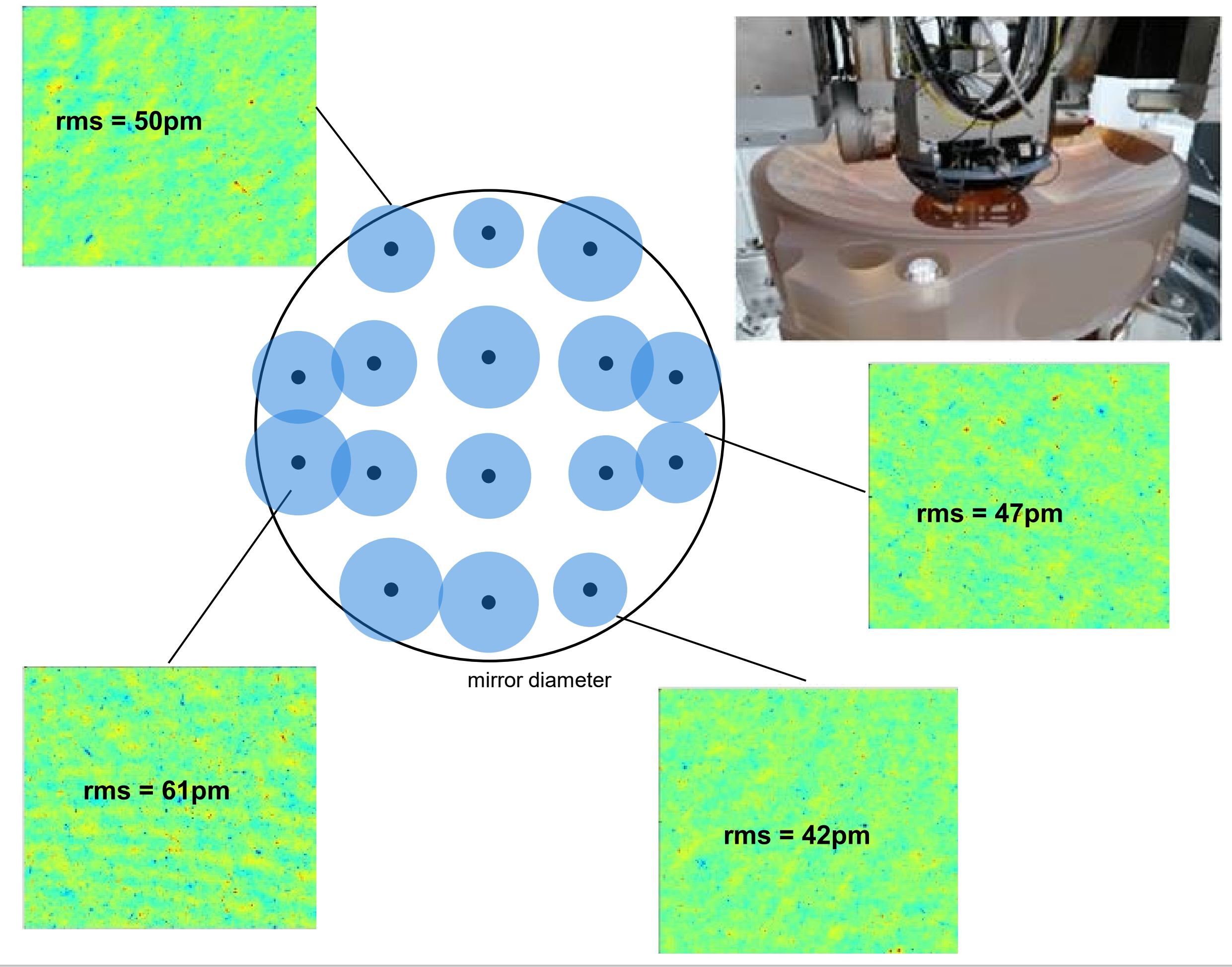
First mirror ground

Mirror roughness after polishing

Critical quality parameters for polishing of optical surfaces



Micro Interferometer (Field of View ~5mm) for mid spatial frequency range

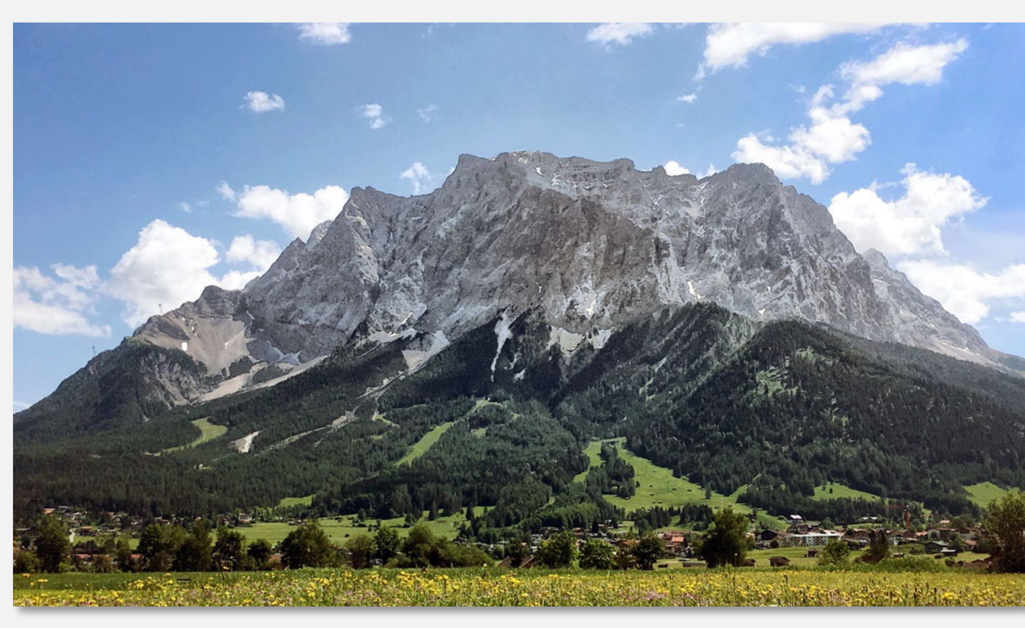


Challenges scale with accuracy and size

Atomic level figuring required

Zugspitze

2962m



High-NA mirror

RMS ~ 20 pm

Scale to size of Germany by ~1 million

heights of ~20µm in Germany

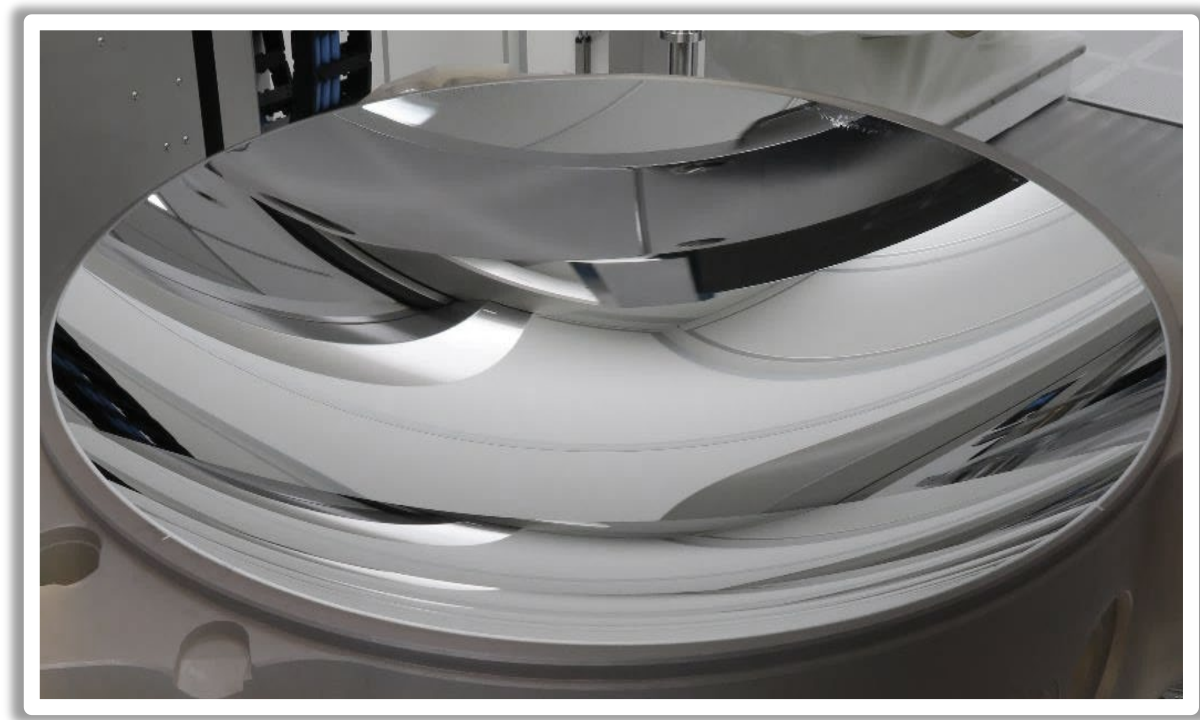
or

1/5 of a human hair

Mirror metrology is operational and supports mirror manufacturing requirements

