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Actinic Inspection tool characterization using mask speckle

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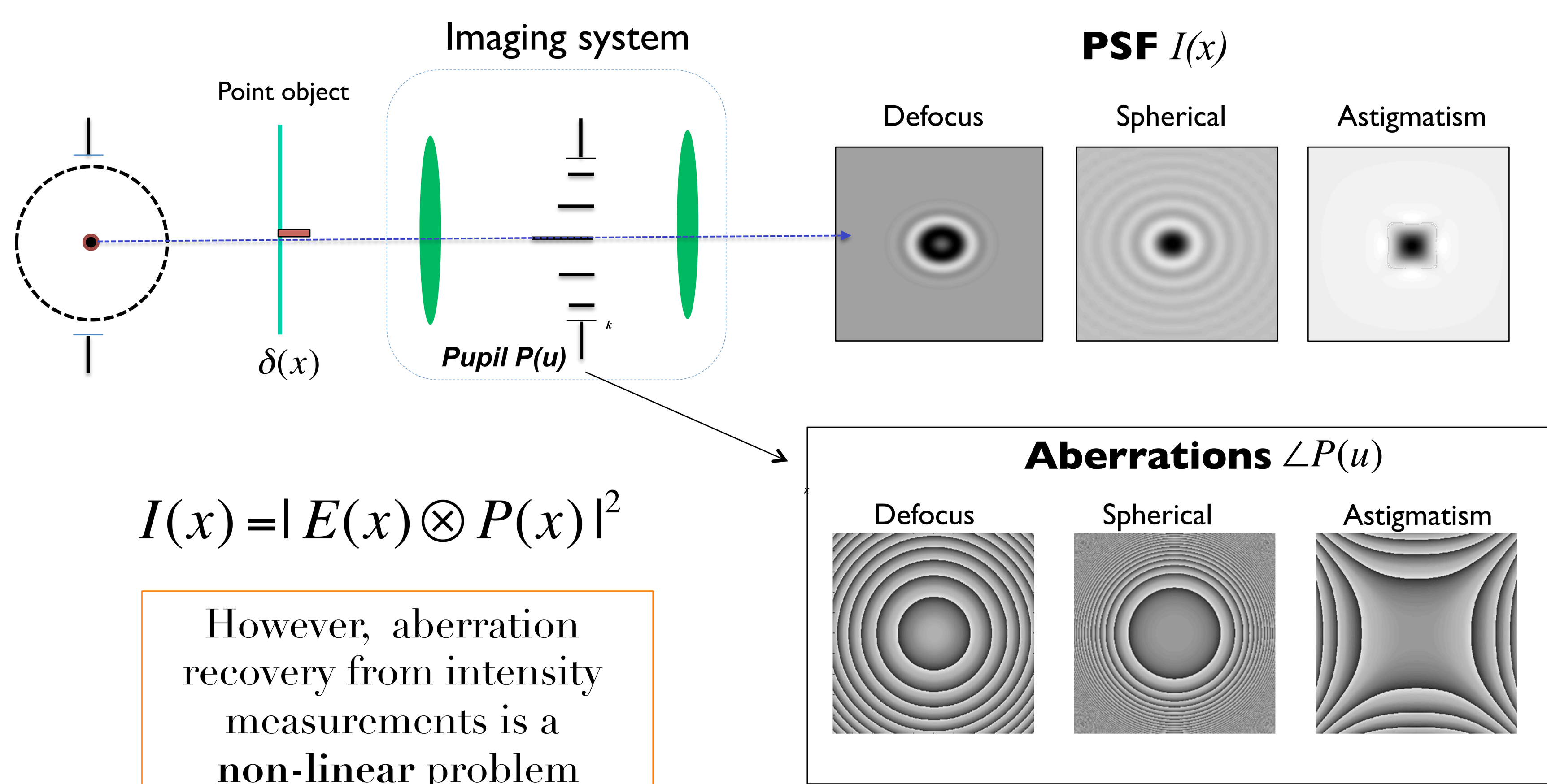
Imaging system performance degraded by aberrations

