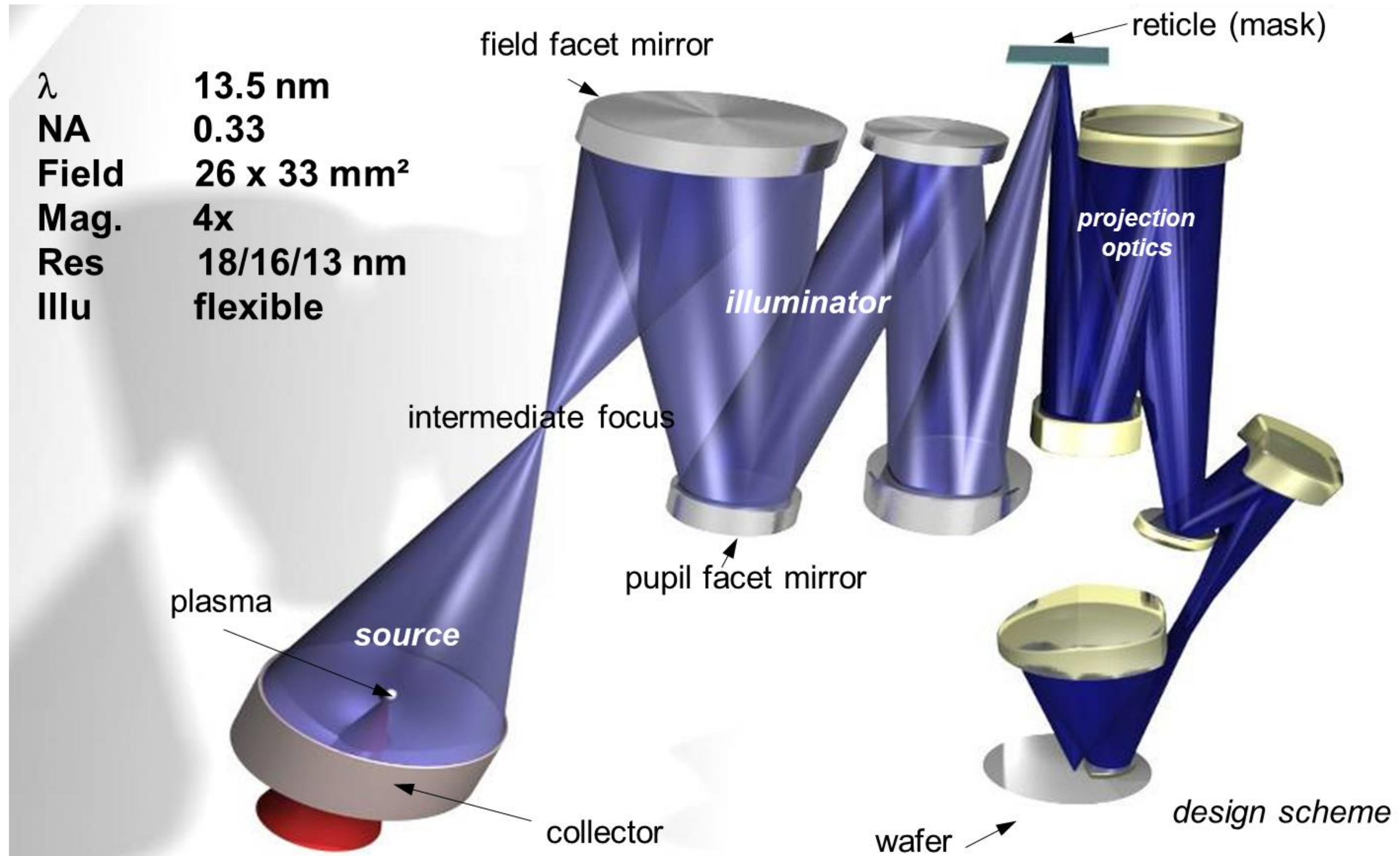
Latest developments in EUV optics

Jack Liddle (Zeiss), Joerg Zimmermann (Zeiss), Jens Timo Neumann (Zeiss),Matthias Roesch (Zeiss), Ralf Gehrke (Zeiss), Bernhard Kneer (Zeiss).

Eelco van Setten (ASML), Jan van Schoot (ASML), Mark van de Kerkhof (ASML)

