EUREKA: A Industry EUV Research Center at LBNL

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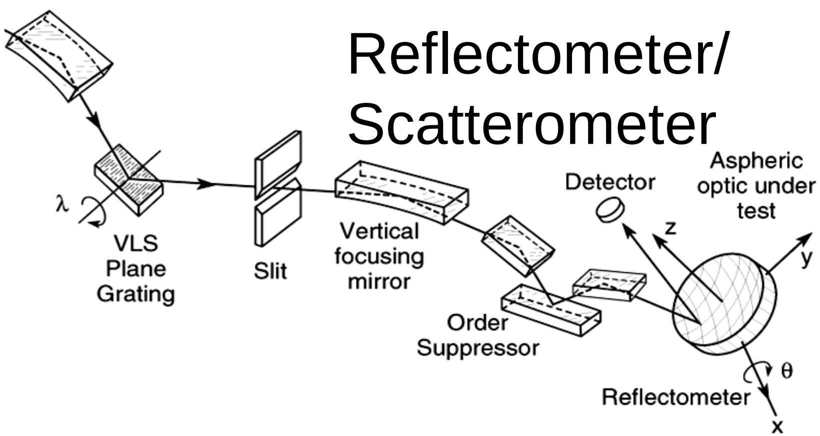
Outline

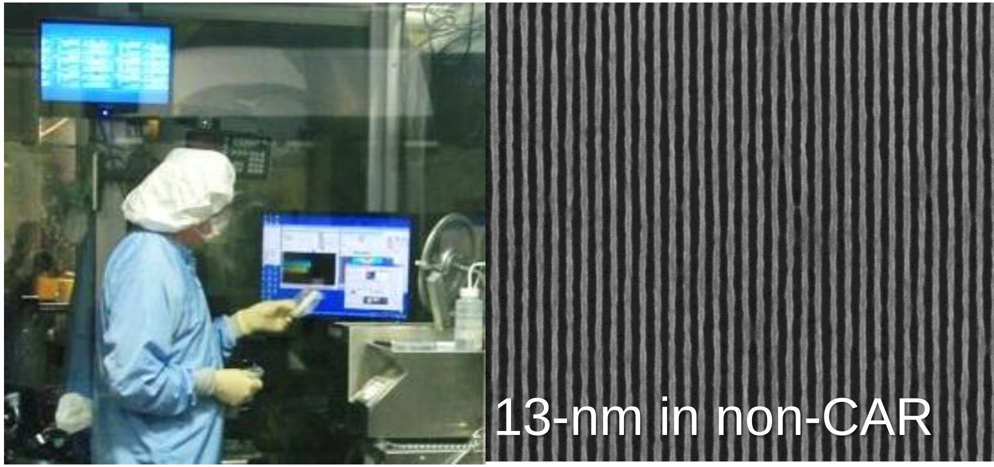
- Reflectometry
- Mask review: SHARP
- 0.3-NA MicroExposure: MET3
- 0.5-NA MicroExposure: MET5
- Other

Cornerstone tools

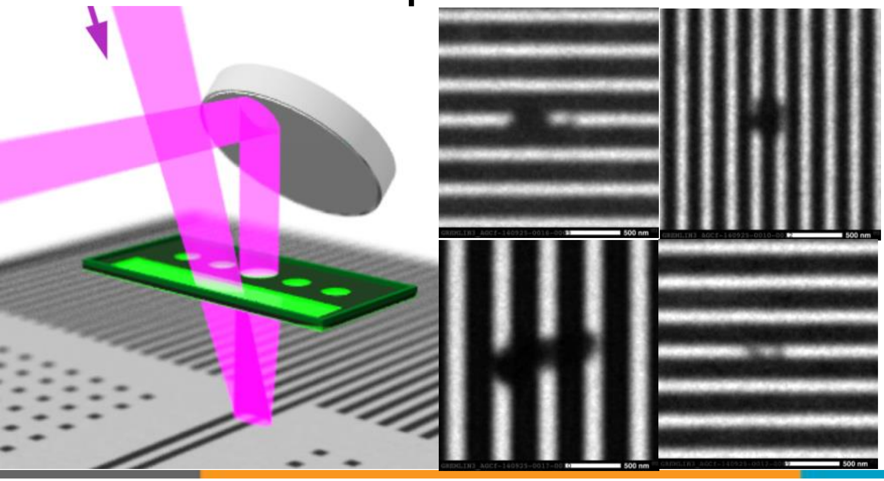
Reflectometer/ Scatterometer



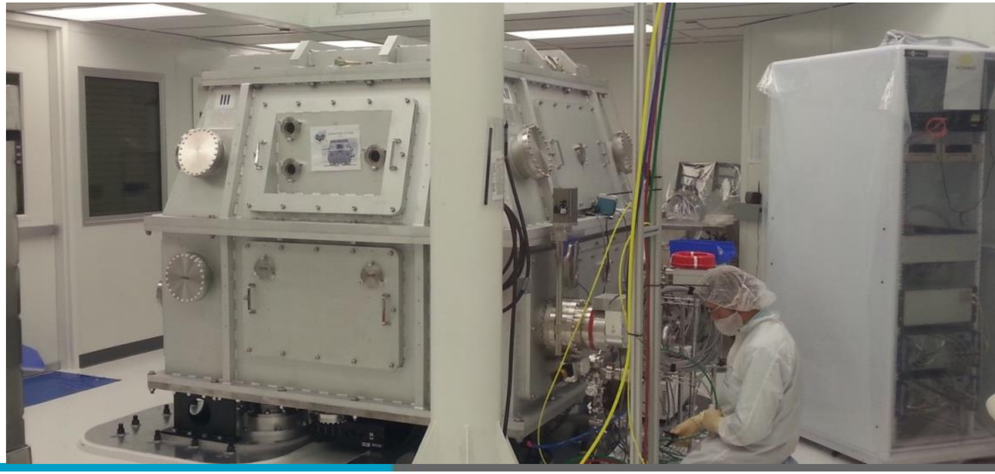
0.3-NA Litho



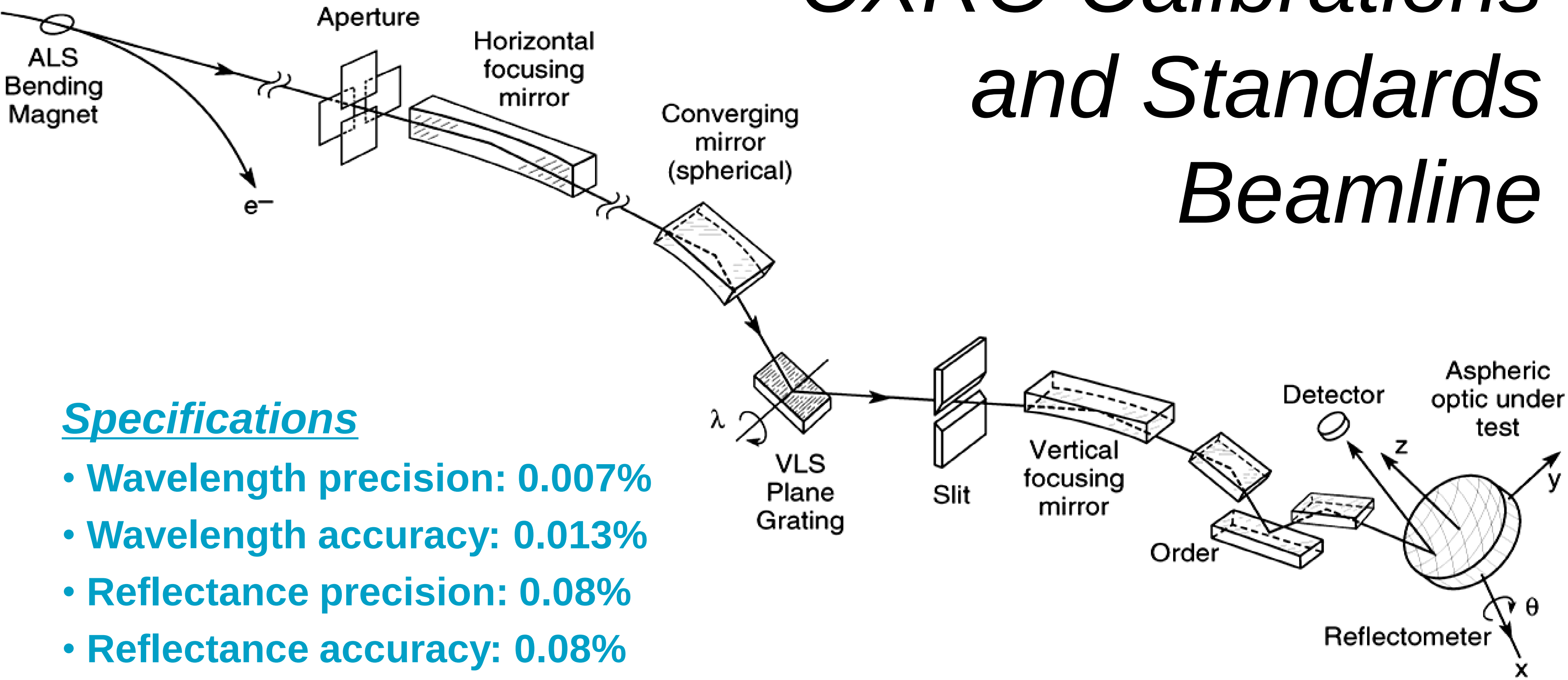
EUV AIMS up to 0.6 NA



0.5-NA Litho coming soon



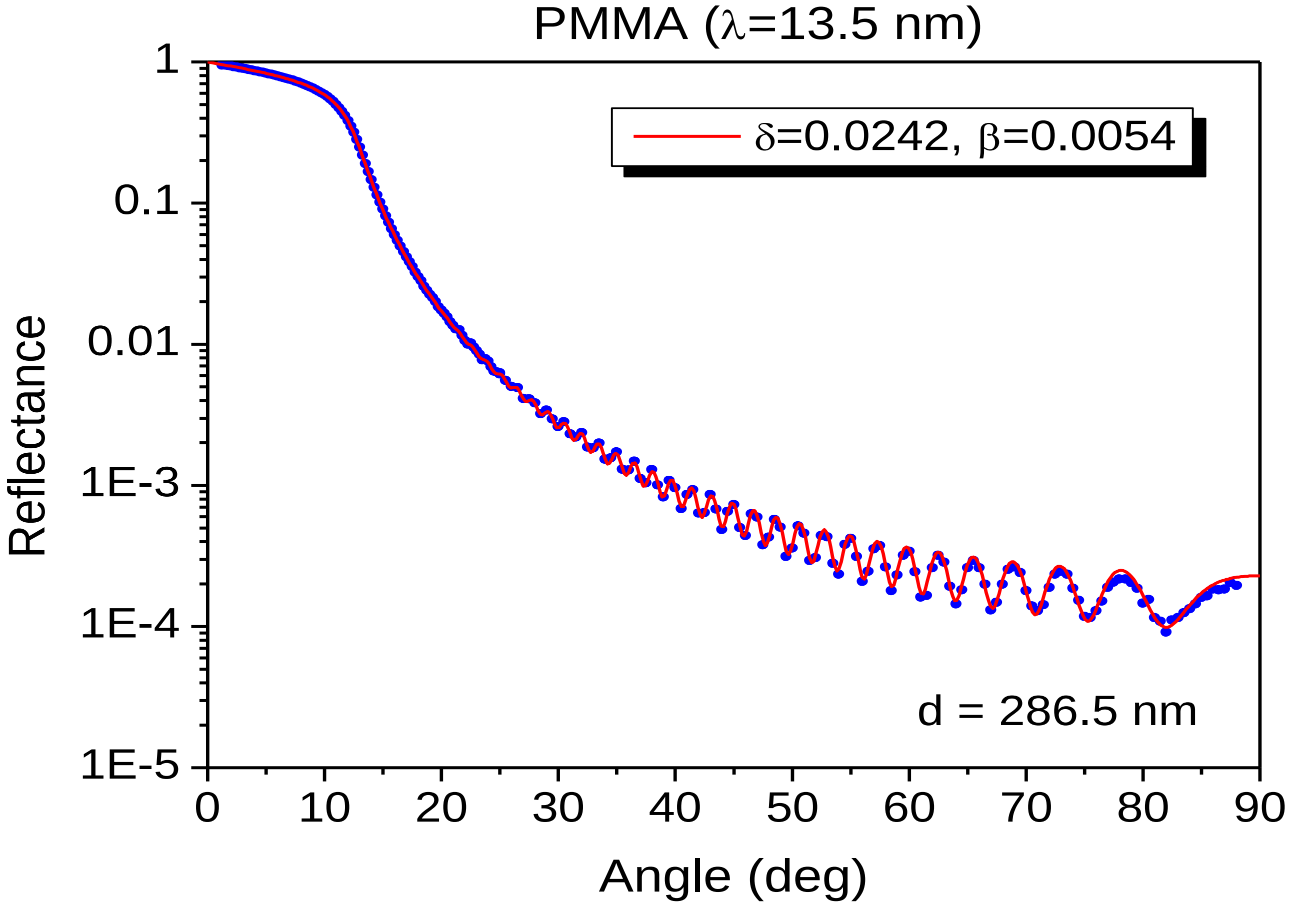
CXRO Calibrations and Standards Beamline