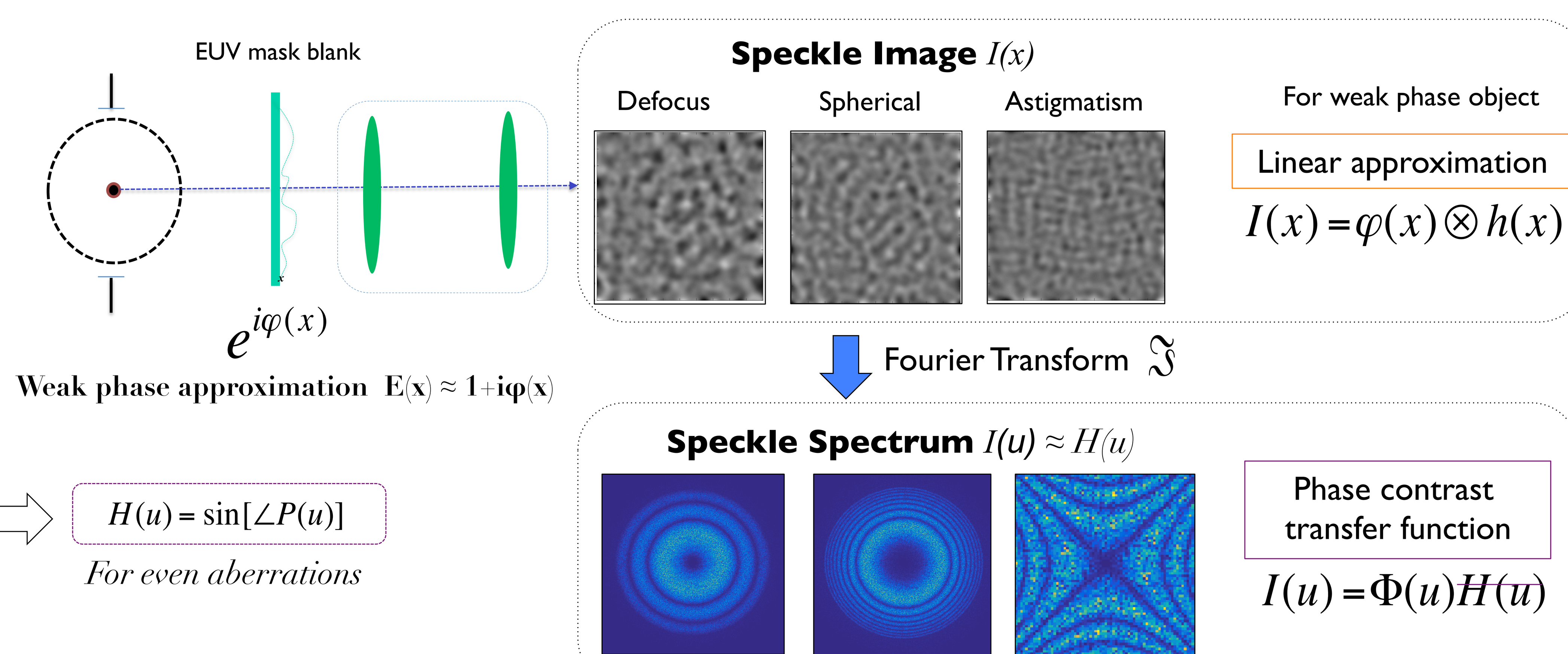


$$I(x) = |E(x) \otimes P(x)|^2$$

However, aberration recovery from intensity measurements is a non-linear problem

u : spatial frequency , x : spatial coordinate

Speckle from blank mask encodes system aberrations in its spectrum[1,2]



