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Title

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Extreme Ultraviolet Phase Contrast Imaging

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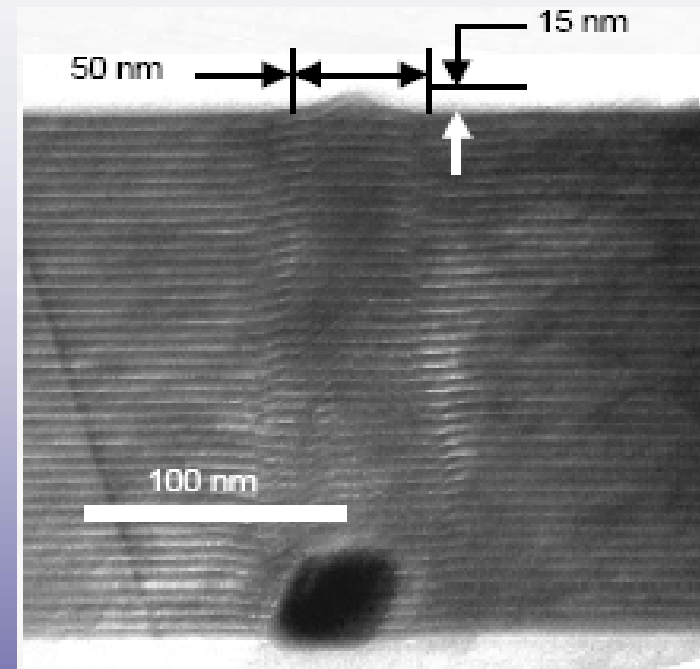
Outline

- ❑ **Motivation – high resolution phase contrast imaging**
- ❑ **Approach**
 - **High resolution zone plate optics with Zernike Phase Contrast**
- ❑ **Experimental design**
- ❑ **First imaging results**

EUV Phase Defects

- Pits or bumps under the Mo/Si multilayer used for the masks in EUV lithography will cause a local phase shift in the reflected radiation
- It is important to find the phase defects and measure the phase shift to determine the effect of the defect on the image formation and to work toward remediation if necessary
- A bump or pit of 2 nm at the surface of the Mo/Si multilayer may be printable

Phase contrast imaging can determine the phase shift and reflectivity change of defects with high resolution to help in the understanding of the cause and possible remediation



