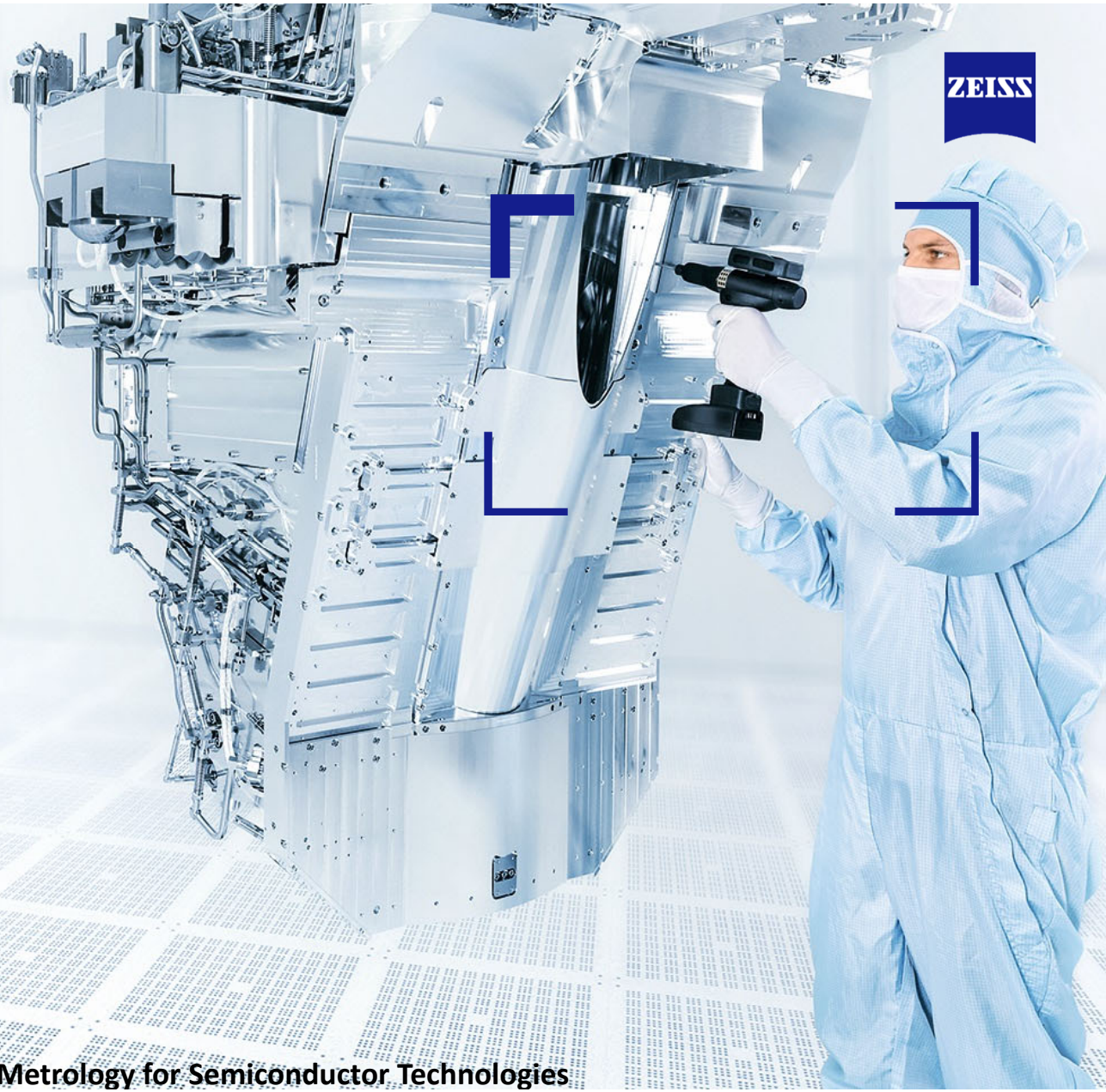


EUV-Lithography Optics: Challenges in Metrology

Dr. Kathrin Aziz-Lange
Head of Coating & Surface Roughness Metrology
Carl Zeiss SMT GmbH

Outline

- Carl Zeiss SMT GmbH
- Driving EUV-Lithography to the next level
- Challenges in metrology for the optics manufacturing process

FACTS

ZEISS Worldwide

Employees (rounded)

35,000

Locations worldwide (rounded)

100

Countries (rounded)