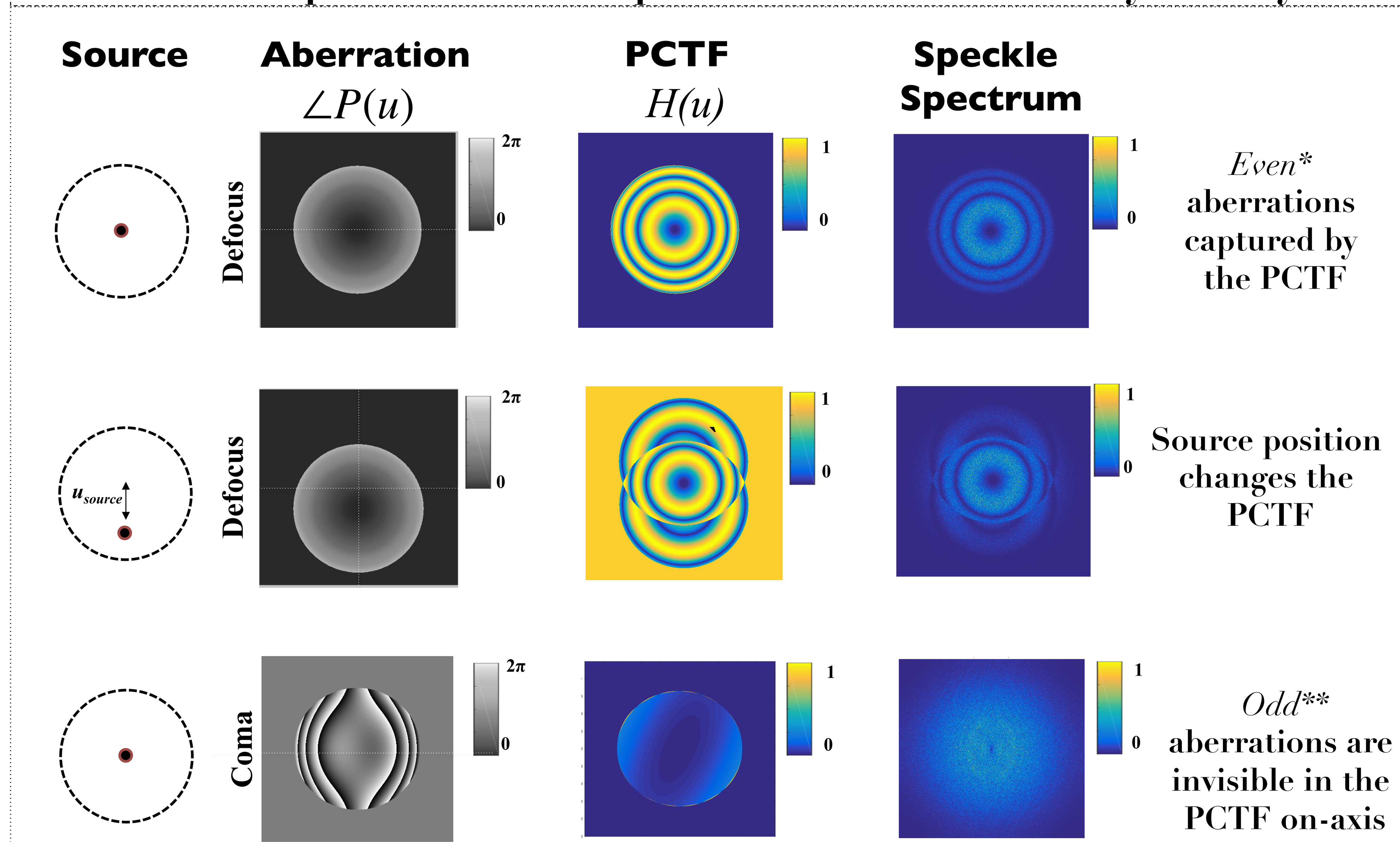
$I(u) \approx H(u) \approx \sin[\angle P(u)]$ *since the speckle spectrum* $\Phi(u)$ *is flat*

Properties of the Phase Contrast Transfer function (PCTF) imaged by speckle spectrum