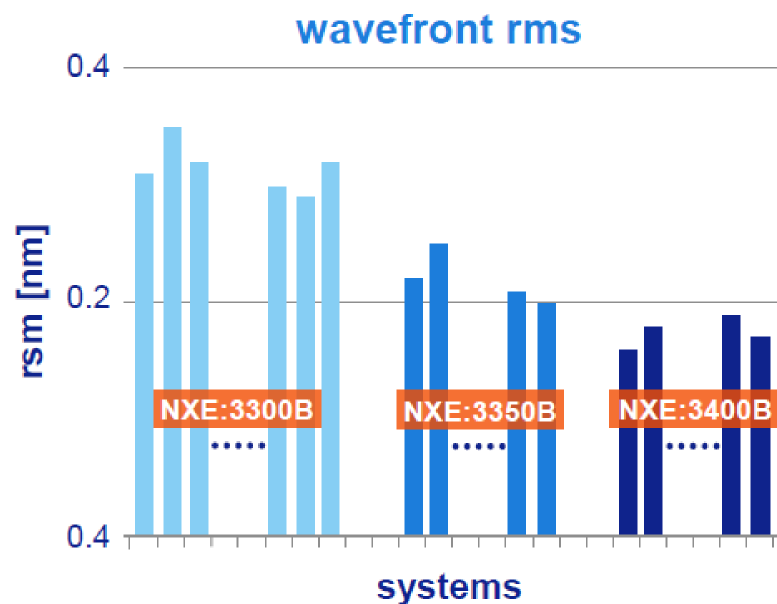
2017-06-15

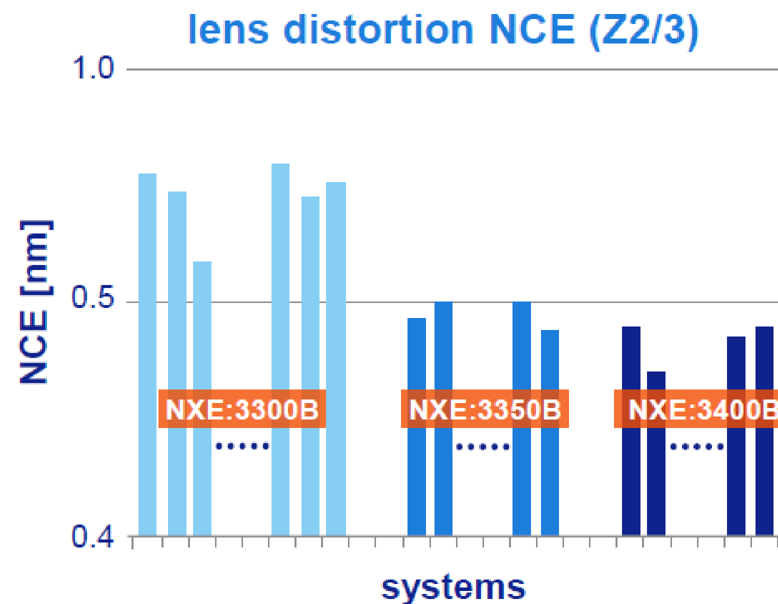
Starlith® 3300/3350/3400 optical train



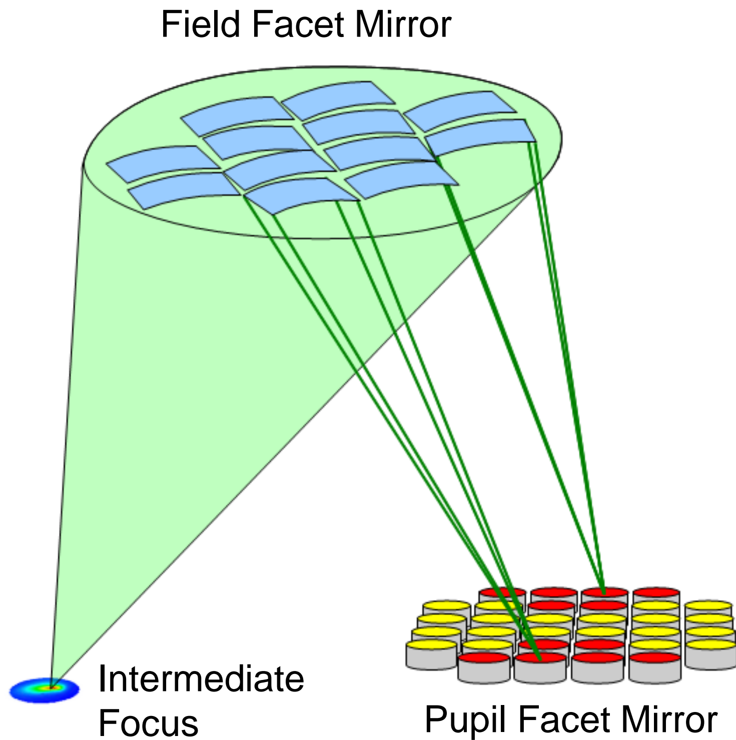
Evolutionary improvements in EUV optics
Enabling 7 nm and 5 nm nodes for imaging, focus and overlay

Population shows wavefront improvements towards NXE:3400

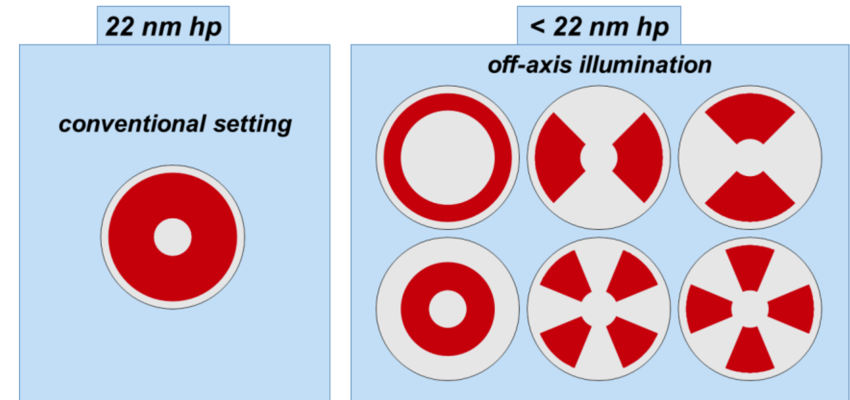




Starlith® 3300 illuminator
Actuated fly's eye unit enables lossless setting changes



Standard pupil shapes



Starlith® 3400 decreases resolution limit

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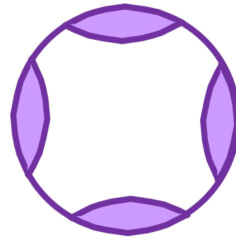
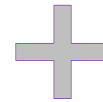
Decrease pupil filling

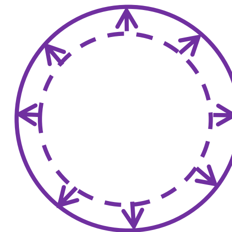
Starlith® 3350
- 2 pupil facets per field facet

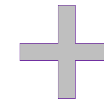
Starlith® 3400
- many pupil facets per field facet