*P.B. Mirkarimi et al, SPIE Microlithography
March 2005*

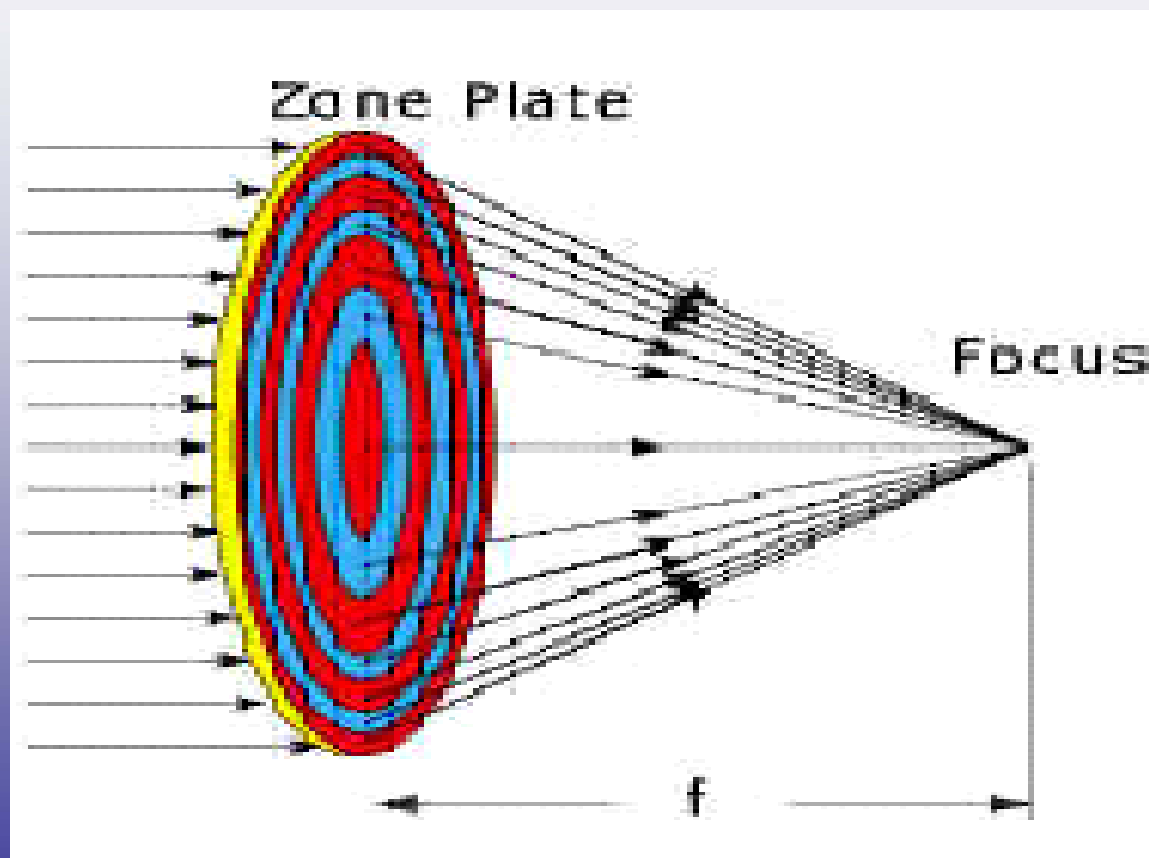
Phase Contrast

- By aligning a phase disk in the back focal plane of the zone plate imaging optic, Zernike phase contrast can be employed
- This phase contrast mode will also provide sub-nm measurements of the phase shift from phase defects
- Coupled with the 30 nm spatial resolution zone plate optics for imaging, this technique will provide the accurate maps of the phase shift across phase defects to better understand the causes of the defects, learn which are relevant to printing in EUV lithography, and to work toward repair strategies for the defects



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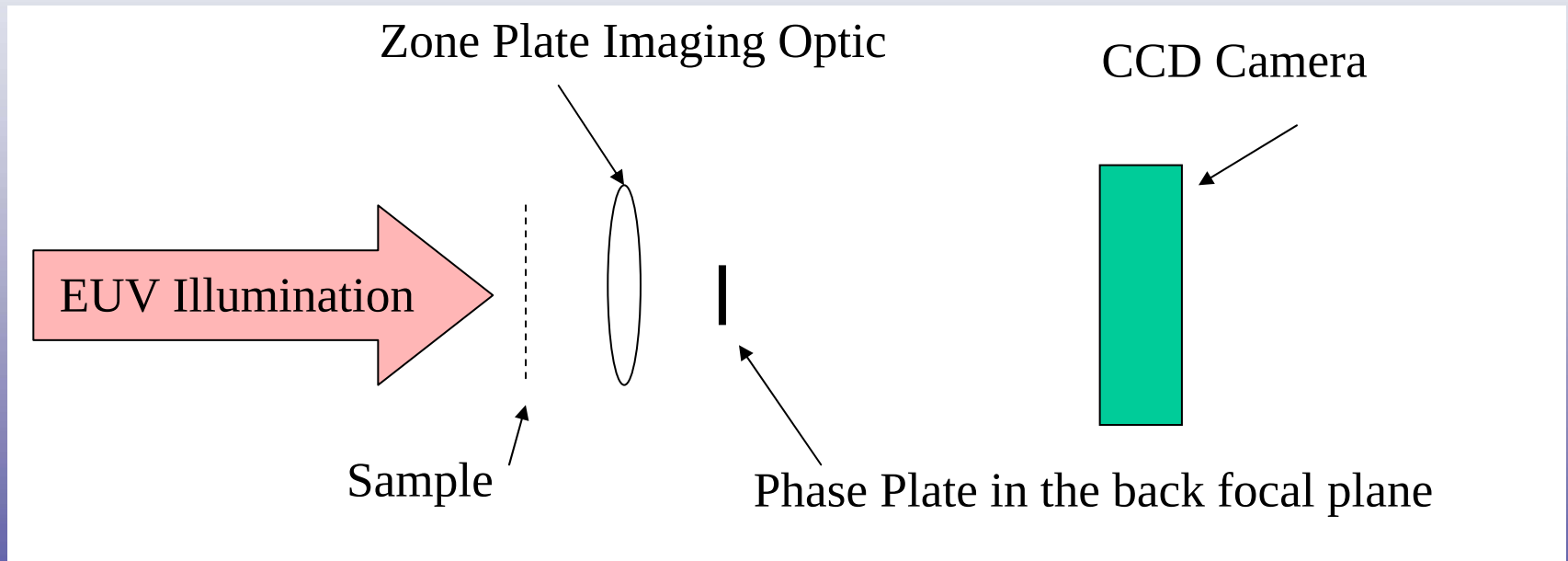
Zone Plates – High resolution optics for short wavelength radiation