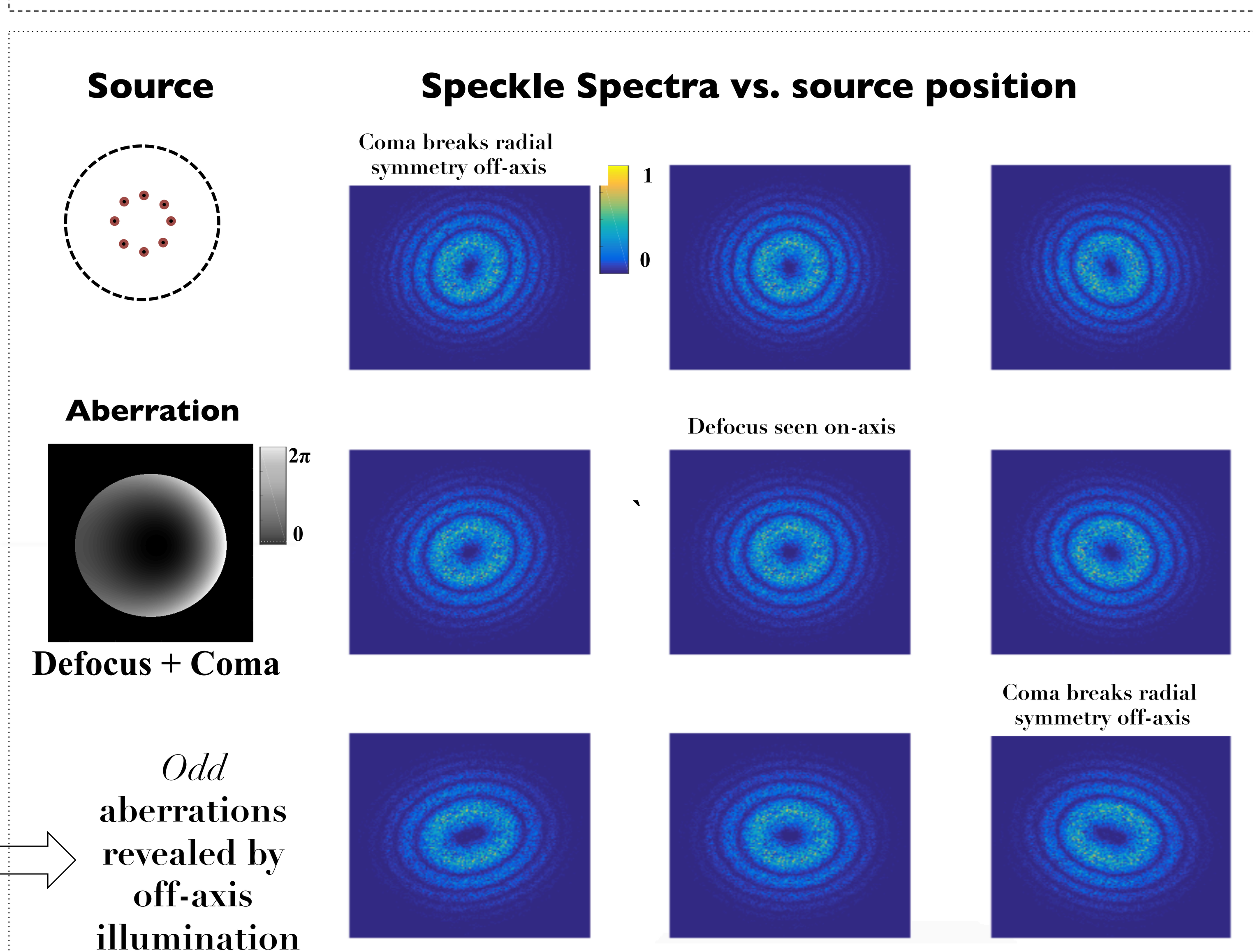
The PCTF *: coherent system pupil + its flipped conjugate*

