EUV Lithography Industrialization and future outlook

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EUVL FEL Workshop
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Outline

- NXE Roadmap
- NXE:33x0B litho performance and productivity
- NXE:3400B
- High NA EUV system

EUV extension roadmap

introduction	55 WPH	125 WPH	145 WPH	185 WPH	Overlay [nm]
2013	NXE:33 B				7
2015		350B			3.5
2017		NXE:3400B			3
			NXE:next		<3
				High N	<2

At customer upgradable

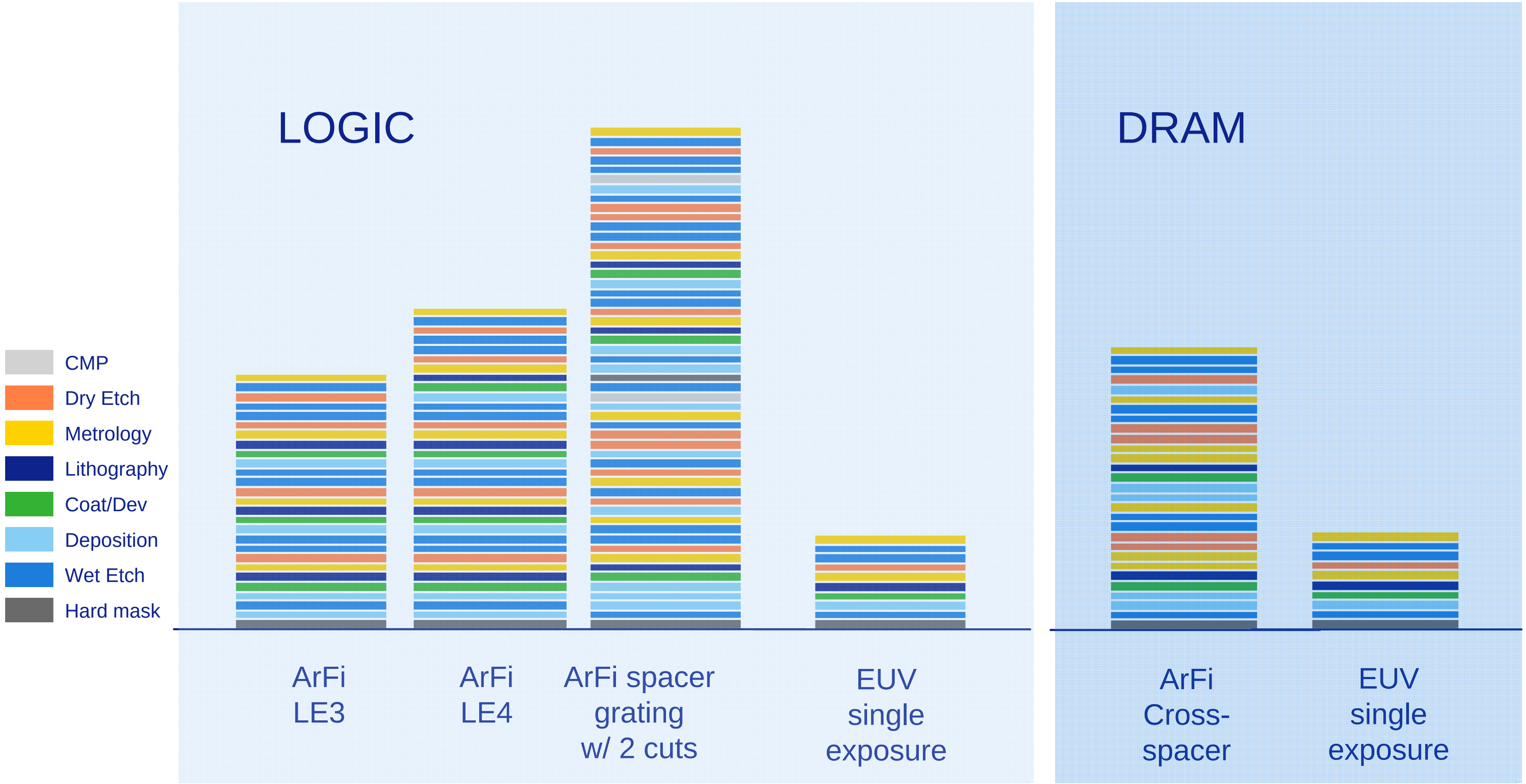
New platform

products under study

Roadmap: October 2016

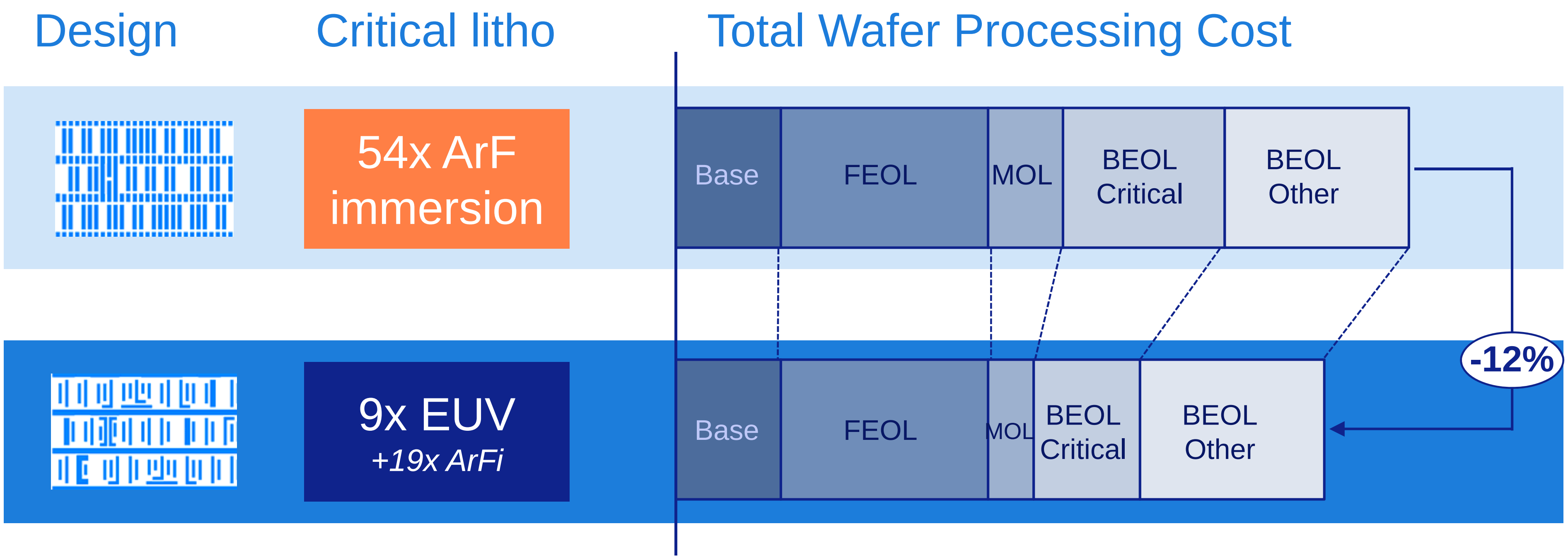
EUV reduces multi-pattern process complexity

Process steps per layer



LE3=Litho+Etch+Litho+Etch+Litho+Etch

7 nm study with leading Logic chip maker projects lower wafer cost for EUV based processes



Cost per wafer calculated for ASML cost model, all process steps

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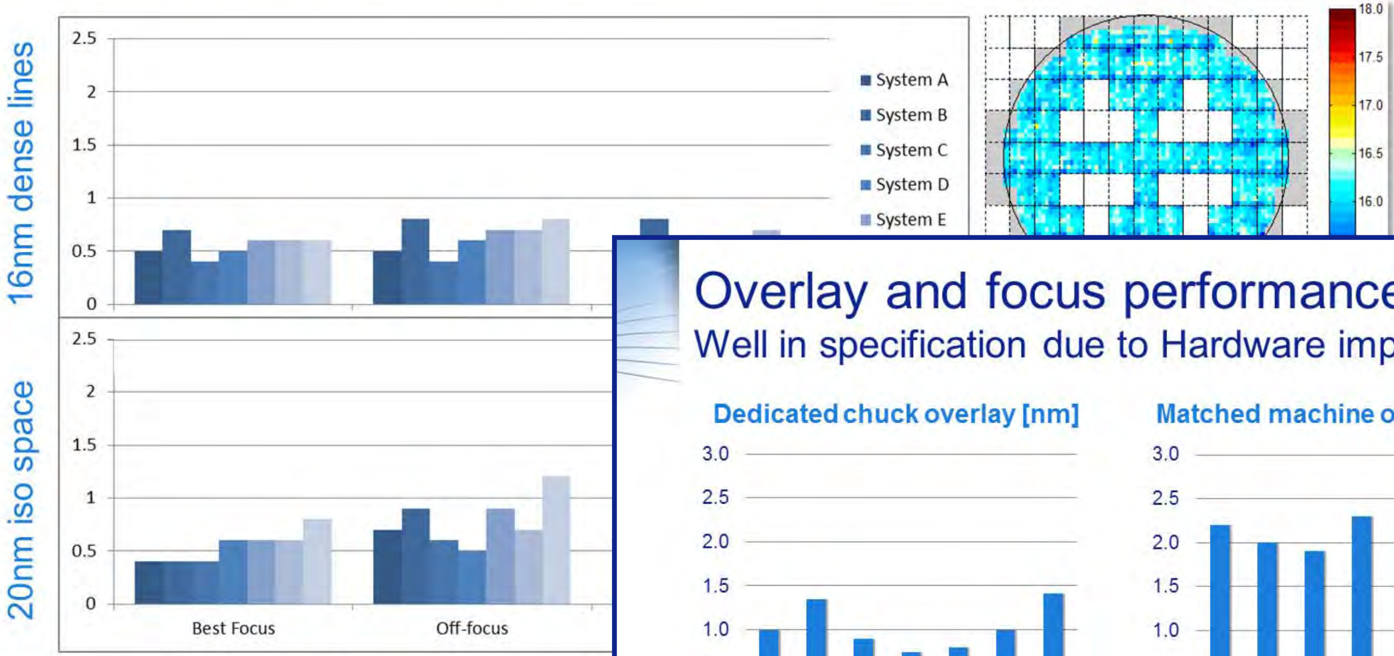
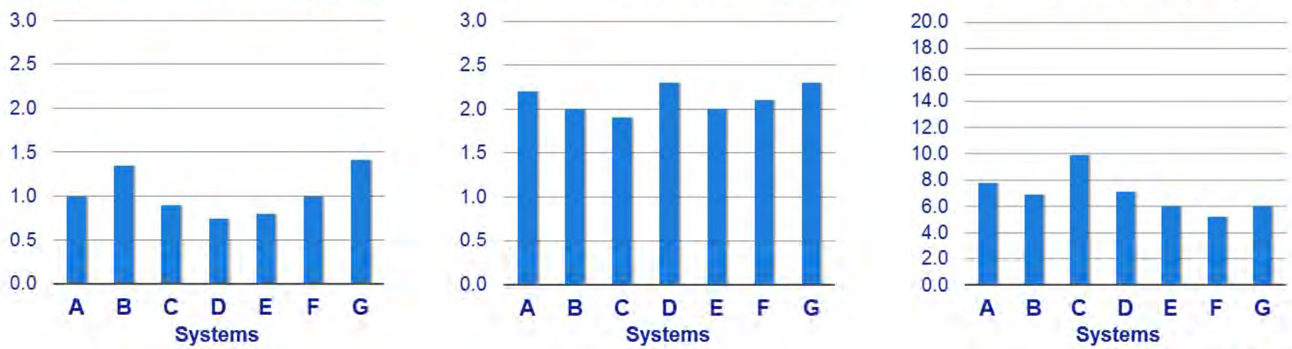
NXE:3350 Imaging: 16nm dense lines and 20nm iso space consistently achieve <1.0nm Full Wafer CDU at 80W source power