50

Revenue in € billion

7.5

Headquarters:
Oberkochen, Germany

Employees incl. Corporate functions and SSCs
Status: September 30, 2021

Shaping the Future

Semiconductor Manufacturing Technology

2.298 € billion in revenue

5,211 employees

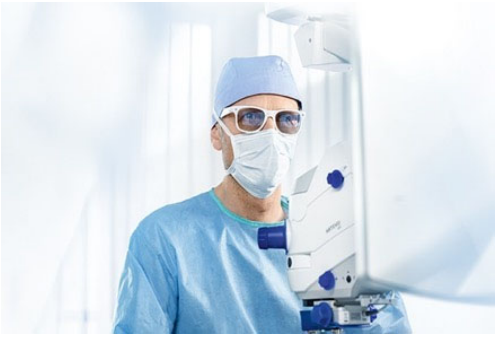
Status: September 30, 2021

Industrial Quality & Research

1.801 € billion in revenue

7,363 employees

Medical Technology



1.951 € billion in revenue

5,866 employees

Consumer Markets

1.394 € billion in revenue

12,721 employees

Locations and Employees

Employees

5,211

thereof 30% in research and development

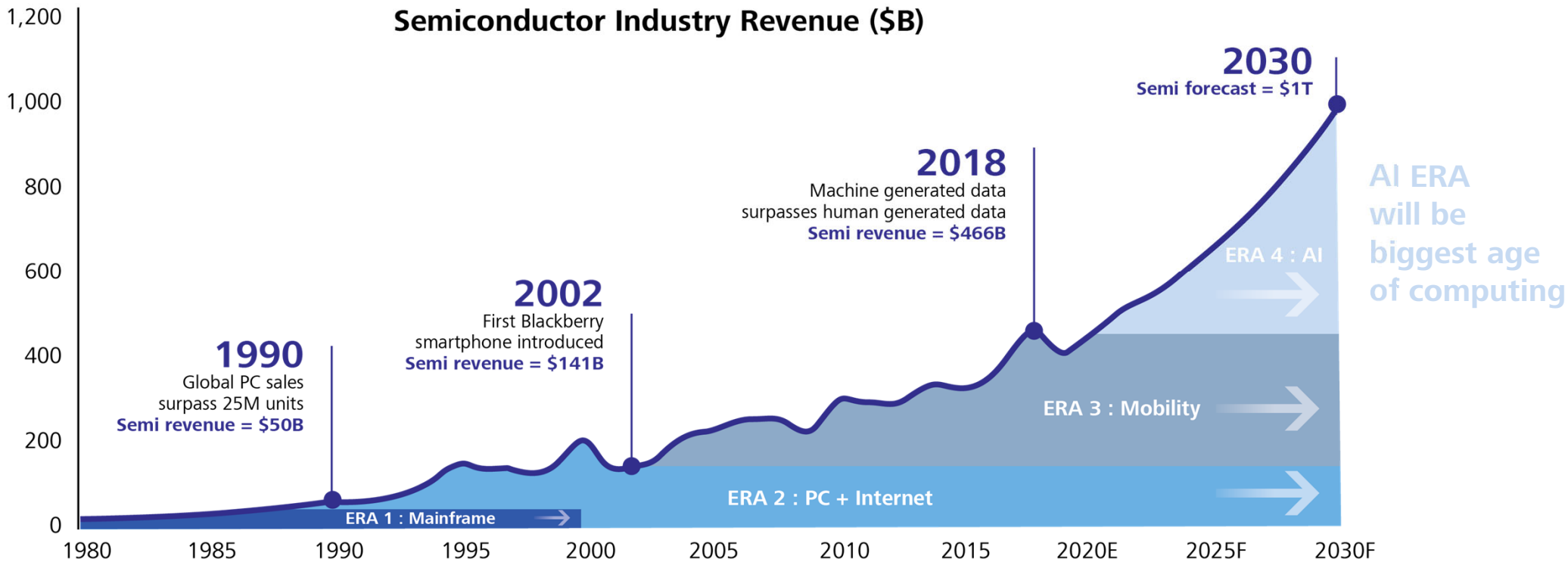
Locations

7

in 3 countries: Oberkochen, Jena, Wetzlar, Rossdorf, Dublin (USA), Peabody (USA), Bar Lev (Israel)

Headquarters:
Oberkochen, Germany

Artificial Intelligence as a Global Driver



Source: AMAT Investor Meeting, April 2021

PORTFOLIO

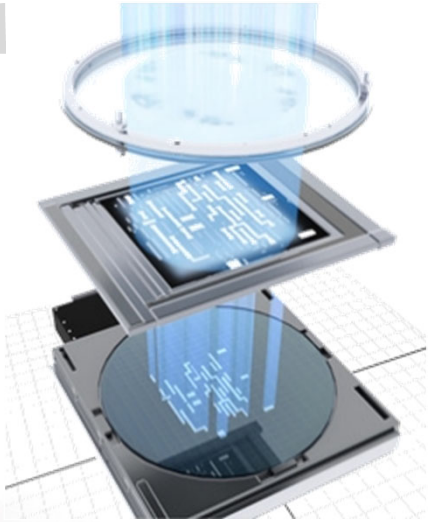
Semiconductor Manufacturing Optics

- Lithography optics
- Mirror blocks and wafer chucks
- Optical systems, metrology devices and components for wafer inspection and lithography lasers
- Synchrotron optics
- Collectors

