Low-Order Aberrations Correction of Extreme Ultraviolet Imaging Objective with Deformable Multilayer Mirror

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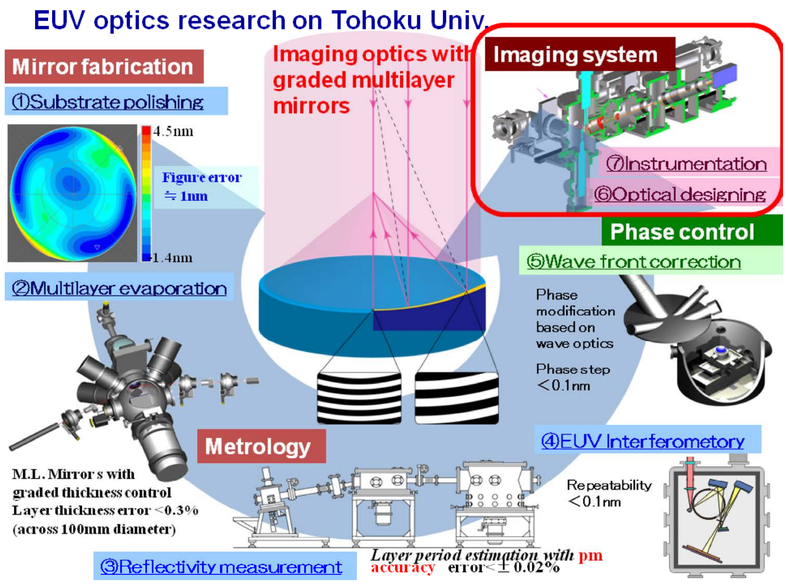
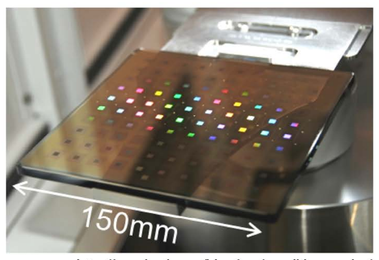
MEDSI 2016 — MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION

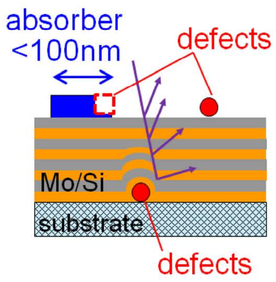
Introduction



At-wavelength inspection of EUVL mask



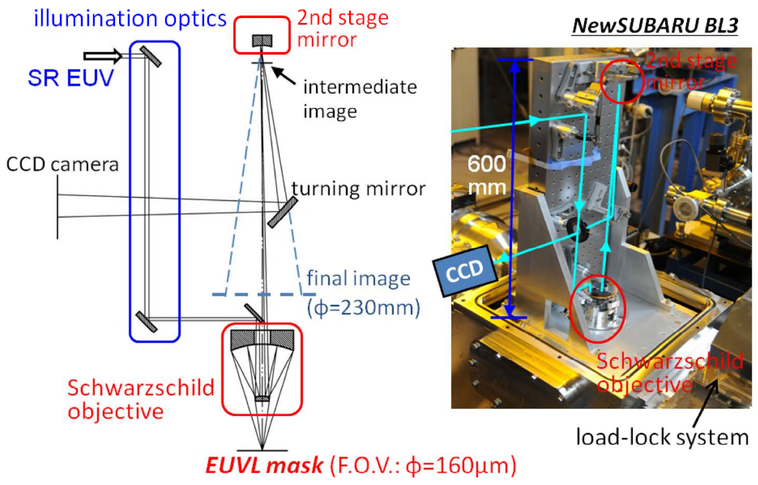
http://semimd.com/blog/tag/euv-lithography/



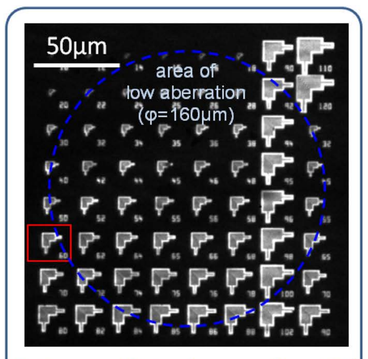
Requirements for an inspection tool

- ✓At-wavelength observation (λ=13.5nm)
- ✓High spatial resolution (δ<40nm)
- ✓Wide field of view for a rapid whole mask inspection

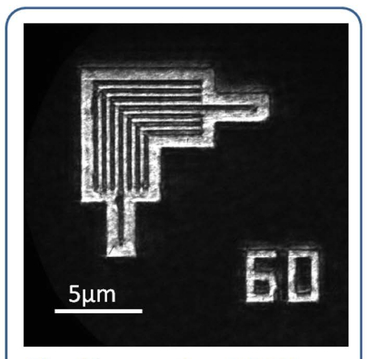
EUV microscope with multilayer mirror optics



Reflection image of EUV lithography mask



Intermediate image (m=30)
Exp. time: 0.25 sec.