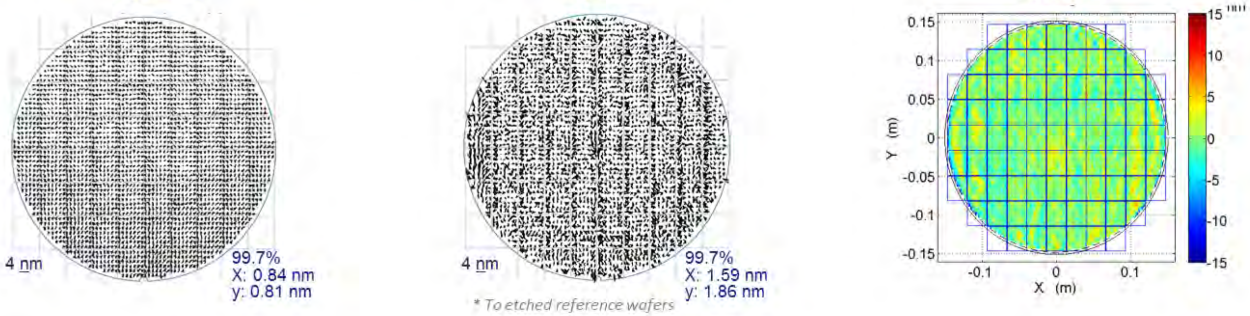


Illumination: Dipole 90 degrees. Dos

Overlay and focus performance NXE:3350B

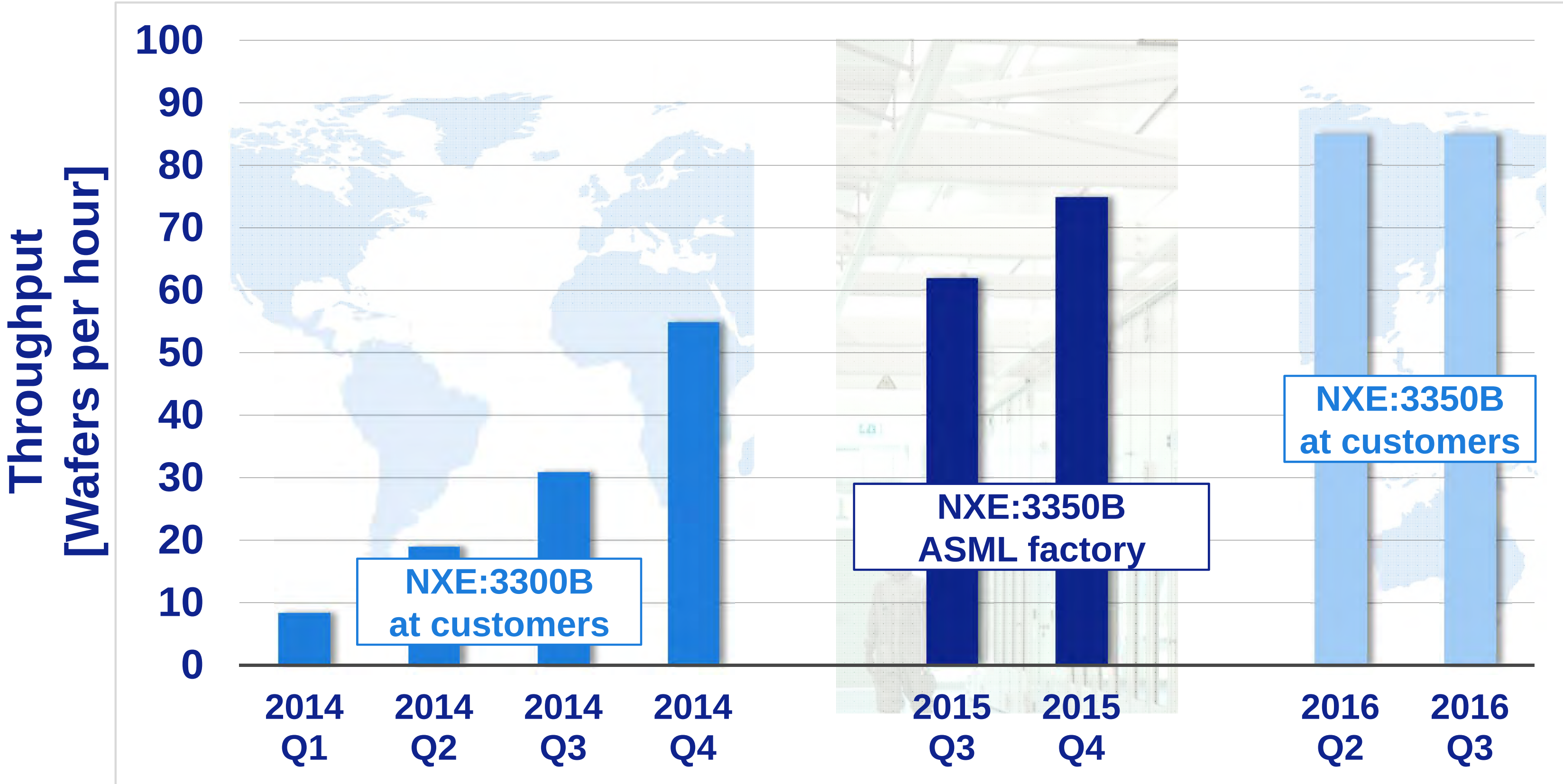
Well in specification due to Hardware improvements and new calibrations





Demonstrated 85 wafers per hour on NXE:3350B

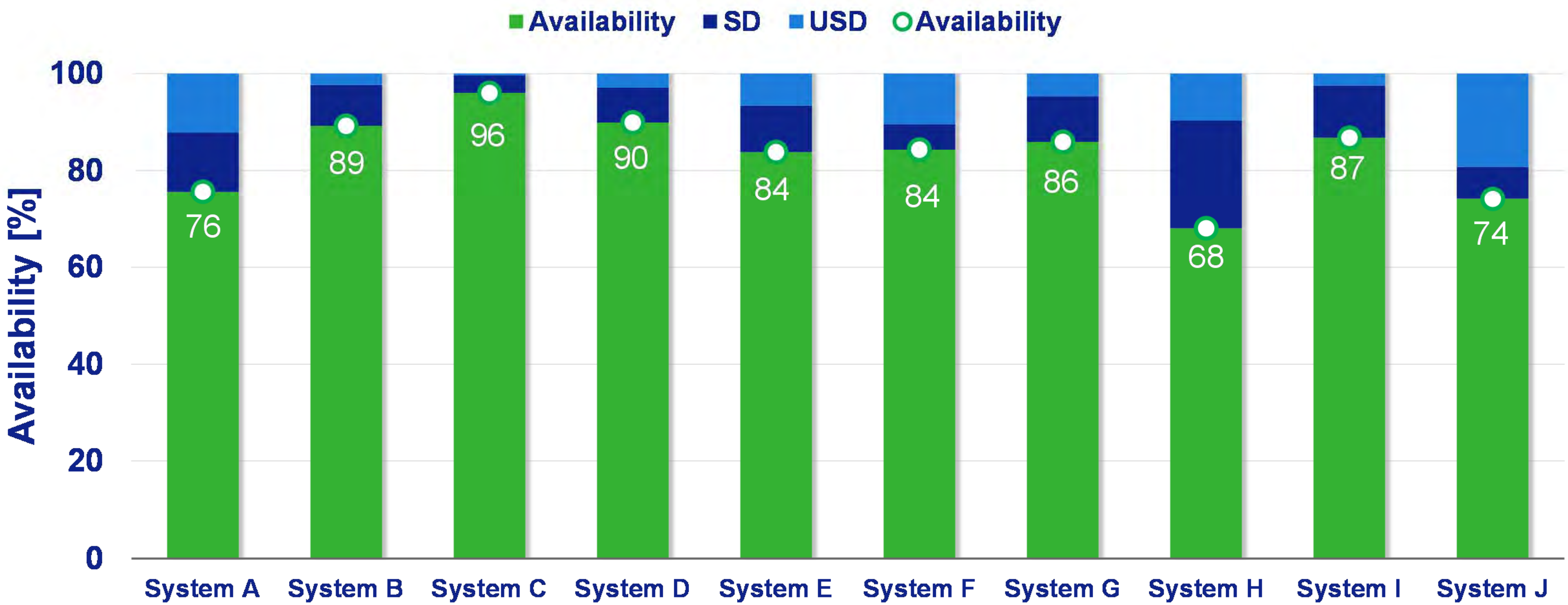
Achieved with 125W source configuration



- NXE:3350B ATP test: 26x33mm2, 96 fields, 20mJ/cm2

7 systems achieved over 80% availability (4 wk average)

