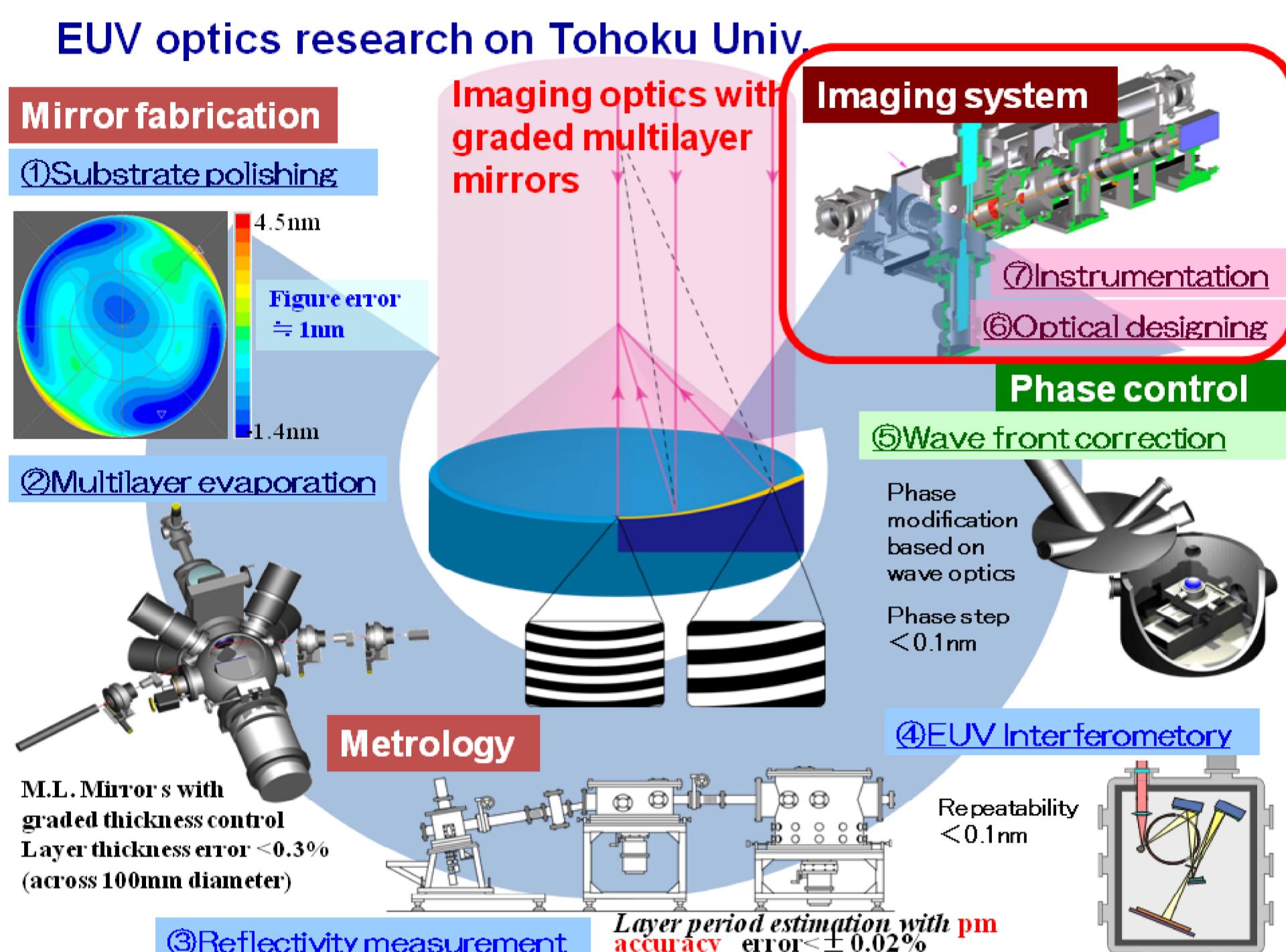


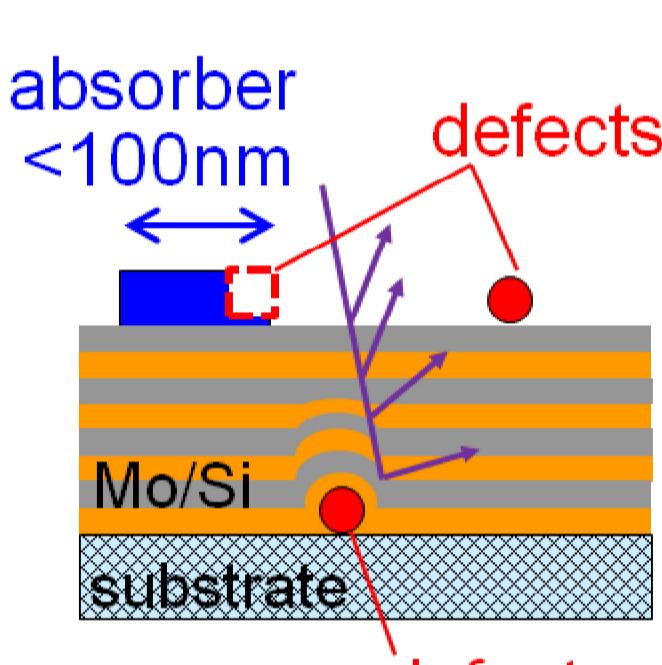
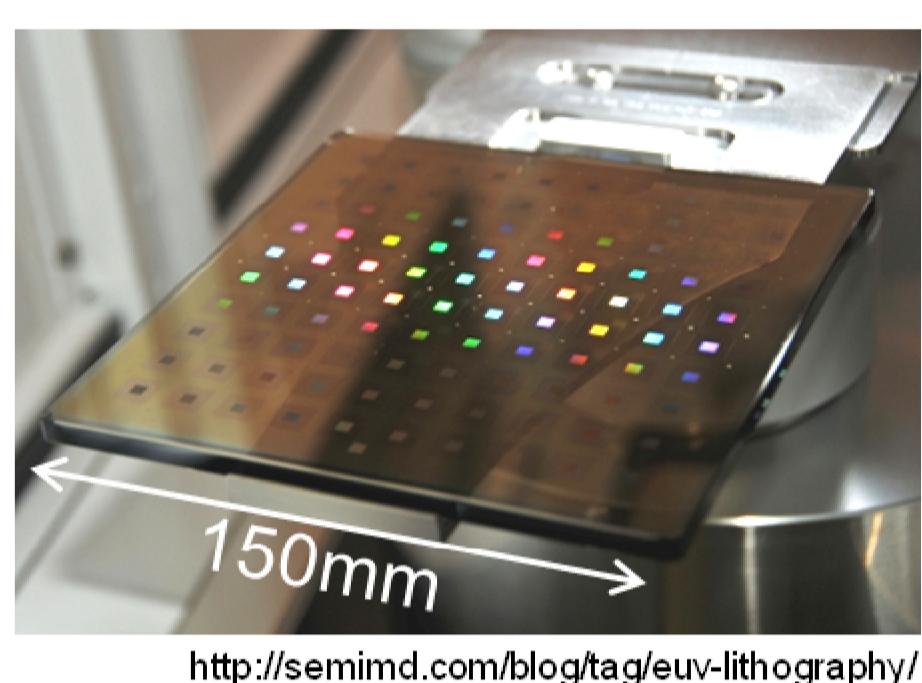
Low-Order Aberrations Correction of Extreme Ultraviolet Imaging Objective with Deformable Multilayer Mirror