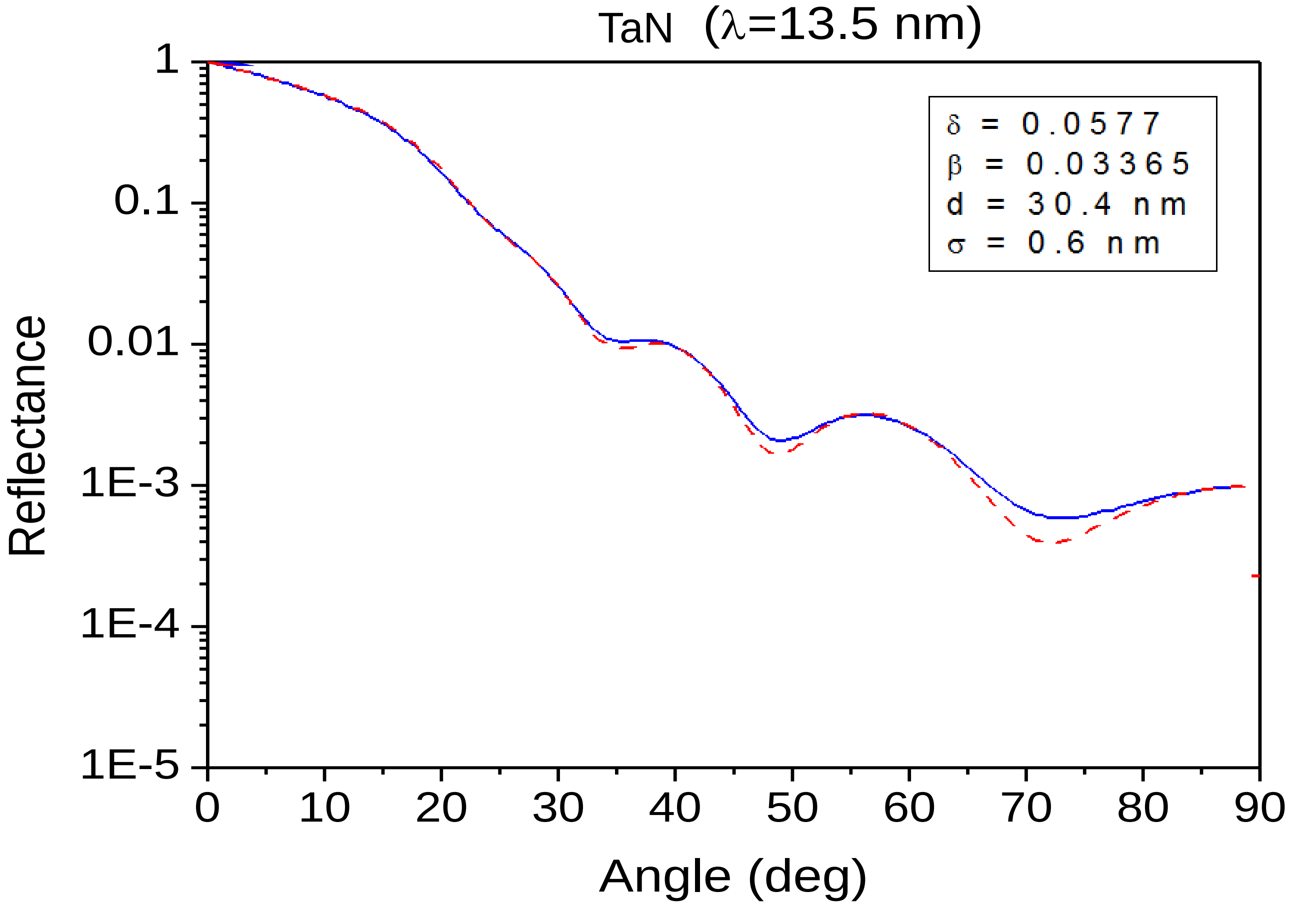
Specifications

- **Wavelength precision: 0.007%**
- **Wavelength accuracy: 0.013%**
- **Reflectance precision: 0.08%**
- **Reflectance accuracy: 0.08%**
- **Spectral purity: 99.98%**
- **Dynamic range: 10^{10}**

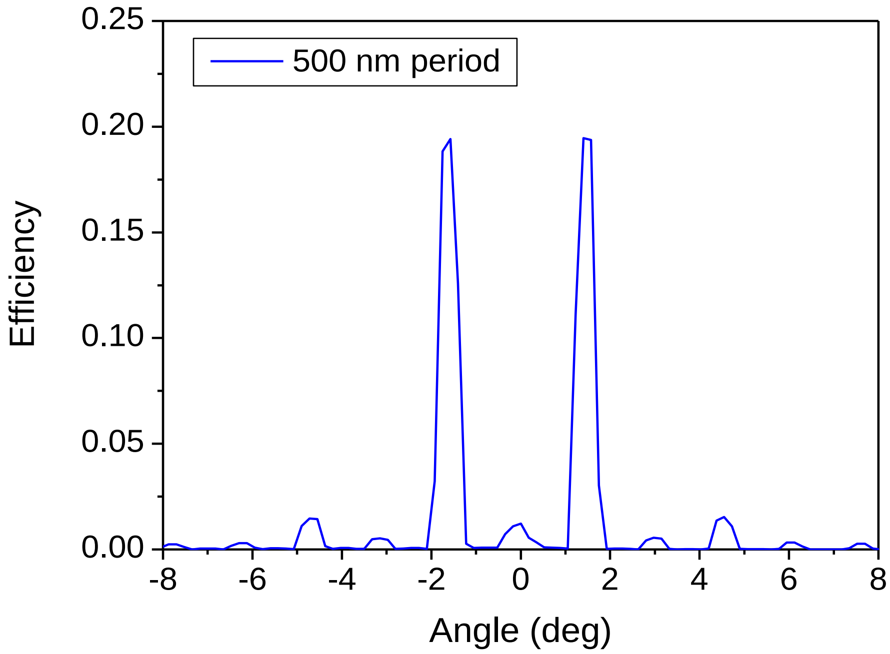
High accuracy measurements of optical constants of EUV resist and mask materials

