# Characterization of EUVL Mask Defects by EUV Far-Field Scattering Patterns

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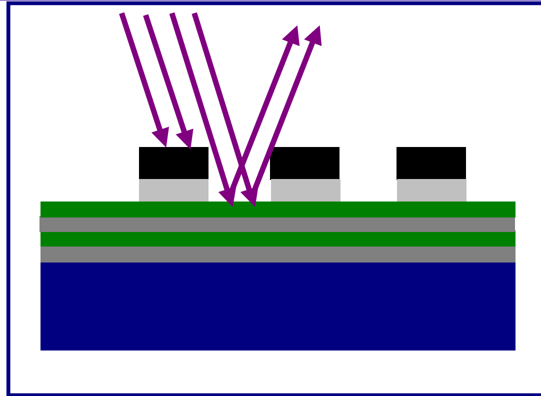
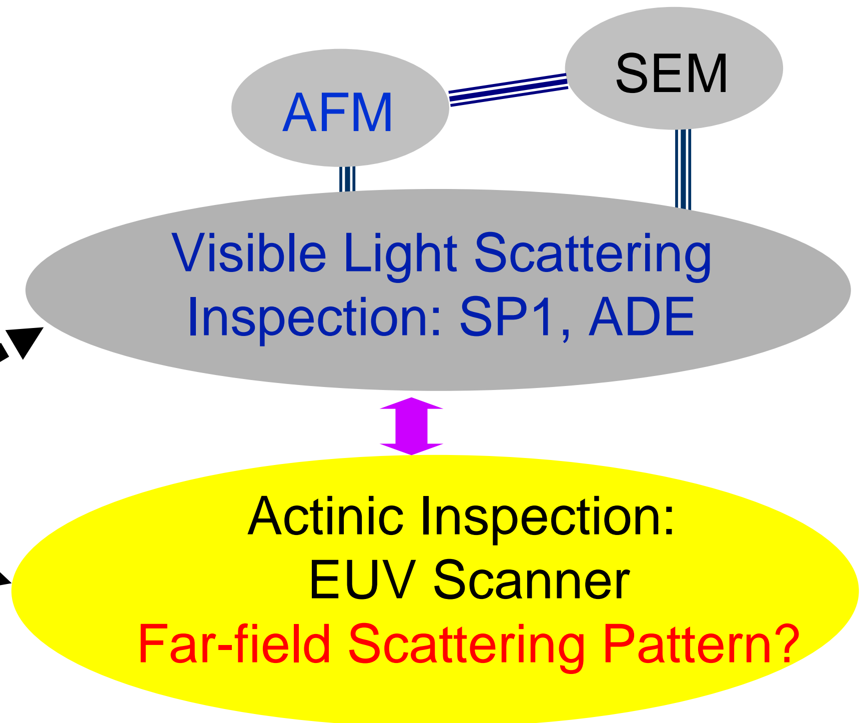
We present far-field scattering characteristics of programmed phase and opaque defects on extreme ultraviolet lithography mask blanks. Phase defects and opaque defects could be distinguished by their diffraction characteristics. Non-specularly scattered diffraction fringe pattern contrast was very distinct at the dark field observation of both of phase and opaque defects. Regardless of the opaque or phase defects, the fringe spacing of far-field diffraction patterns were dependant on the defect size. Through the observation of far-field diffraction patterns, some preliminary results of the defect classification result are reported