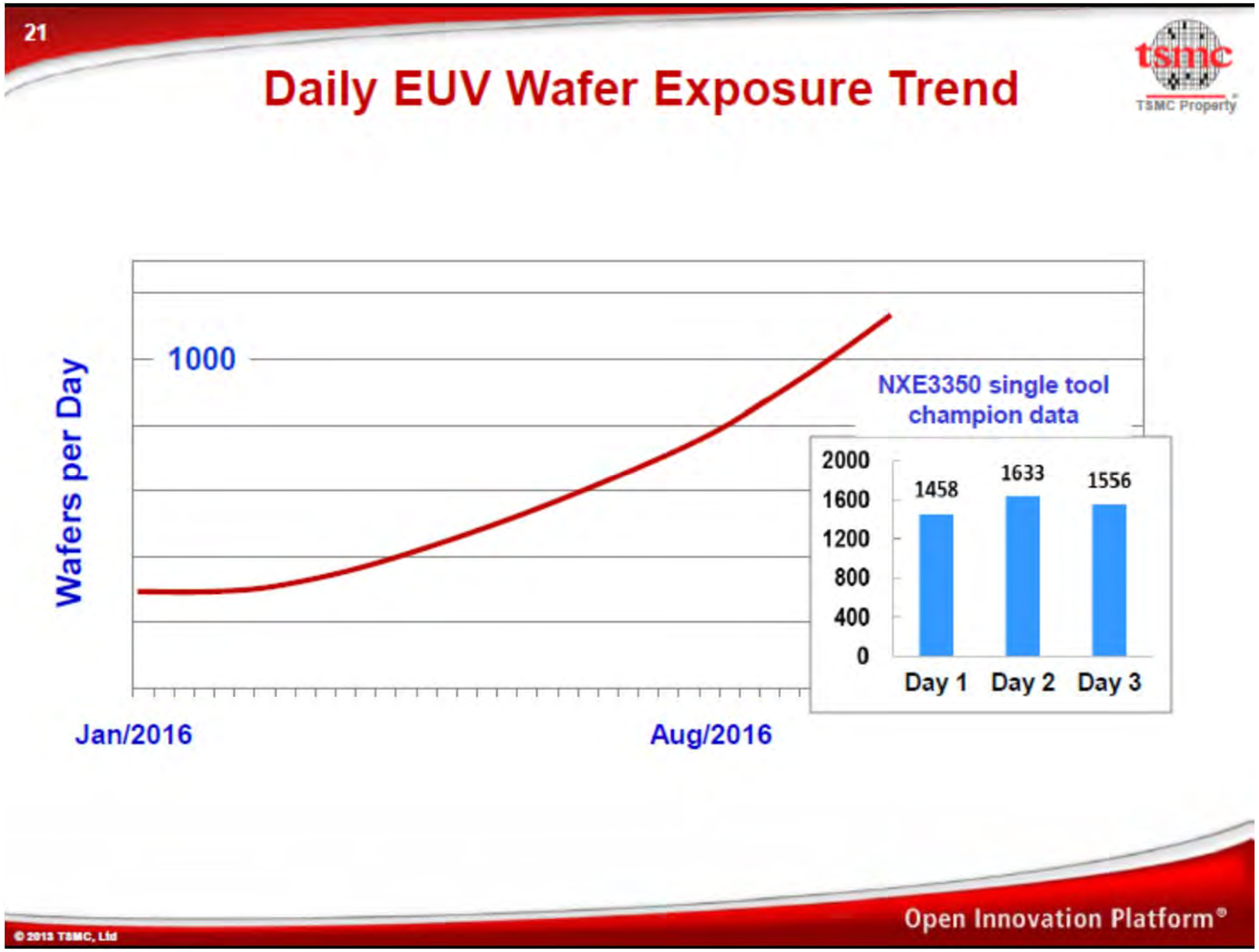
Consistency to be improved



Graph showing the maximum availability of each system over a 4 week period

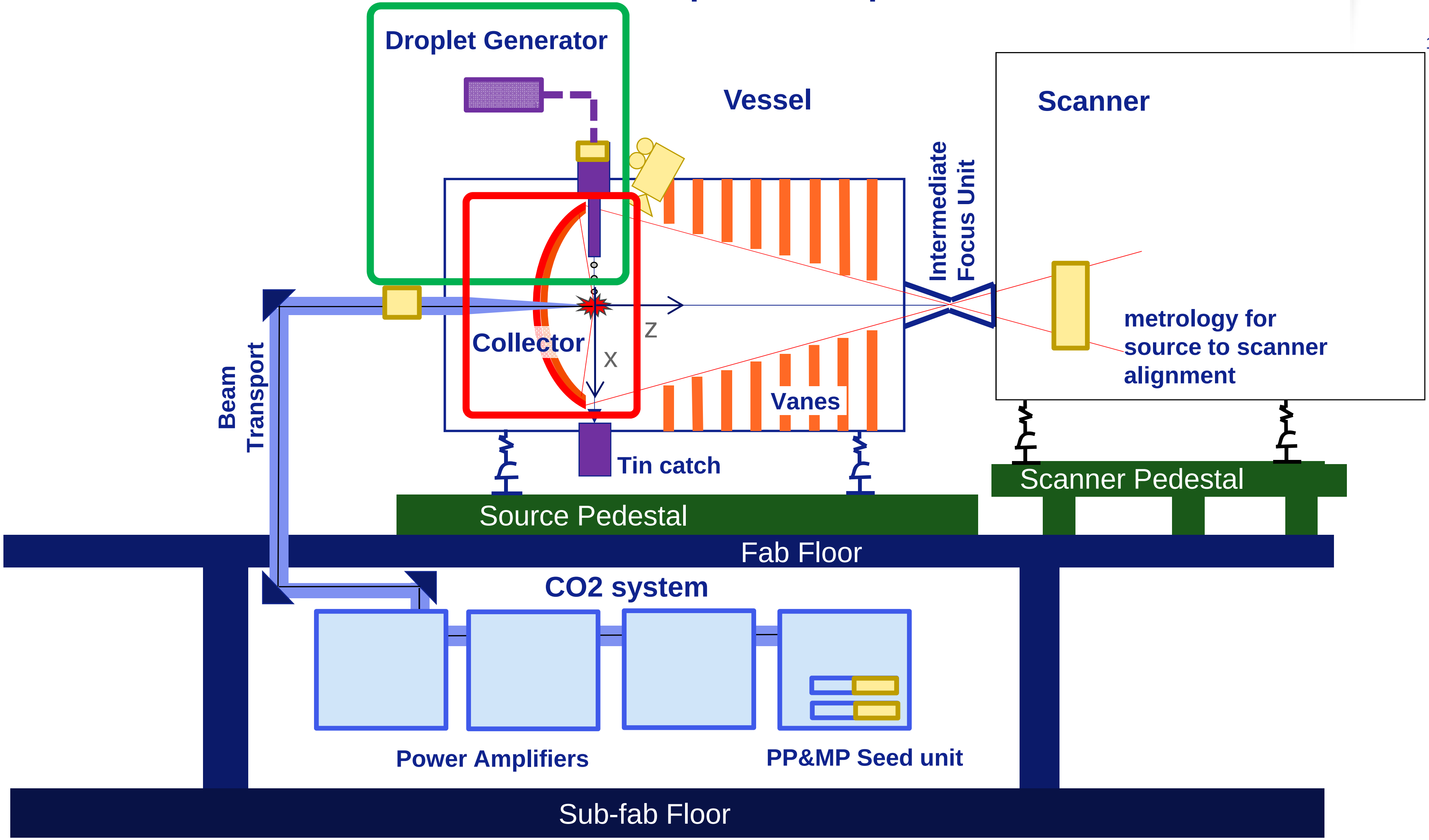
Productivity improvement also available to customers

3-day average of >1500 WpD achieved on NXE:3350B

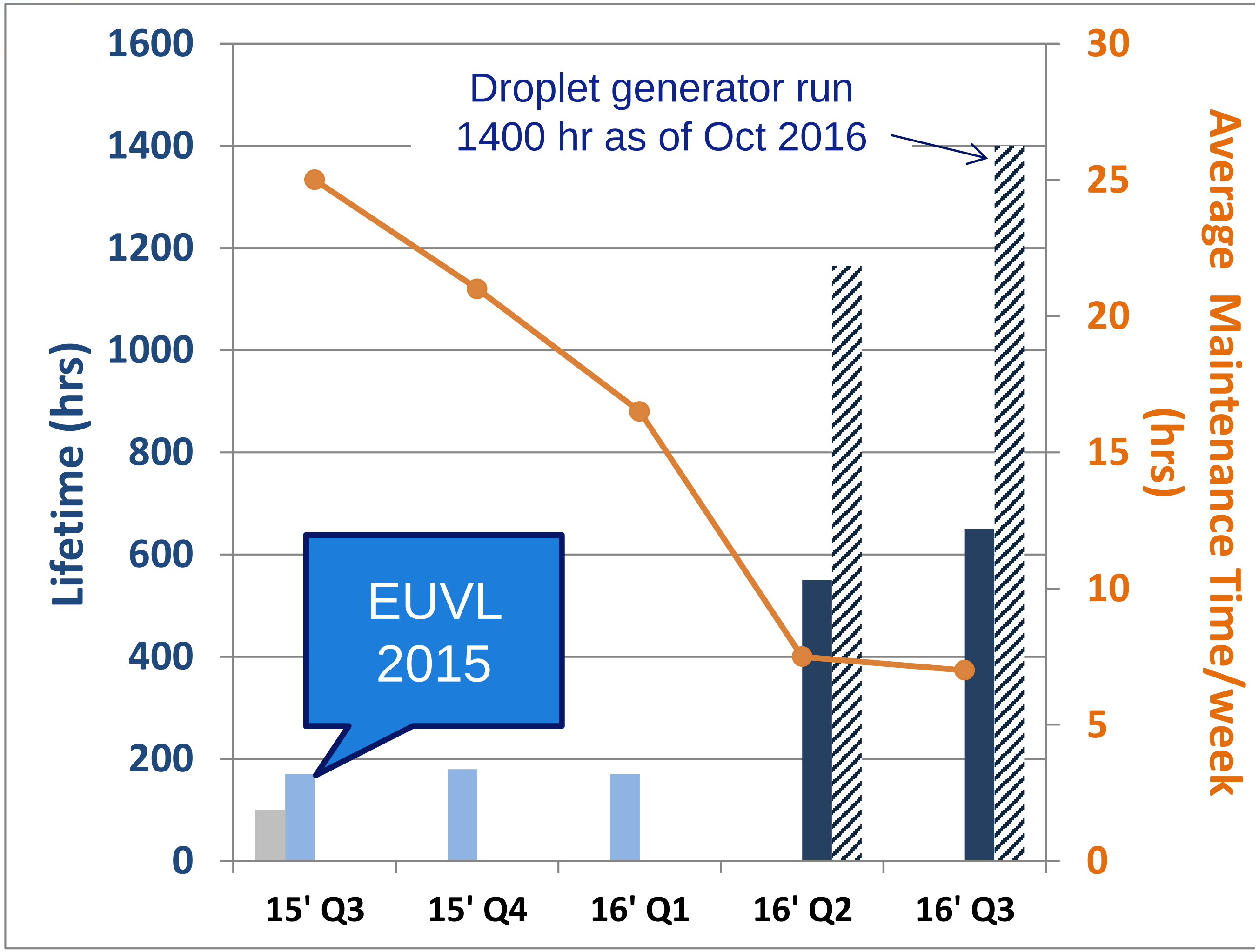


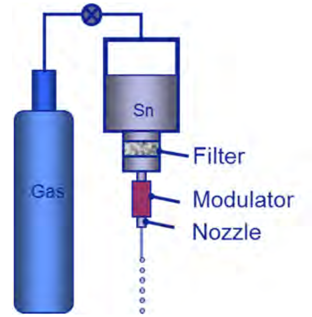
Source: L.J. Chen (TSMC), EUVL Symposium, Hiroshima, Japan (24-26 Oct 2016).

EUV Source - Principle of operation



Third generation Droplet Generators: average lifetime ~600 hours. Achieved >1000 hrs on multiple systems at multiple customers