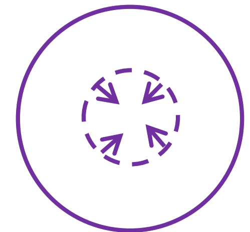




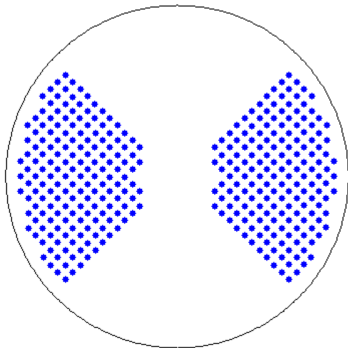
Extend sigma range





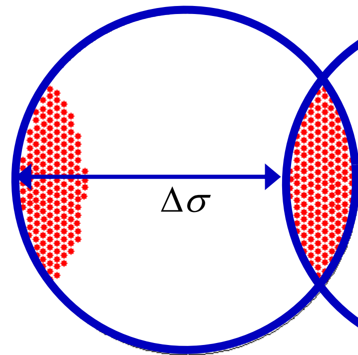


Starlith® 3350

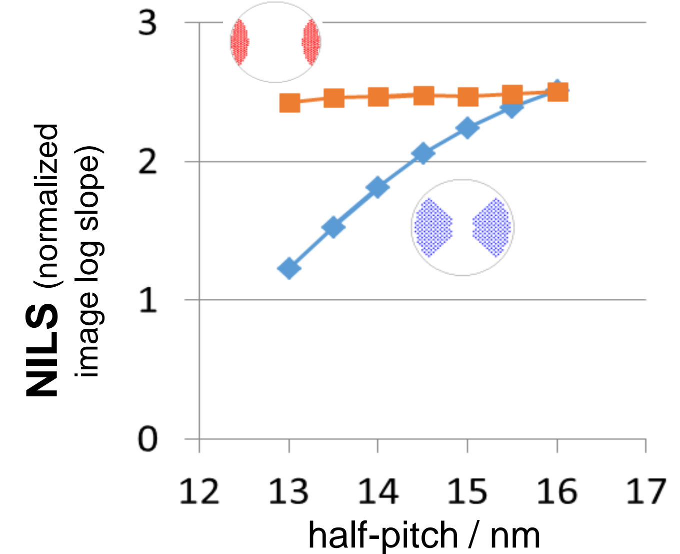


≈ 40% pupil fill ratio

Starlith® 3400



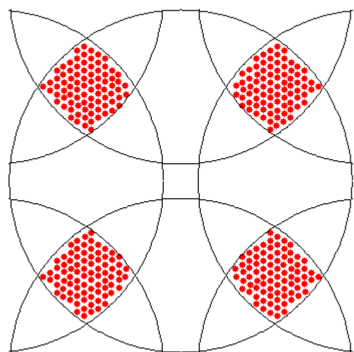
≈ 20% pupil fill ratio



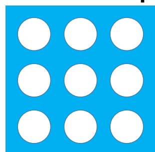
13 nm resolution at full throughput

New application specific pupil types

Quasar

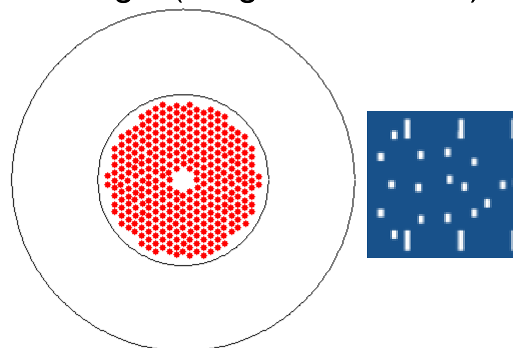


Contact Hole array
18 nm half-pitch

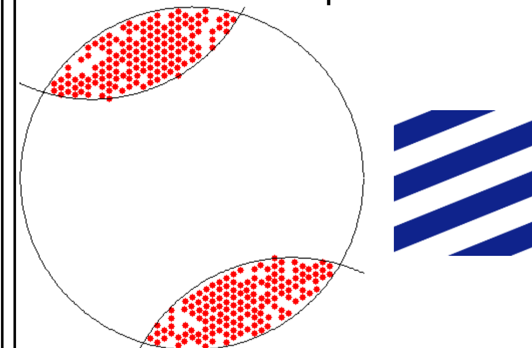


H&V Lines&Spaces
18 nm half-pitch

Small conventional
Logic (irregular contacts)

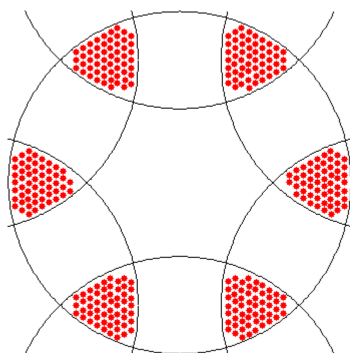


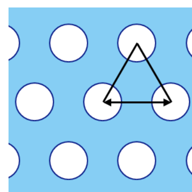
Rotated Dipoles 22°
13 nm hp SE

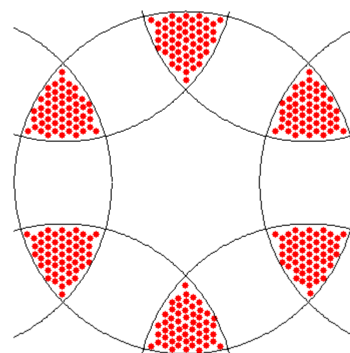


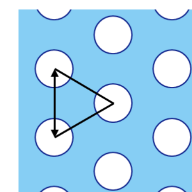
for DRAM active area

Hexapoles
for DRAM storage node (hexagonal contact hole array)
16.5 nm half-pitch Single Exposure

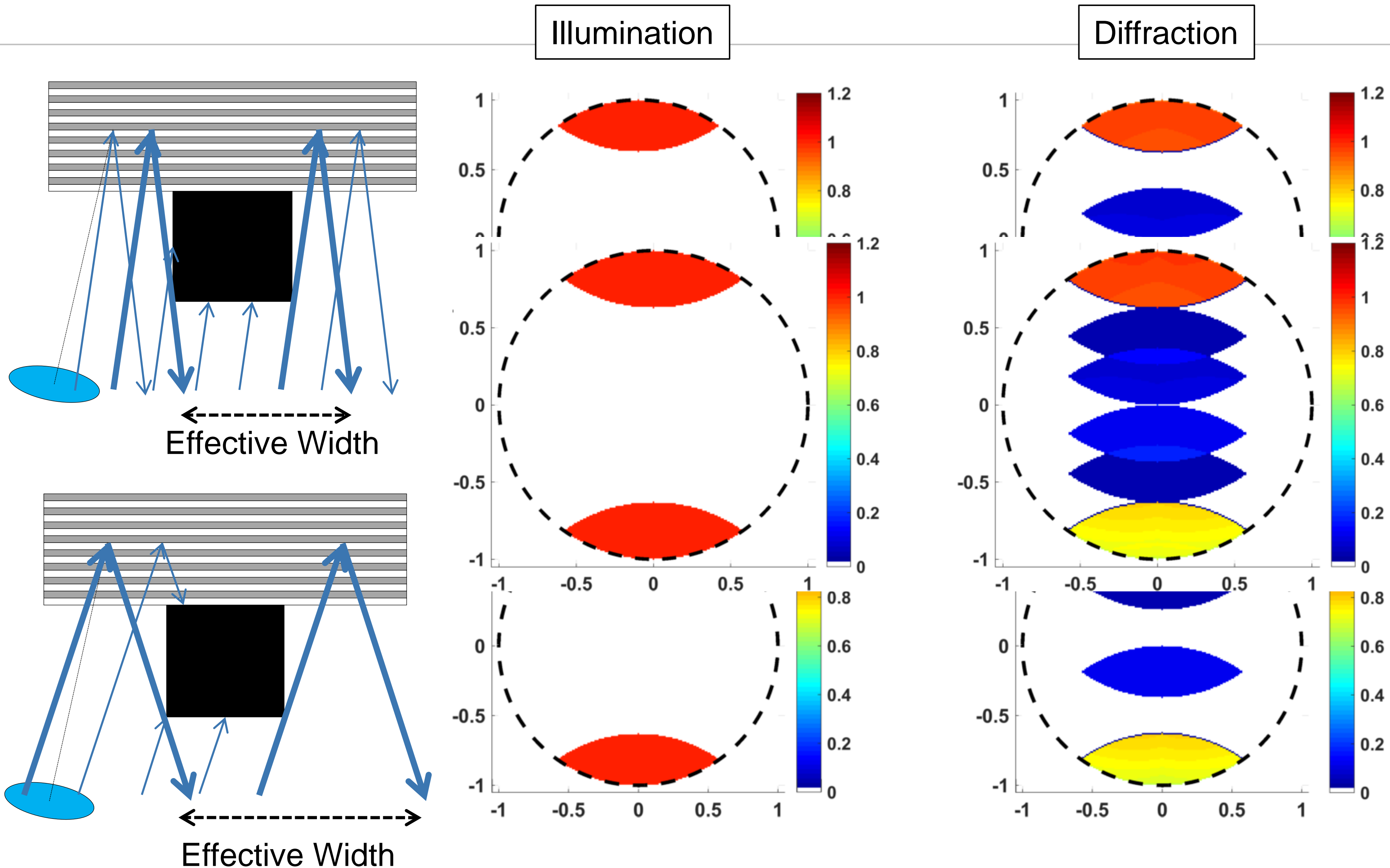








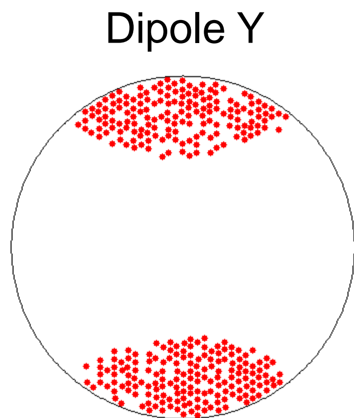
3D mask induced pattern shift through focus
Origins