# Actinic Inspection of EUVL mask blank



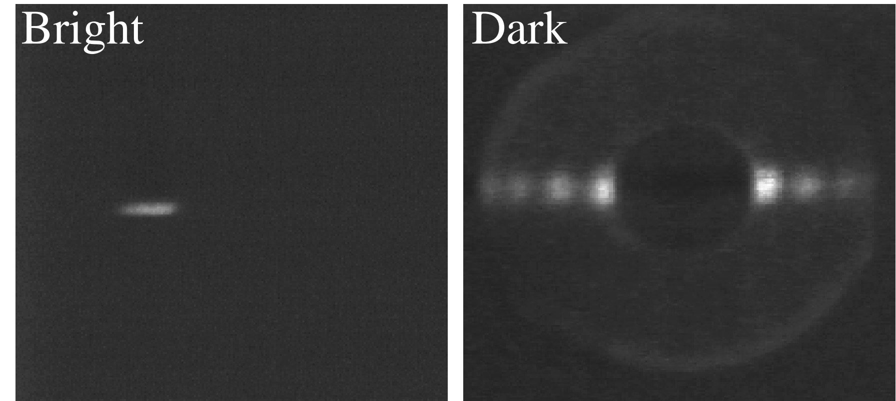



Low Defect Density Deposition Tool

- Optical inspection tool measures optical scattering cross section of defects:
- Cross correlation with actinic tool for probing the printability of defects
- Optical inspection tool might not detect all the printable defects?
- Detection by spatially integrating the scattered signal in the far field
- Far-field scattering characteristics from Actinic inspection tool ?

# Far-Field Scattering Detection Scheme from EUV Mask Scanner



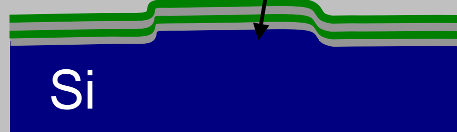



- Raster Scanning under Focused Beam
- Detect Reflectivity Drop (Bright Field) or Increase in Scattering (Dark Field)
- Bright and Dark Field Scattering patterns on Phosphor was captured by CCD camera.
- Spot Size: 2.5 x 5 $\mu m$
- Programmed opaque and phase defects sizes from 1.5X8 $\mu m^2$ to 0.2X0.2 $\mu m^2$

# Programmed EUV Mask Defects

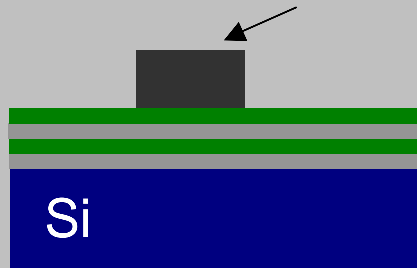
Phase Defect

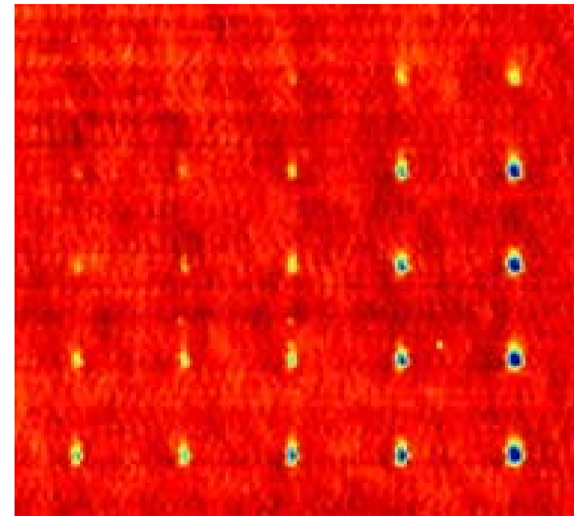
25 nm high programmed defect




Opaque Defect

Absorber(Al 150 nm)