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Introduction



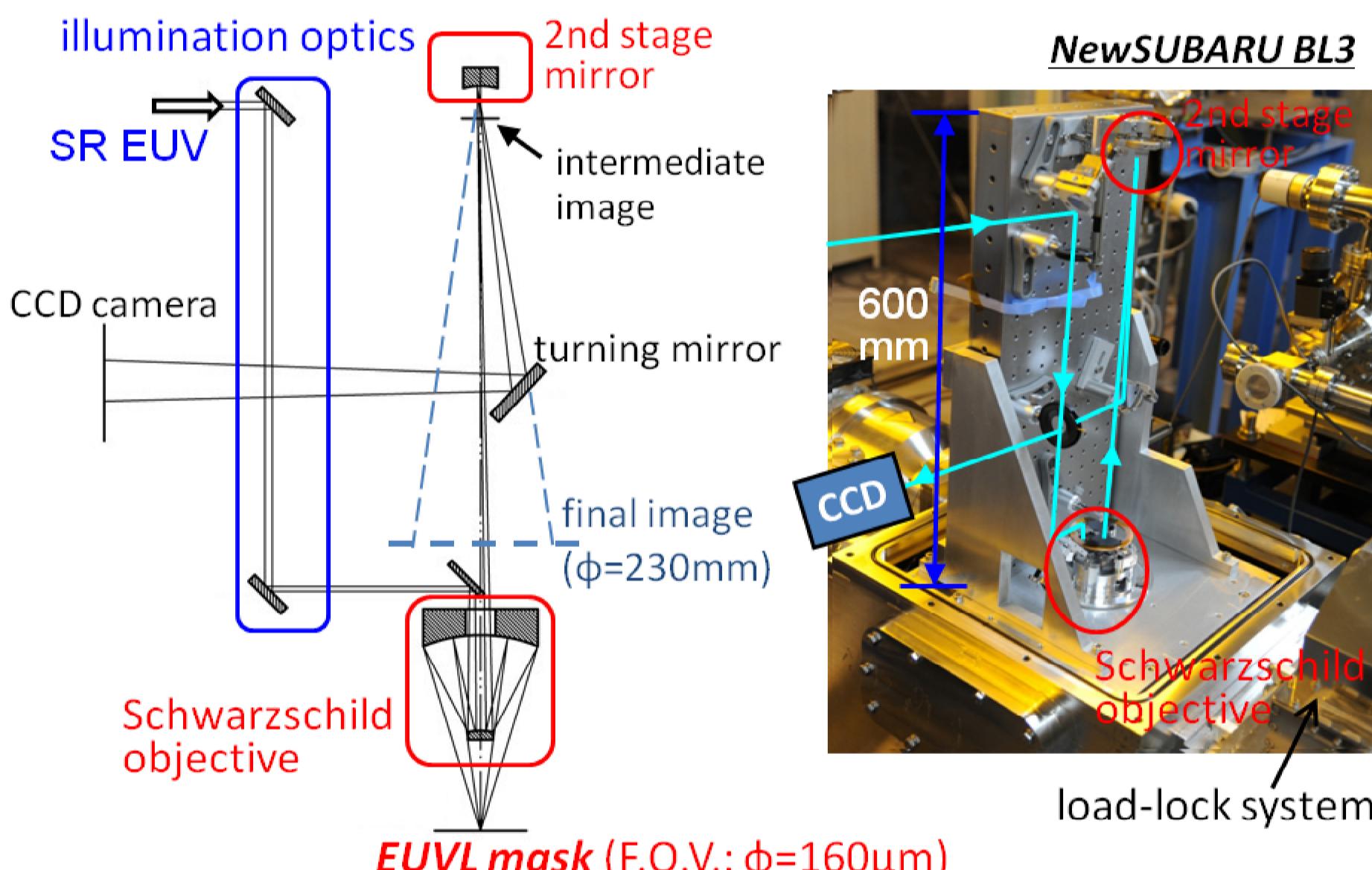
At-wavelength inspection of EUVL mask



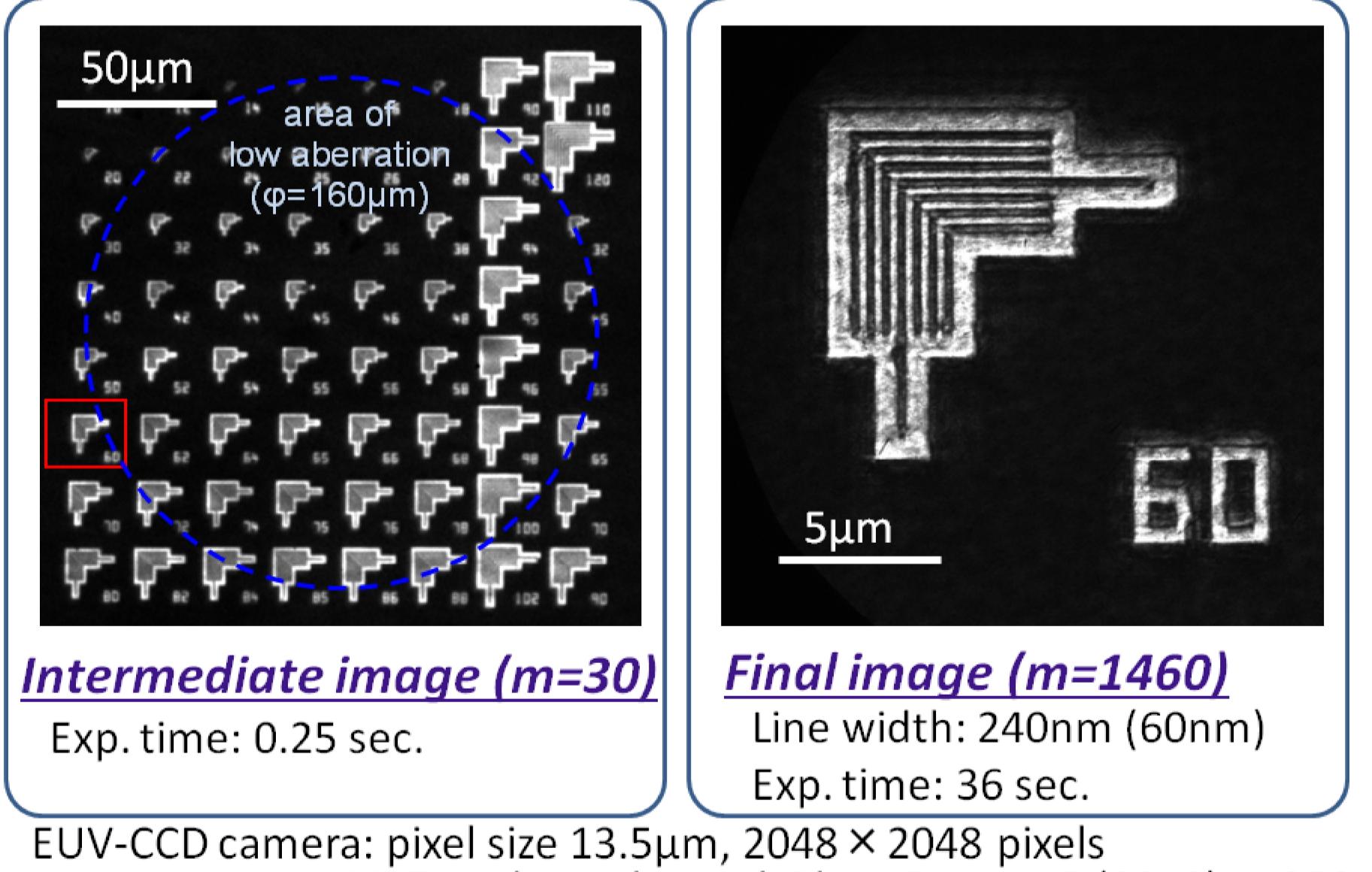
Requirements for an inspection tool

- ✓ At-wavelength observation ($\lambda=13.5\text{nm}$)
- ✓ High spatial resolution ($\delta<40\text{nm}$)
- ✓ Wide field of view for a rapid whole mask inspection