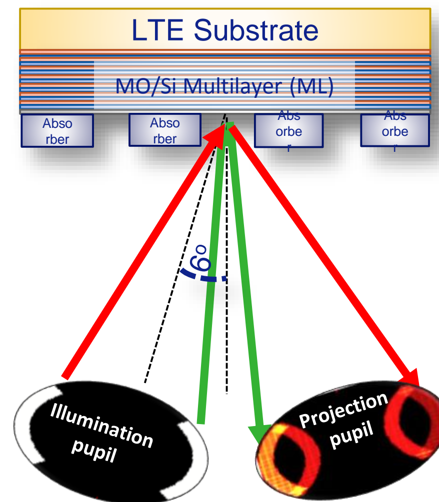


3D mask induced pattern shift through focus
Consequences

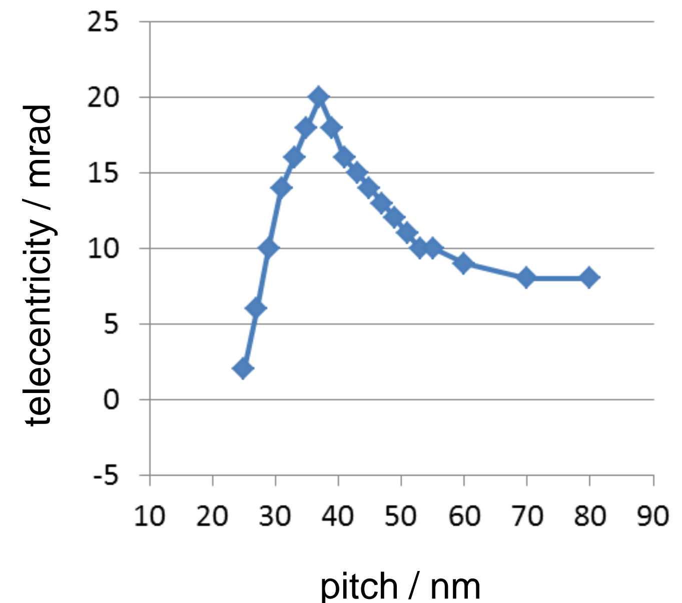
Due to oblique incidence on mask,
3D mask effect can induce imaging telecentricity
(placement error divided by defocus)

Dipole Y





Pattern shift through focus



Pupil tuning can compensate for 3D mask induced pattern shift through focus

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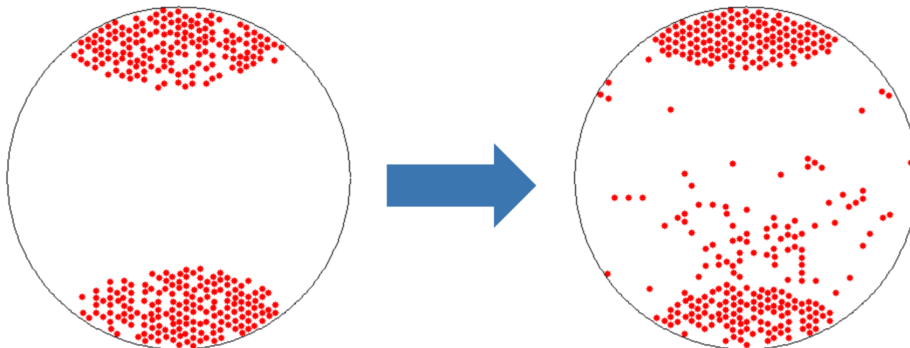
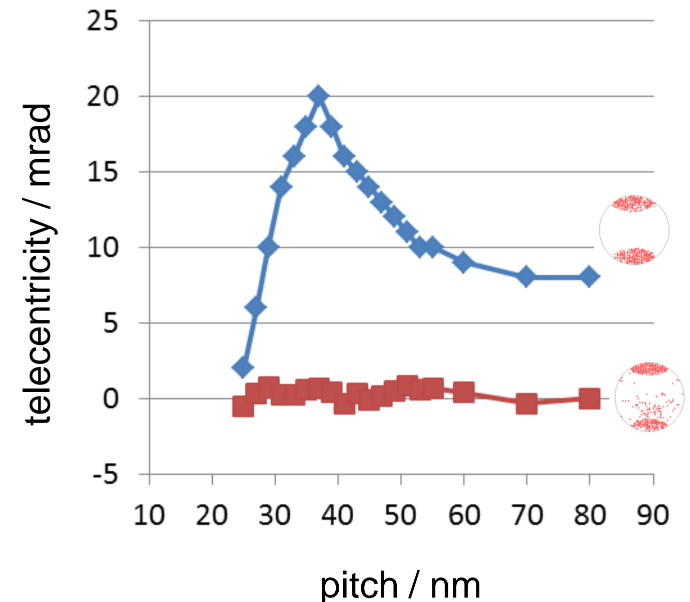
Adjust the pupil (induce a pupil imbalance) to compensate for the 3D mask induced telecentricity through pitch (while maintaining the proximity behavior)

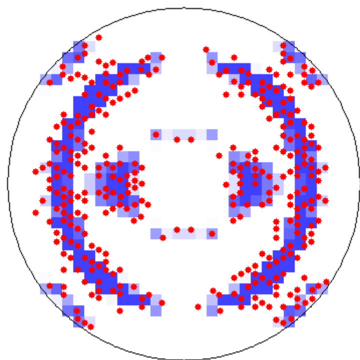




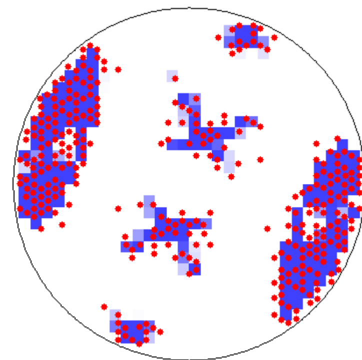
Freeform pupil shapes

ZEISS

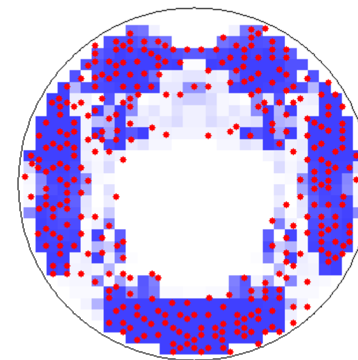
SMO pupil
for logic cut mask



rotated pupil shape
for DRAM brickwalls



y-asymmetric
3D mask compensation



target shape

EUV pupil

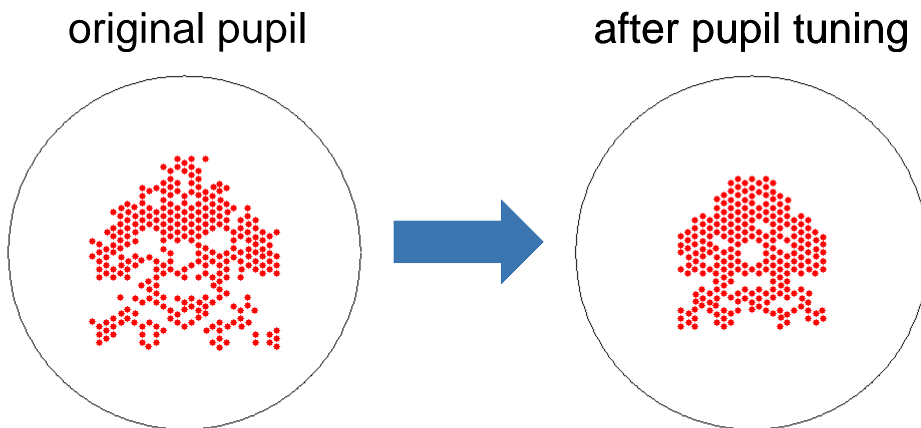
all examples without light loss (100% illuminator efficiency) on Starlith® 3400 illumination system