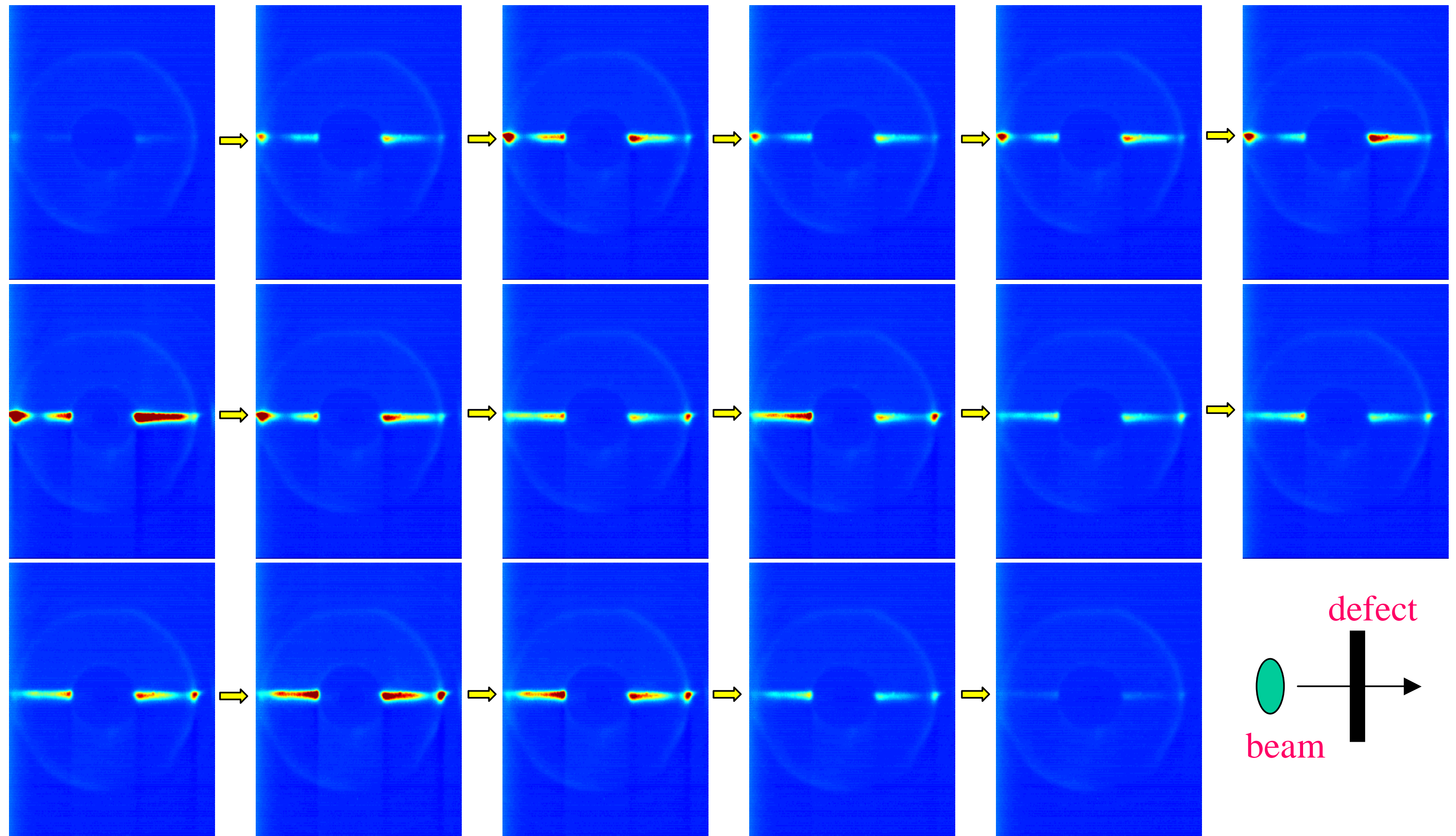


5x5 Defect Array

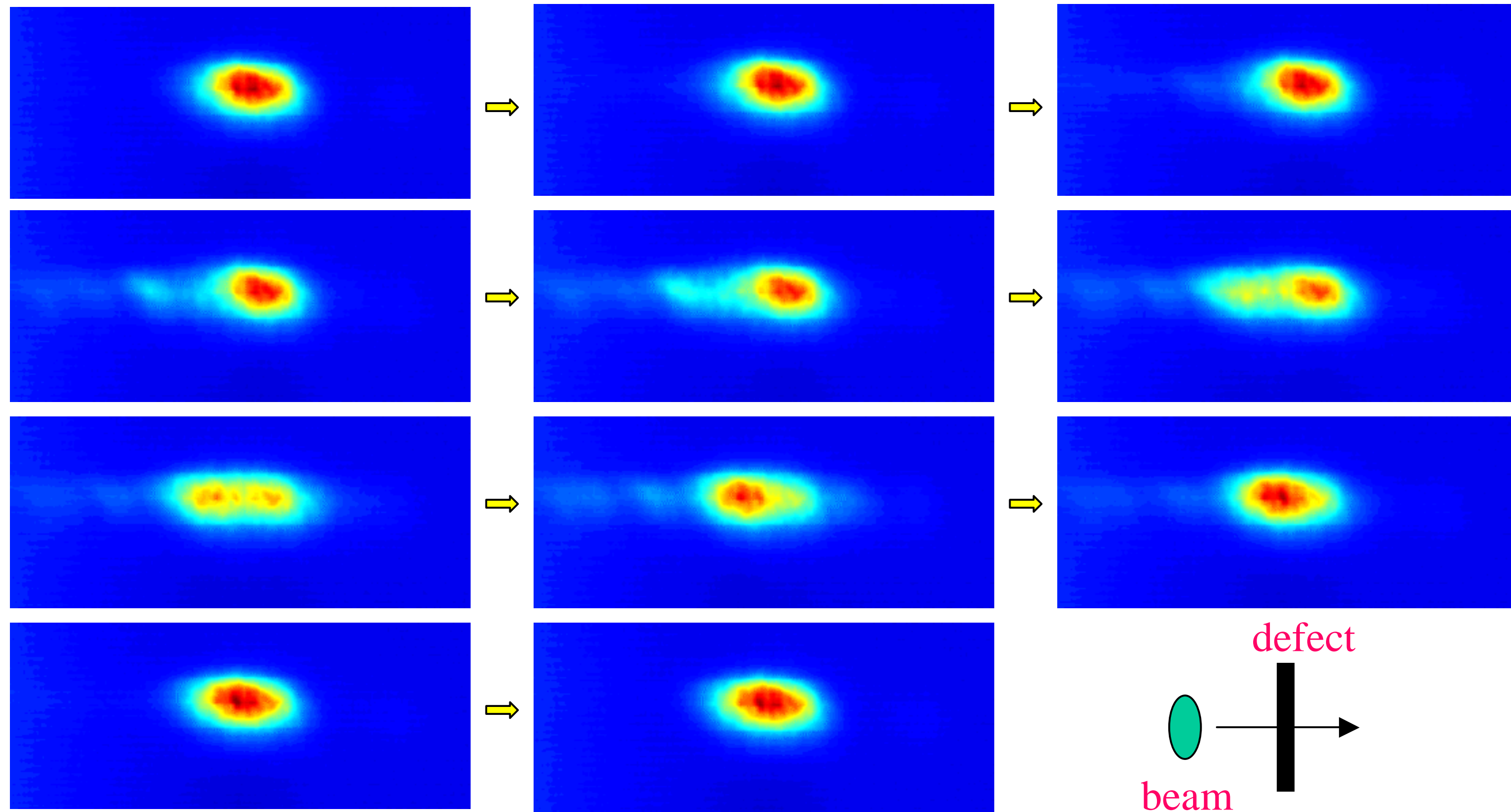
- 5 x 5 array of programmed opaque and phase defects with 80 µm spacing
- size: 1.5 x 8 µm - 0.2 x 0.2 µm
- Patterning with Optical Lithography