EUV microscope with multilayer mirror optics

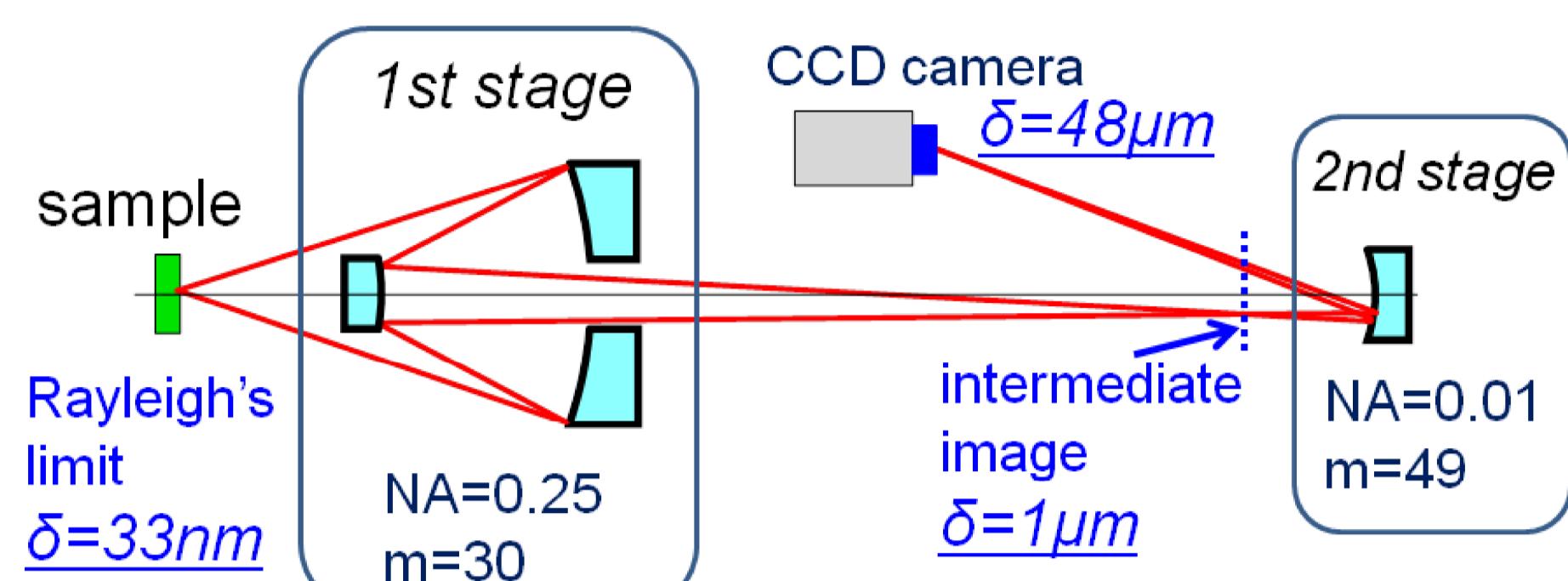


Reflection image of EUV lithography mask



Deformable Mirror

Two-stage imaging system for high magnification



- ✓ High magnification (x1500) : CCD video observation
- ✓ Small off-axis aberrations: Wide FOV ($\phi=200\mu\text{m}$)

Wavefront control with sub-nm accuracy

Maréchal criterion for diffraction-limited imaging

Allowable Wave aberrations

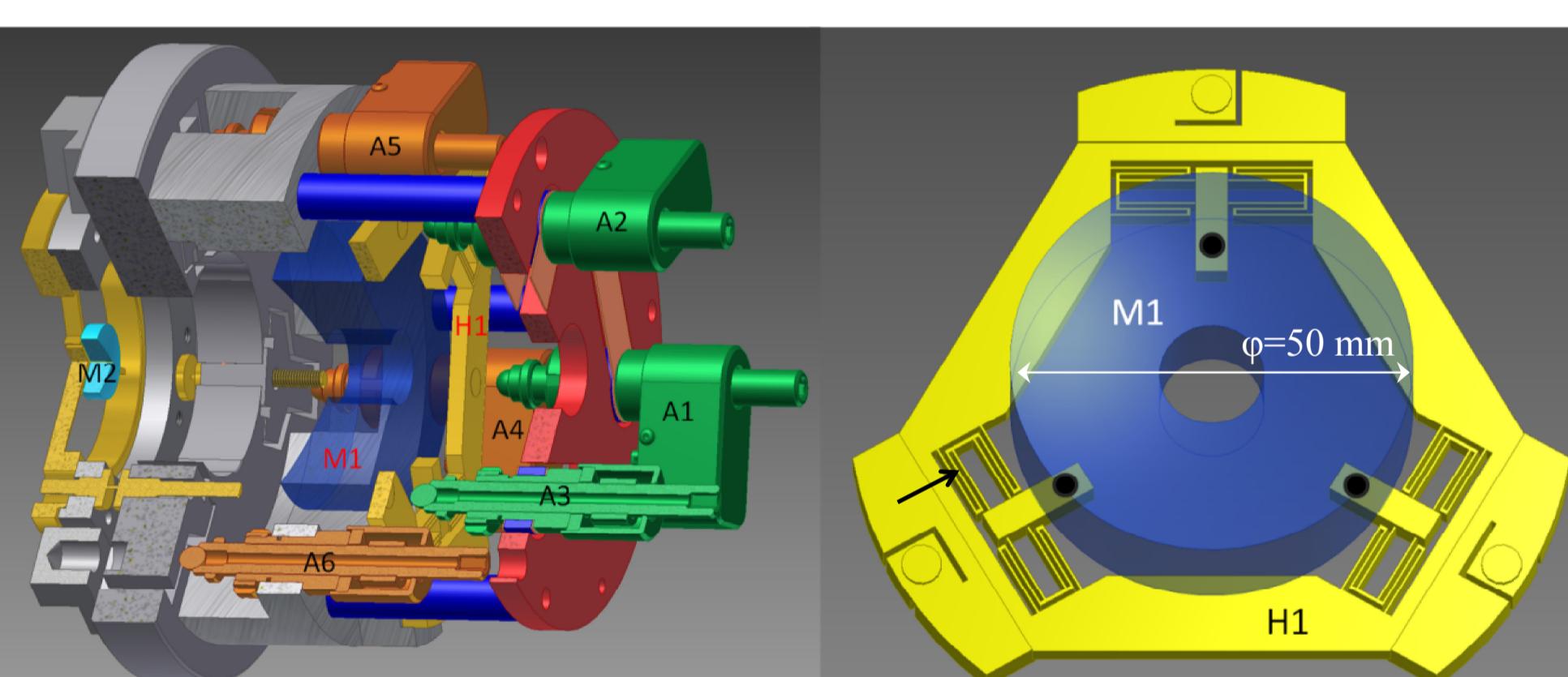
$$W = W_{\text{Design}} + W_{\text{FigureError}} + W_{\text{Decenter}} < \frac{\lambda}{14} = 1\text{ nm rms.}$$