$$H(u) \propto P(u - u_{source}) - P^*[-(u + u_{source})]$$

PCTF depends on source position and aberration symmetry

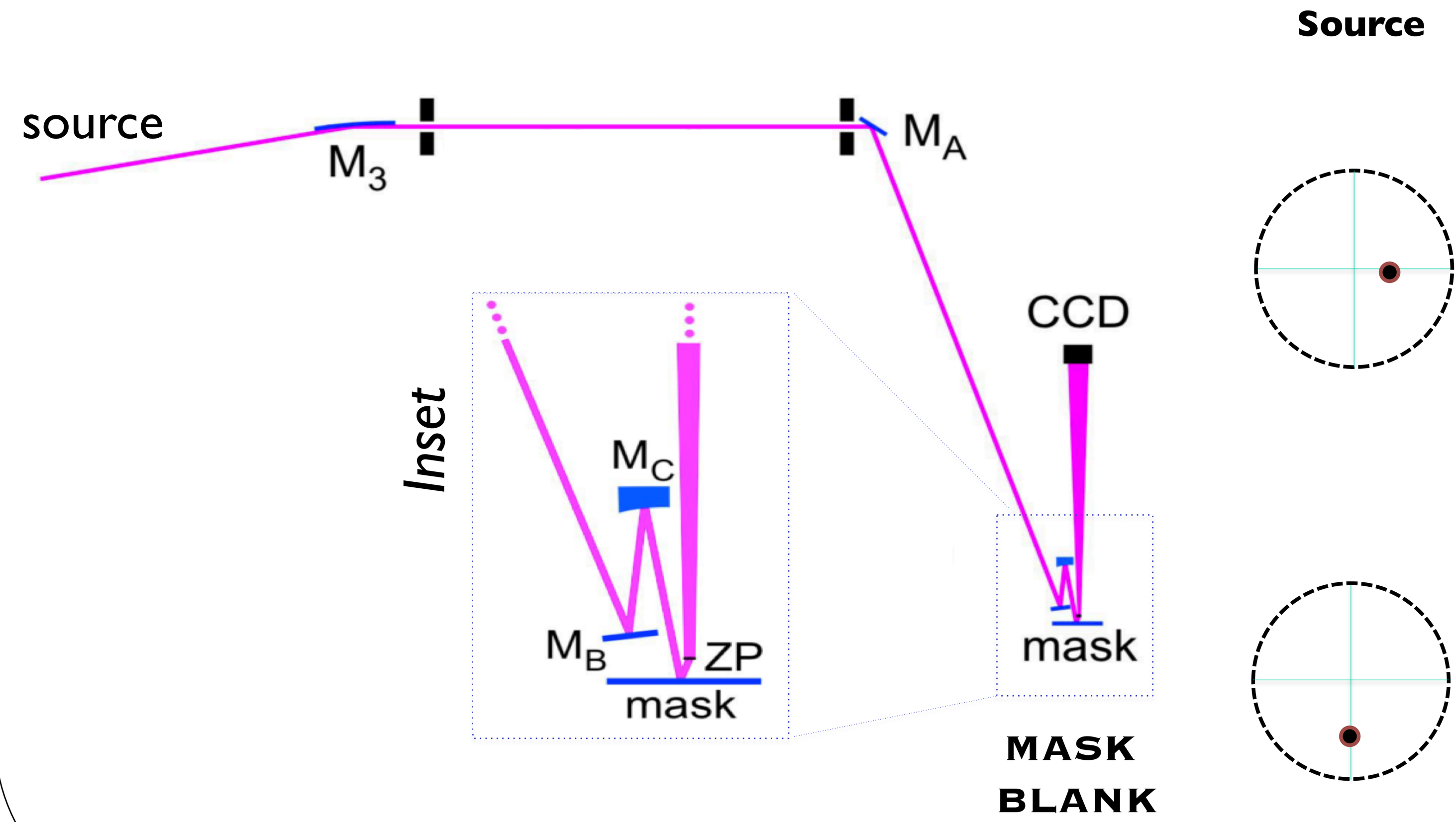


Diffraction Tableaux[4]: Off-axis measurements can recover odd aberrations

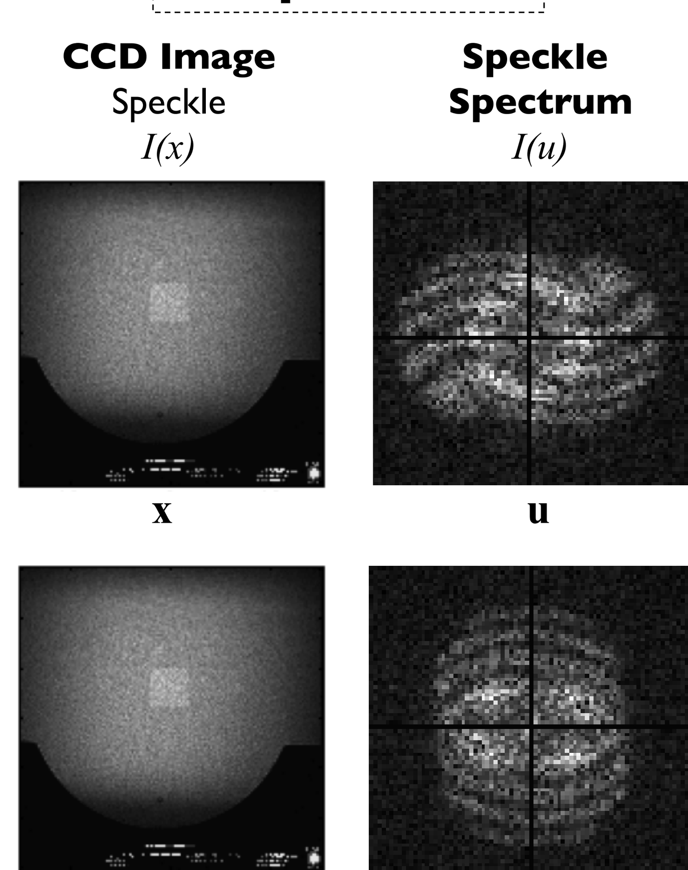


*Even aberration(centro-symmeric) : $\angle P(u) = \angle P(-u)$ **Odd aberration (centro-antisymmetric) : $\angle P(u) = -\angle P(-u)$