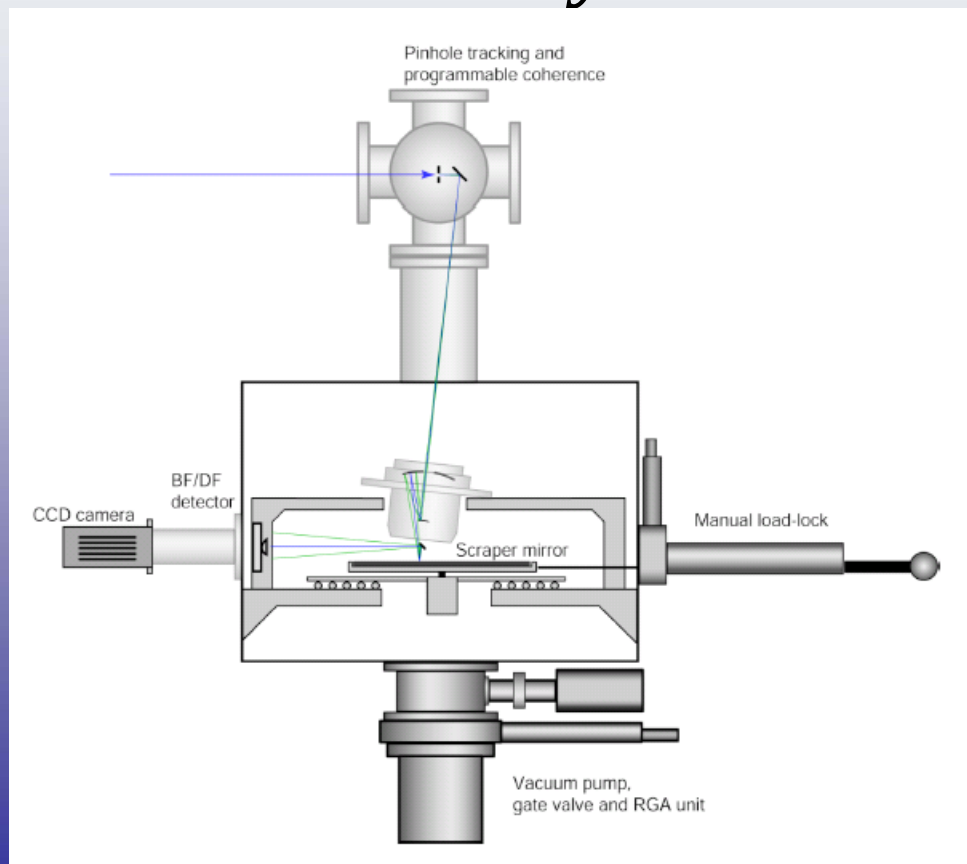
The path length from neighboring transparent zones
to the focus differs by one optical wavelength