# Dark Field Scattering Overlap



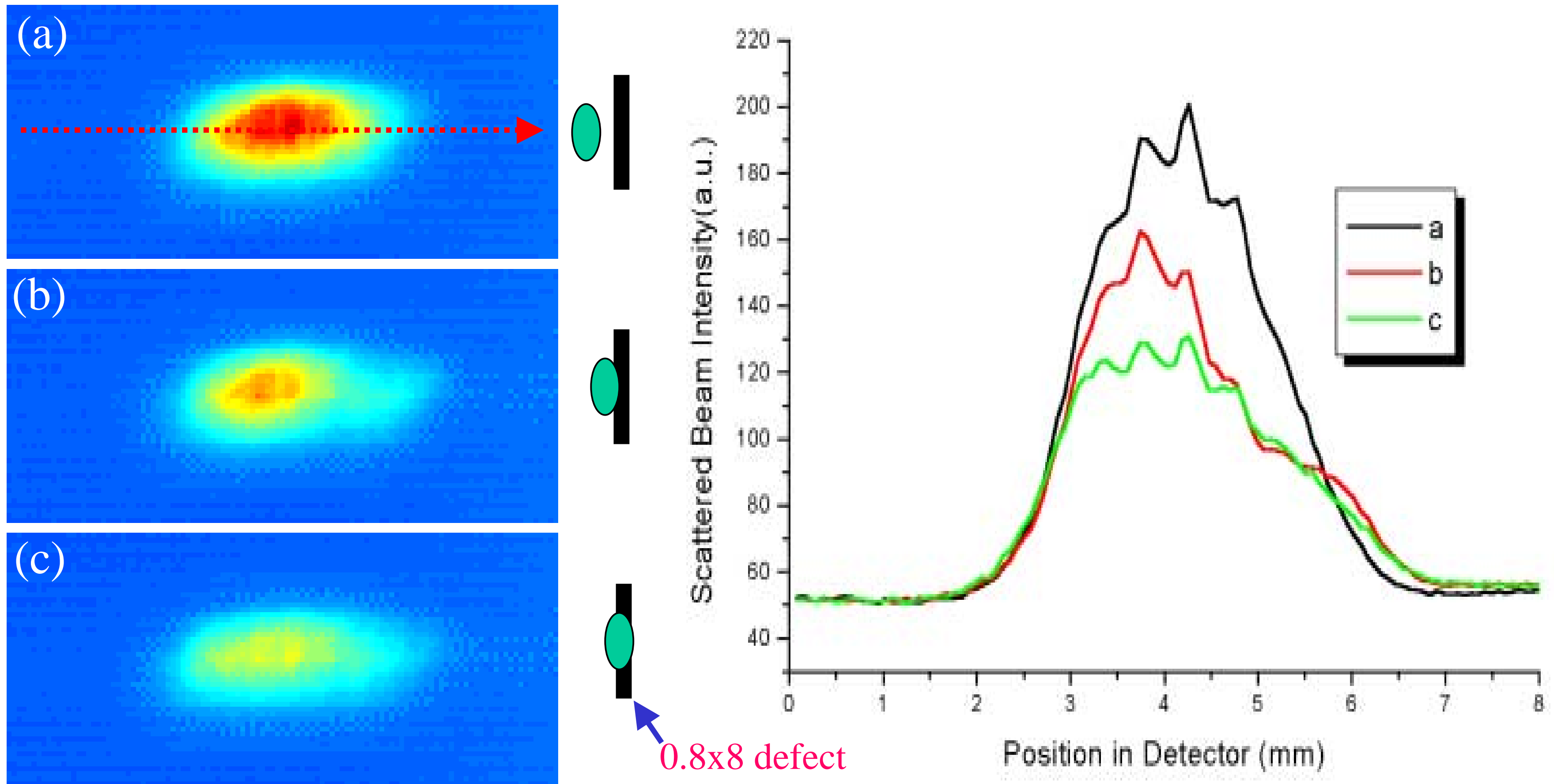

• 40 image frames are averaged at each relative beam positions with respect to the defect.