P A R T N E R

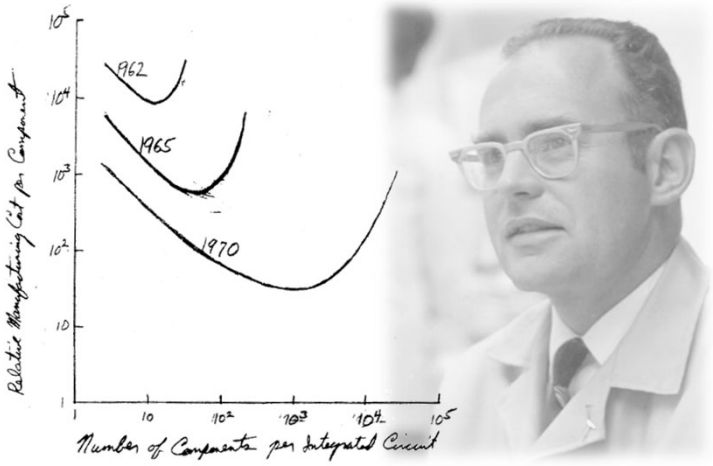
Integration of ZEISS systems into the ASML-Wafer scanners

Around **80 percent** of the world's microchips are manufactured using ASML lithography systems with ZEISS optics.



Moore‘s law can be transformed into litho requirements using Abbe‘s equation

Moore‘s Law (1965)



„Transistor density doubles every 24 months.“

Abbe-Equation (1873)

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

CD … Critical Dimension

k_1 … Process Factor

λ … Wavelength

NA … Numerical Aperture

$$d = \frac{\lambda}{2n \sin\alpha}$$

„Every litho optics generation improves by 30%.“

High Numerical Aperture enables better resolution

Driving EUV-Lithography to the Next Level

1995 2003 2006 2009 2012 2015 2018 2022

MET
Micro Exposure Tool

ADT
(α-Demo Tool)