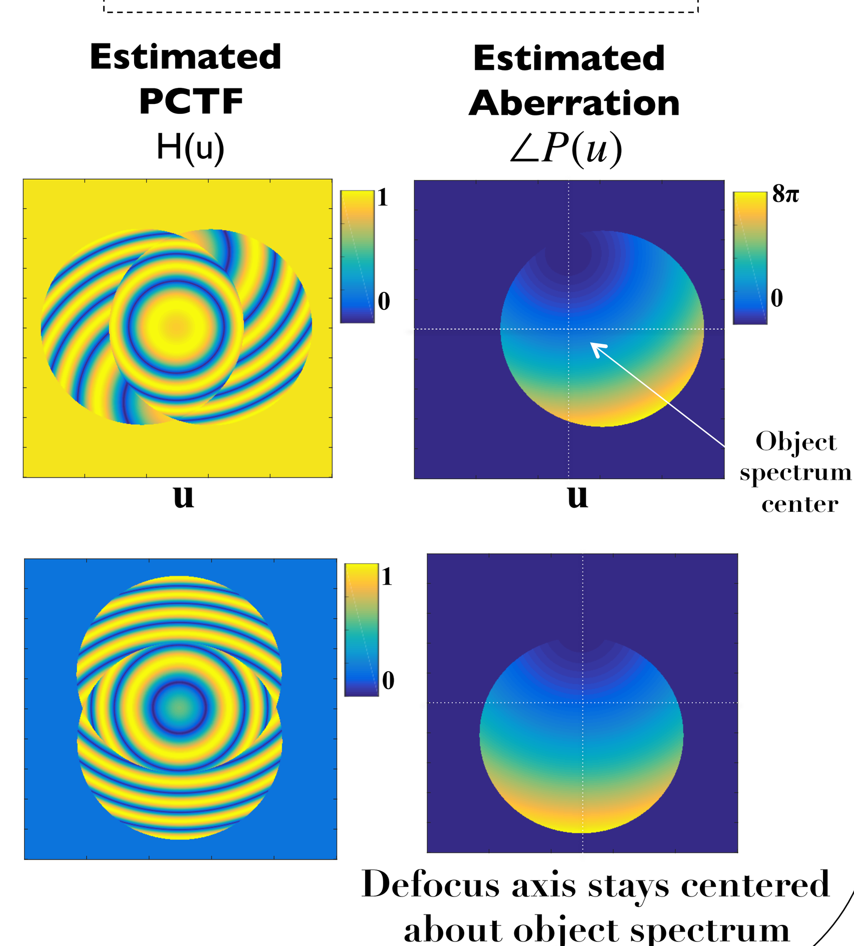
Recovering Aberrations in SHARP EUV MICROSCOPE



Experiment



Aberration Estimation



Defocus axis stays centered about object spectrum

CONCLUSIONS

Speckle from a blank mask is used to estimate system aberrations.

Both even and odd aberrations can be estimated using illumination angle tilt.

Future: use knowledge of system aberrations to improve imaging accuracy.

References:

[1] Meitav et al., "Point spread function estimation from projected speckle illumination", Light: Science & Applications (2016) 5, e16048.

[2] G. Gunjala, A. Shanker, V. Jaedicke, N. Antipa, and L. Waller, "Optical transfer function characterization using a weak diffuser," Proceedings of SPIE (2016).

[3] H. Rose, "Nonstandard imaging methods in electron microscopy" Ultramicroscopy (1977).

[4] F. Zemlin, K. Weiss, P. Schiske, W. Kunath, and K.-H. Herrmann, "Coma-free alignment of high resolution electron microscopes with the aid of optical diffractograms," Ultramicroscopy 3, 49 – 60 (1978).

Acknowledgement

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