# Bright Field Scattering Overlap



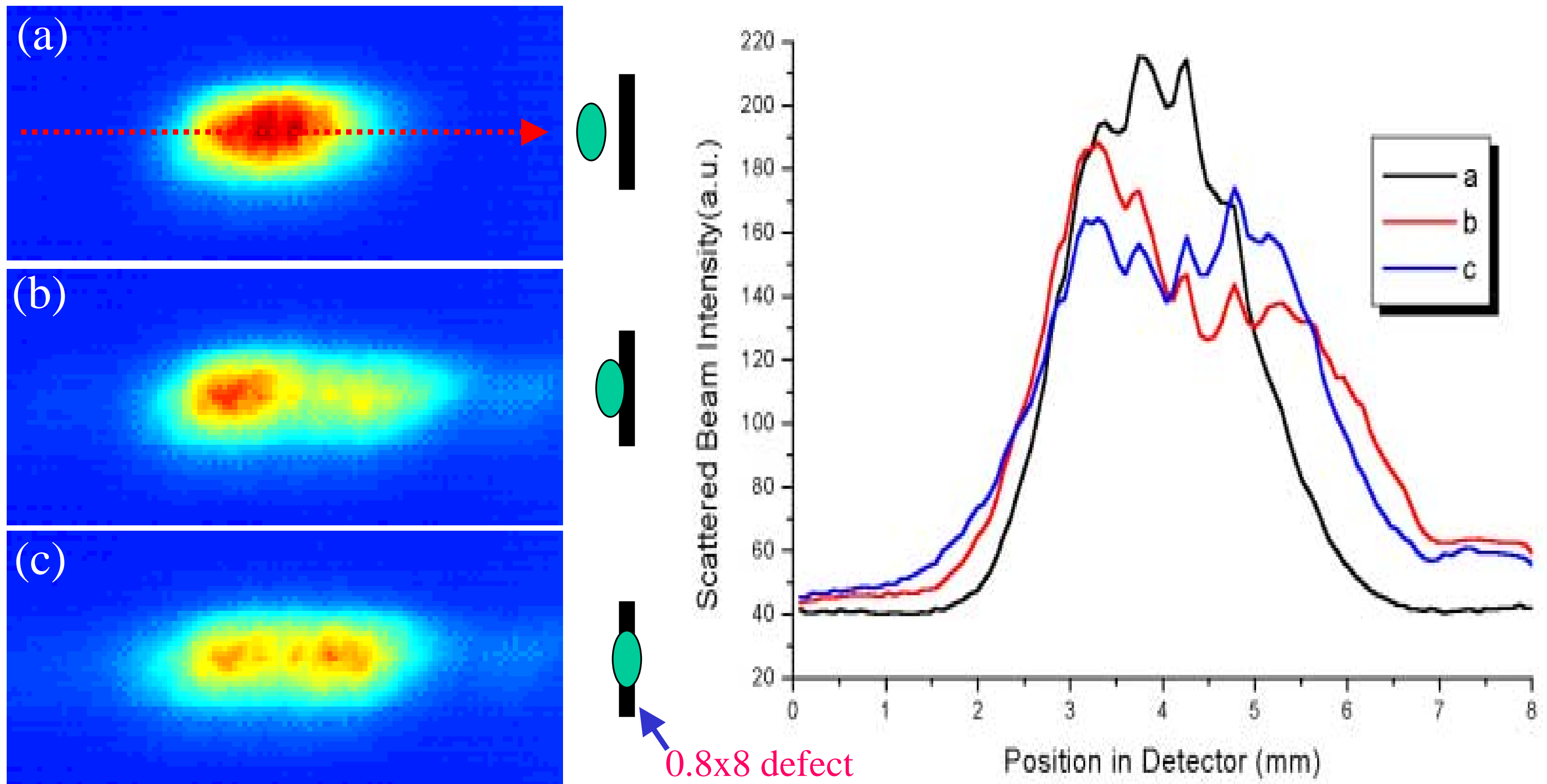

• To detect bright field, the detector assembly was positioned so that the specular beam hit the MCP/phosphor assembly.

# Bright Field Scattering of Opaque Defects



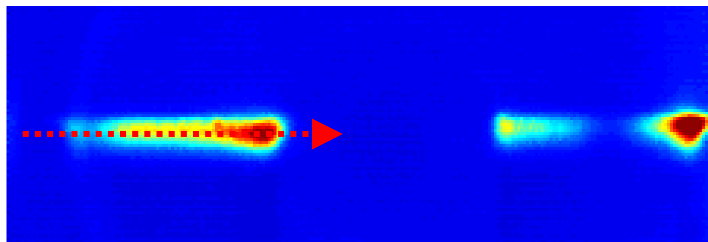

- Specular beam intensity was decreased as the incident beam passes through the defect.
- Specular beam width was changed very little when the beam hit the defect.