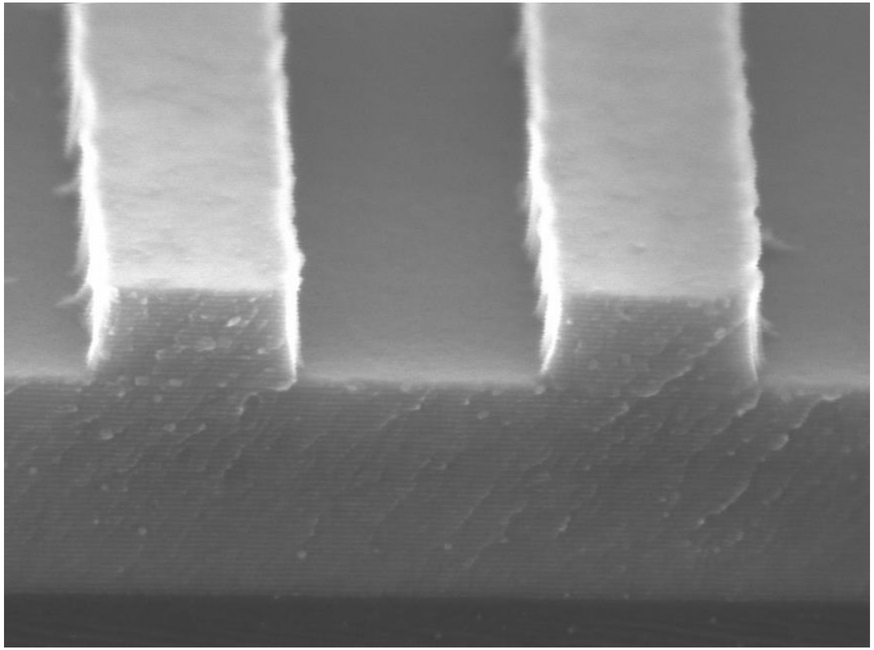


High accuracy measurements of optical constants of EUV resist and mask materials



Diffraction characterization of EUV masks

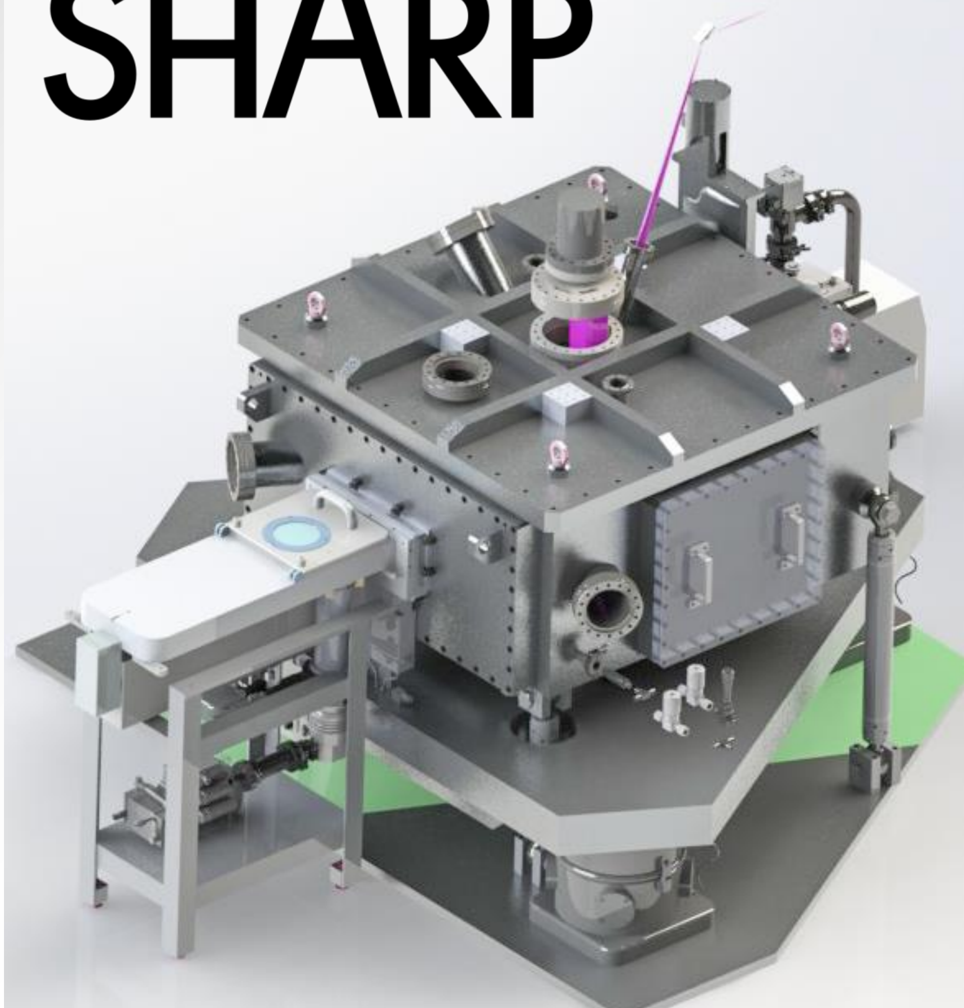




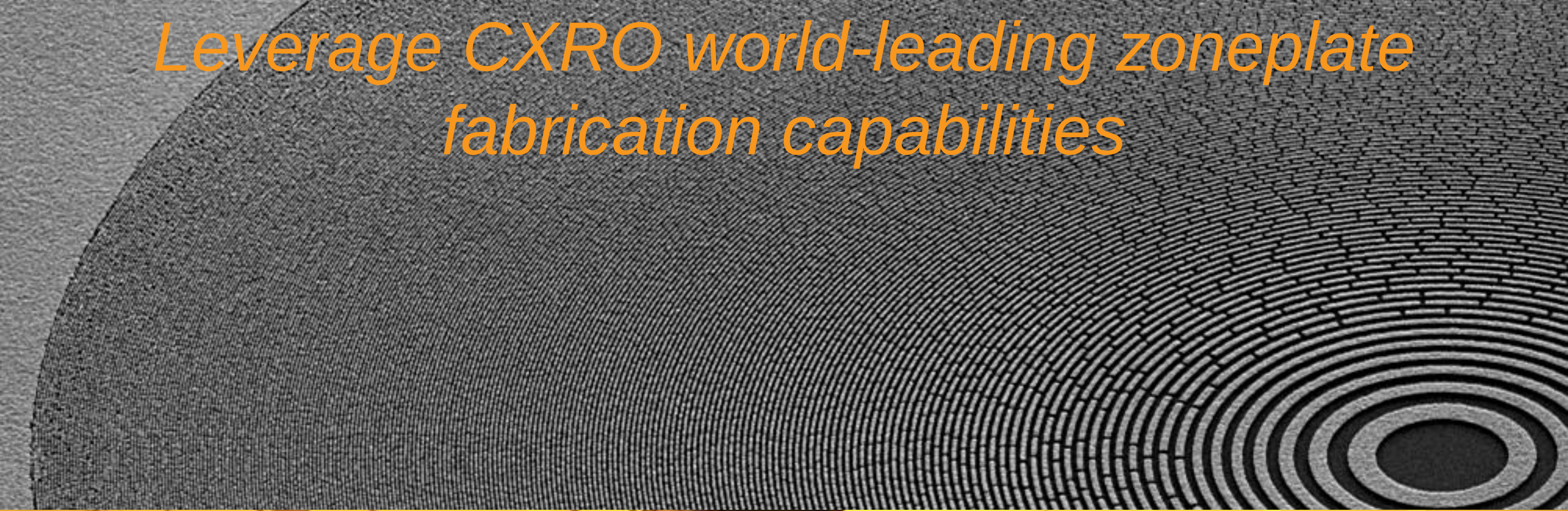
EUV High NA review tool

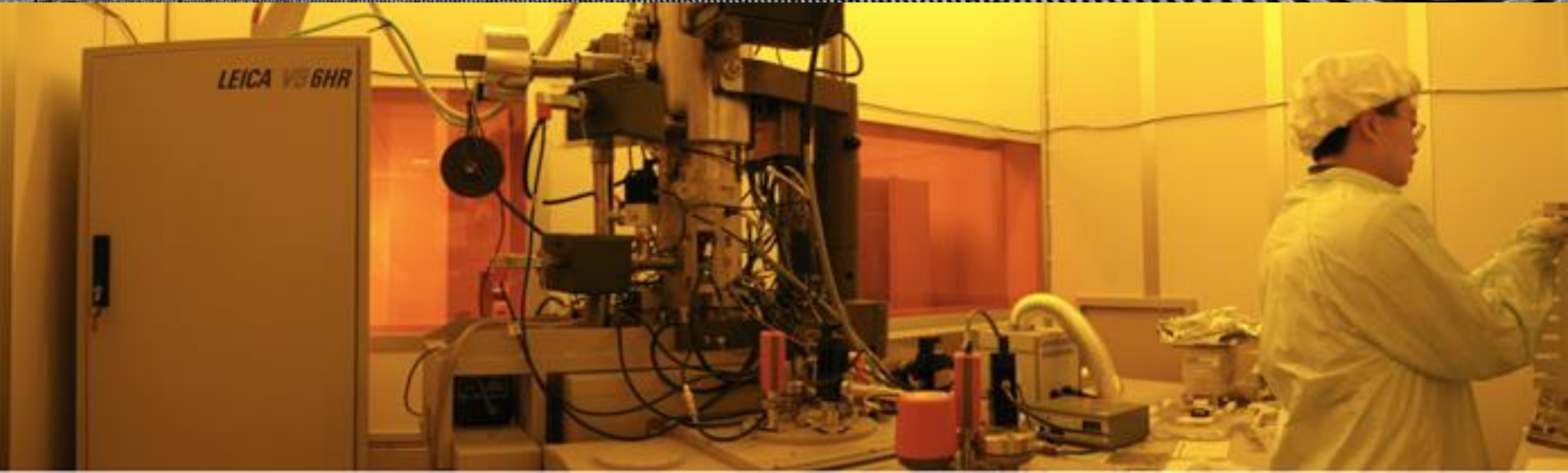
SHARP

- **Optics:**
  Zoneplate-lenses
- **Effective NA:**
  0.250–0.625
- **Coherence:**
  Programmable