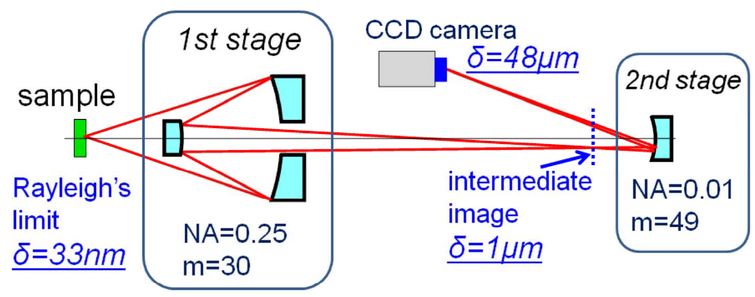


Final image (m=1460)
Line width: 240nm (60nm)
Exp. time: 36 sec.

EUV-CCD camera: pixel size 13.5μm, 2048 × 2048 pixels
M. Toyoda et.al., Appl. Phys. Express **5** (2012) 112501

Deformable Mirror

Two-stage imaging system for high magnification



- ✓ High magnification (x1500) : CCD video observation
- ✓ Small off-axis aberrations: Wide FOV (ϕ=200μm)

Wavefront control with sub-nm accuracy

Maréchal criterion for diffraction-limited imaging

Allowable Wave aberrations

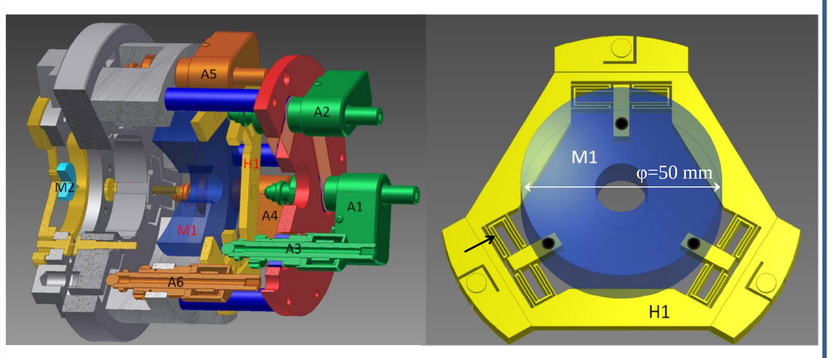
$$W = W_{Design} + W_{FigureError} + W_{Decenter} < \frac{\lambda}{14} = 1\,\text{nm rms.}$$

- ✓ Imperfect polishing of substrate
- ✓ Small forces of *Holding and Gravity* applied to mirror

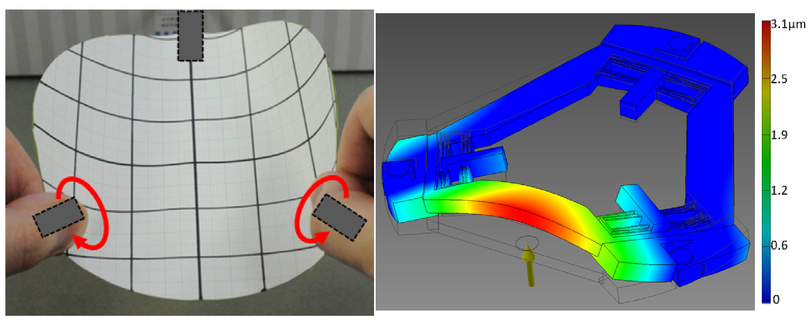
⇒ Primary effect is **Astigmatism**

Aim of study:
Deformable mirror (Stigmator) to correct astigmatism with sub-nm accuracy.