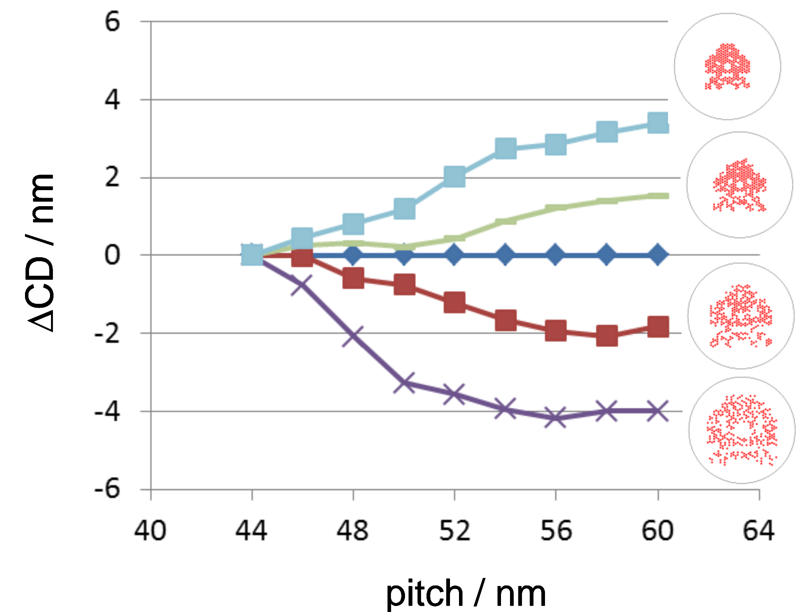
Pupil tuning can adjust proximity bias

ASML ZEISS

After mask tape-out, tweek the process to adjust the proximity curve, i.e. iso-dense bias?

→ adjust the pupil by switching a few pupil spots





NXE:3400 ready for 5nm logic
Full-wafer CDU 0.2nm

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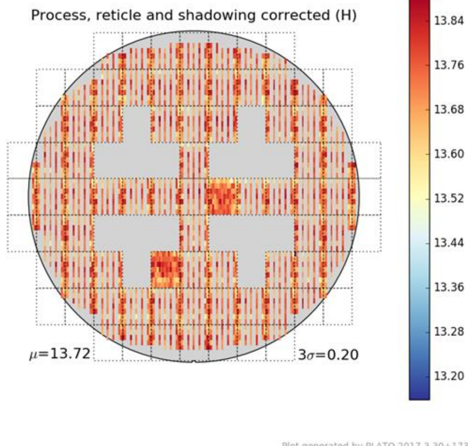
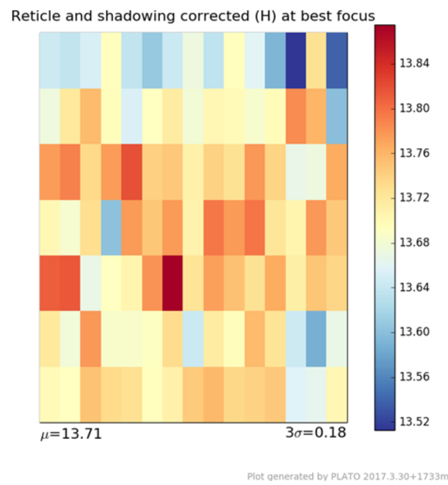
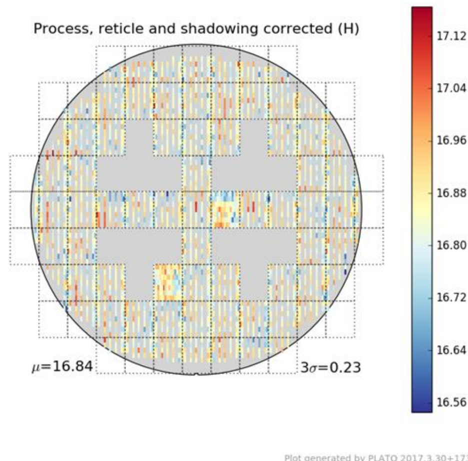
Full wafer plot (H) | Intrafield plot (H)

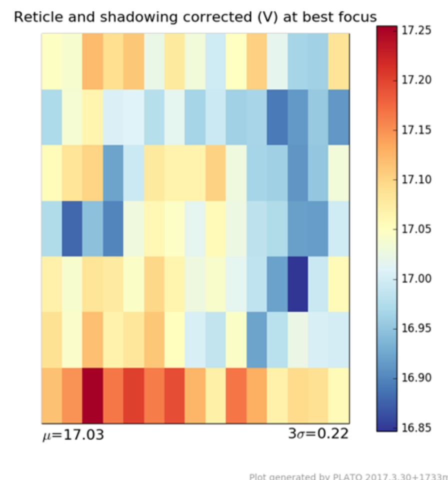
13m dense lines





16m isolines





Imaging 16nm isolated spaces CDU - H		
Test item	**Unit**	**Actual**
Full wafer at nominal focus	nm	**0.2**
Intrafield at best focus	nm	**0.2**
Intrafield at ±30 nm off focus	nm	**0.2**

Imaging 16nm isolated spaces CDU - H		
Test item	**Unit**	**Actual**
Full wafer at nominal focus	nm	**0.2**
Intrafield at best focus	nm	**0.2**
Intrafield at ±30 nm off focus	nm	**0.3**

Imaging 16nm isolated spaces CDU - V		
Test item	**Unit**	**Actual**
Full wafer at nominal focus	nm	**0.3**
Intrafield at best focus	nm	**0.2**
Intrafield at ±30 nm off focus	nm	**0.3**

NXE:3400 illuminator gives proven LCDU gains

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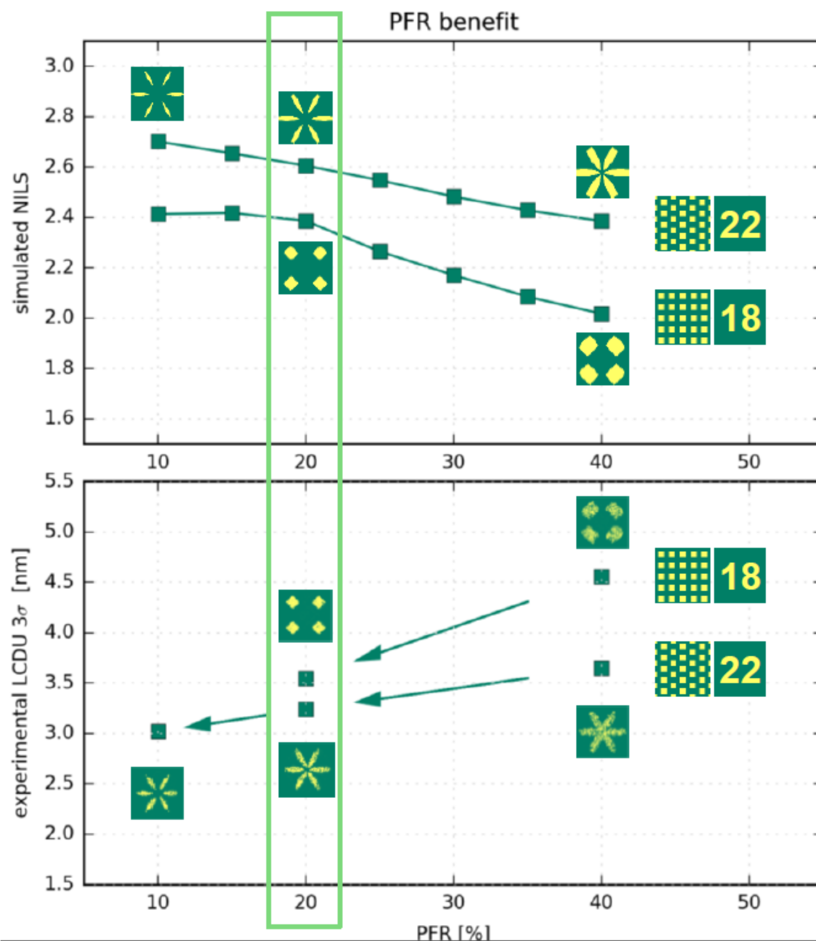