- ✓ Imperfect polishing of substrate
- ✓ Small forces of Holding and Gravity applied to mirror
- ⇒ Primary effect is **Astigmatism**

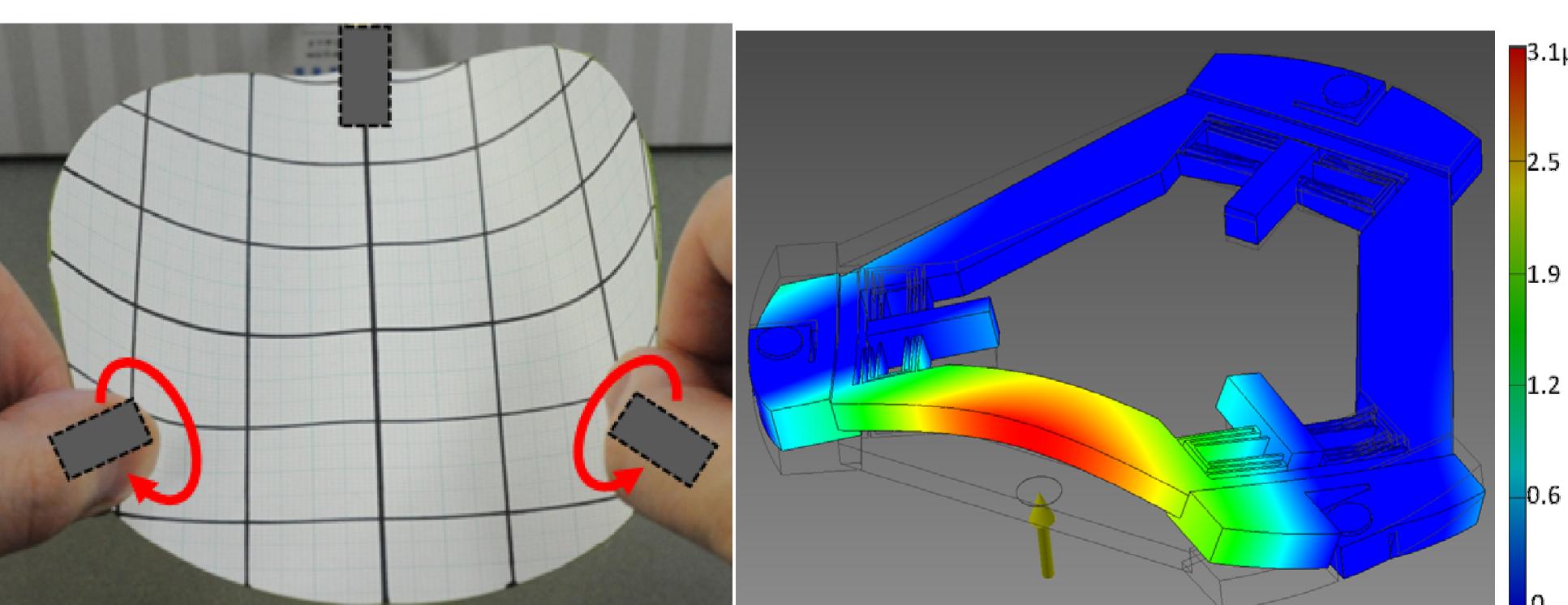
Aim of study:

Deformable mirror (Stigmator) to correct astigmatism with sub-nm accuracy.