Experimental Configuration for first phase contrast Imaging



This phase contrast imaging will soon be incorporated into the Actinic Inspection and Defect Review system

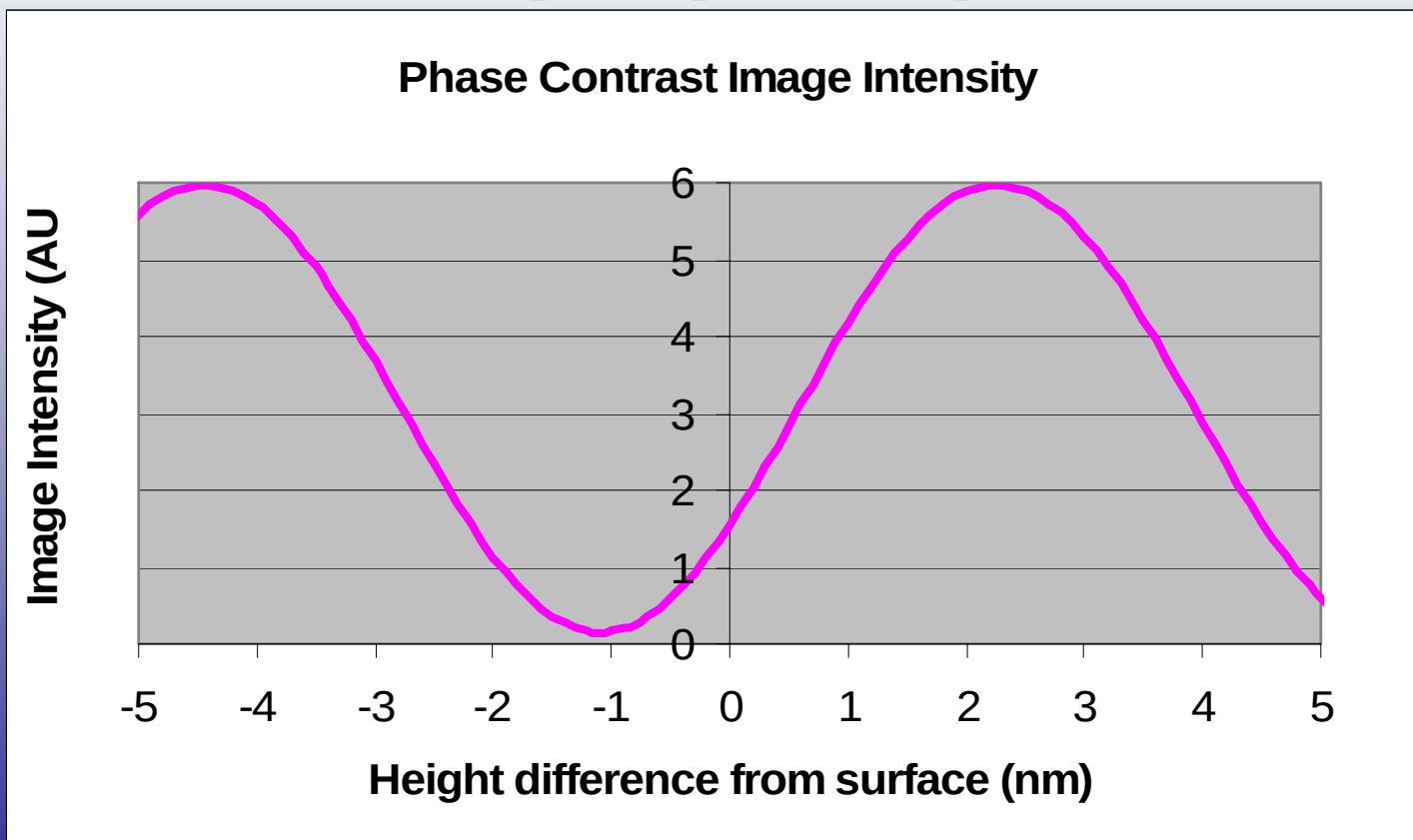


Anton Barty, Yanwei Liu, Eric Gullikson, John S. Taylor and Obert Wood, SPIE March 2005