- Reduced PFR translates in improved contrast and LCDU, (without loss of light down to 20% PFR)

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Looking to the future…
High-NA anamorphic systems

High NA EUV

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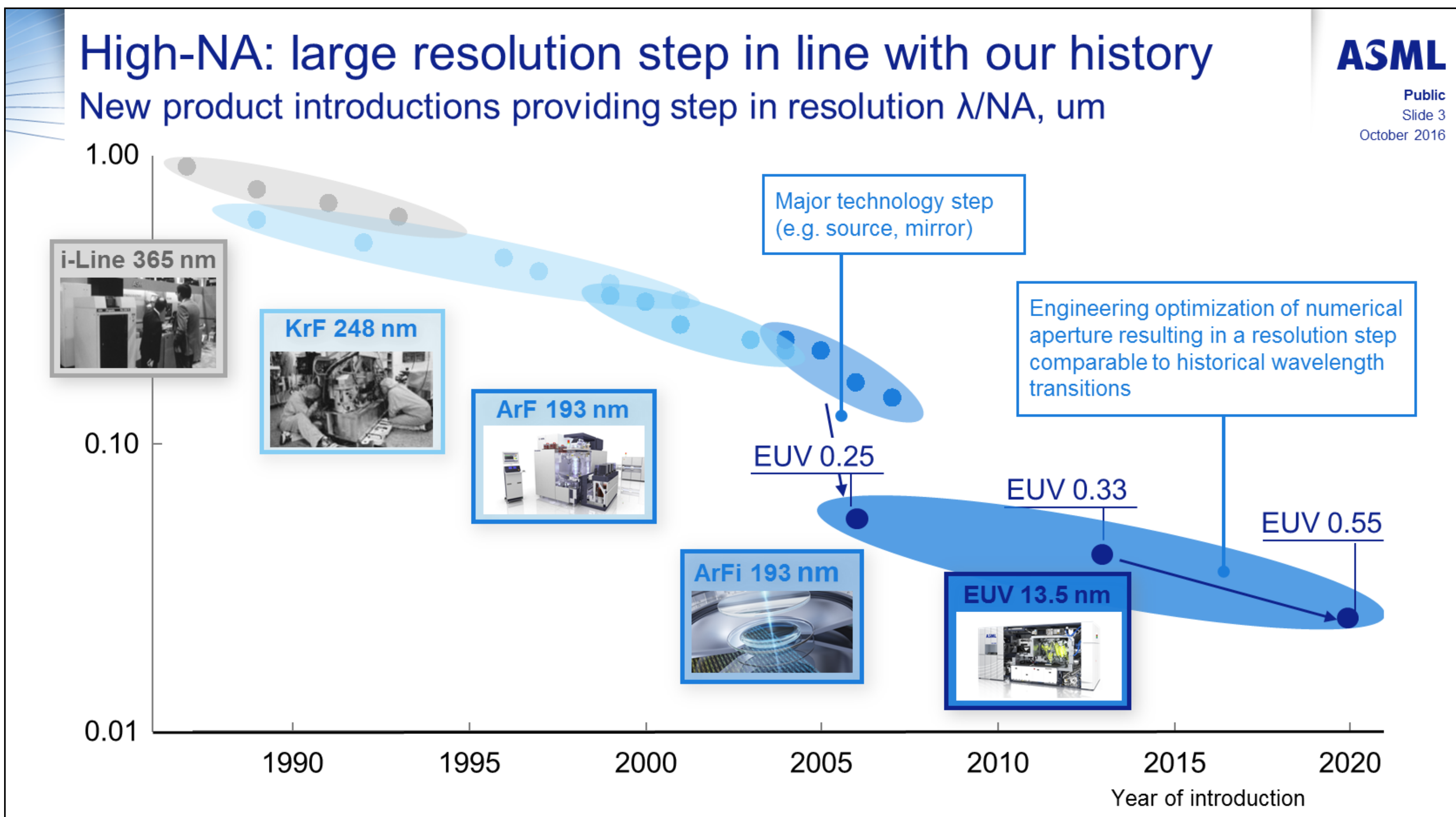
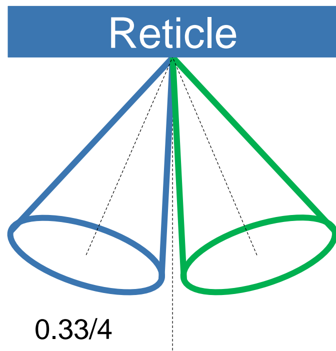
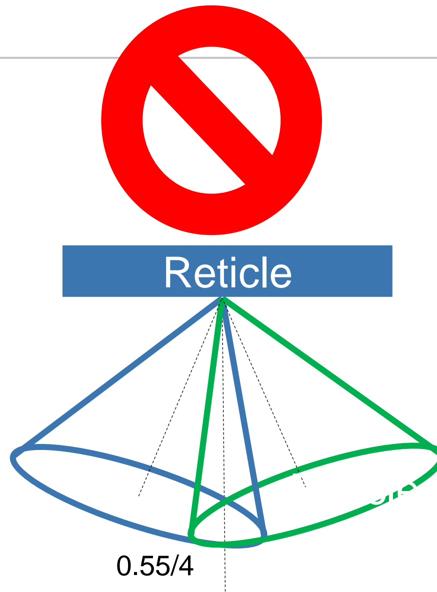


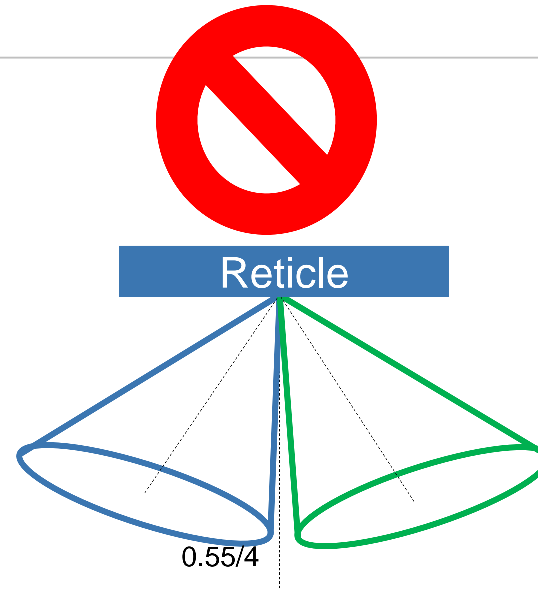
EUVL 2016, “EUV roadmap extension by higher Numerical Aperture”, Jan van Schoot

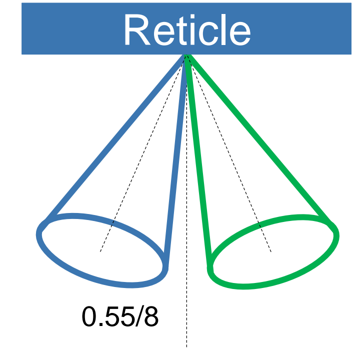
Why anamorphic?