Mechanical design

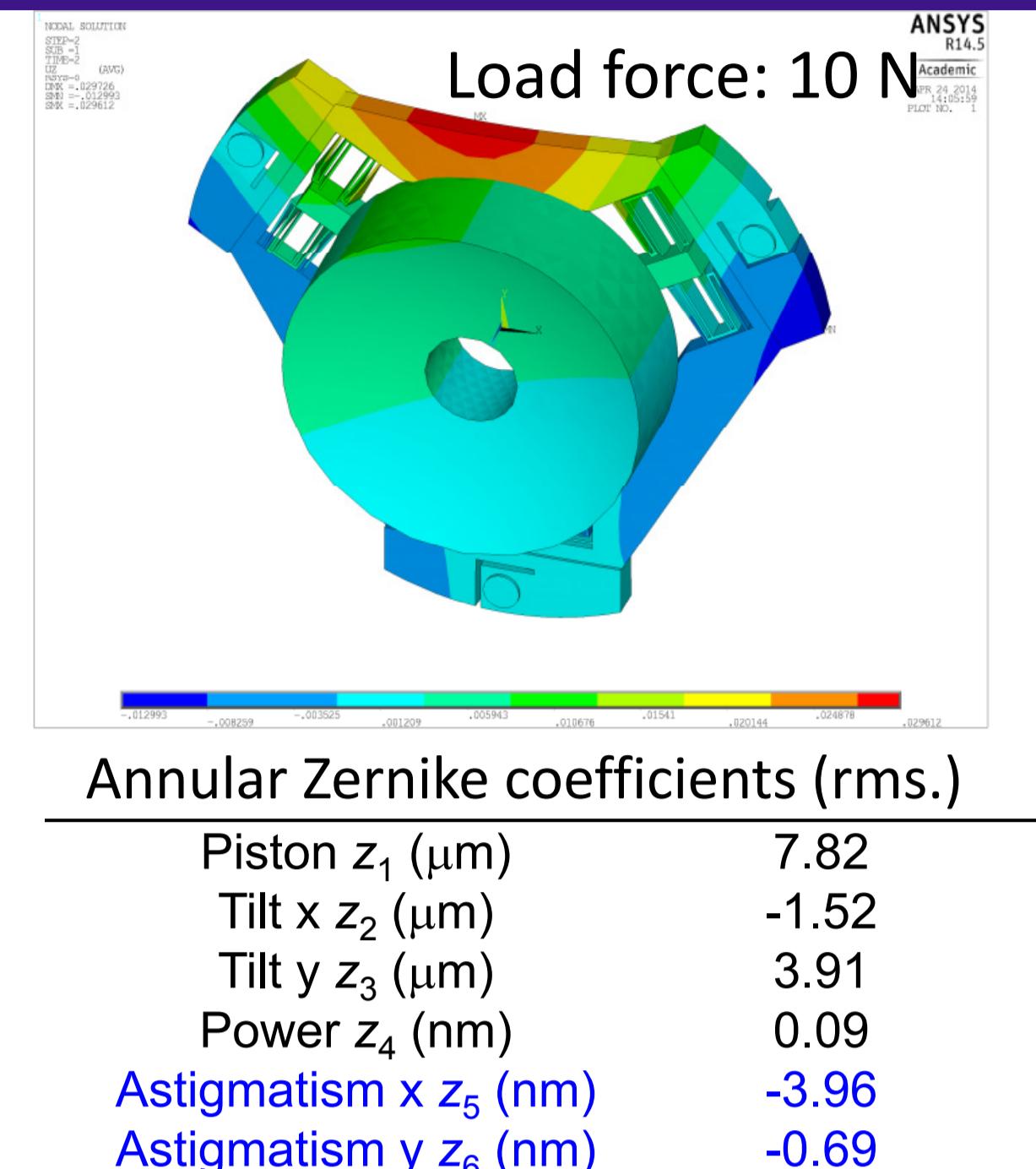


- ✓ Concave mirror (M1) is glued to three holding arms.
- ✓ Flexure springs (arrow) absorb thermal expansion.
- ✓ Picomotors (A1-A3) can apply force (max: 20 N) on holding plate (H1) to correct astigmatism.
- ✓ Three-axis stage with Picomotors (A4-A6) for fine alignment of convex mirror (M2).