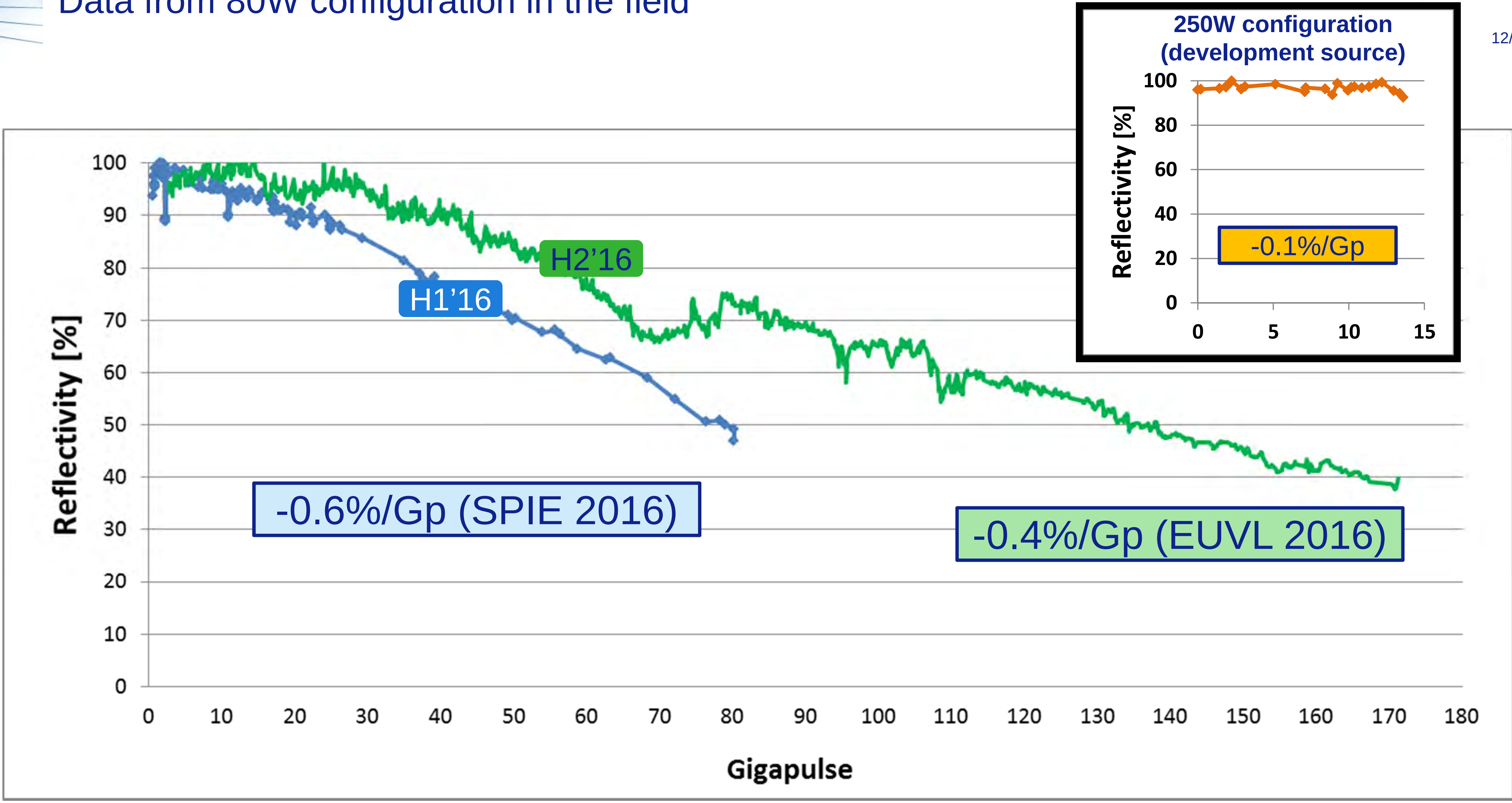


Type 3:
- capability of tin refill and restart
- enhanced particle elimination

- *Average lifetime and maintenance time improved by factor >3*

Typical collector lifetime improved by factor 1.5 in 2016

Data from 80W configuration in the field



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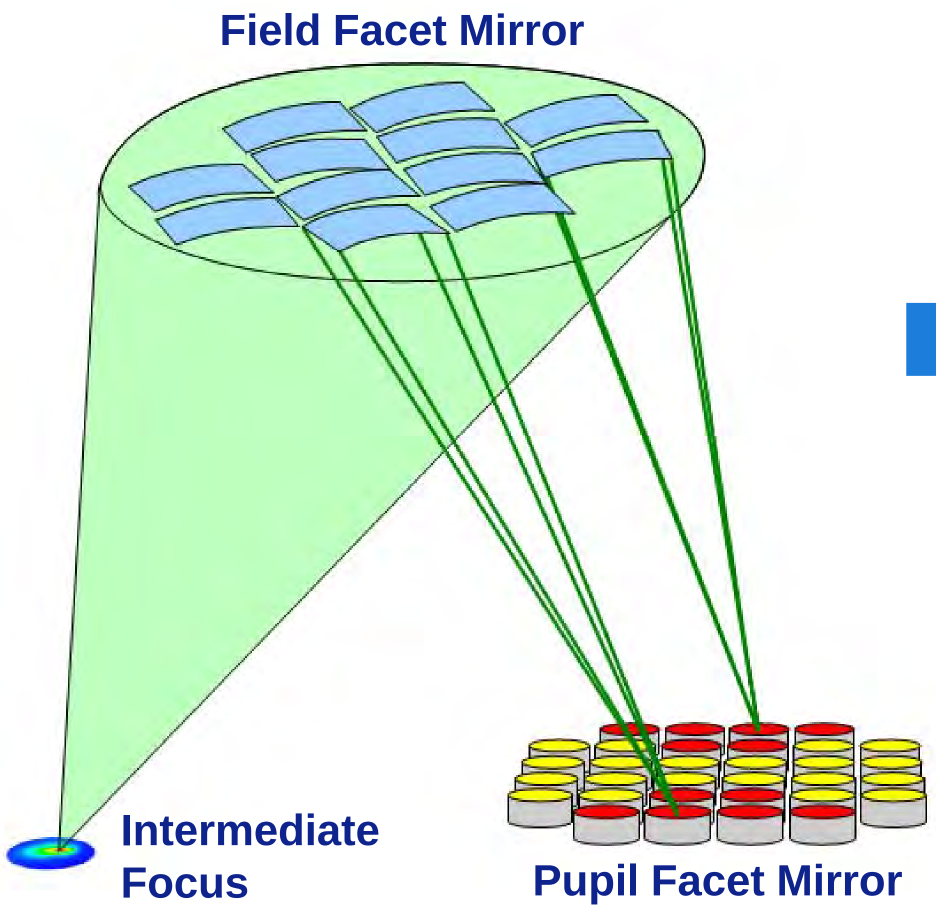
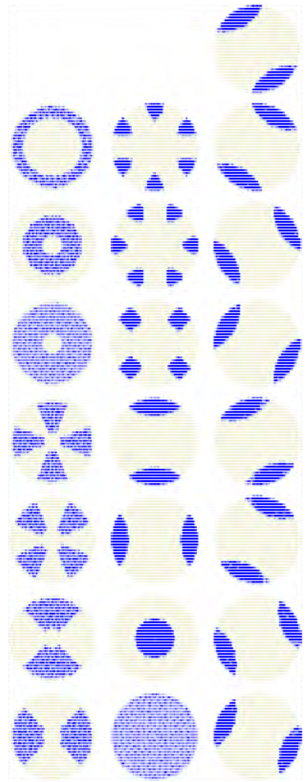
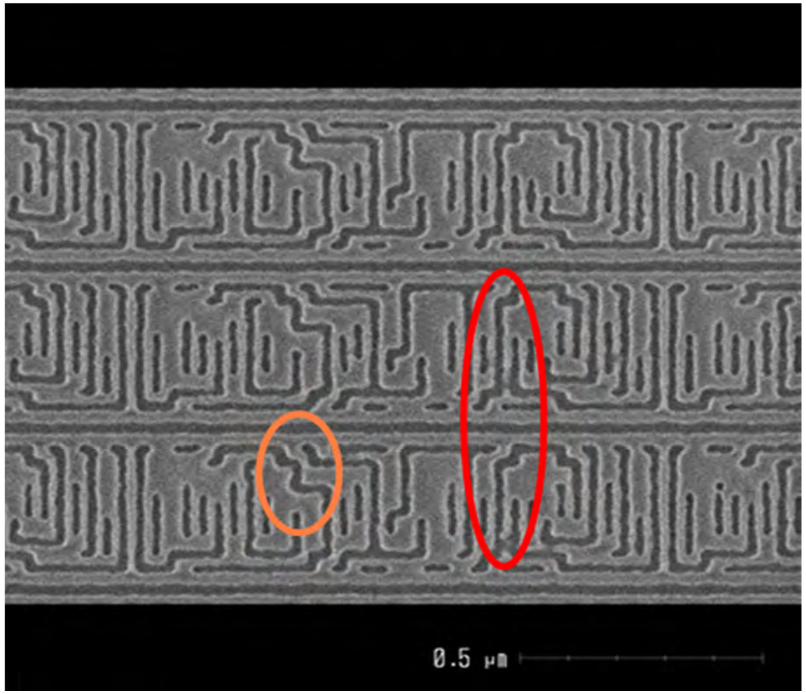
NXE:3400B illuminator: increased pupil flexibility at full throughput

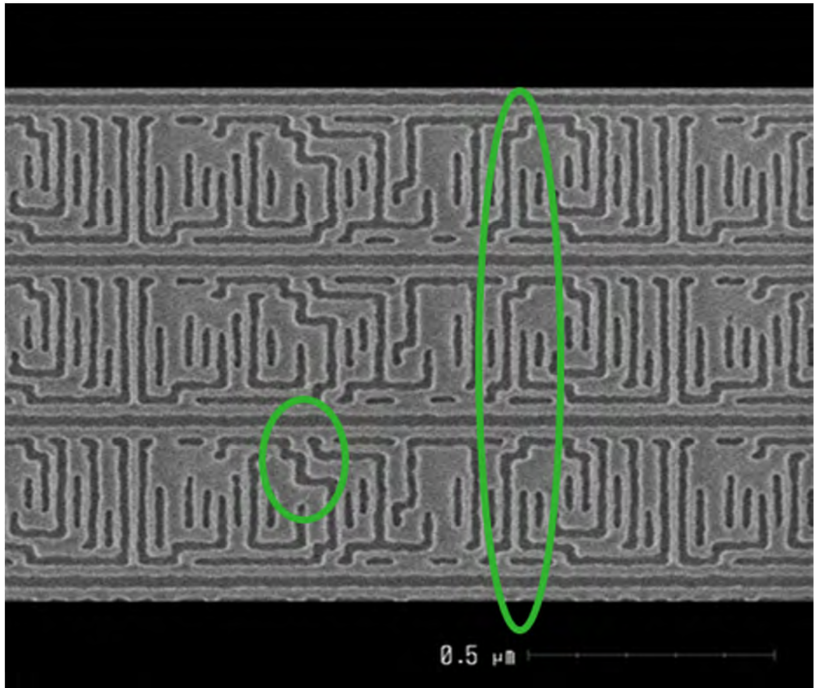


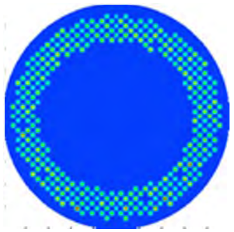


2D clips: pitch 32nm in x- and y- direction, k_1=0.39

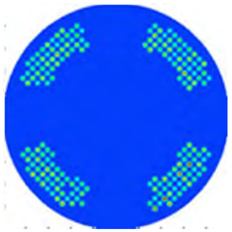
Better pattern fidelity with lower Pupil Fill Ratio







Pupil Fill Ratio=40%

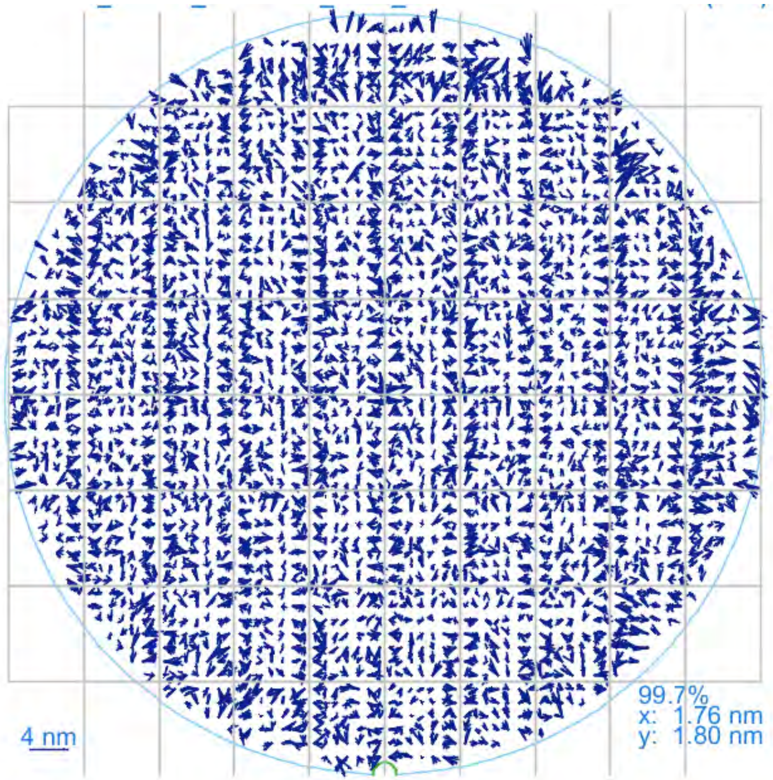


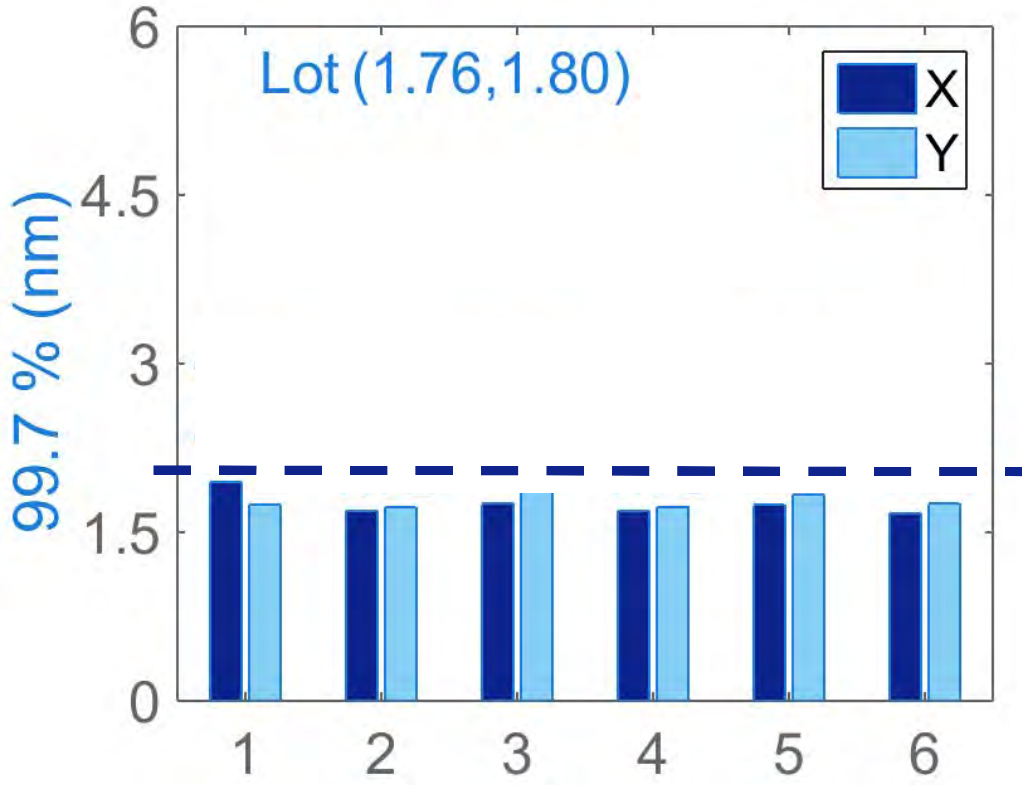
Pupil Fill Ratio=20%

SPIE 9776, Jo Finders "Contrast optimization for 0.33NA lithography"
Exposures done on a NXE:3350B system. On NXE:3350B, 20% PFR leads to loss of light.