a handful

Starlith® 3100

dozens

Starlith® 3300

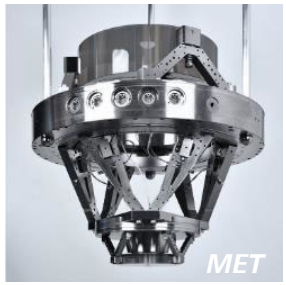
hundreds

Starlith® 3400

Starlith® 3600

High NA EUV

field size:
200 x 200 µm²

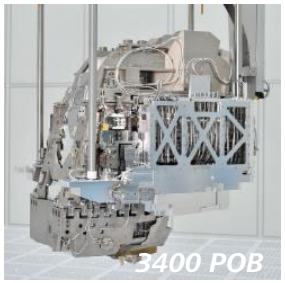


NA = 0.3

field size:
26 x 2 mm²

NA = 0.25

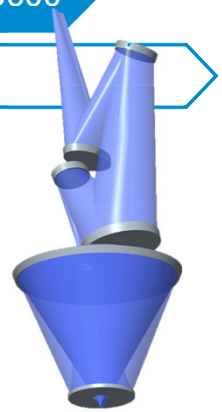
fixed pupil



NA = 0.33

flex pupil

higher productivity

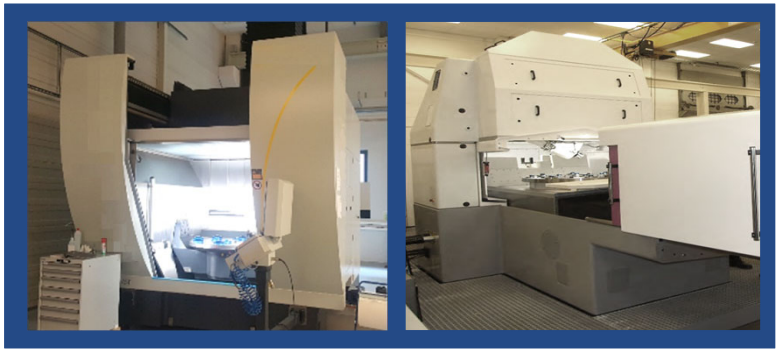


NA = 0.55

Production readiness achieved

Development phase ongoing

Metrology for the optics manufacturing process



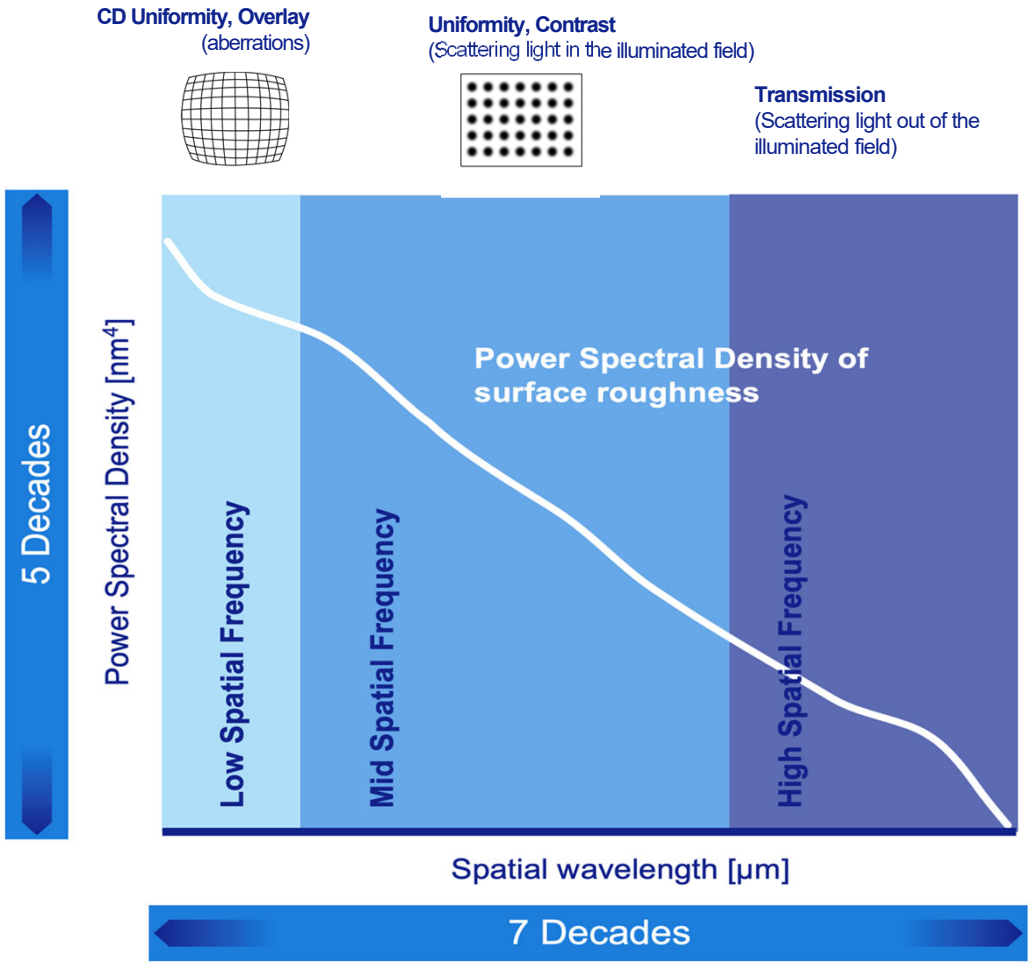
Roughness metrology

Grinding → Polishing → Ion beam Figuring → Coating

Surface Figure Metrology

Reflectivity metrology

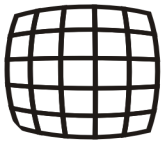
Challenges in metrology: figure and roughness



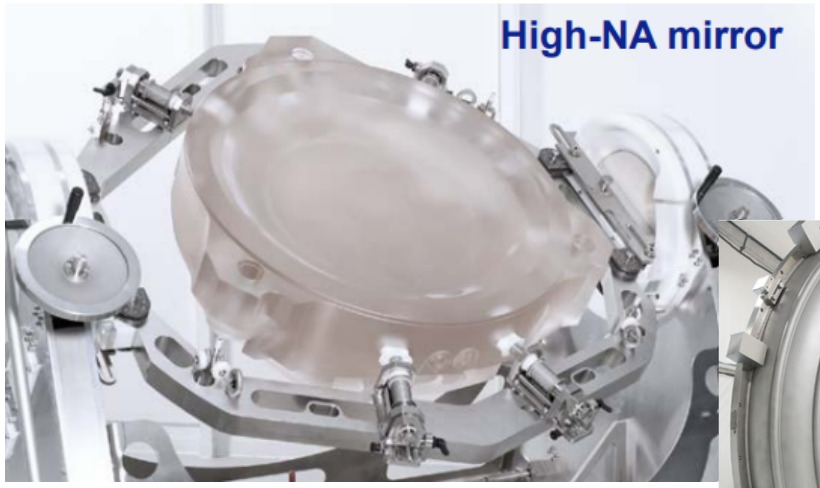
Surface figure metrology

Figure
[pm rms]