- **Magnification:**
  Variable
- **Imaging modes:**
  Bright, Dark, Zernike phase, DIC …

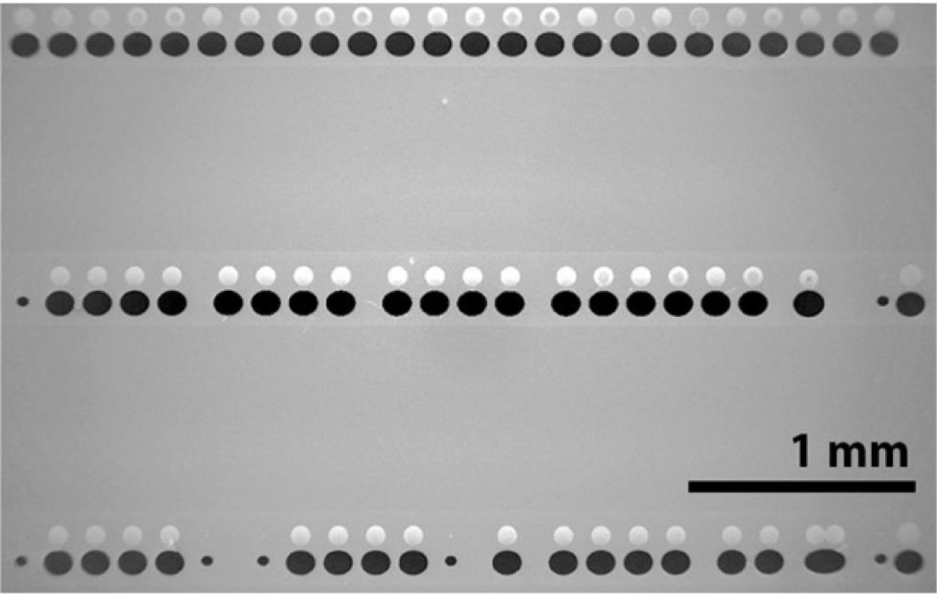


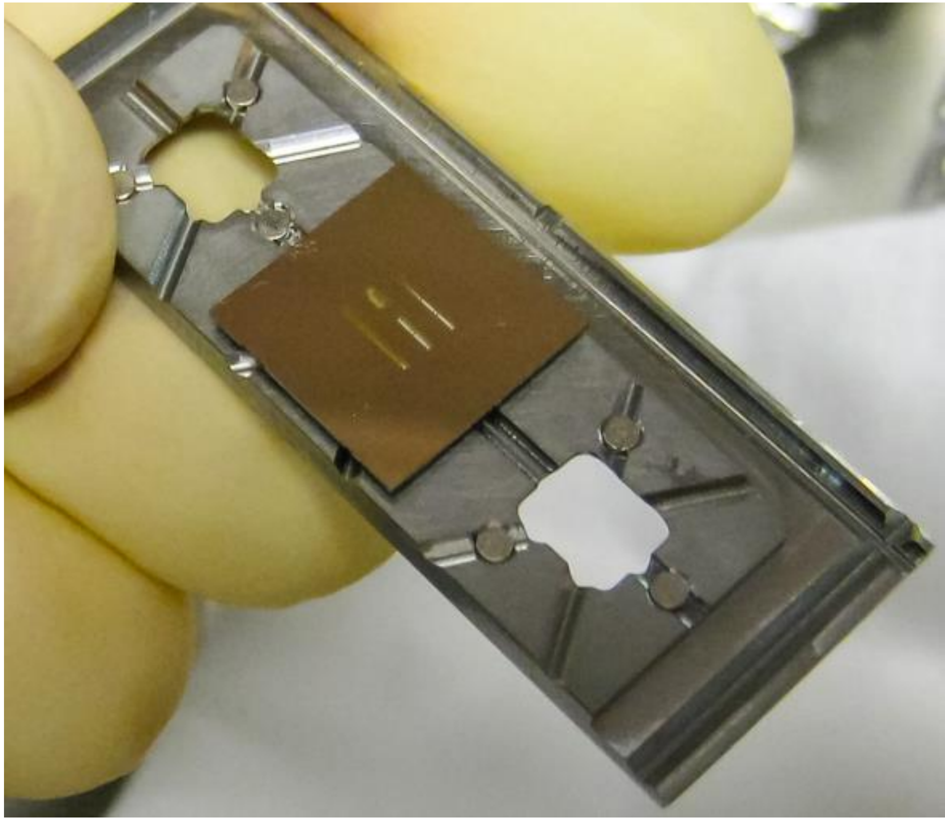
Leverage CXRO world-leading zoneplate fabrication capabilities





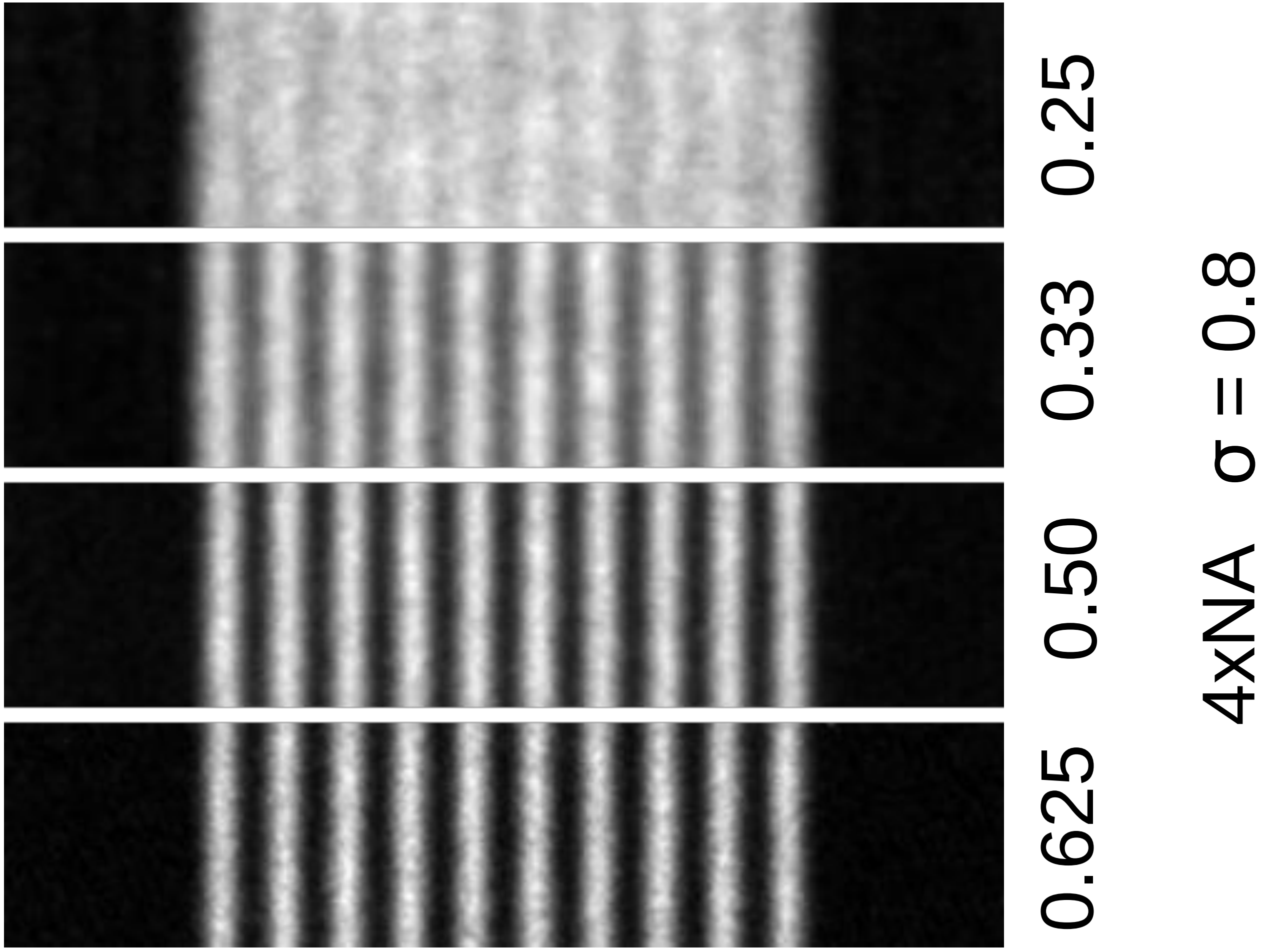
Select between hundreds of lenses on the fly





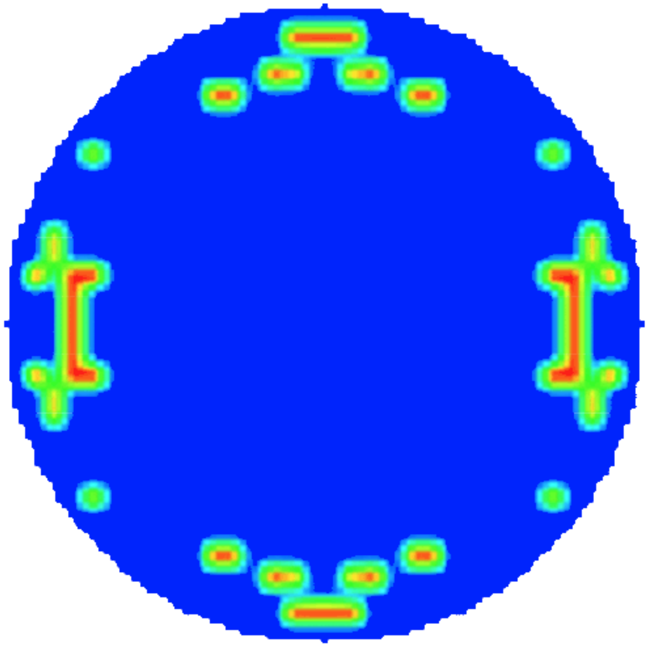
0.625 effective NA demonstrated

16-nm code lines (64-nm on mask)