Matched Machine Overlay 1.8nm, meets NXE:3400B specification

NXE:3400B overlay improvements include calibrations and new wafer table

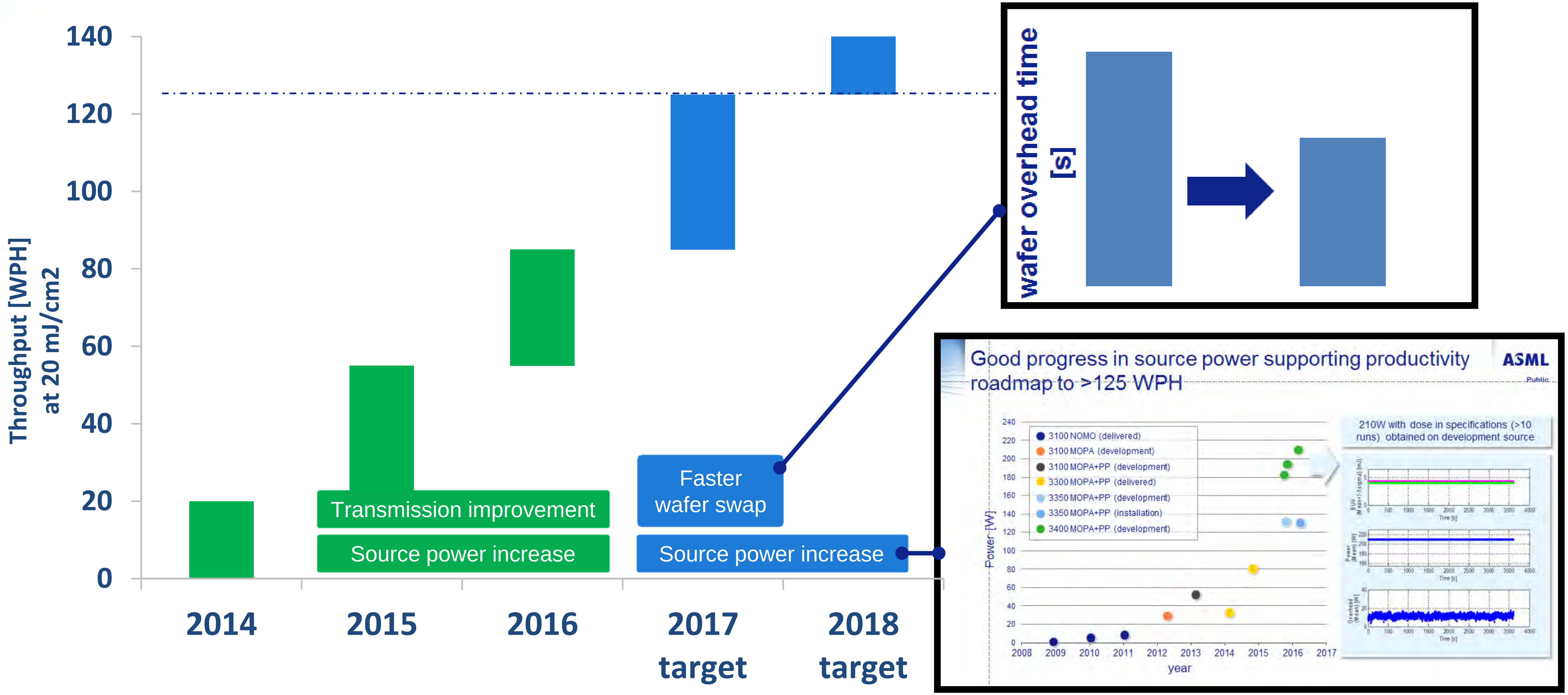




NXE:3400B-like system. Matching to etched reference wafers exposed on immersion

Productivity roadmap towards >125 WPH in place

Throughput at targeted availability (>90%) sufficient for HVM insertion



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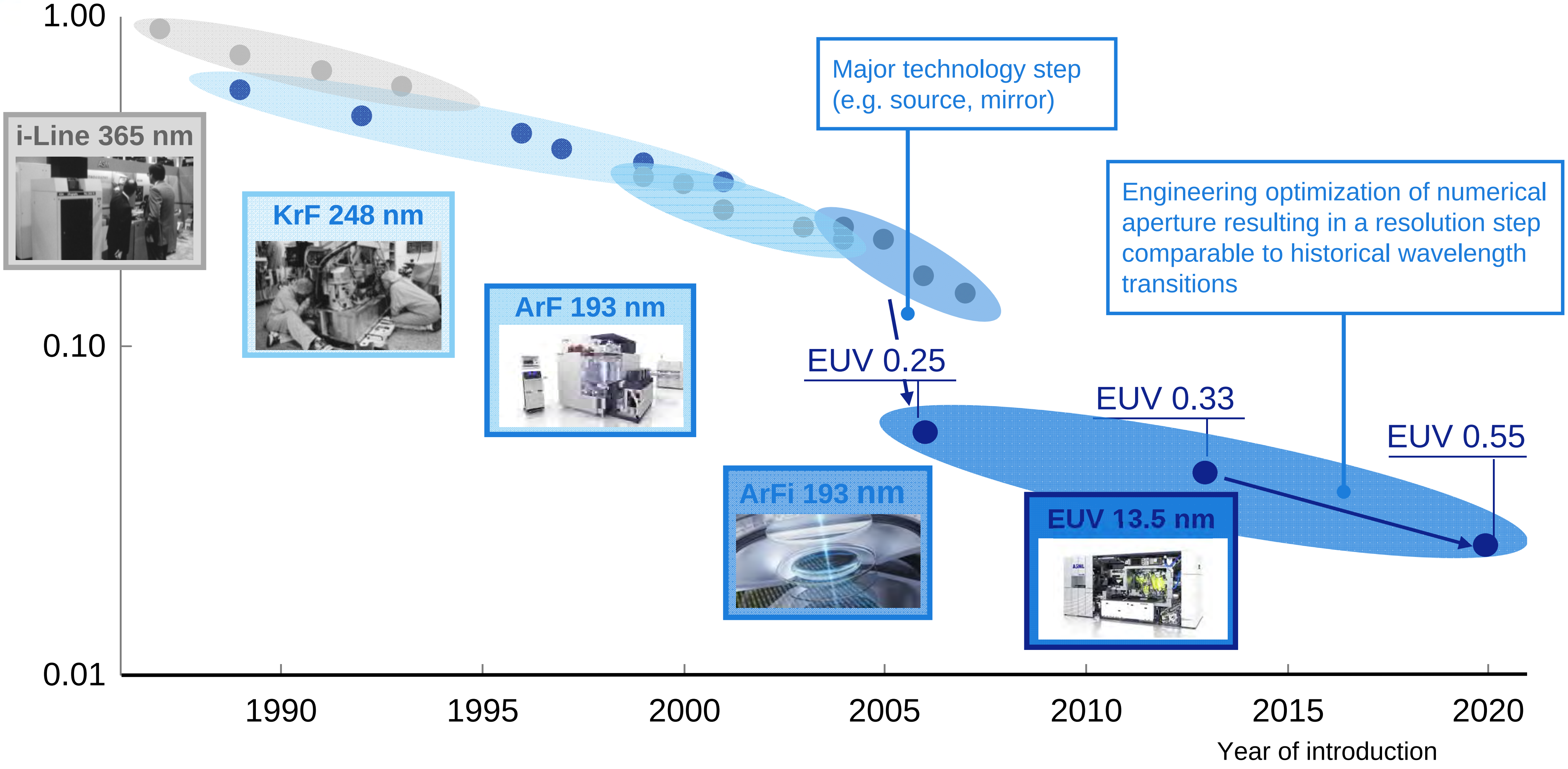
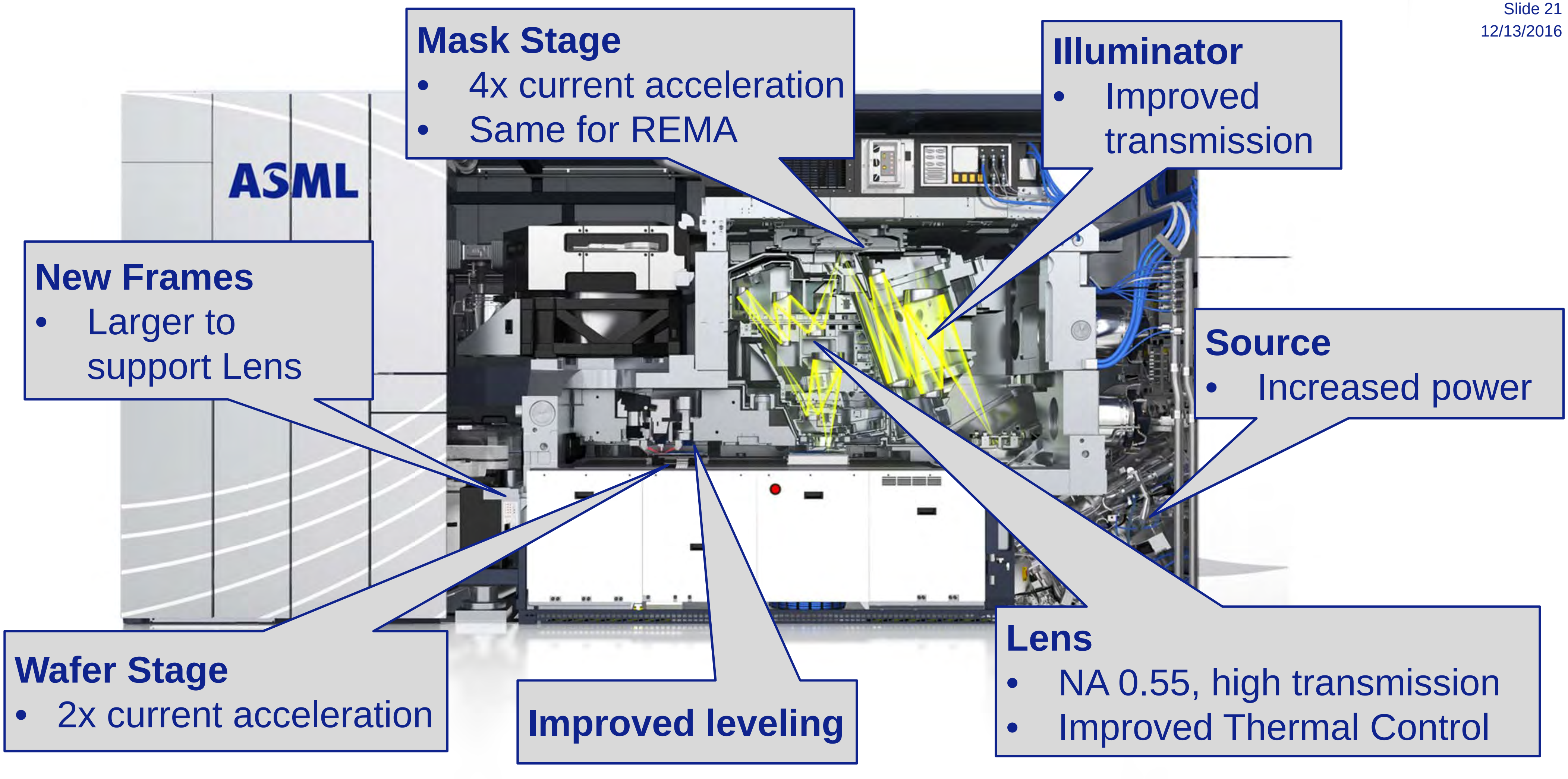
High-NA: large resolution step in line with our history