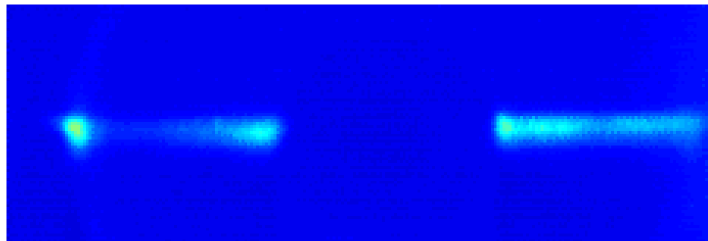
# Bright Field Scattering of Phase Defects

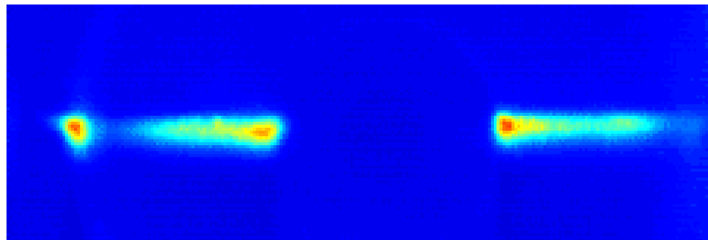



- The specularly scattered beam from phase defect was not decreased much in its intensity and the scattered beam width became wider than opaque defects case.

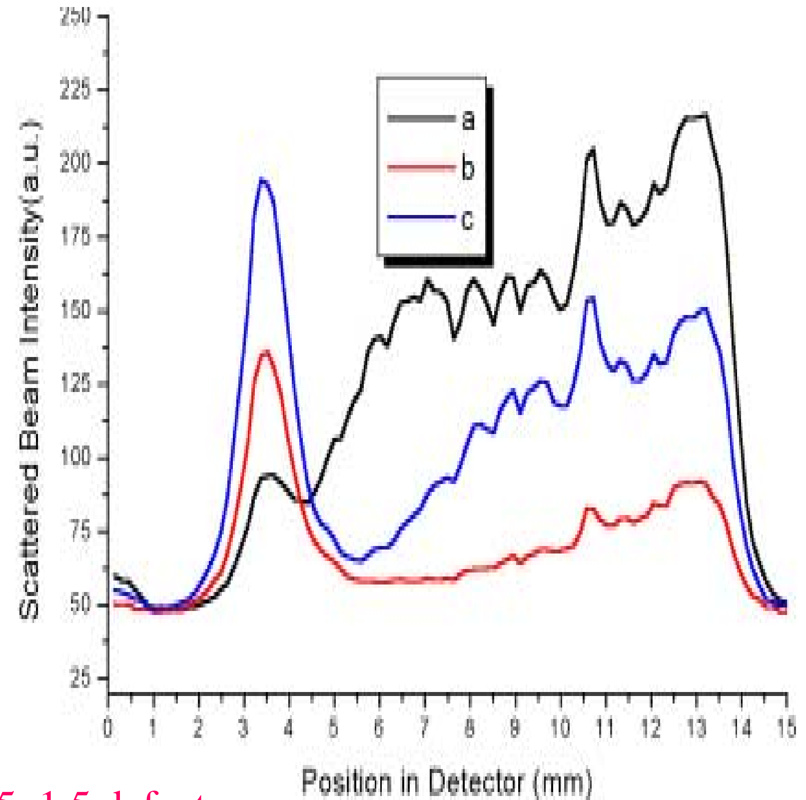
# Dark field Scattering of Phase Defects