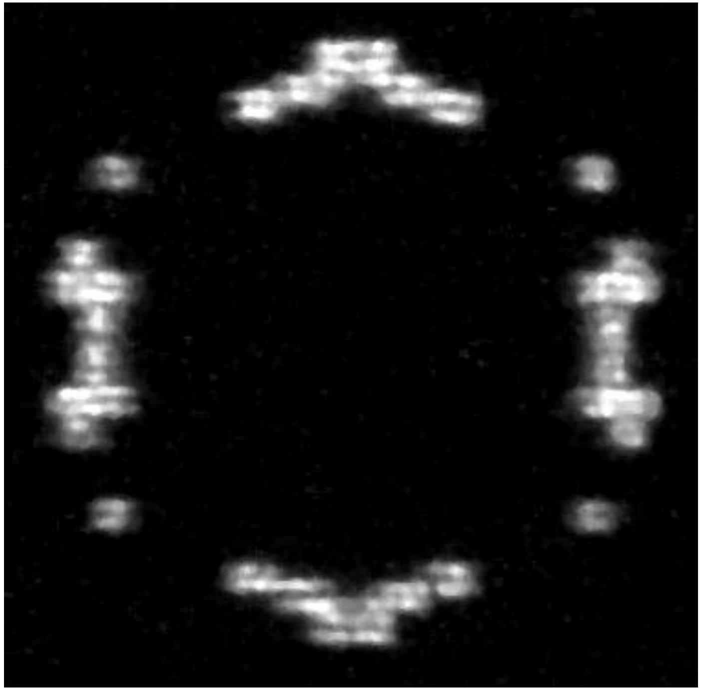


Freeform source capabilities

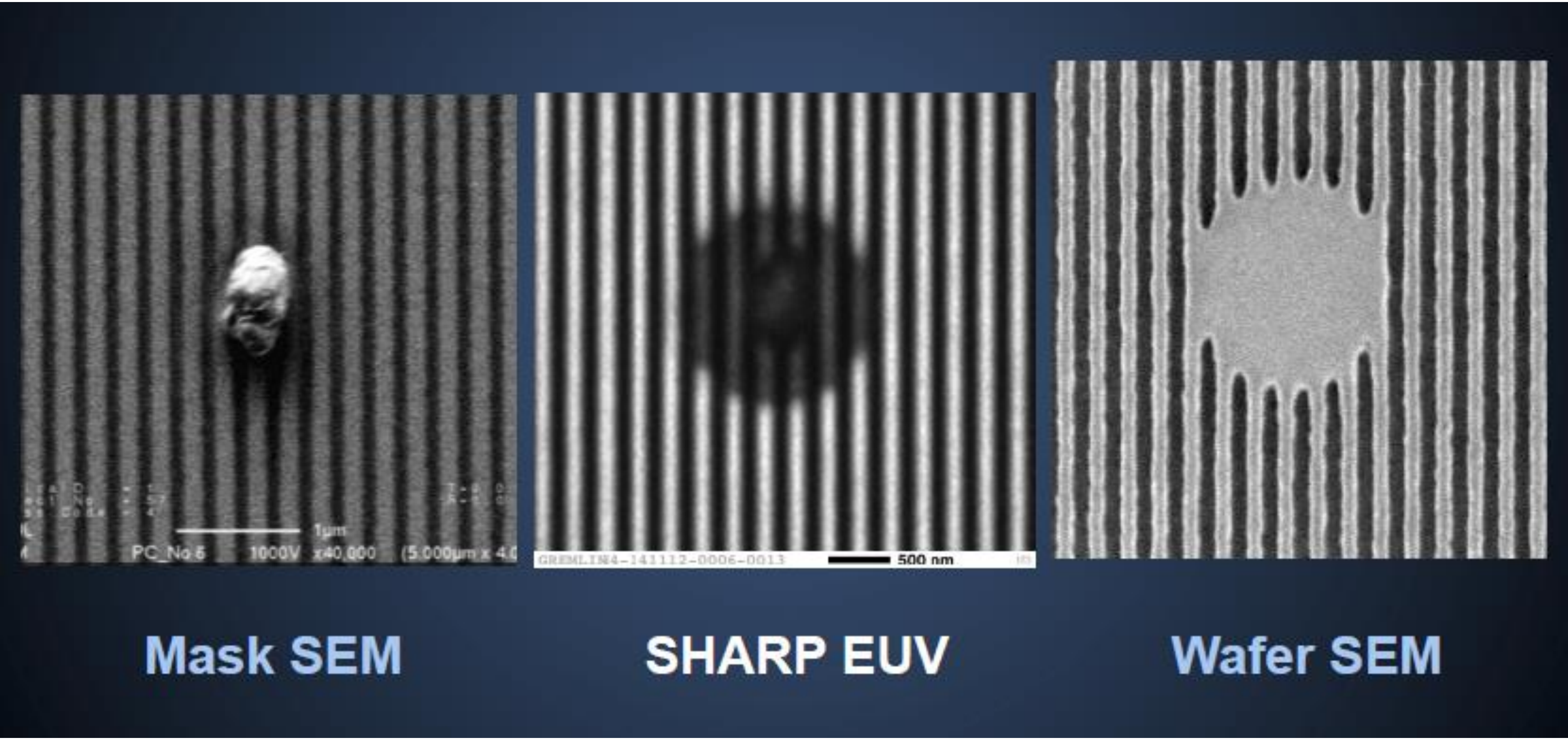
Target source shape



Measured source shape



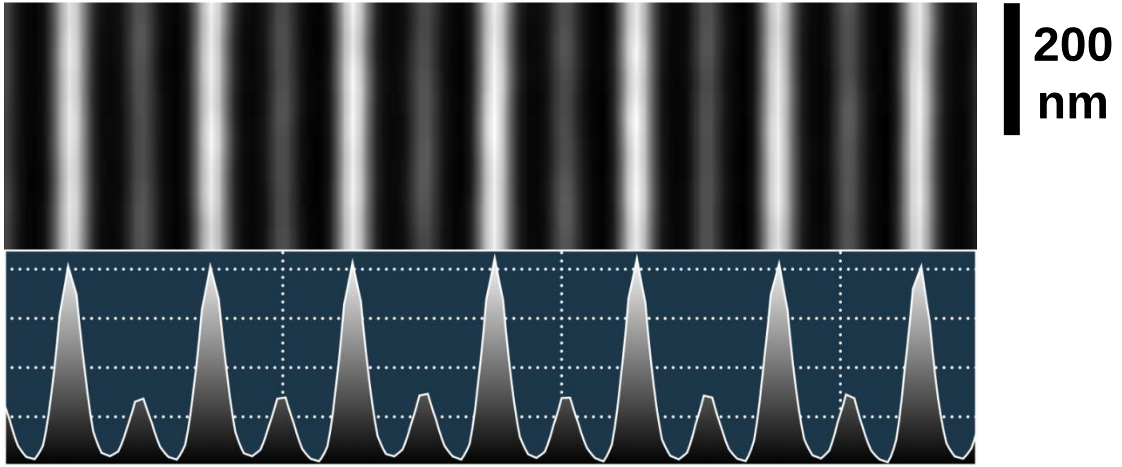
SHARP true to wafer print



Quantitative phase

Resolving SRAFS

I



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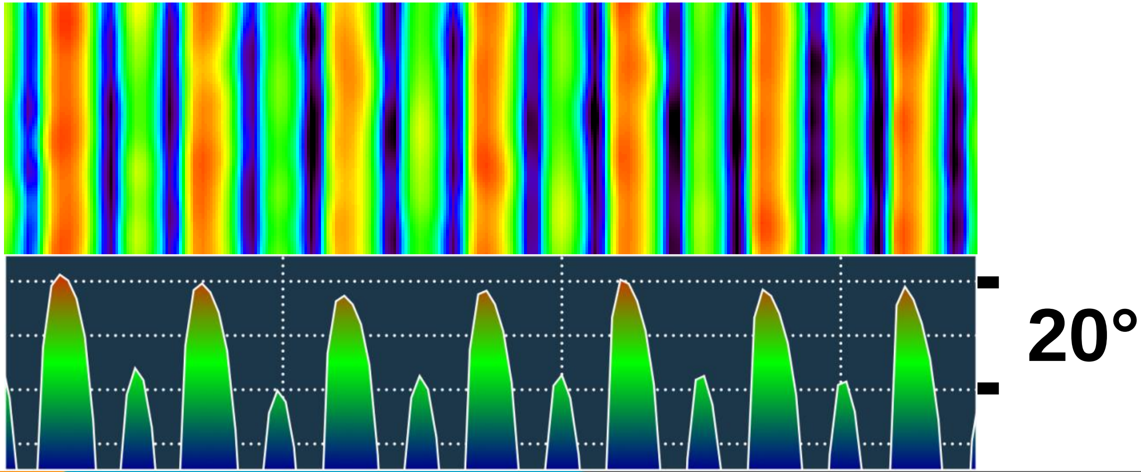
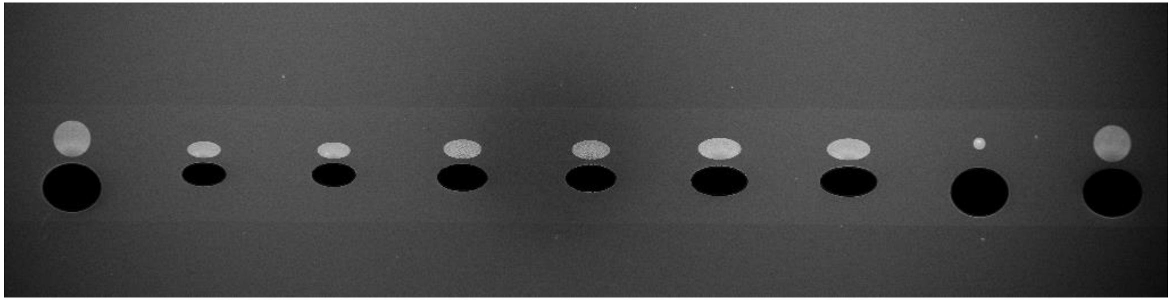
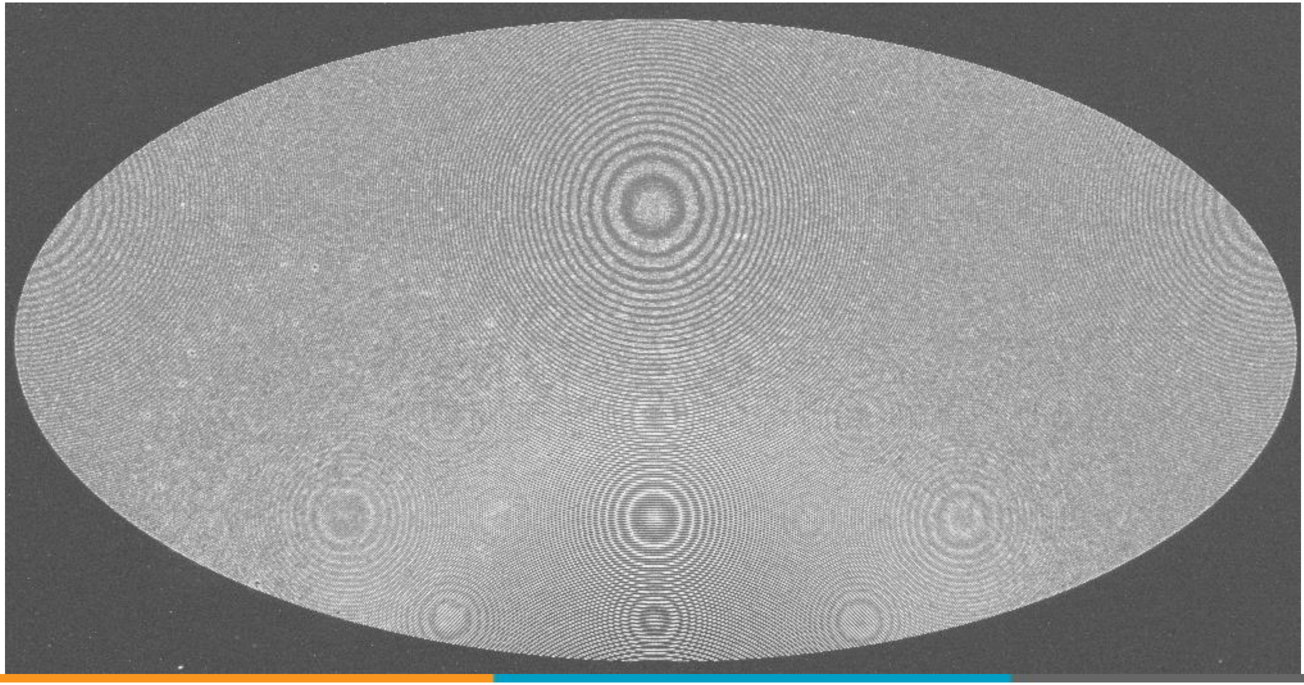
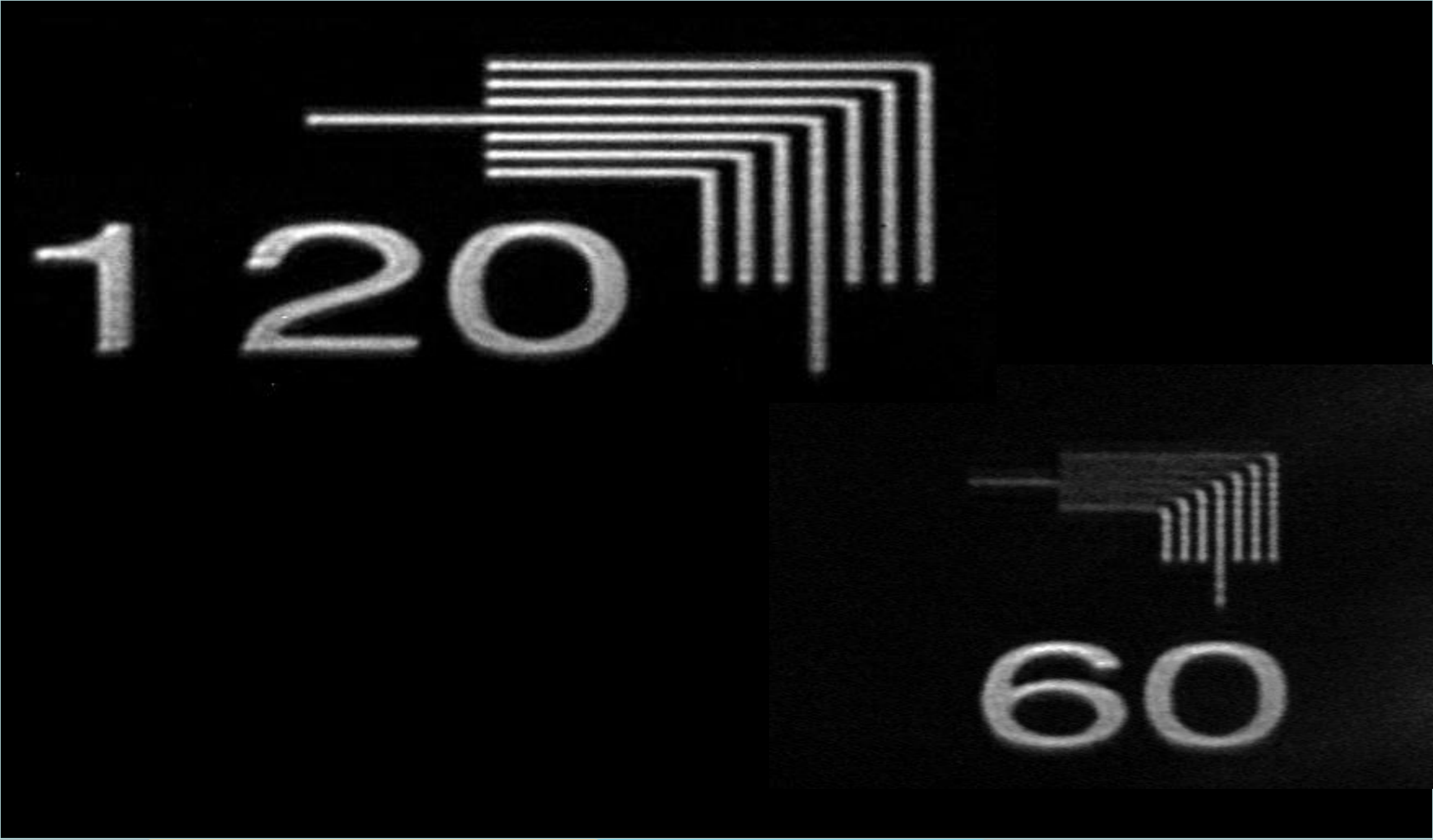