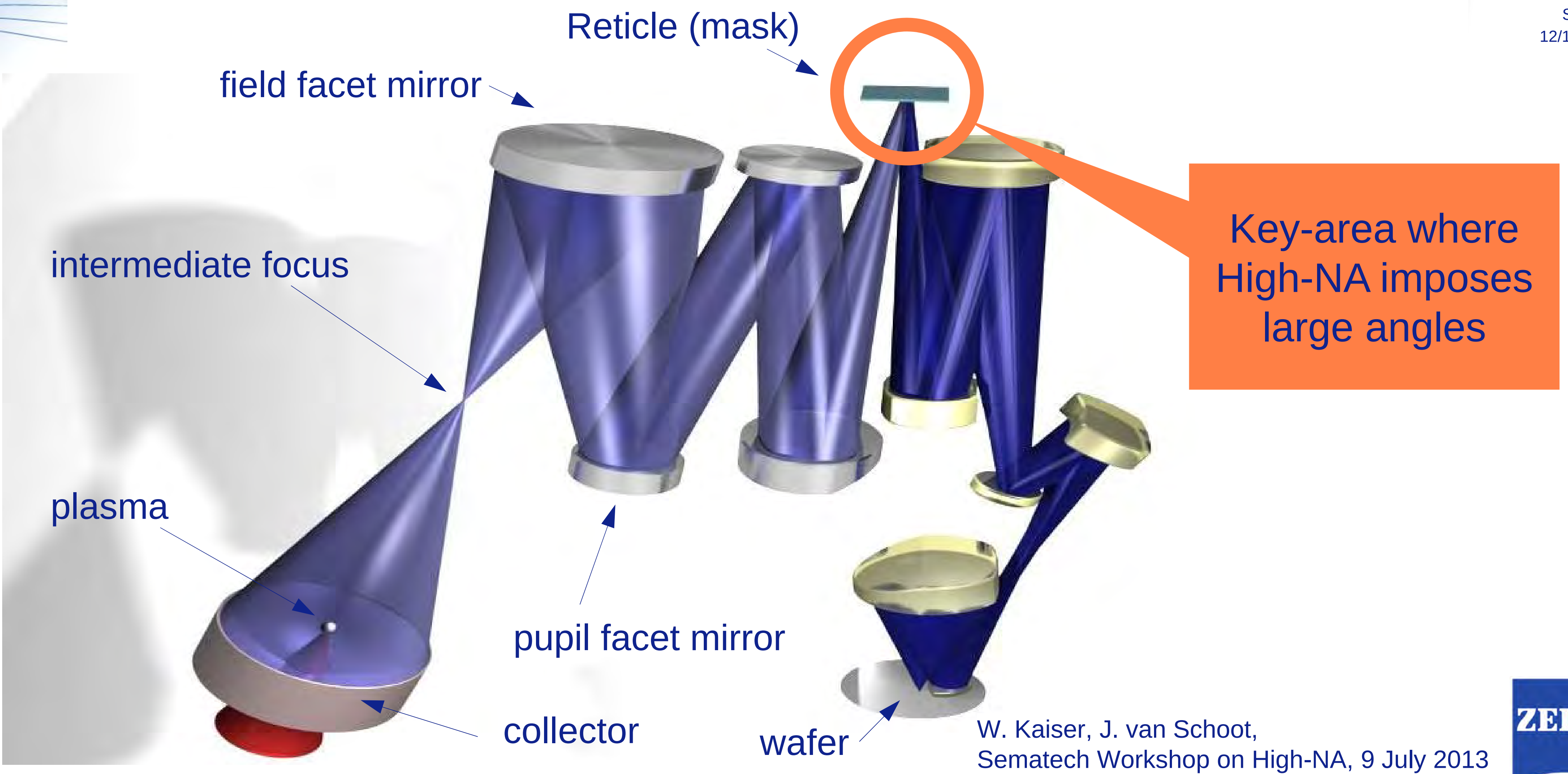
New product introductions providing step in resolution λ/NA, um



Overview main System Changes High-NA tool



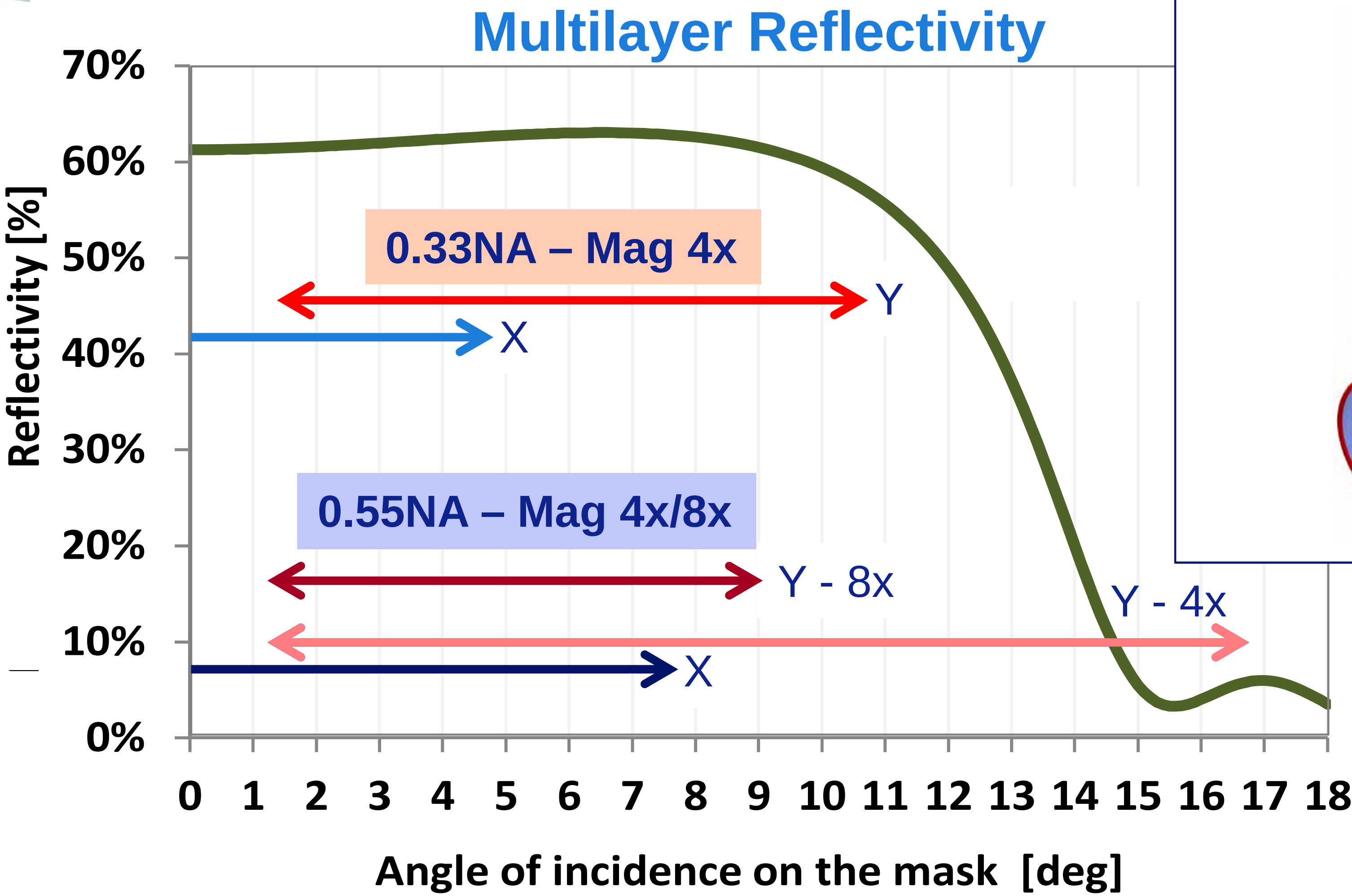
EUV Optical Train

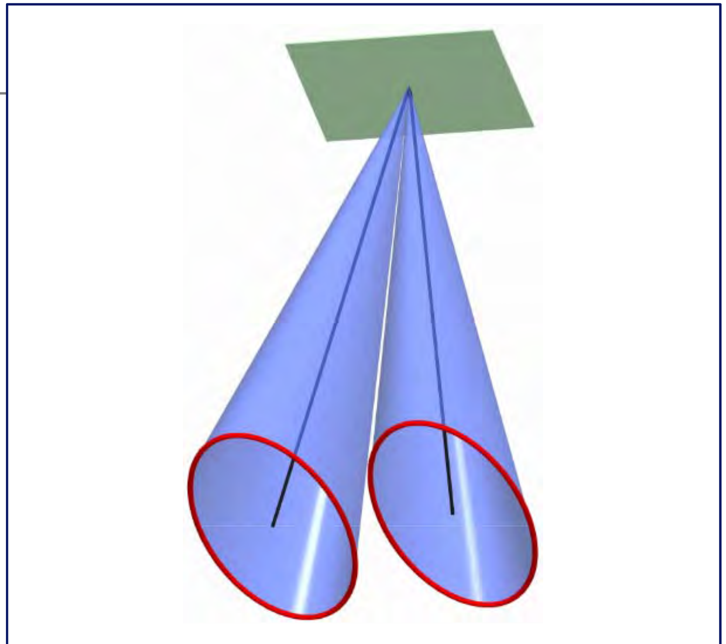


W. Kaiser, J. van Schoot,
Sematech Workshop on High-NA, 9 July 2013

ZEISS

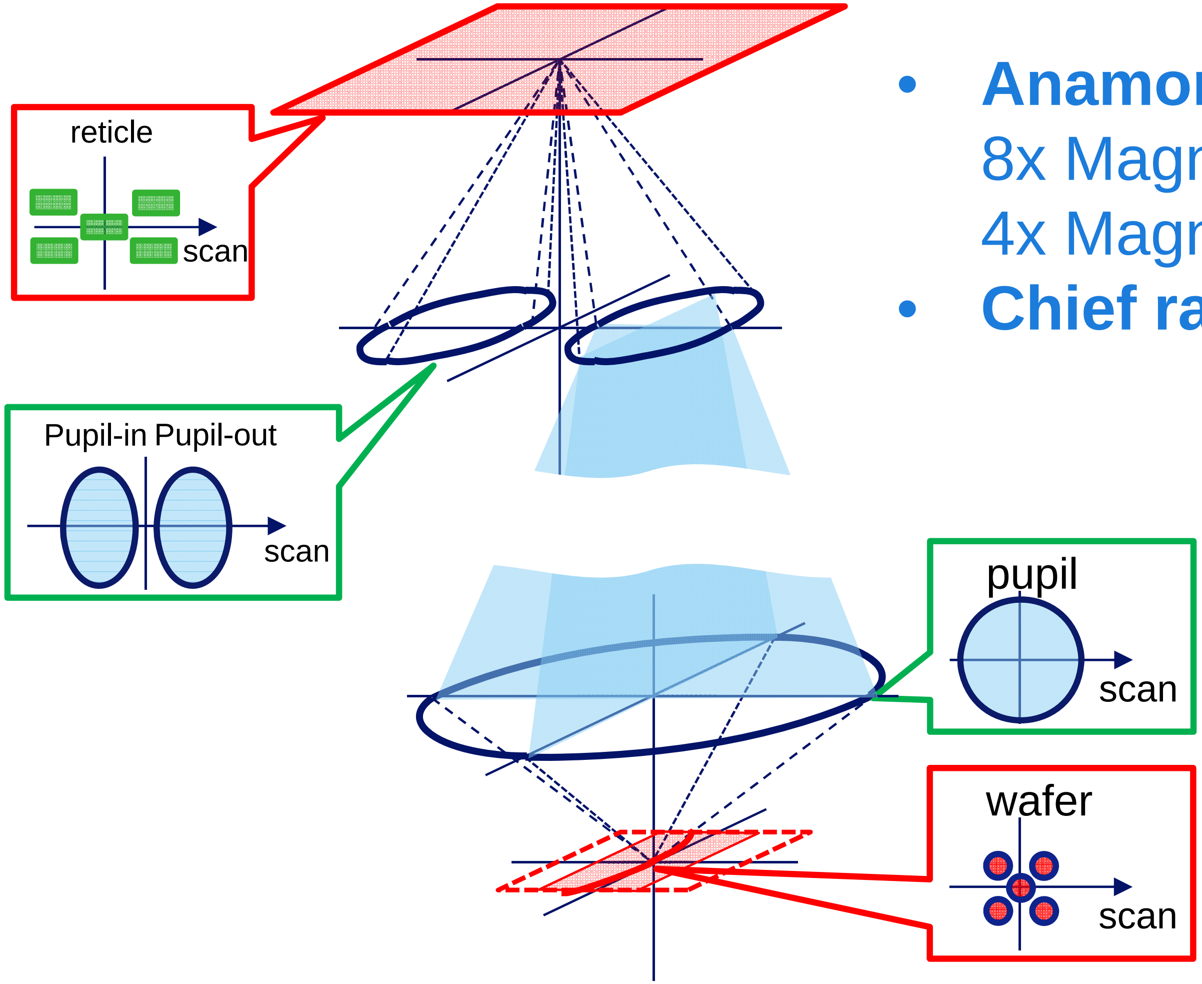
Anamorphic magnification solves the problem at the mask