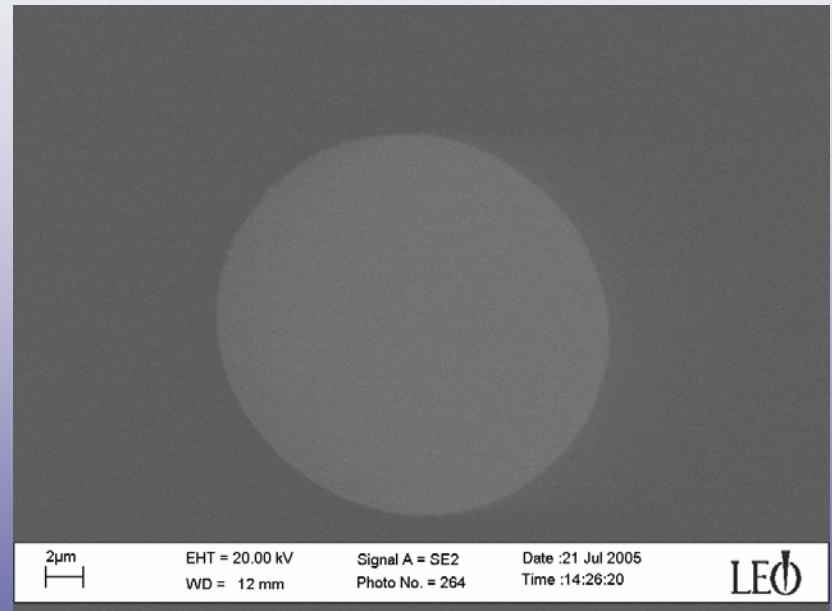
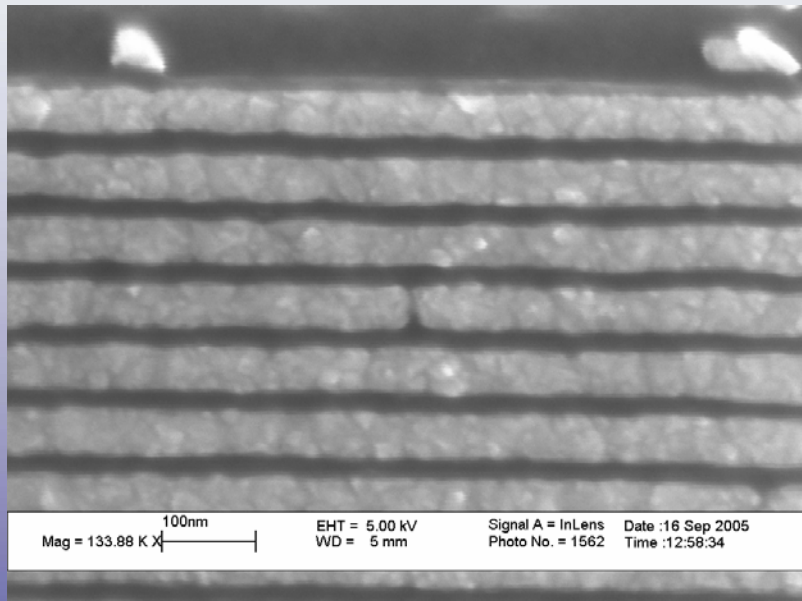


Image Contrast

Contrast for shifts of the reflecting “surface”
for a 21 nm Mo phase plate ($\pi/4$ phase shift)