M. Benk, K. Goldberg, A. Wojdyla

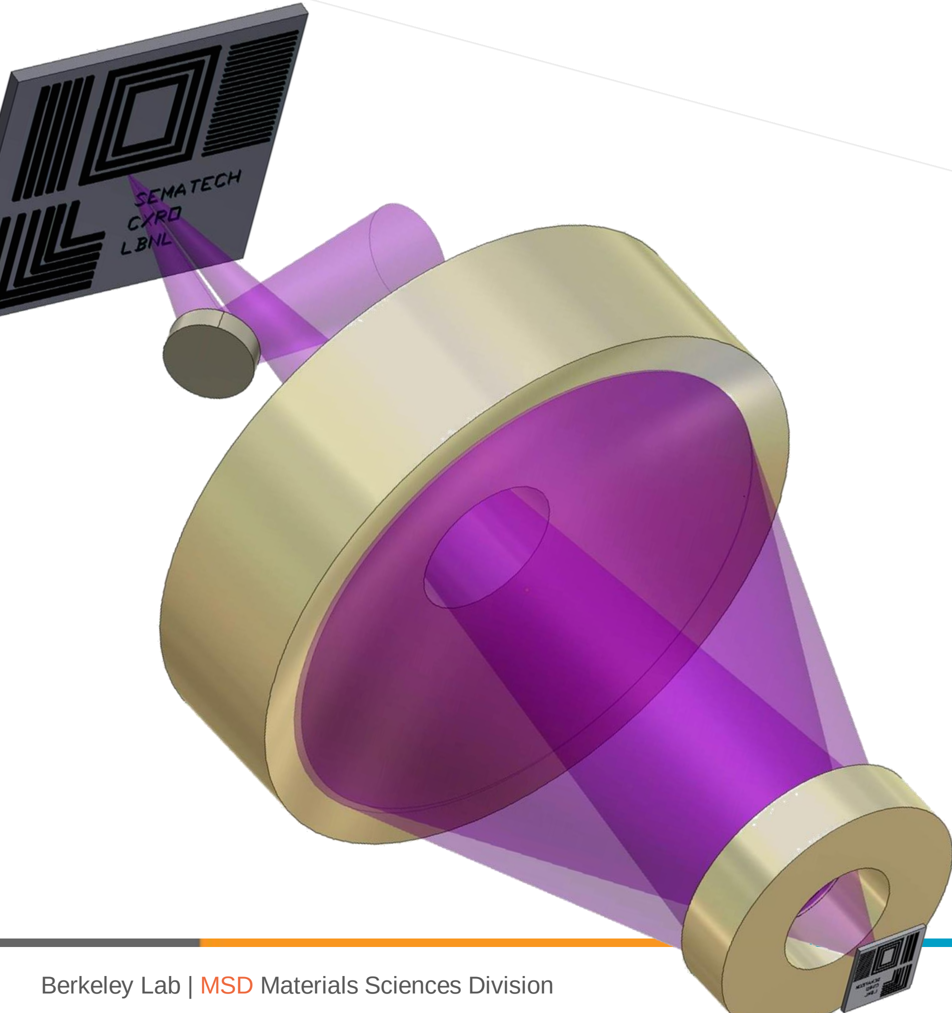
Anamorphic NA capabilities

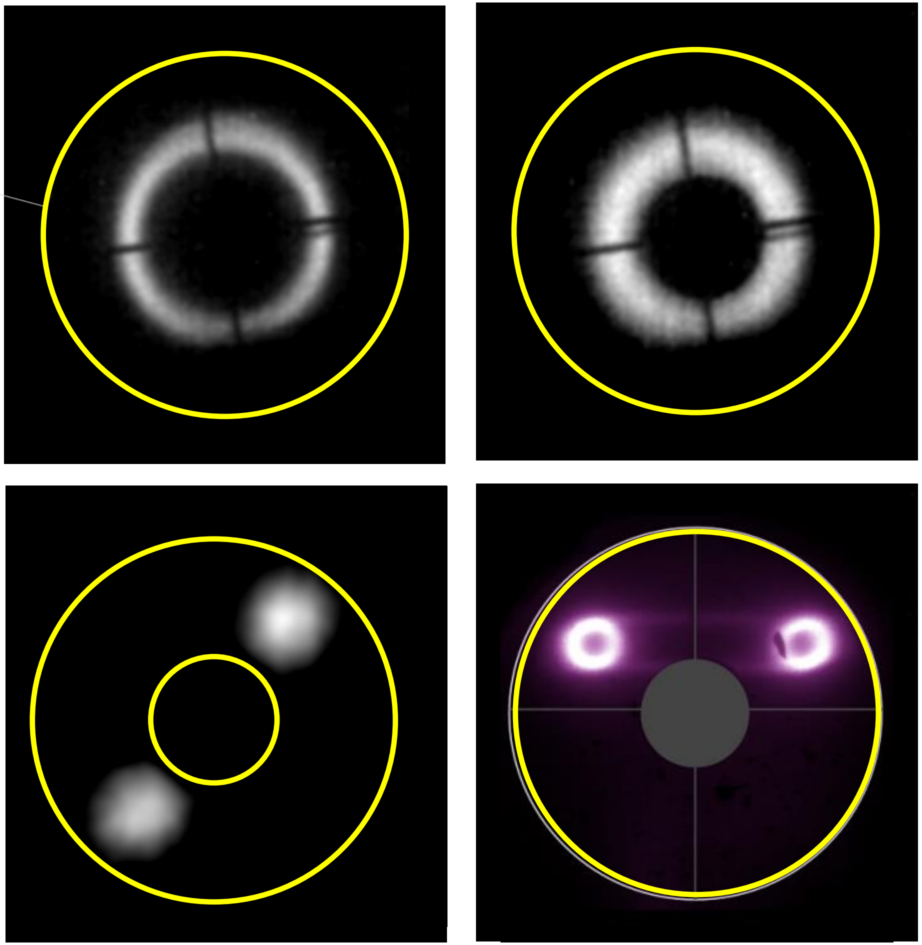




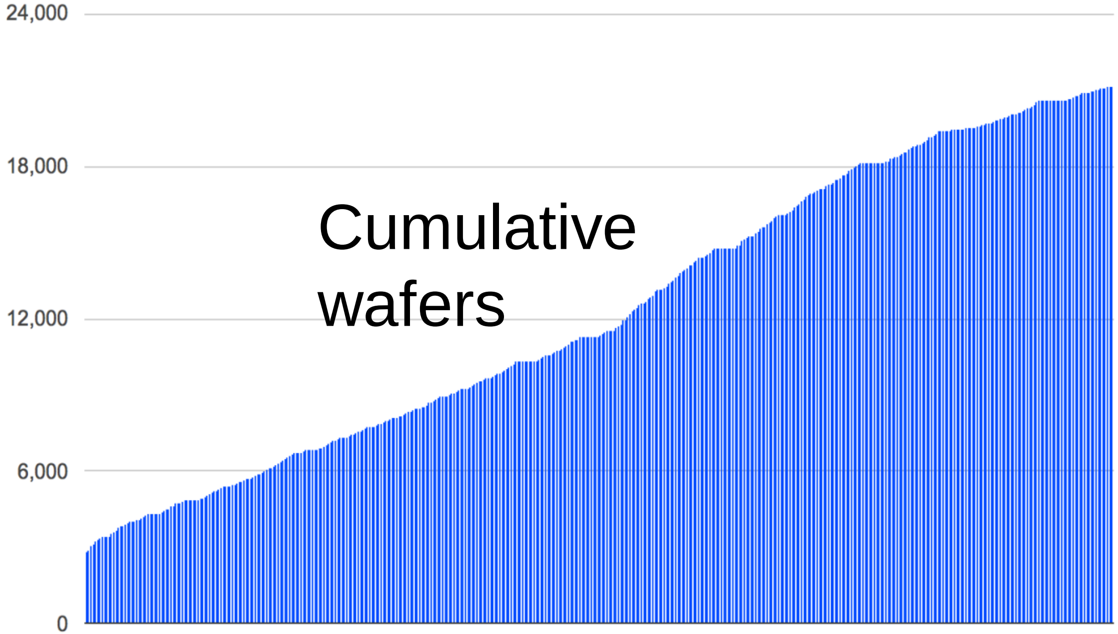

120
60

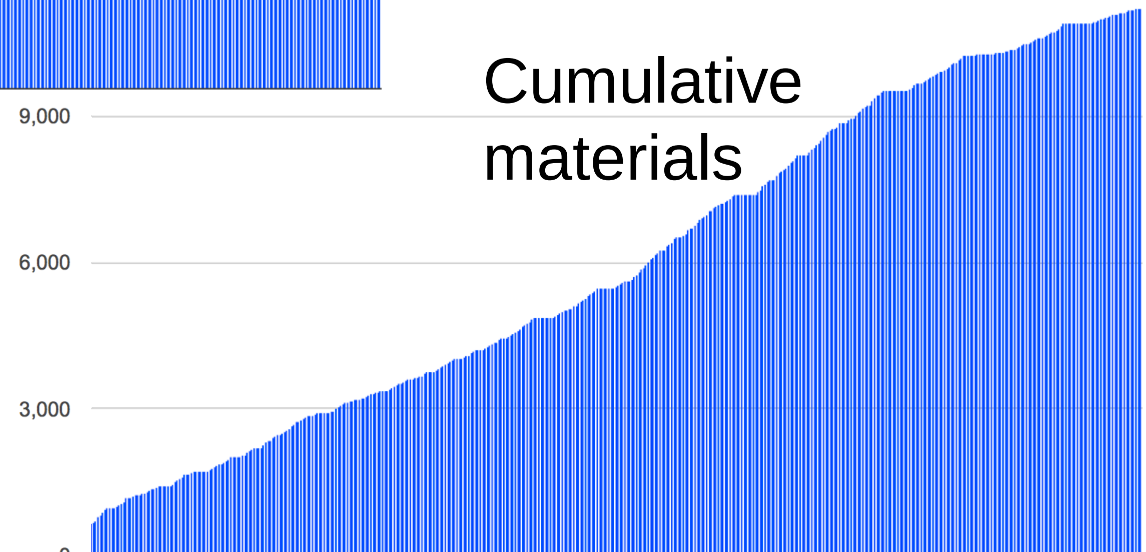
EUV 0.3-NA MET



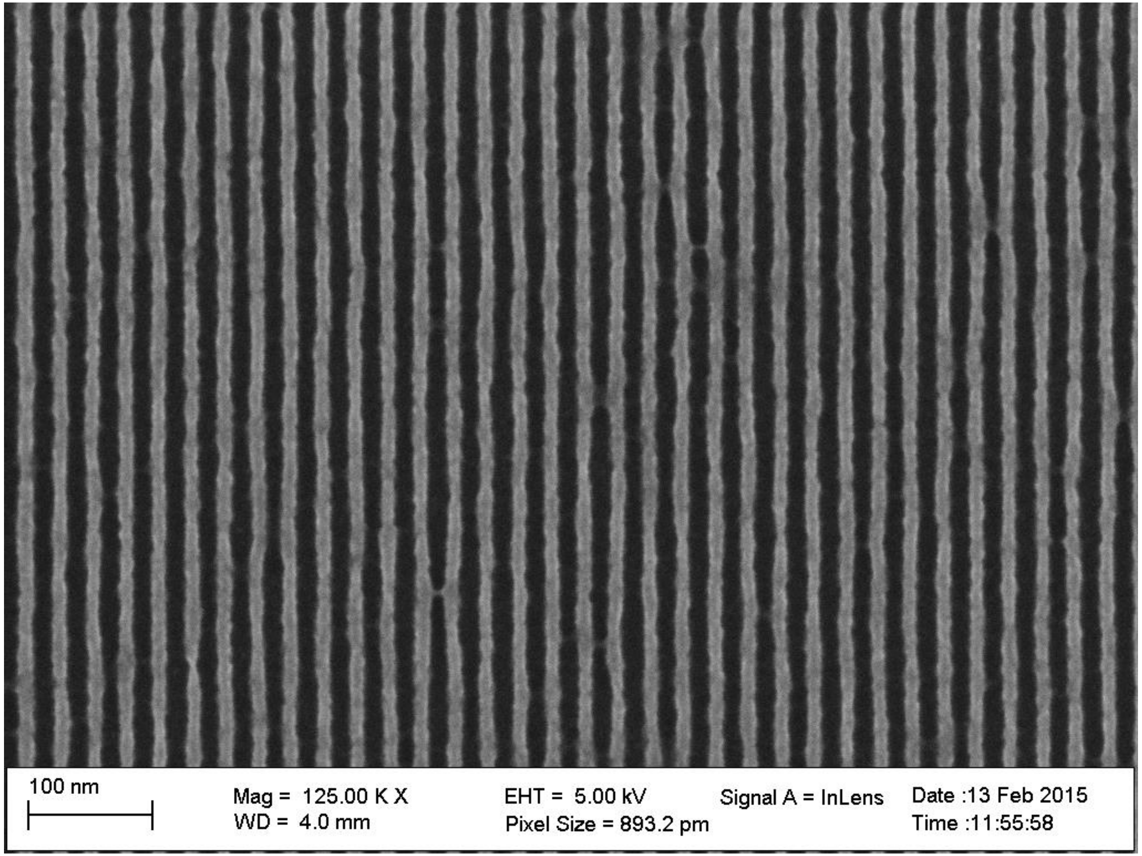


MET: engine for materials learning



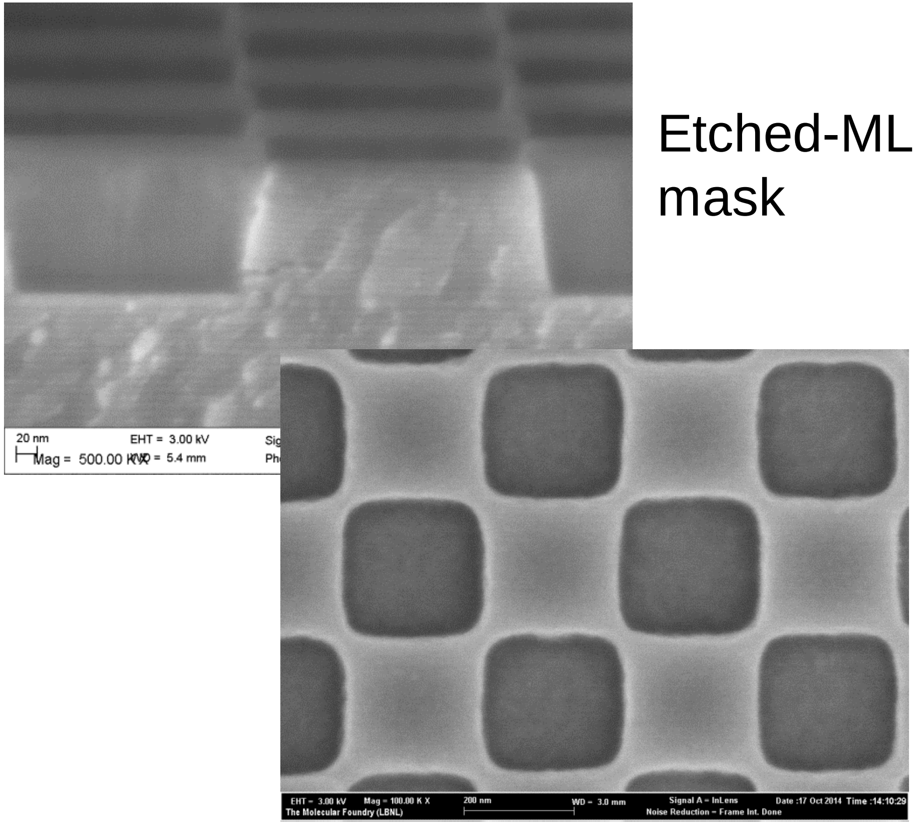


13-nm patterning achieved in non-CA resist



LWR
= 3.1 nm

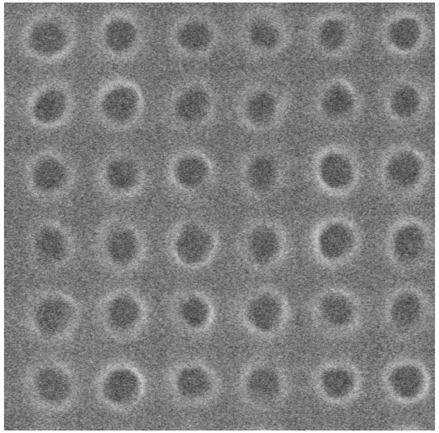
7x throughput gain on 25-nm contacts with PSM mask