Surface figure performance: rms < 0.5nm

First dummy coated



ZEISS SMT Campus Oberkochen

HiNA integration

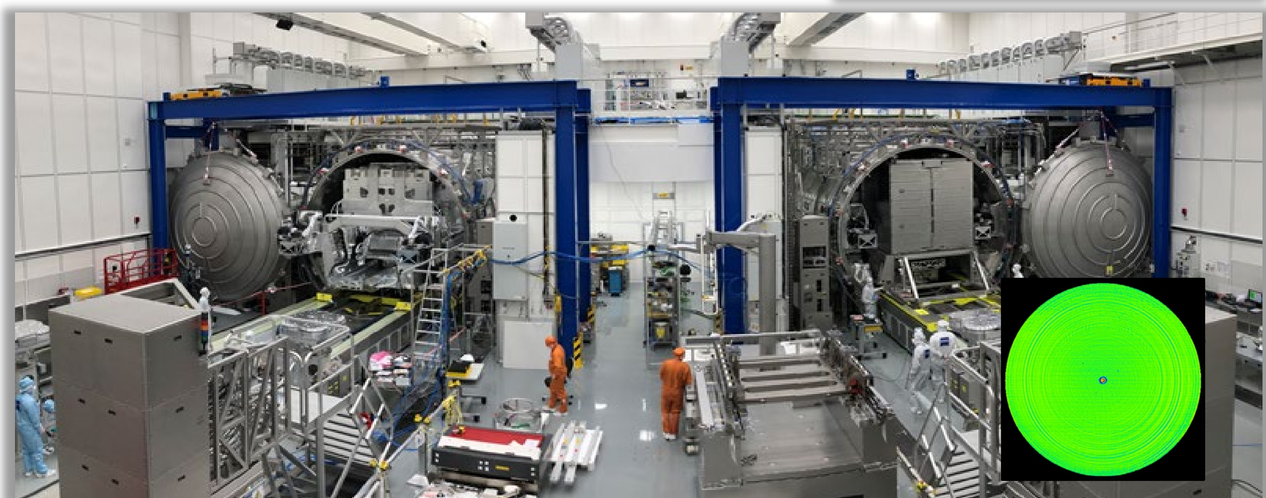
HiNA coating

Mirror Metrology

HiNA optics

Summary

Summary



- We are producing mirrors and frames for High-NA EUV optics at full speed.
- Mirror performance approaches specification level in sub-nanometer regime
- Build up of system integration tools is progressing.

Acknowledgement

Special thanks goes to:

Many, many people, too numerous to mention all by name

The high-NA teams at ASML and ZEISS

Our suppliers, customers, and project partners around the globe

This work has received funding form the ECSEL Joint Undertaking (JU) under grant agreements No. 662338, 698522, 737479, and 783247. The JU receives support from the European Union‘s Horizon 2020 research and innovation program and the member states.

The projects on which this publication is based were funded by the Federal Ministry of Education and Research under the funding codes 16ESE0036K, 16ESE0072K, and 16ESE0287K, and by the Federal Ministry for Economic Affairs and Energy under the funding code 16IPCEI605.

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ASML
ZEISS
Thank you!