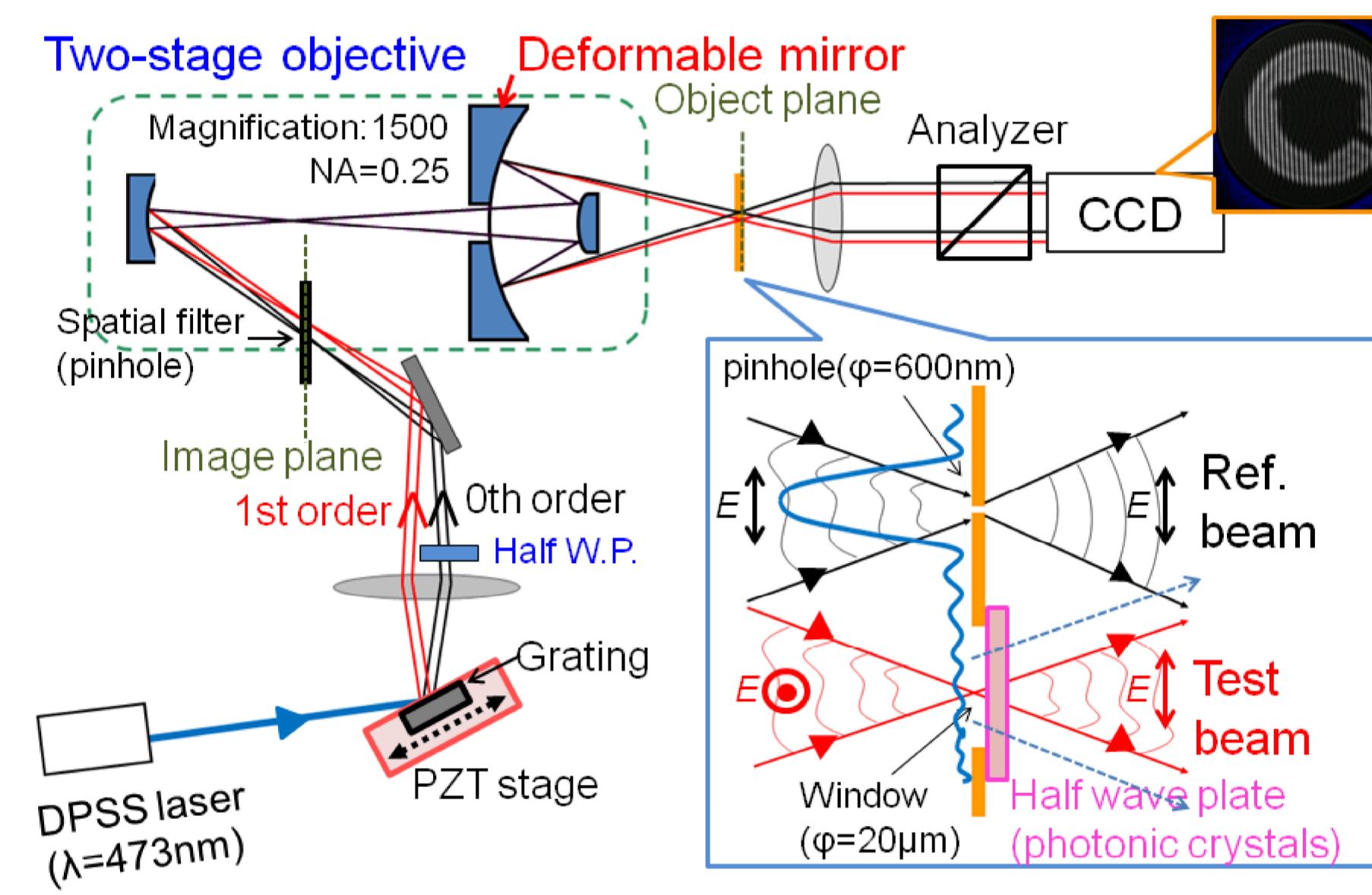
- ✓ Two torsional moments (twists) in opposite direction applied to holding arms (red arrows) modify radius of curvature of mirror surface.
- ✓ Torsional moments are generated with force applied to holding plate (yellow arrow).