Etched-ML mask

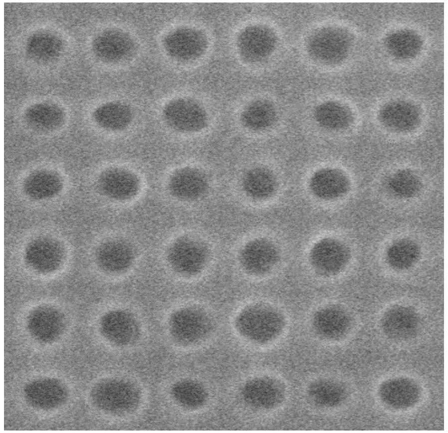
Checker PSM

13 mJ/cm^2



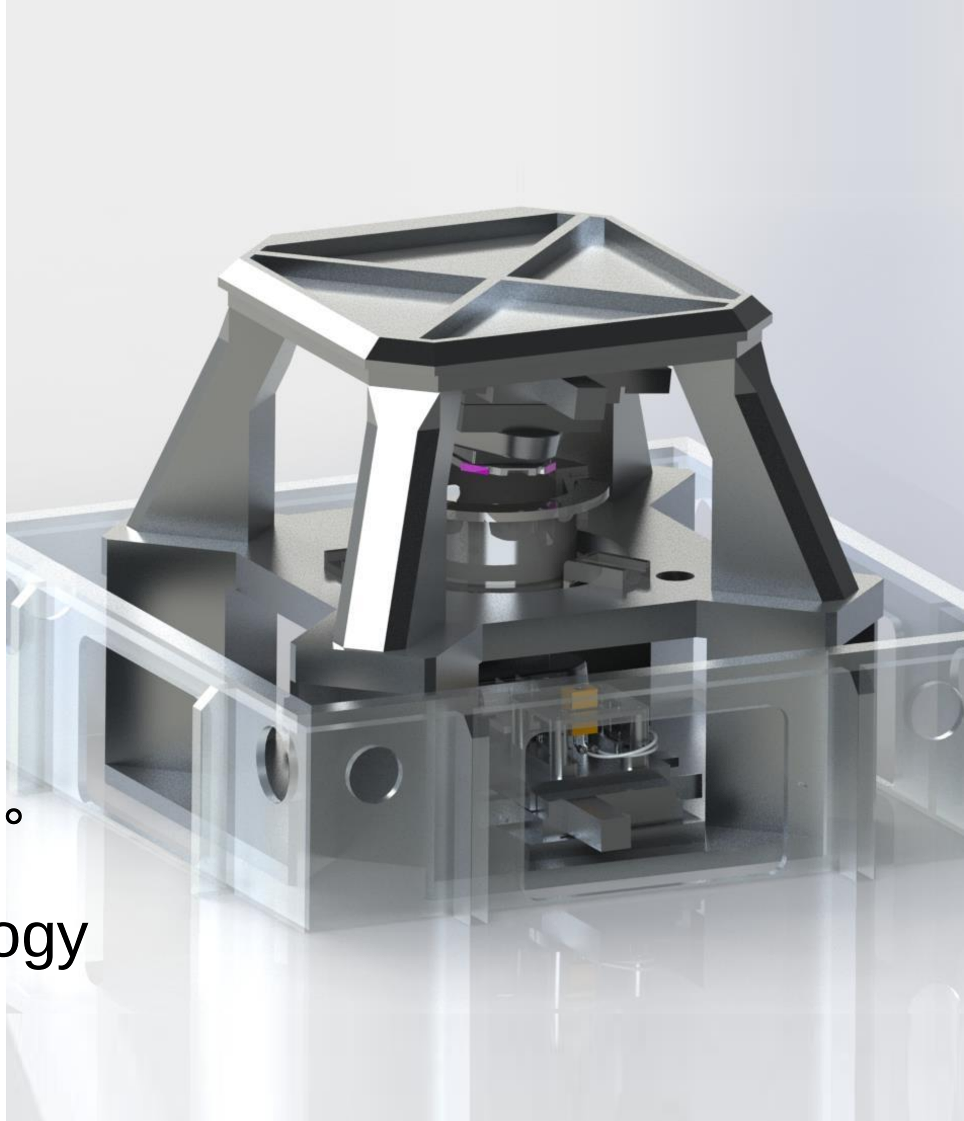
Absorber

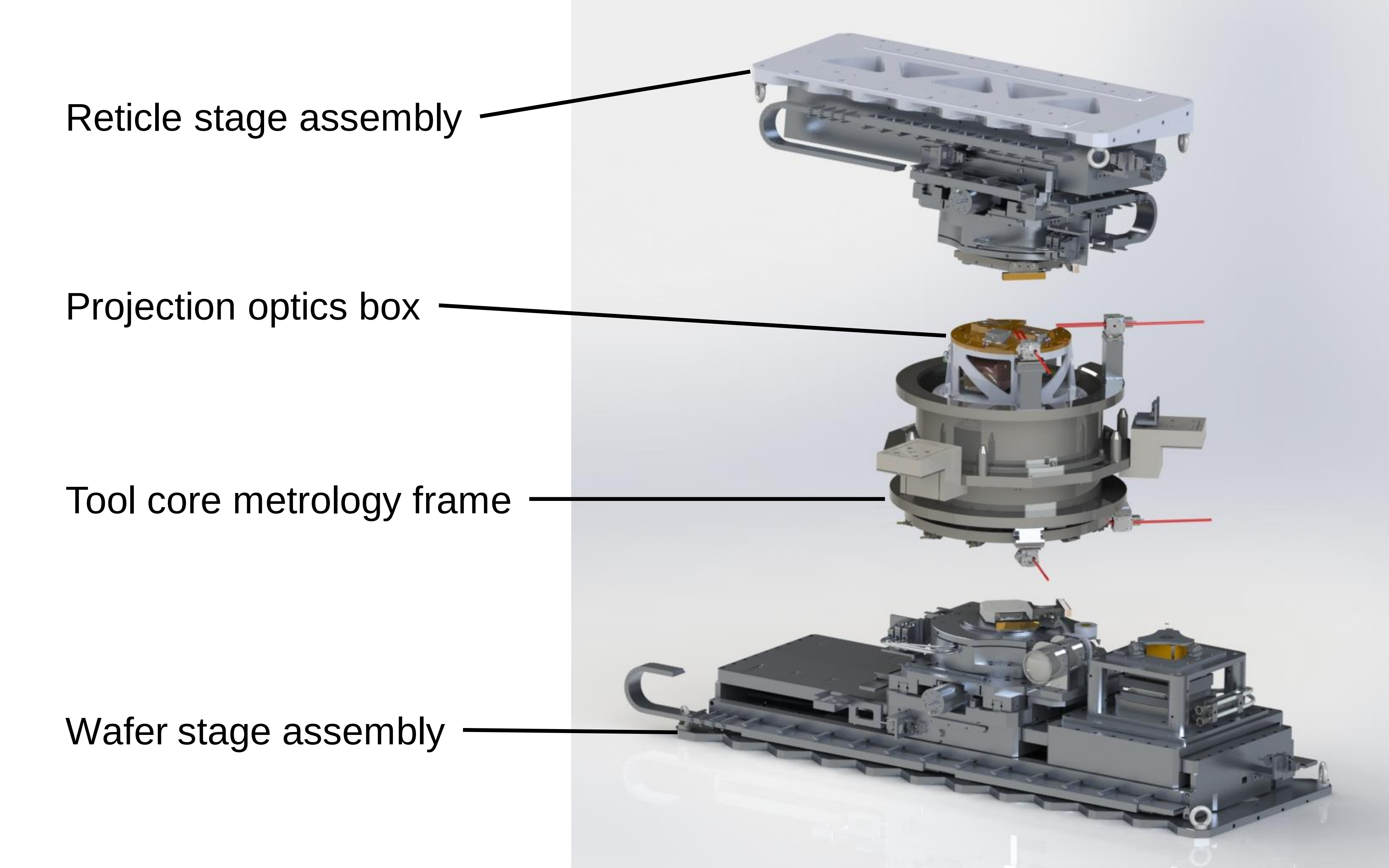
94 mJ/cm^2



MET5

- NA = 0.5
- Magnification = 5x
- Resolution limit = 8 nm
- Programmable pupil fill
- Mask angle of incidence = 6°
- Integrated wavefront metrology
- Robotic linked track





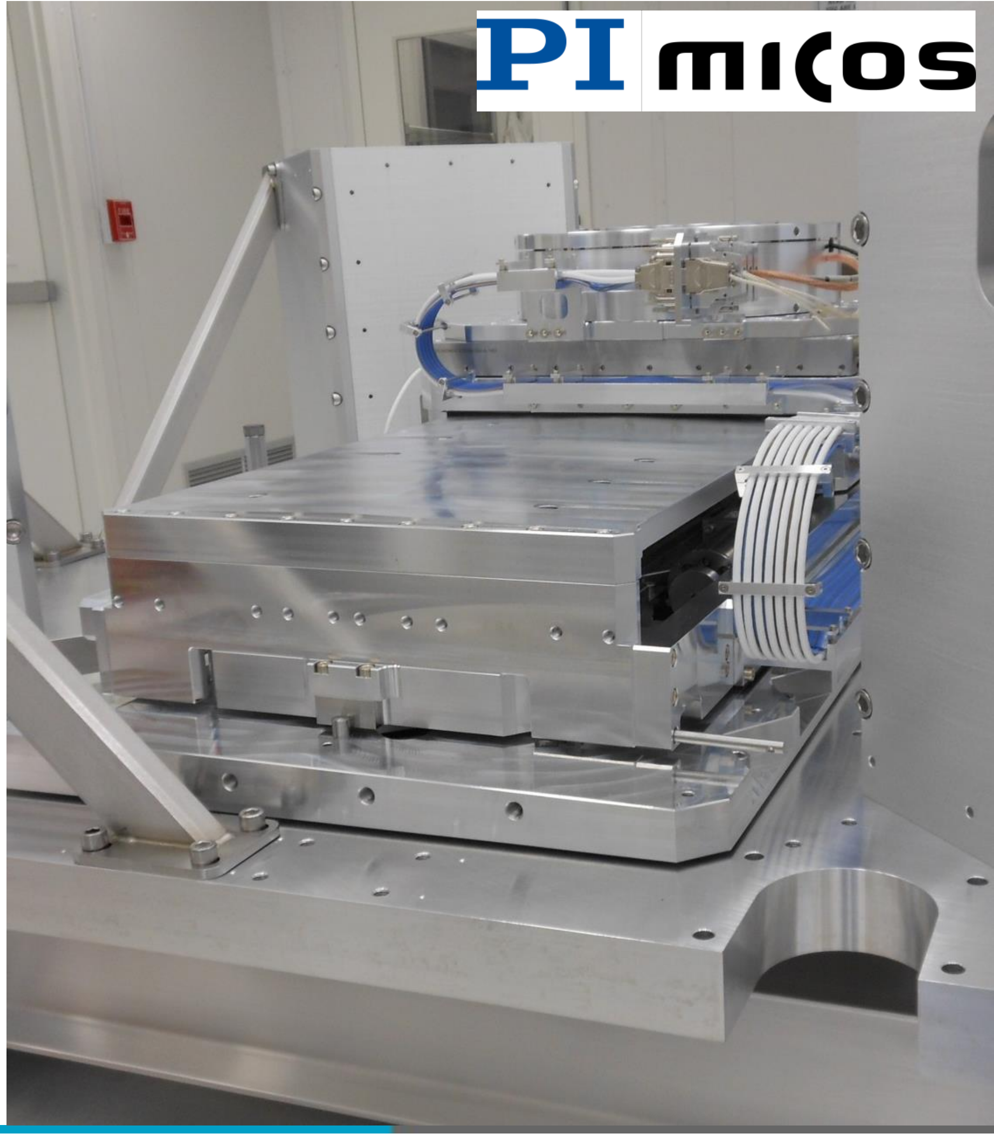
Reticle stage assembly
Projection optics box
Tool core metrology frame
Wafer stage assembly

7-axis reticle stage

	Spec	Measured
XY Low freq. (<2Hz) PV	3 nm	0.92 nm
XY High freq. (>0.5Hz) RMS	2 nm	0.33 nm
Z Low freq. (<2Hz) PV	10 nm	1.7 nm
Z High freq. (>0.5Hz) RMS	3 nm	0.61 nm

5-axis wafer stage/ 2-axis LSI carriage

	Spec	Measured
XY Low freq. (<2Hz) PV	3 nm	0.51 nm
XY High freq. (>0.5Hz) RMS	1 nm	0.65 nm
Tip/Tilt RMS	18 mrad	0.15 mrad
Z Low freq. (<2Hz) PV	10 nm	1.5 nm
Z High freq. (>0.5Hz) RMS	3 nm	0.42 nm

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Individual mirrors better than spec

M1

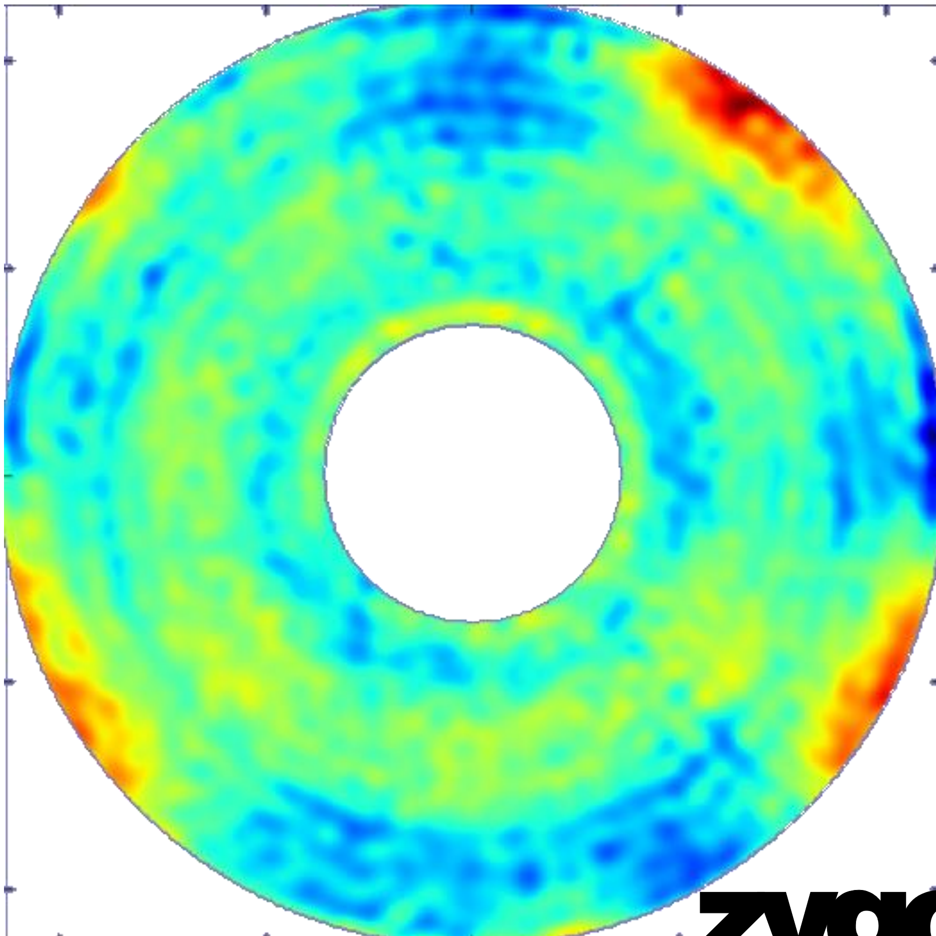
	Range	Specification	Result
Figure	CA – 3mm	< 0.1nm rms	0.04 nm rms
Flare	3mm – 0.43um	< 0.17nm rms	0.12 nm rms
HSFR	1um – 10nm	< 0.15nm rms	0.08 nm rms

M2

	Range	Specification	Result
Figure	CA – 8mm	< 0.1nm rms	0.08 nm rms
Flare	8mm – 1.2um	< 0.17nm rms	0.14 nm rms
HSFR	1um – 10nm	< 0.15nm rms	0.09 nm rms

Predicted POB EUV flare = 2.86%

System wavefront 2x better than spec



Reticle field point (um)	WFE @ 30cycles across aperture (nm rms)
0, 0	0.21 (spec=0.5)
75, 500	0.43 (spec=1.0)
75, -500	0.41 (spec=1.0)
-75, -500	0.34 (spec=1.0)
-75, 500	0.36 (spec=1.0)