Separate light cones while preserving the angles on the mask

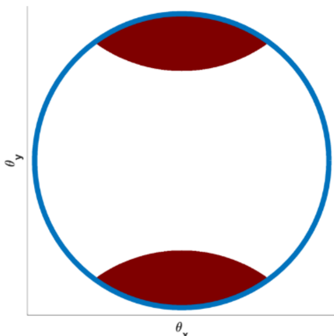


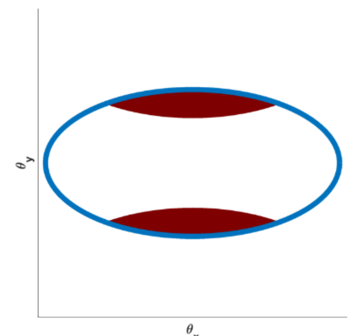






NA 0.33 4x4 Isomorphic CRA ~ 6°	NA 0.55 4x4 Isomorphic CRA ~ 6°	NA 0.55 4x4 Isomorphic CRA > 6°	NA 0.55 4x8 Anamorphic CRA ~ 6°





Why is there an obscuration?
Limiting angle on the mirror

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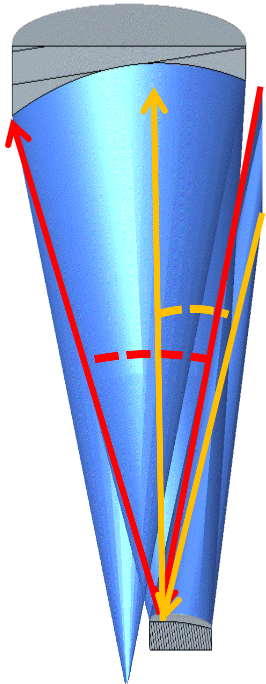
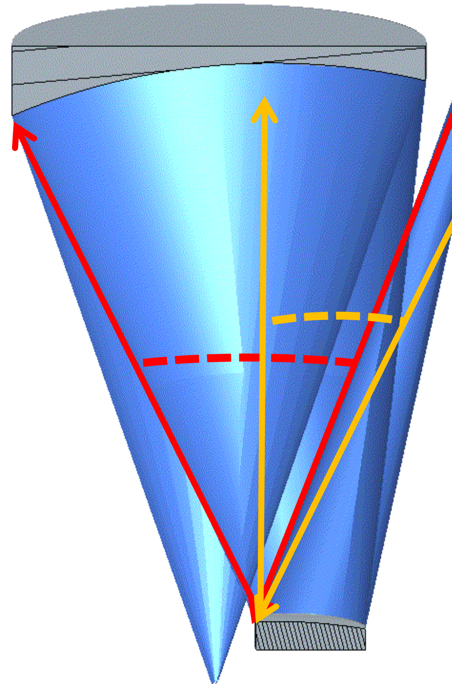
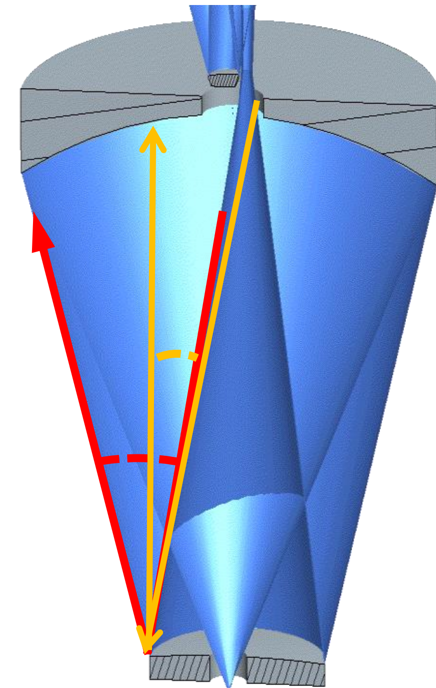
Medium NA