<40



aberrations



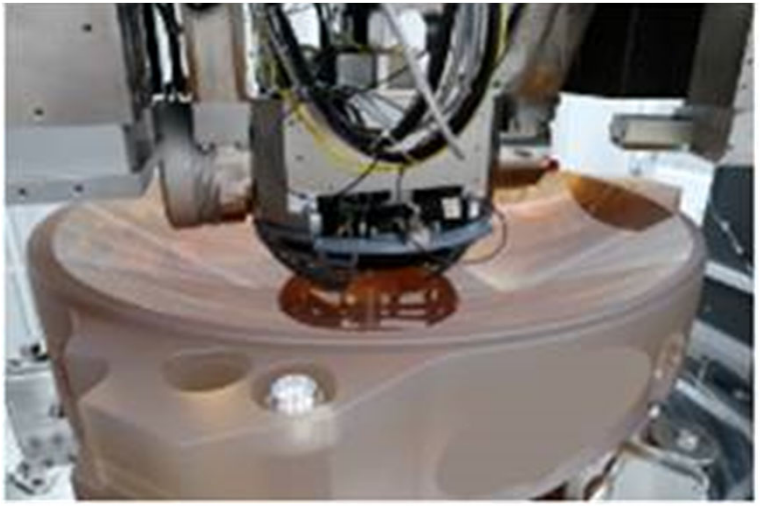
Single mirrors sizes <0.5m for EUV 3600 and >> 0.5m for EUV high NA

Surface figure control < 40pm

Scaling mirror size
to Baden-Württemberg:
No mountain higher
than **5 µm**

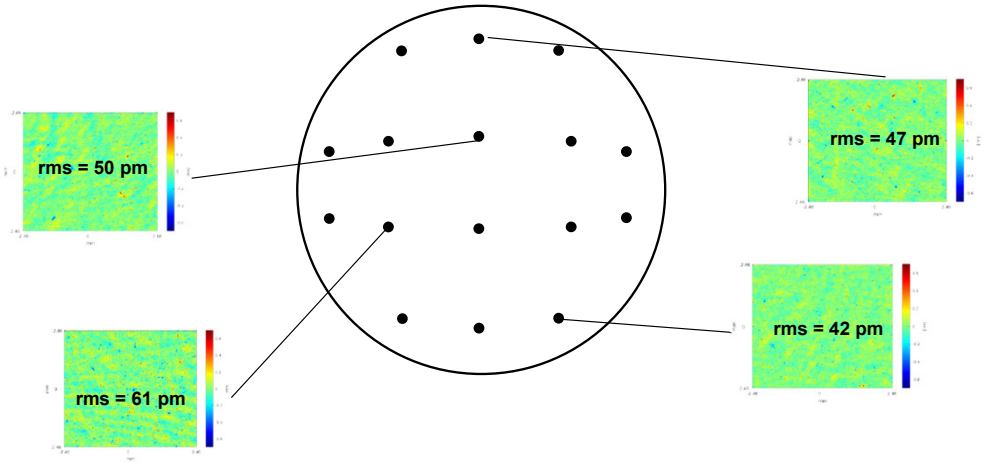
Mirror roughness metrology

MSFR [pm rms]	<80		**flare**
HSFR [pm rms]	<100		**light loss**



Micro Interferometry

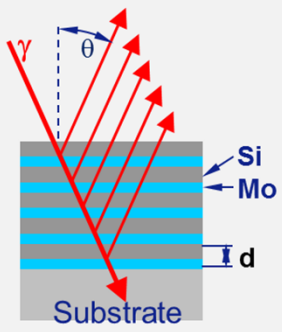
Si atom Ø 210 pm

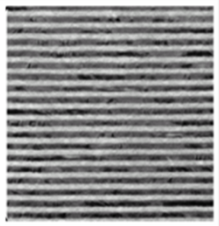


Mirror roughness after polishing <61 pm rms for all measurement points. Measured on Micro Interferometer