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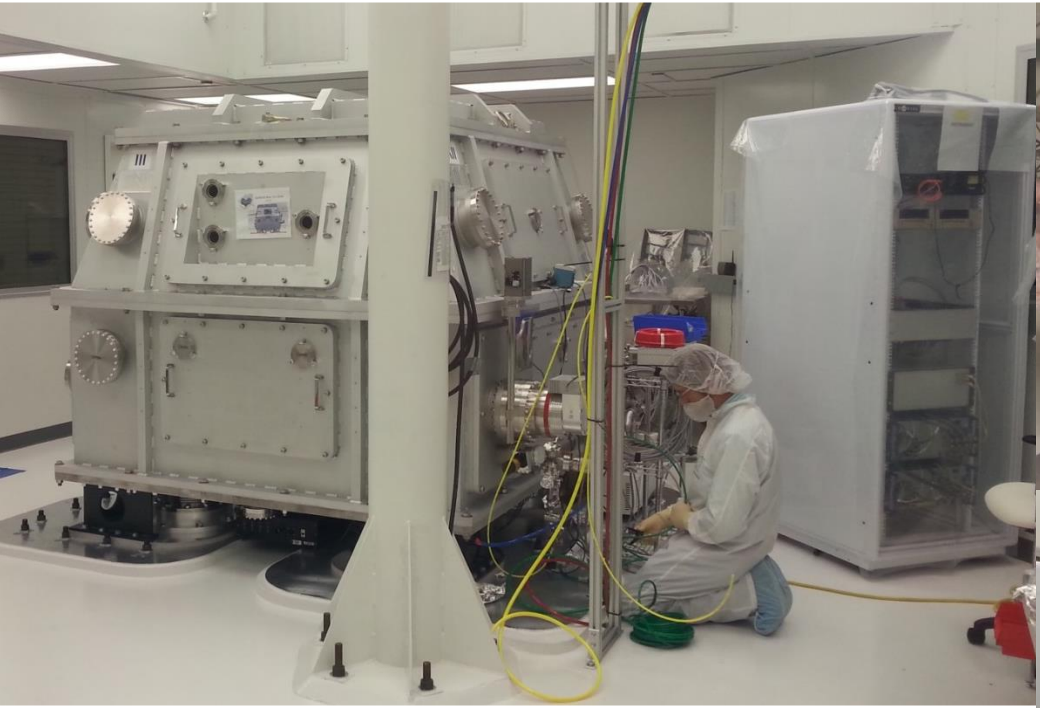
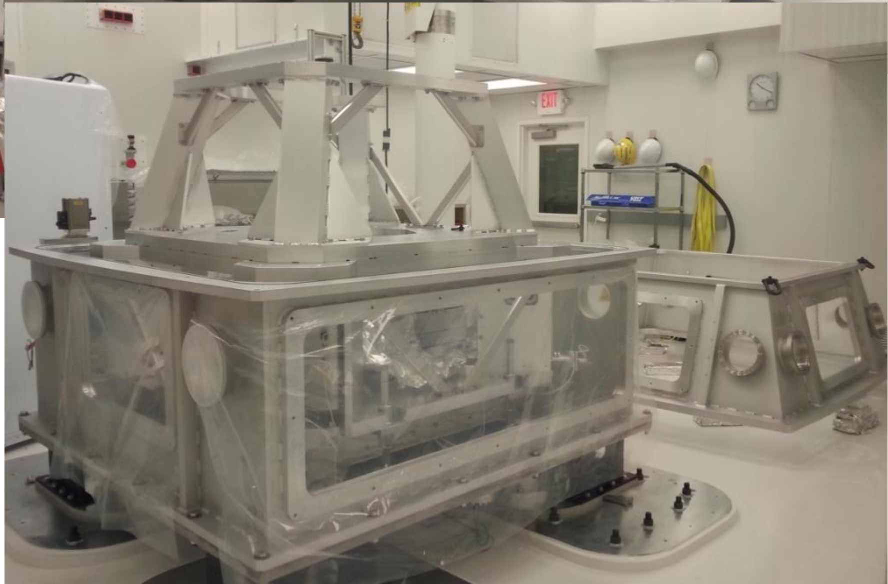
Platform integration nearly complete

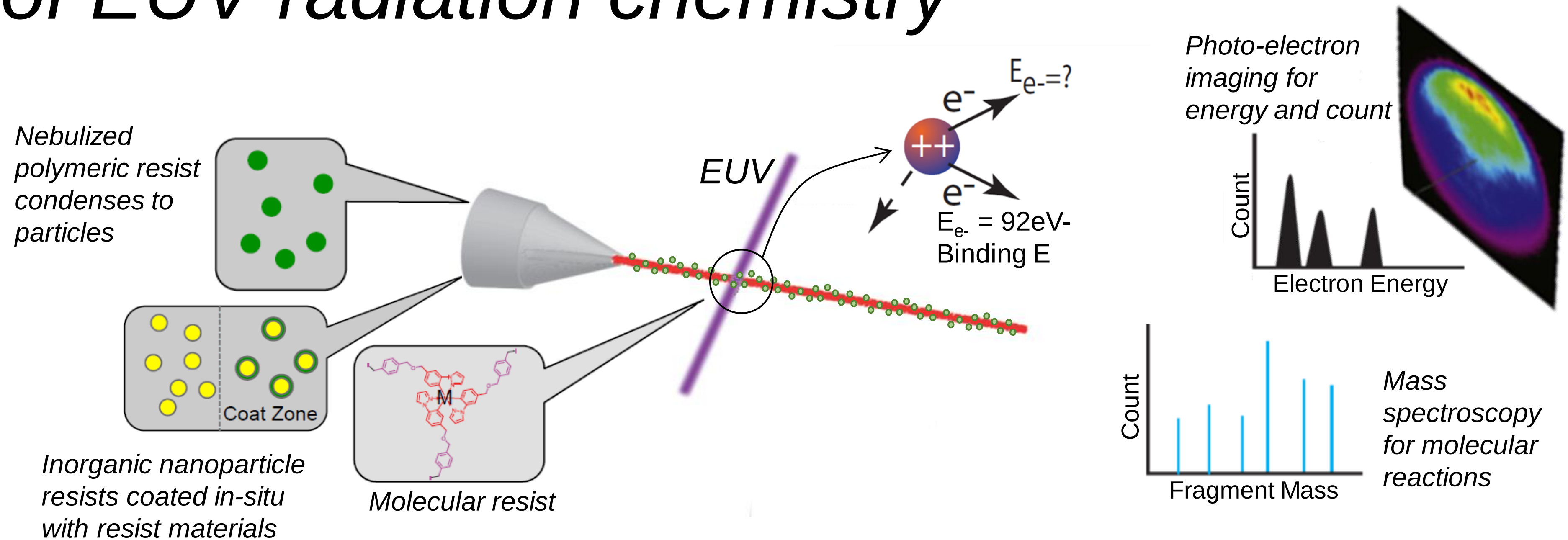




MET5

Potential expansion of EUREKA program resources

Instrumentation for direct characterization of EUV radiation chemistry



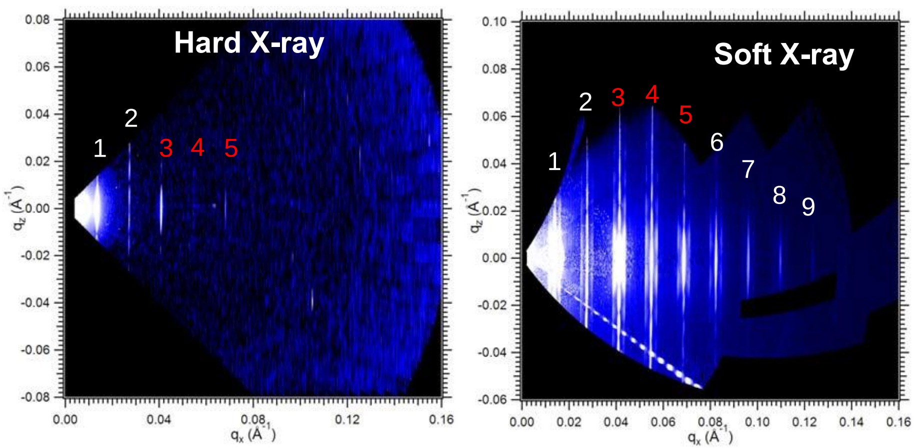
1: Introduce materials as molecular or nanoparticle beam

2: Irradiate with EUV or electrons

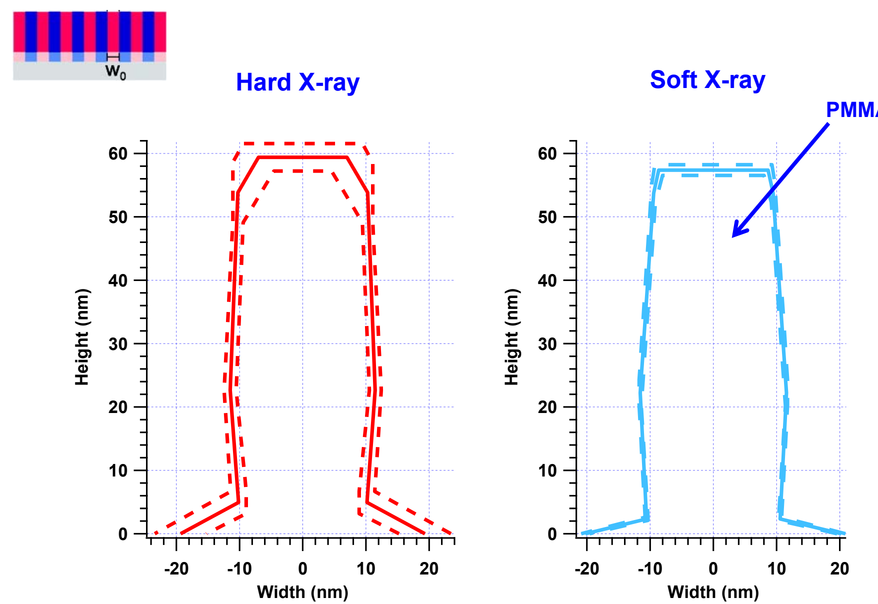
3: Measurement of electrons and chemistry

RSoXS: soft-x-ray potential for 3D chemically sensitive profile metrology

CD-RSoXS on Polymer Lithography Grating



Sunday et al. **JM3** 12 (3), 2013, 031103

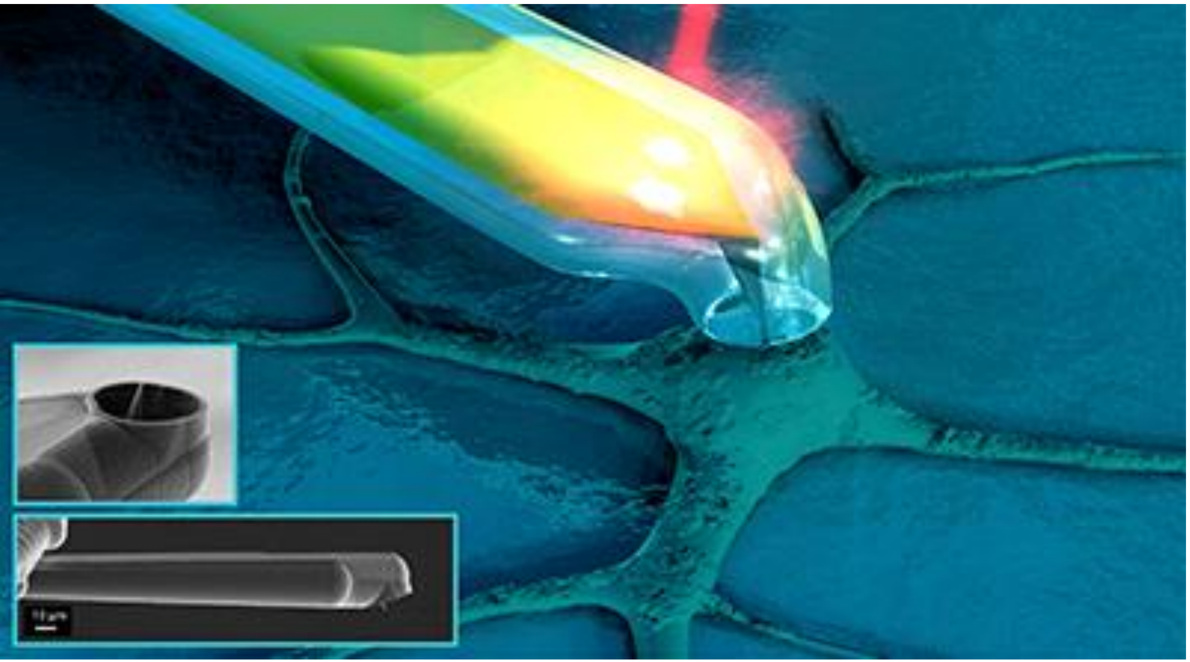


Compares favorably to hard X-ray and provides benefit of chemical sensitivity for potential use in latent images

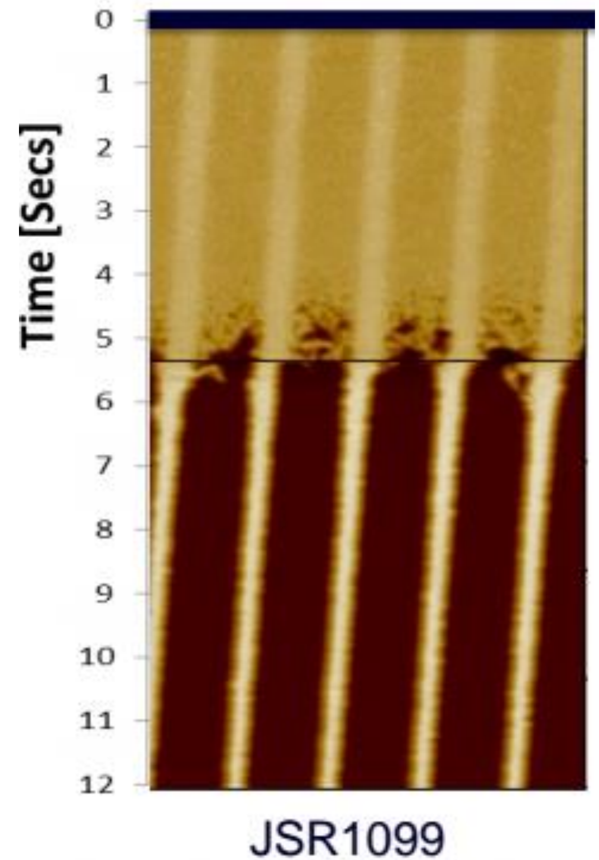
A. Hexemer

Realtime in liquid AFM for development studies

Encased cantilever for fast response in liquid



Start of developer injection



MOLECULAR FOUNDRY

P. Ashby

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Seno Rekawa, LBNL
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CXRO

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