Mechanical design

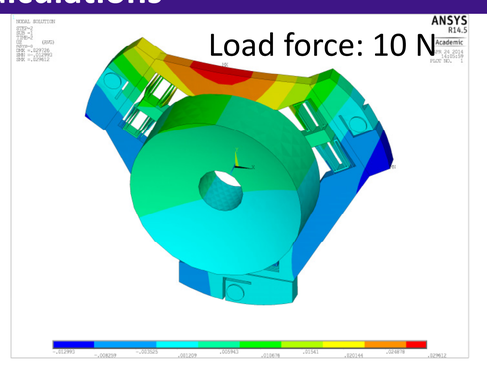


- ✓ Concave mirror (M1) is glued to three holding arms.
- ✓ Flexure springs (arrow) absorb thermal expansion.
- ✓ Picomotors (A1-A3) can apply force (max: 20 N) on holding plate (H1) to correct astigmatism.
- ✓ Three-axis stage with Picomotors (A4-A6) for fine alignment of convex mirror (M2).



- ✓ Two torsional moments (twists) in opposite direction applied to holding arms (red arrows) modify radius of curvature of mirror surface.
- ✓ Torsional moments are generated with force applied to holding plate (yellow arrow).

FEM calculations

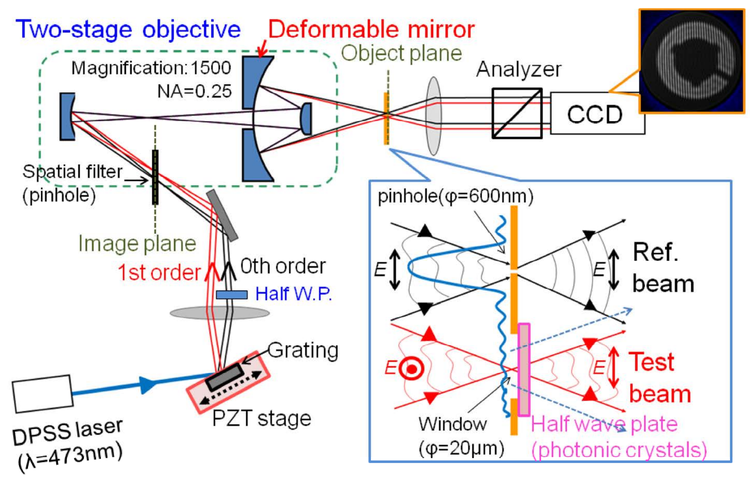


Annular Zernike coefficients (rms.)

Piston z_1 (μm)	7.82
Tilt x z_2 (μm)	-1.52
Tilt y z_3 (μm)	3.91
Power z_4 (nm)	0.09
Astigmatism x z_5 (nm)	-3.96
Astigmatism y z_6 (nm)	-0.69

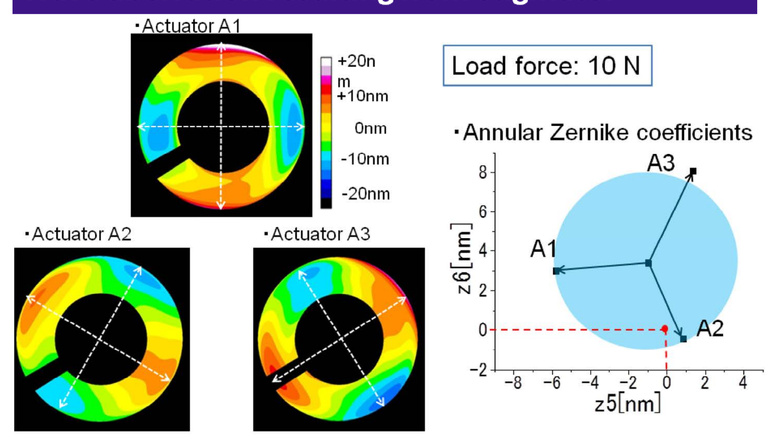
Experimental Results

Point Diffraction Interferometer



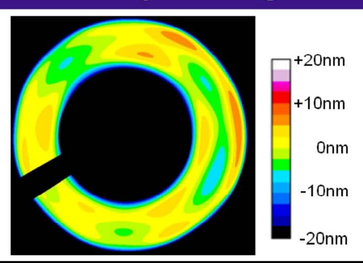
- ✓Wavefront measurement with sub-nm accuracy

Wave aberration resulting from stigmator



- ✓ Astigmatism was clearly observed in all data.
- ✓ Control range as stigmator: ±4 nm rms.

Wave front after fine optical alignment



	Astigmatism		Coma		Spherical	Total
	z5	z6	z7	z8	z9	(z5 to z9)
Wrms.	0.04nm	0.17nm	0.21nm	-0.08nm	0.07nm	0.29nm

- ✓Low-order aberrations were succesfully corrected below 1/3 of Maréchal criterion @λ=13.5 nm

REFERENCES

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