FEM calculations



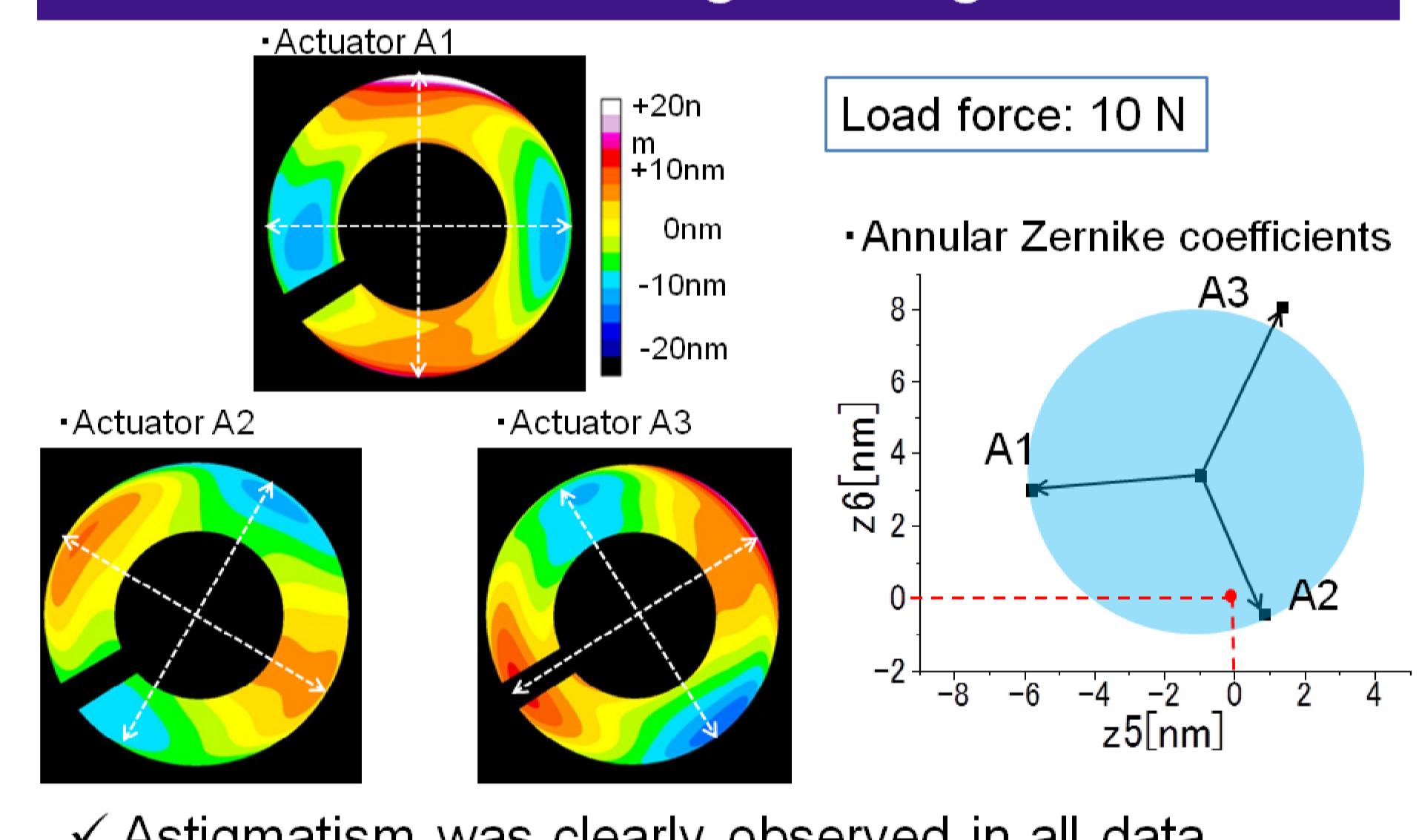
Experimental Results

Point Diffraction Interferometer



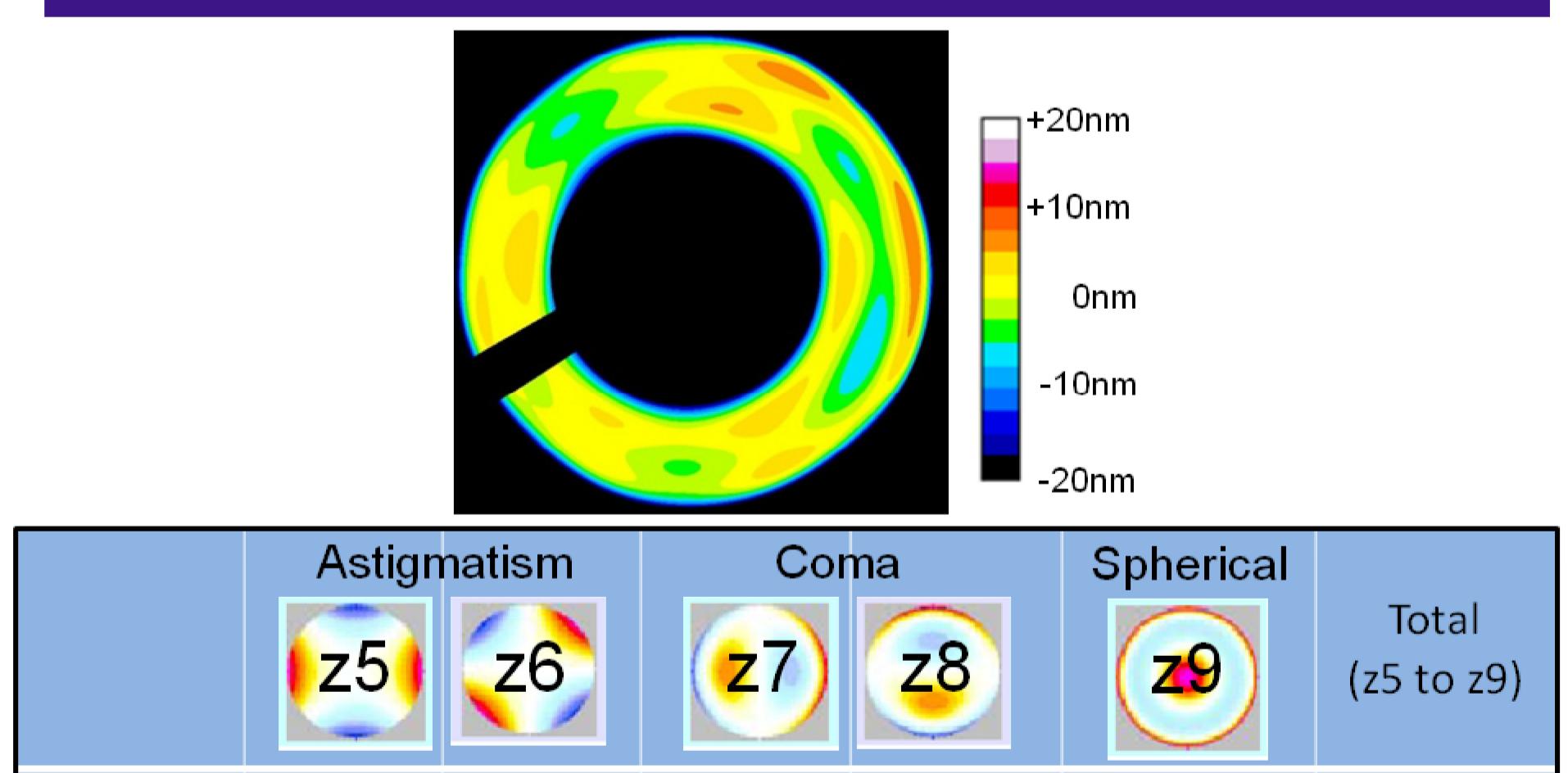
✓ Wavefront measurement with sub-nm accuracy

Wave aberration resulting from stigmator



- ✓ Astigmatism was clearly observed in all data.
- ✓ Control range as stigmator: $\pm 4\text{ nm rms}$.

Wave front after fine optical alignment



- ✓ Low-order aberrations were successfully corrected below 1/3 of Maréchal criterion @ $\lambda=13.5\text{ nm}$

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