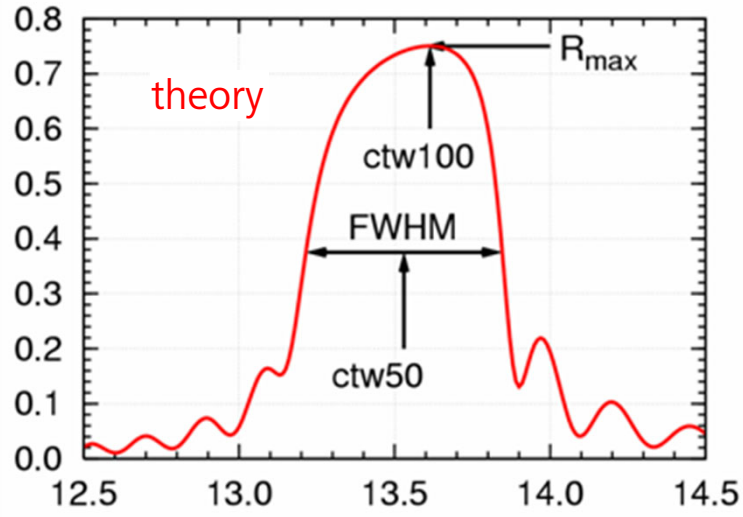
Challenges in metrology: Reflectivity metrology