High-NA



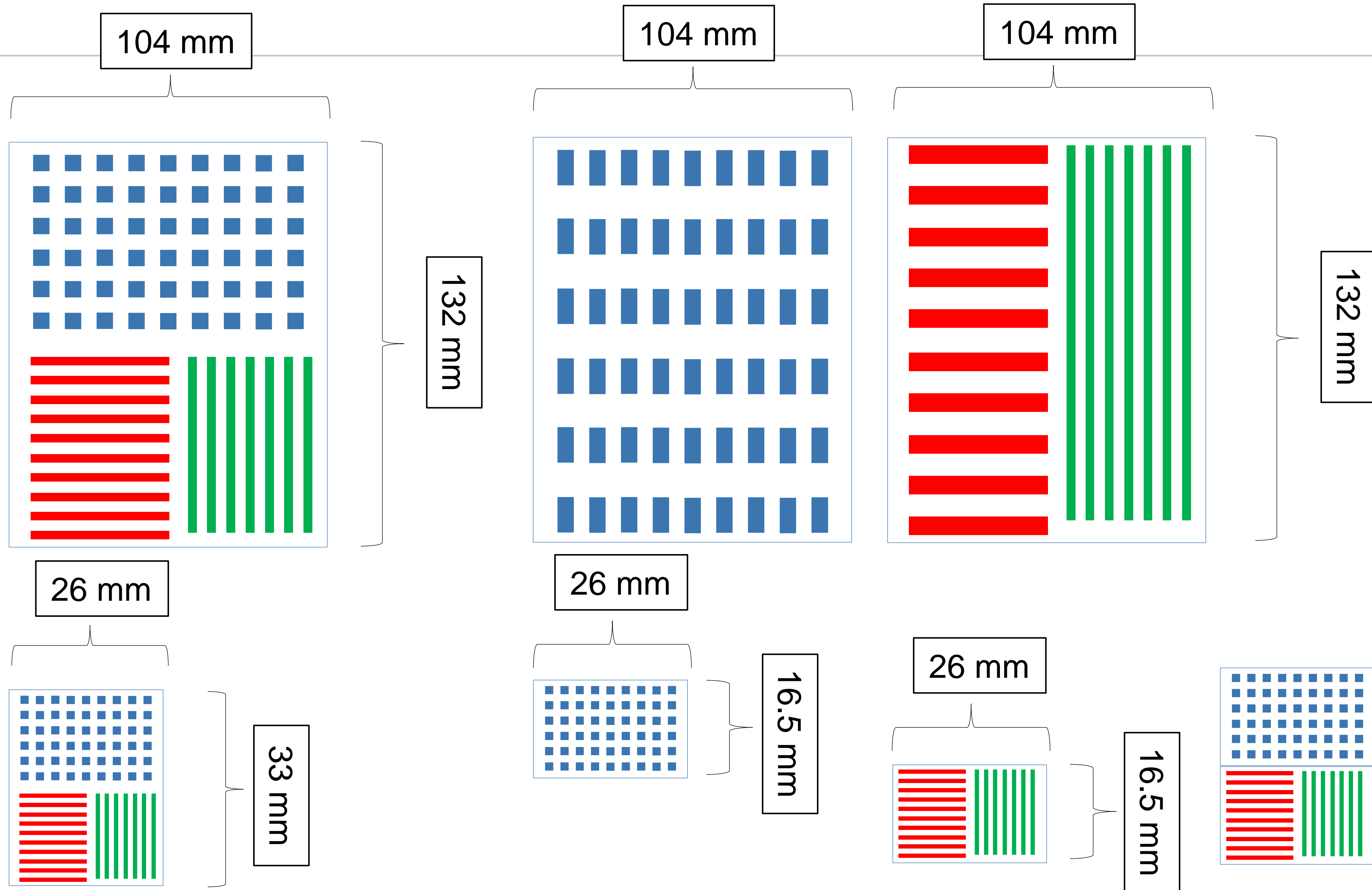
High-NA With obscuration



Standard EUV coatings are not able to reflect the combination of large angles and large angular spread needed for high-NA.

Anamorphic imaging

Prints a half-field using a current 6 inch mask



Imaging evaluation of key lithographic structures:

Comparable performance as 0.33 NA at ~40% lower resolution

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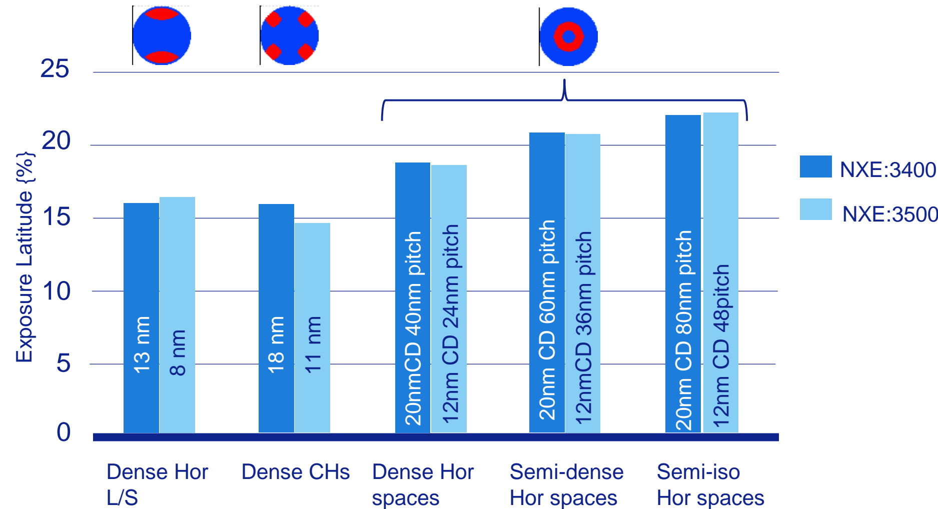
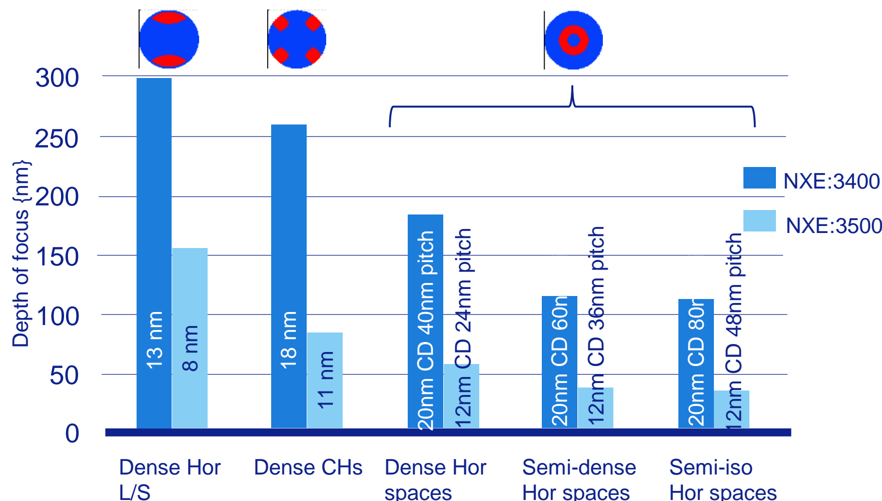


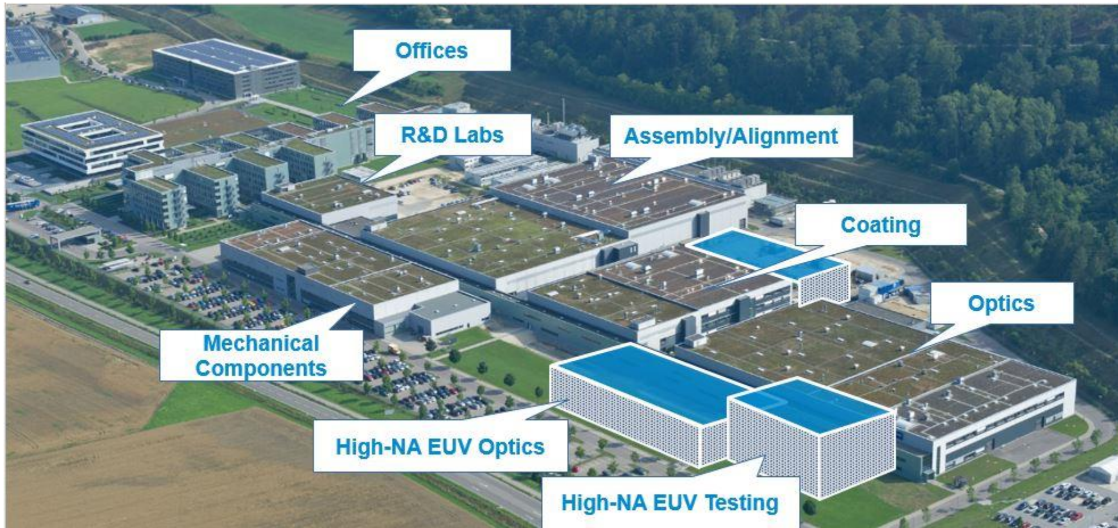
Comparable Exposure Latitude at 40% lower resolution



DOF at equivalent k1 factor

Follows NA scaling → $\left(\frac{0.33}{0.55}\right)^2$

Infrastructure currently under construction by Zeiss



Lead time critical components on order

ASML ZEISS

Conclusions

ZEISS

Starlith 3400

- Better POB
- Flexibility in illuminator
- Improved imaging
- Ready for 7nm and 5nm nodes

High-NA Anamorphic

- Novel design concept
- Anamorphic design. Limits incident angles on mask, enables high contrast
- Obscuration. Limits incident angles on mirrors, enables higher tranmission.
- Infrastructure currently under construction

ZEISS