High-NA >0.5NA 4x/8x anamorphic magnification

Chief Ray Angle at Mask can be maintained



- **Anamorphic optics → half field:**
  8x Magnification in scan
  4x Magnification in other direction
- **Chief ray angle ok → Imaging ok**

The pattern at the mask will be 2x larger →

Scanner prints half fields

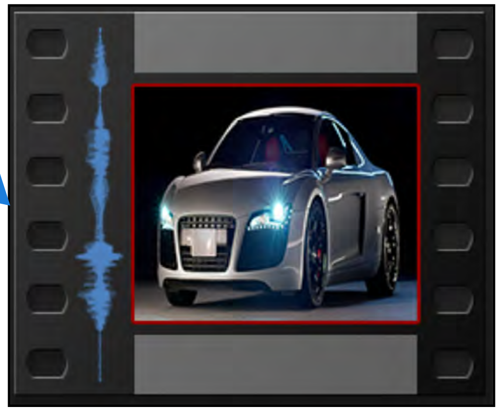
Anamorphic optics are used in cinematography

"Don't change the mask"

16x9

Anamorphic
Camera

"The Mask"
($24x36mm^2$)



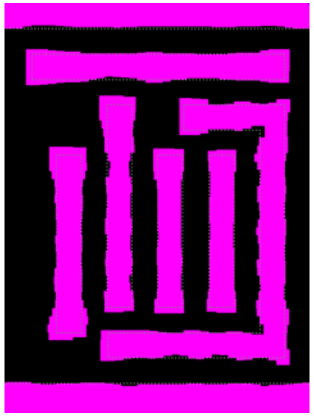
16x9

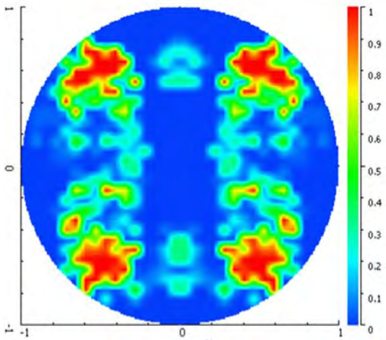
Anamorphic
Projector

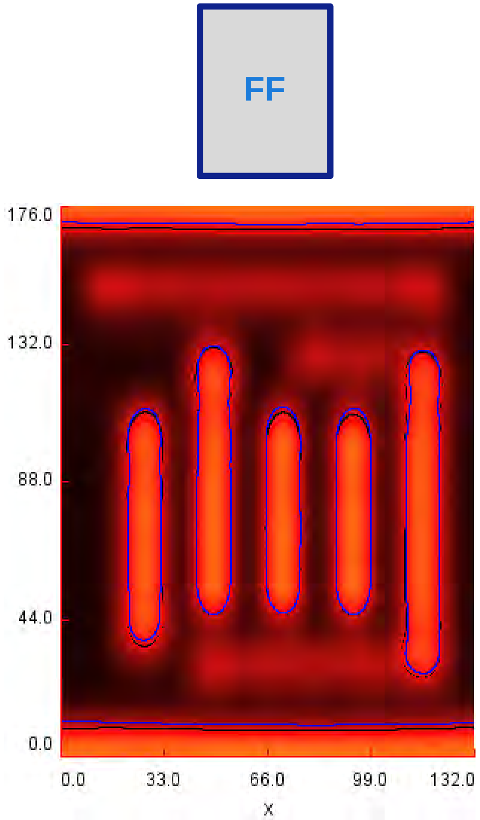
Imaging verification of the new Half Field concept

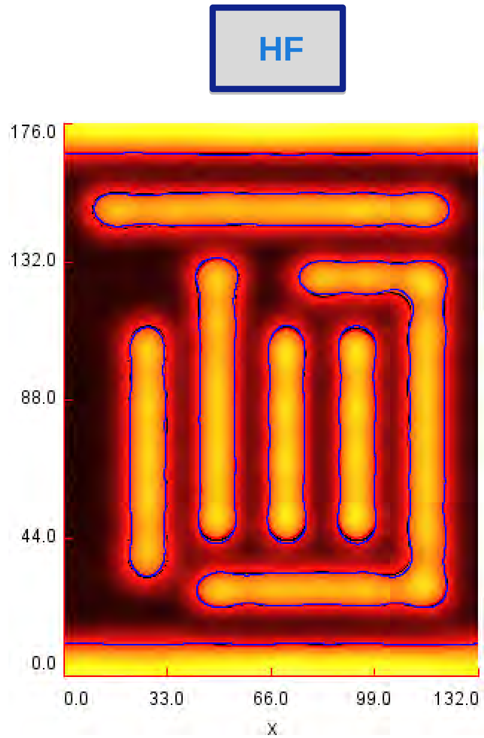
Logic N5 clip Metal-1, 11nm lines, SMO is done at 8x

Aerial Image Intensity in Hyperlith





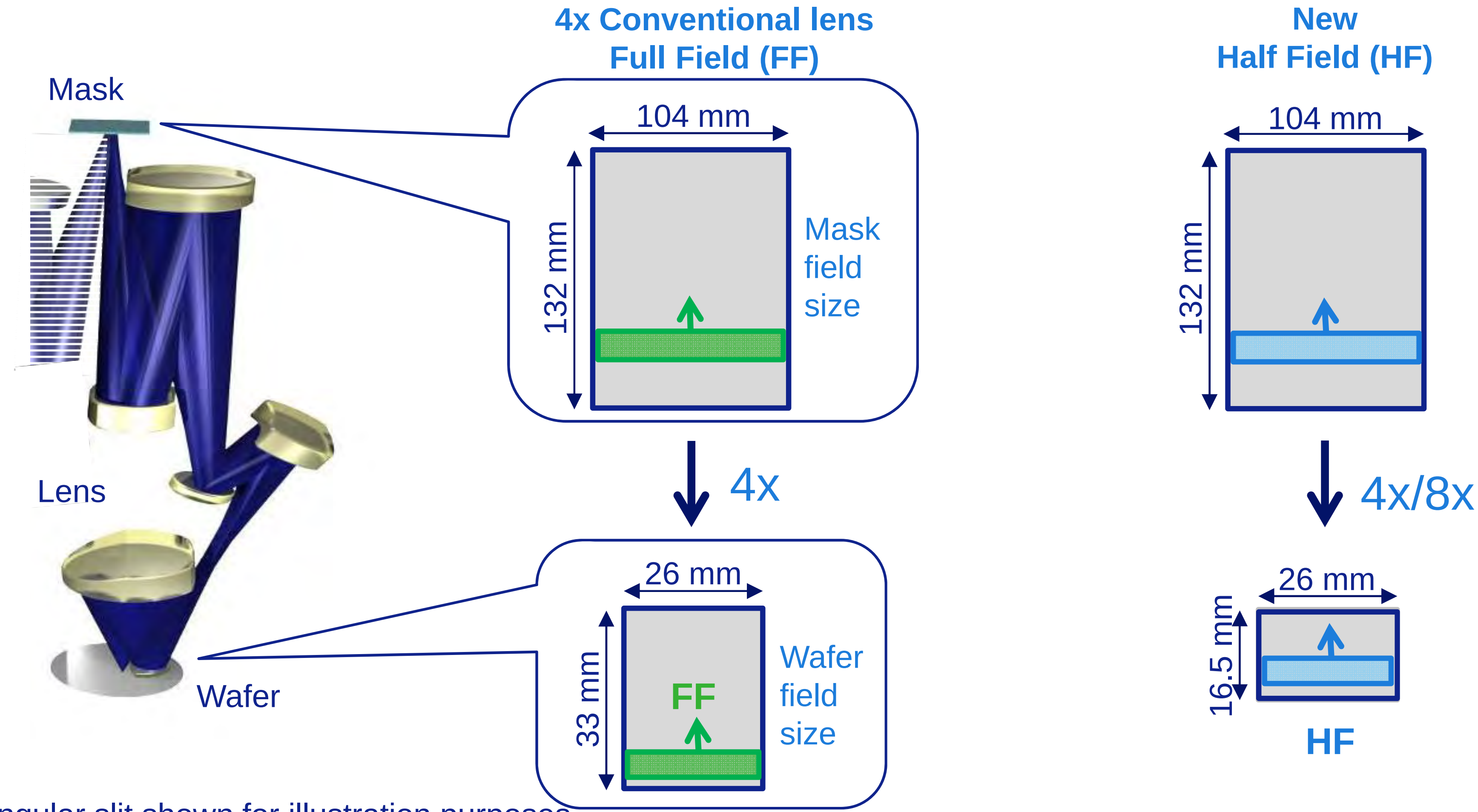




Note:
pictures at same scale, smaller mask reflection is also visible

High-NA Anamorphic Lens prints a half field

By utilizing the current 6” mask



Note: rectangular slit shown for illustration purposes

High-NA anamorphic Half Field concept

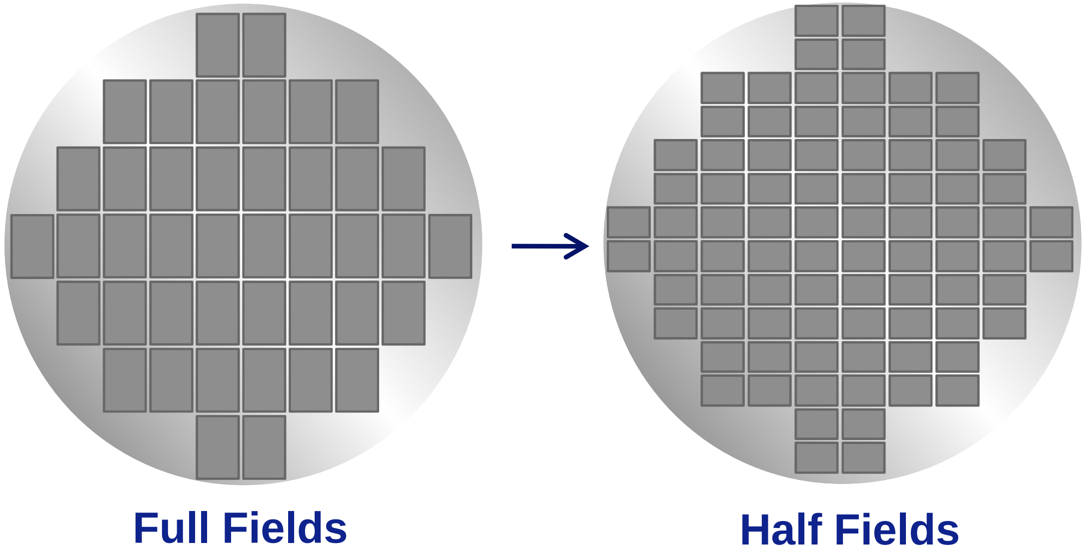
Faster stages enable high productivity

Half Field yields 2x more fields

- 2x wafer stage acceleration maintains overhead while going to twice number of scans