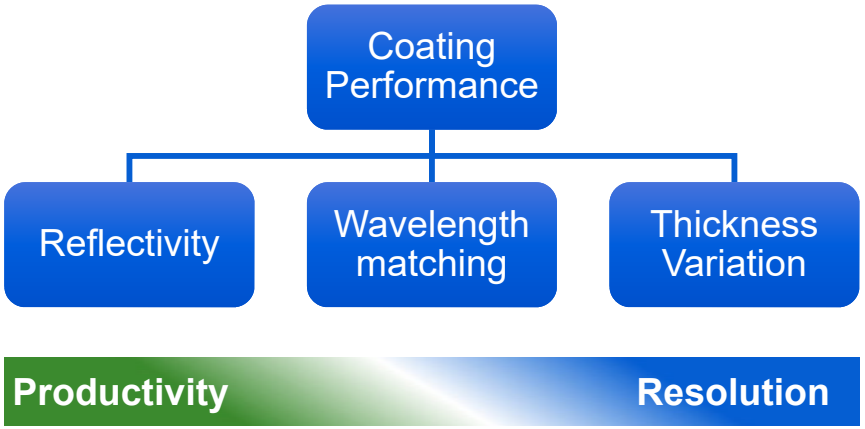
EUV Coating:
Mo/Si
Bragg Reflectors





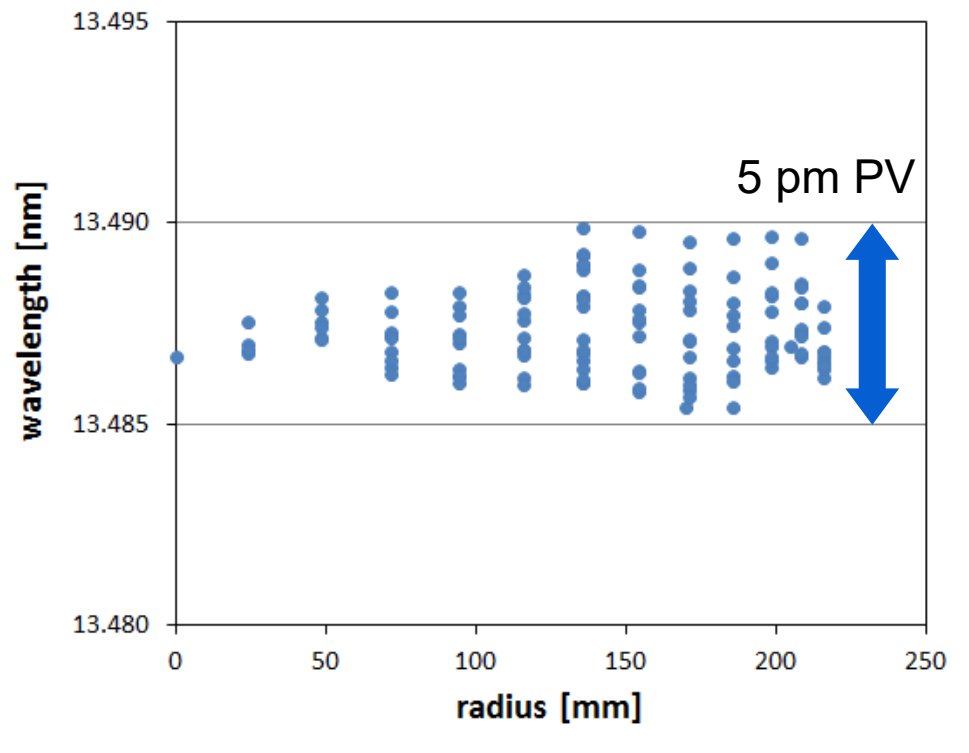
> 50 Bi Layers

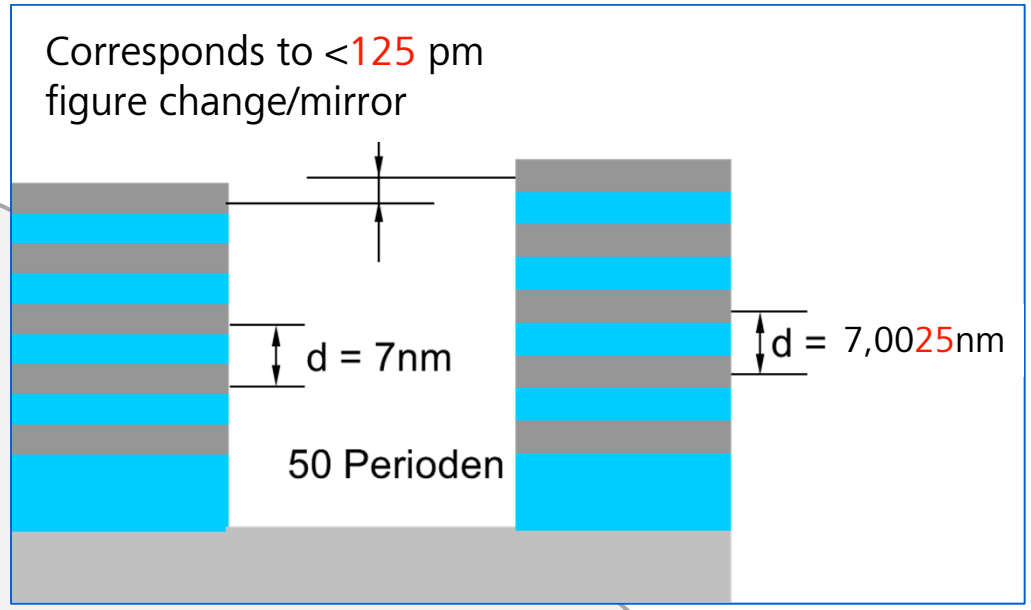




Customer Value

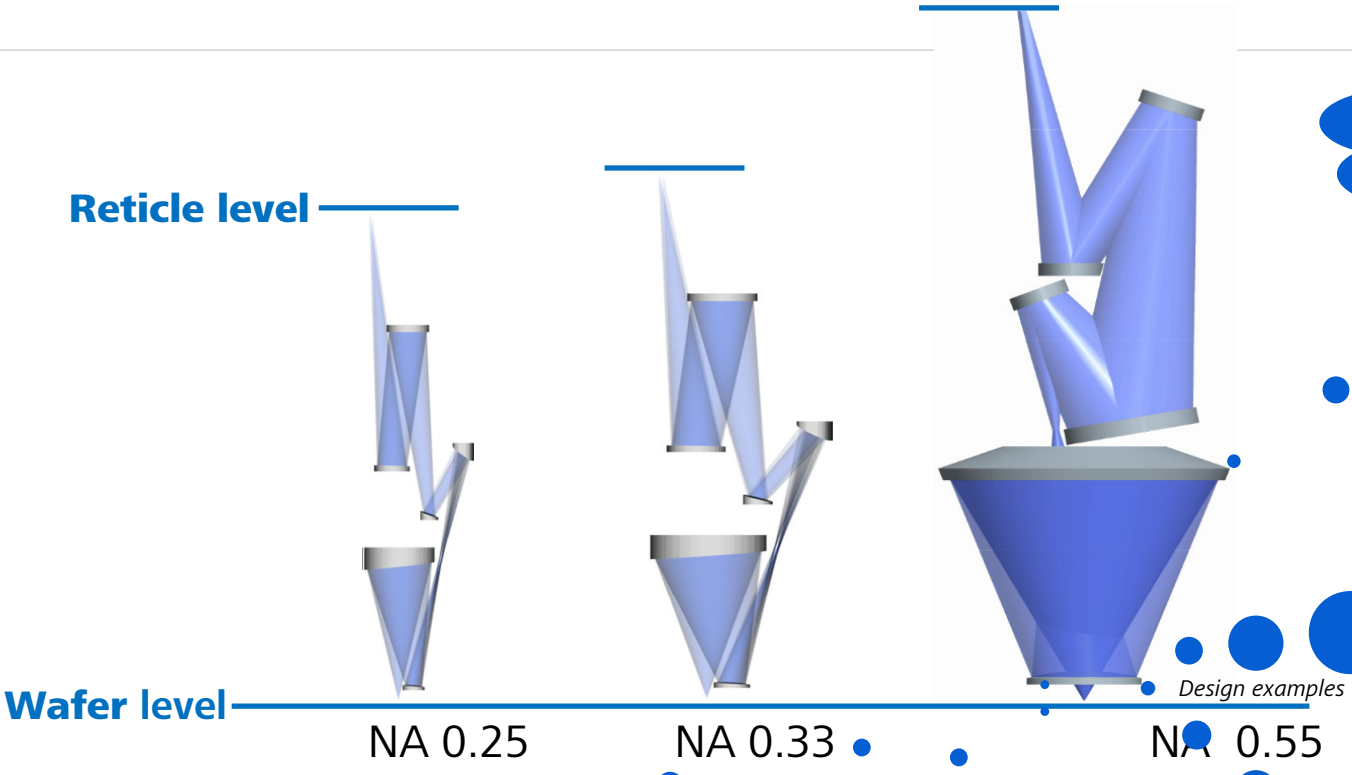
Required performance for EUV coating





Diameter of a Silicon atom
(drawn to scale)

Size matters: The High-NA challenge



Large mirrors require high throughput measurements

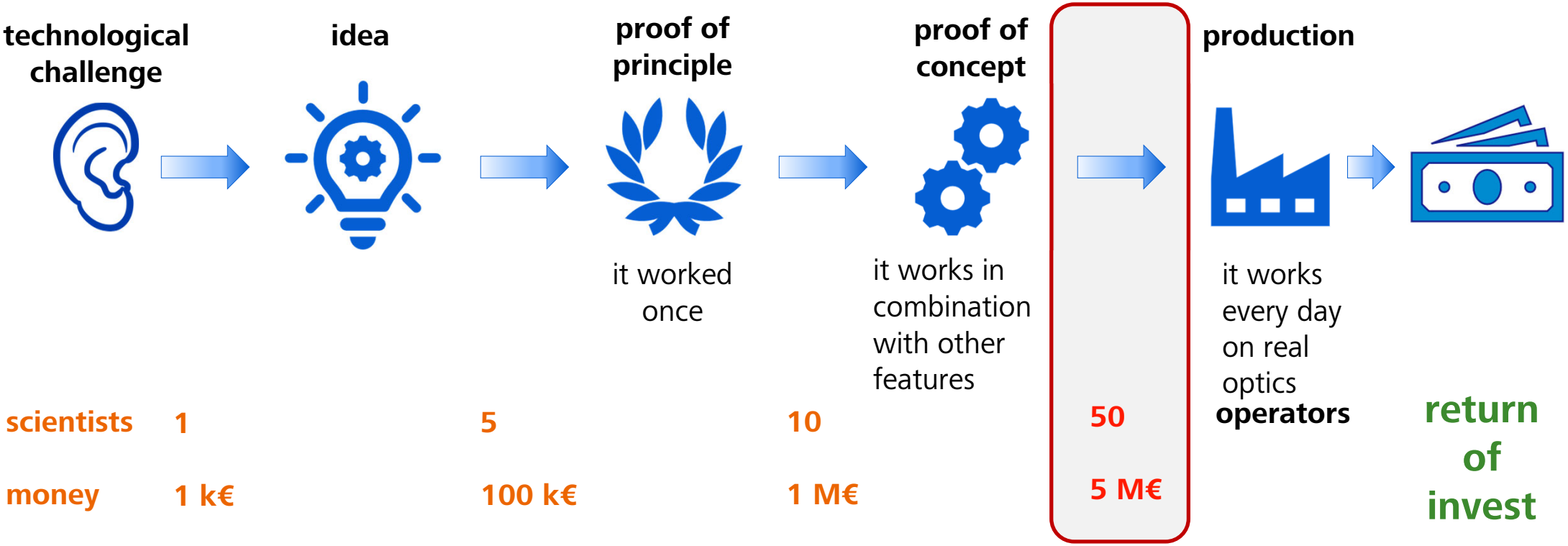
At large angles of incidence (AoI) the angular accuracy becomes critical for the wavelength accuracy. Challenges increase with increasing mass of the mirrors.

long thermalization

Large tooling

Near-ideal raw material and methods for material qualification

The industrialization challenge



Industrialization is the critical step!

arbitrary example

Make it efficient!

If a mirror is critical for a delivery, is it sensible to have a machine waiting for it?

logistics

Can automatic processes speed-up mounting?

arbitrary example, arrows are not to scale

repair → maintenance → calibration → wait → mount → **measure** → un-mount

Which parts need to be on stock to shorten repair times?

To what extent can repair be prevented by maintenance?

engineering

How often do we need to calibrate?

metrology

Can we measure faster? Or less?

OEE is the fraction of time a machine is actually working on the part to be processed. **measure**

Acknowledgements

- Hartmut Enkisch
- Christoph Zaczek
- Franz-Josef Stickel
- Oliver Dier
- **… and many others**

Thank you!

ZEISS

Seeing beyond