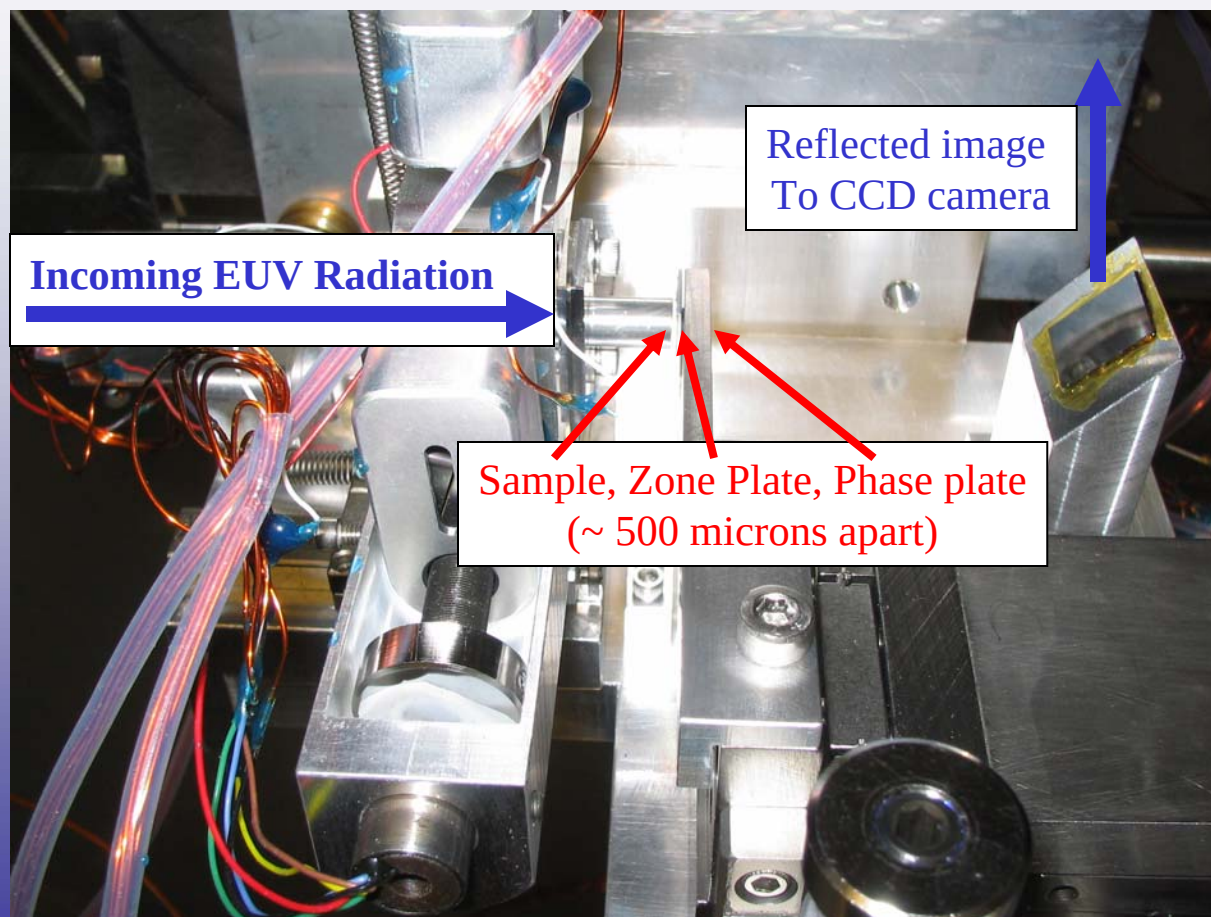
Zone Plate and Phase Plate



Both are fabricated on a SiN membrane

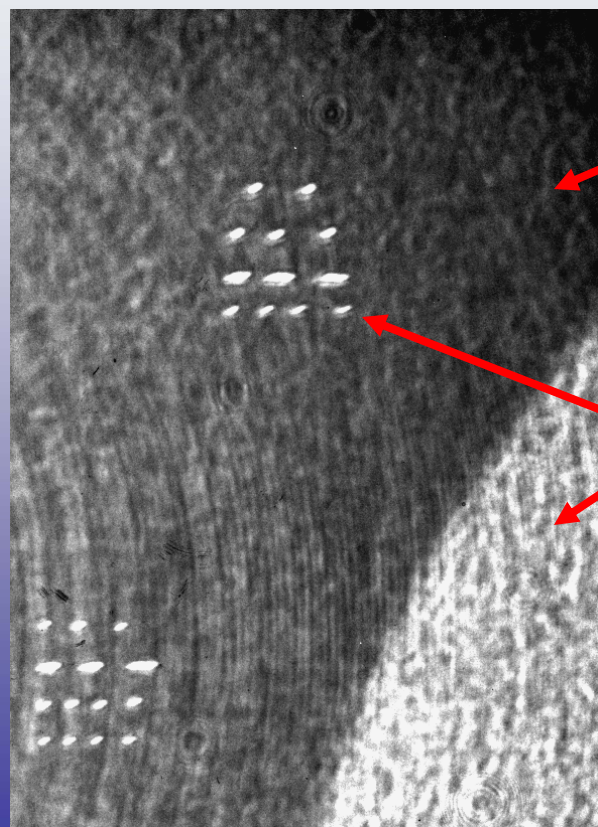


Experimental Configuration



First Images

Bright field image
Phase disk removed

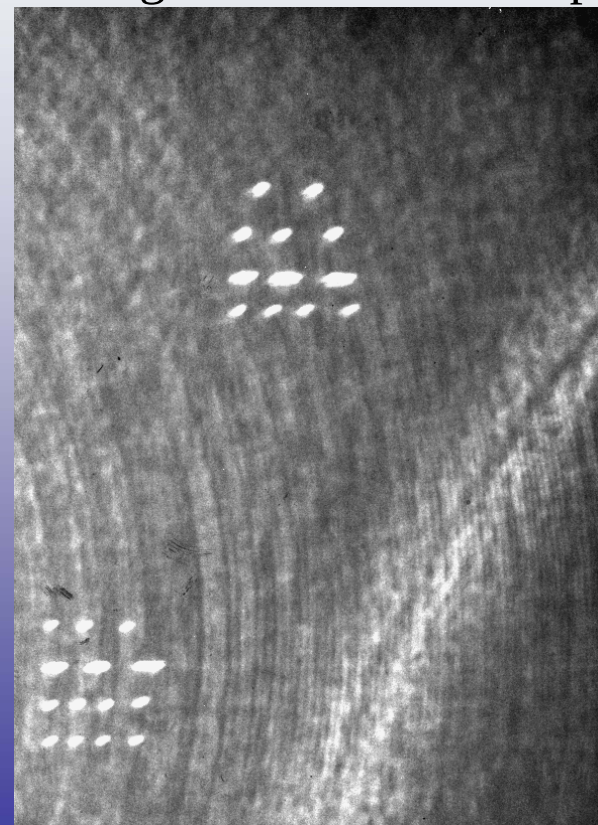


Molybdenum sample
Nominally 60 nm thick
70% transmission
2.2 radian phase shift

Clear regions of sample
(No molybdenum)

12 microns

Dark-field image
Absorbing disk in back focal plane



Conclusions

- ❑ **Zone plate microscopy provides high resolution imaging of EUV masks**
- ❑ **Using phase plates in the back focal plane of the objective lens can provide contrast mechanisms for measurement of the phase shift from defects on the mask**
- ❑ **The first high resolution EUV Zernike phase contrast images have been acquired**
- ❑ **Future work will include phase contrast mode in reflection from an EUV mask to directly measure the reflectivity and phase shift from defects**