Y-magnification 4x → 8x

- 2x wafer acceleration results in 4x mask acceleration

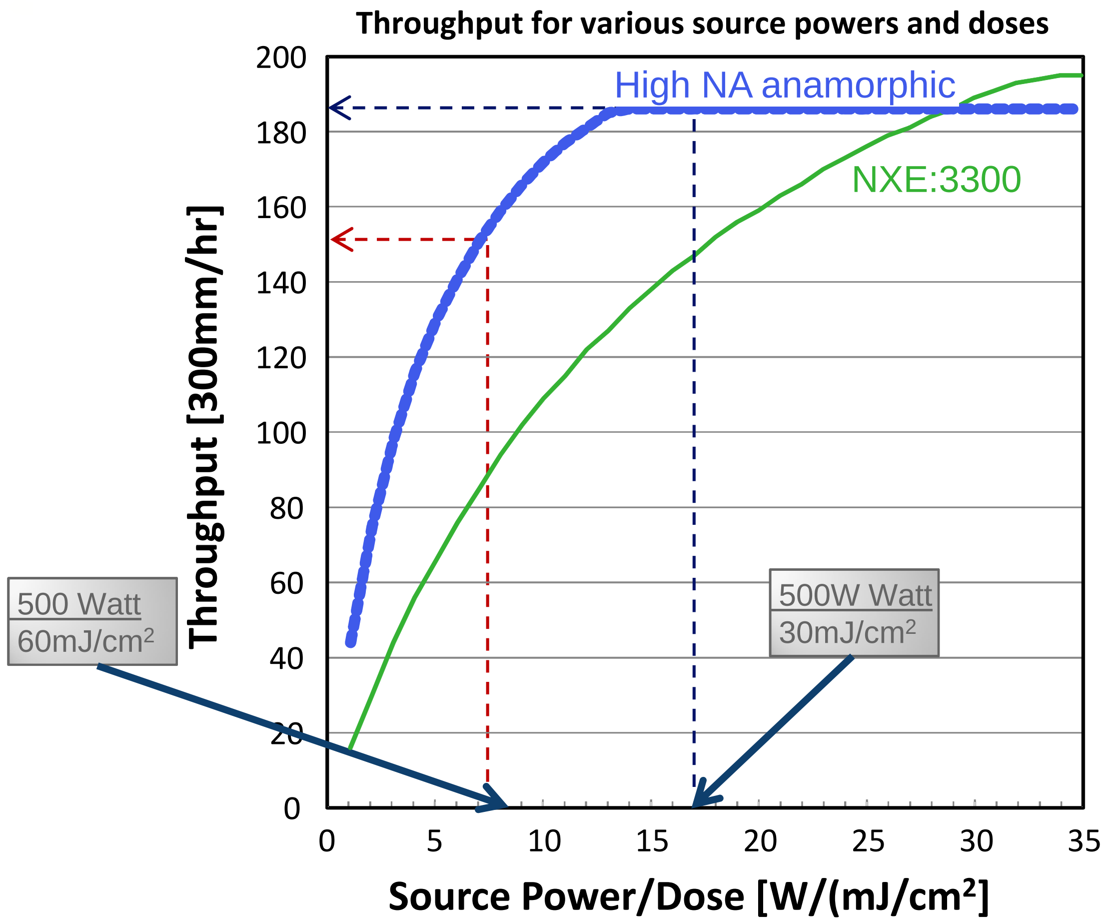


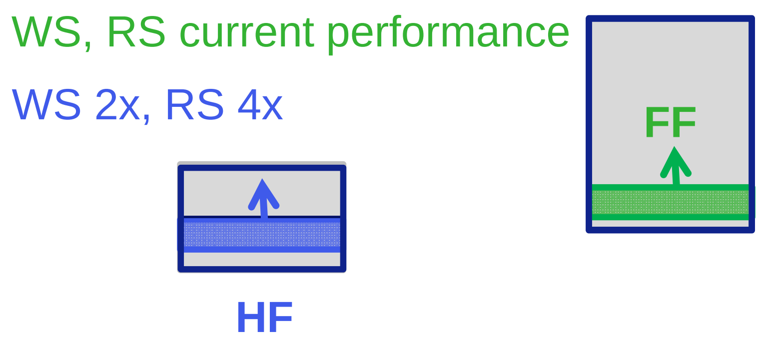
Acceleration of wafer stage ~2x

Acceleration of mask stage ~4x

High-NA Field and Mask Size productivity

500W enables throughput of >150wph with anamorphic HF





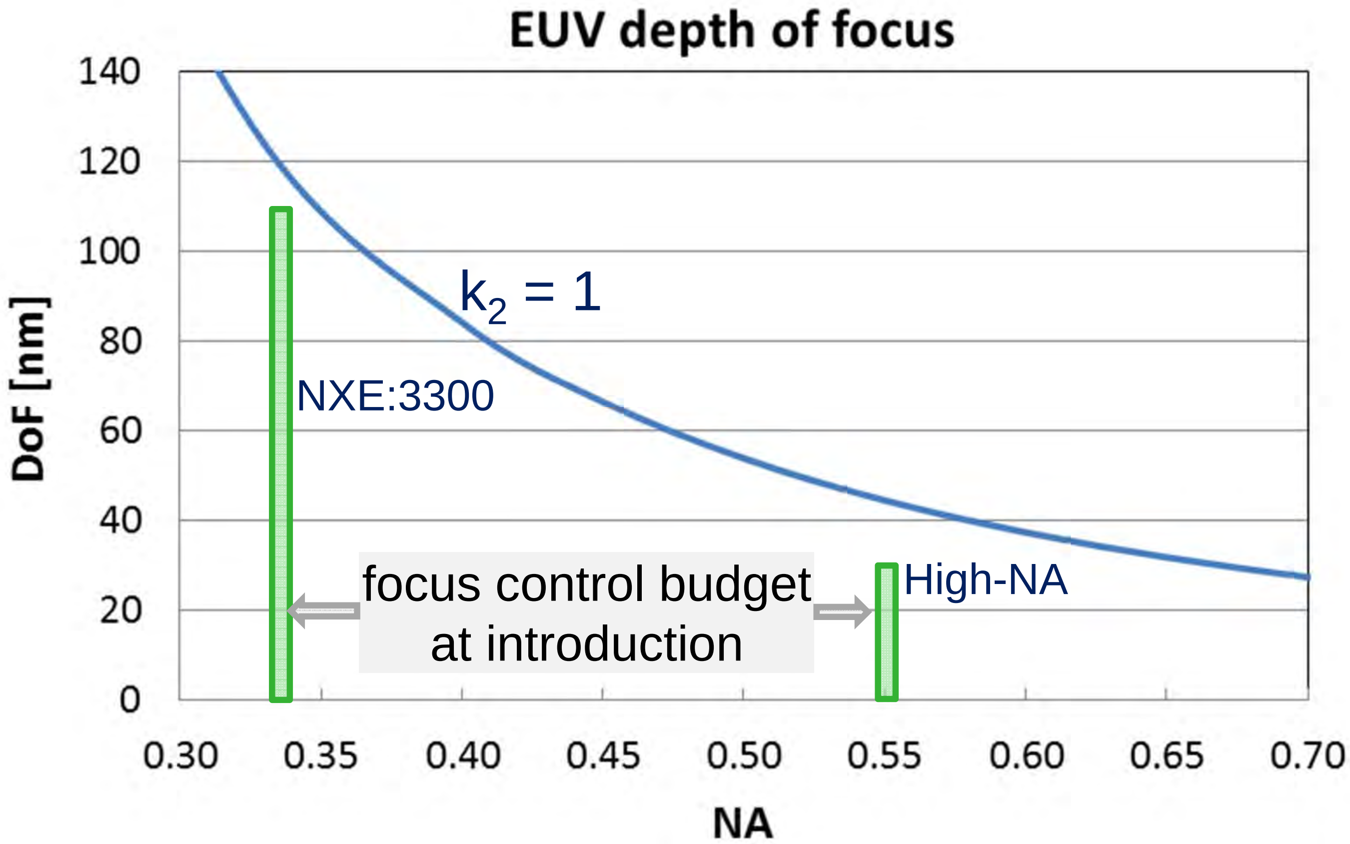
High-NA Half Field scanner needs 500W for 150wph at 60mJ/cm²

High-NA calls for tight focus control

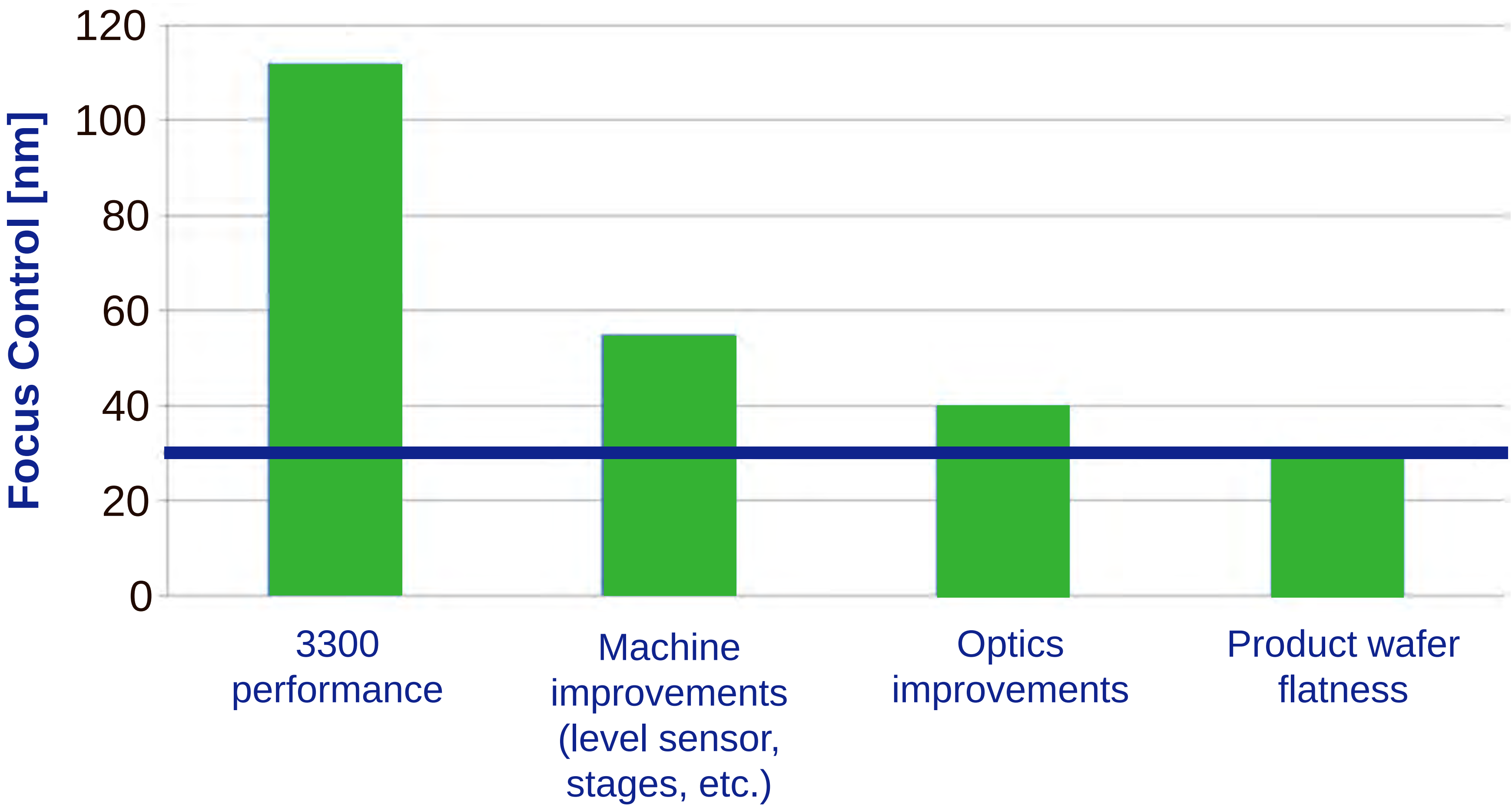
High-NA scanner will be introduced in line with focus scaling

Rayleigh

$$DoF = k_2 \frac{\lambda}{NA^2}$$



Way forward to 30 nm focus control



Summary

EUV into production in 2018-2019

- More than 1,500 wafers per day (WpD) exposed on a NXE:3350B at a customer site on average over three days at 85WpH configuration. Roadmap in place to secure >125WpH
- Best performance is four-week average above 90% on a NXE:3300B system
  - consistency between tools and across sites still needs to be significantly improved
  - Roadmap to >90% availability, with consistent performance, in place
- ASML expects that customers will take EUV into production in 2018-2019 timeframe

High-NA extends Moore's Law into the next decade

- New anamorphic concept enables good imaging with existing mask infrastructure resulting in a Half Field image
- New stages technologies and high transmission optics enables cost effective litho-scaling
- On going feasibility studies support design targets

ASML