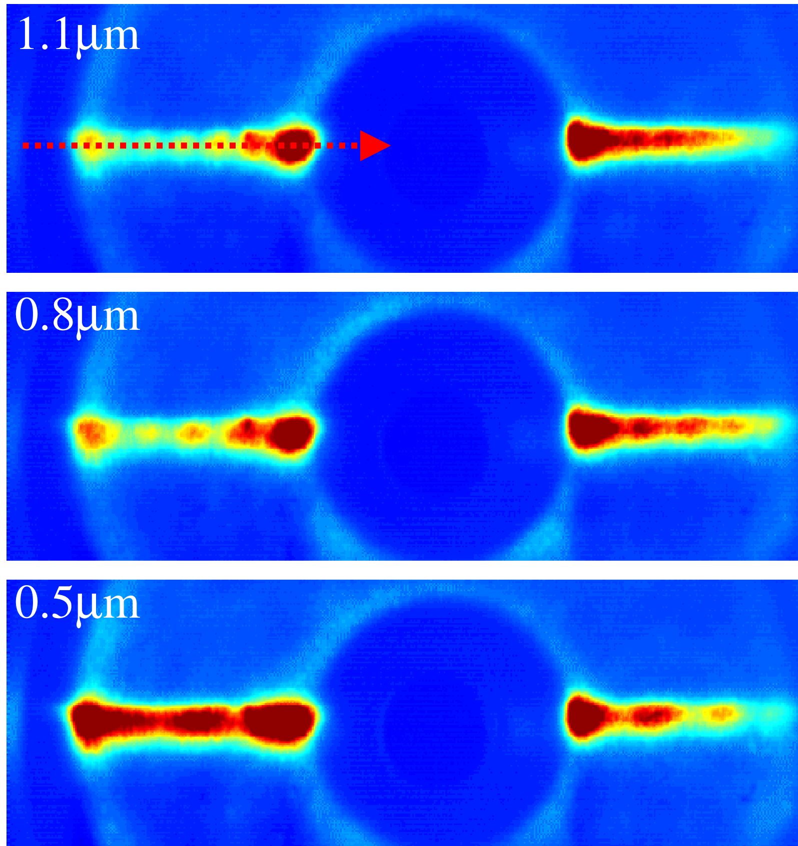


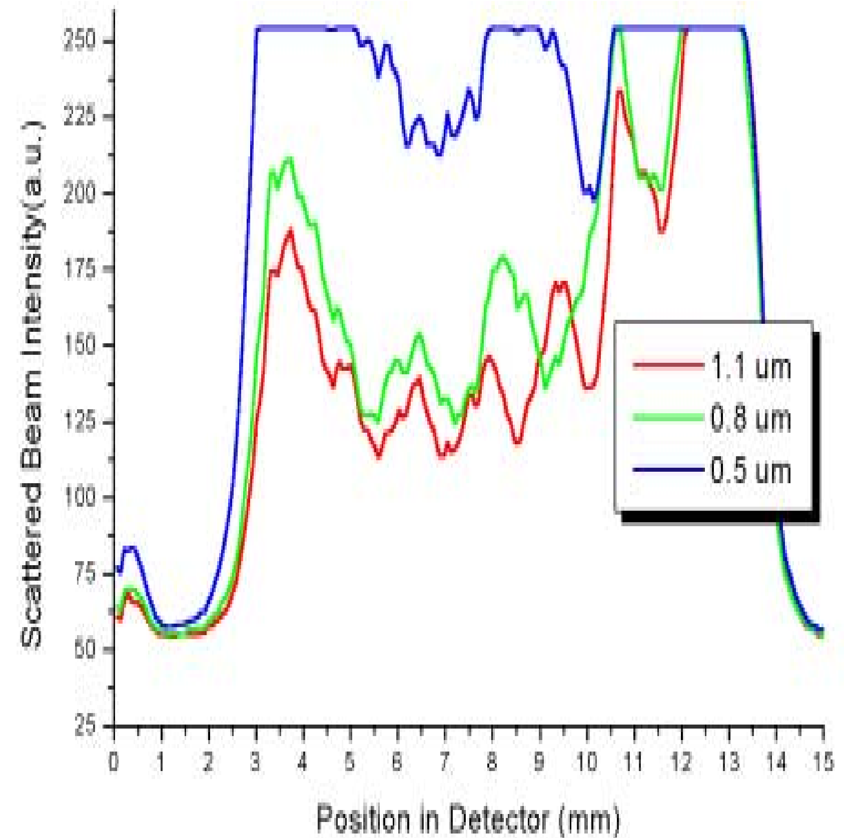
1.5x1.5 defect




- The intensity when the beam hits either edge of the defect, was higher than when beam hit right on the defect.

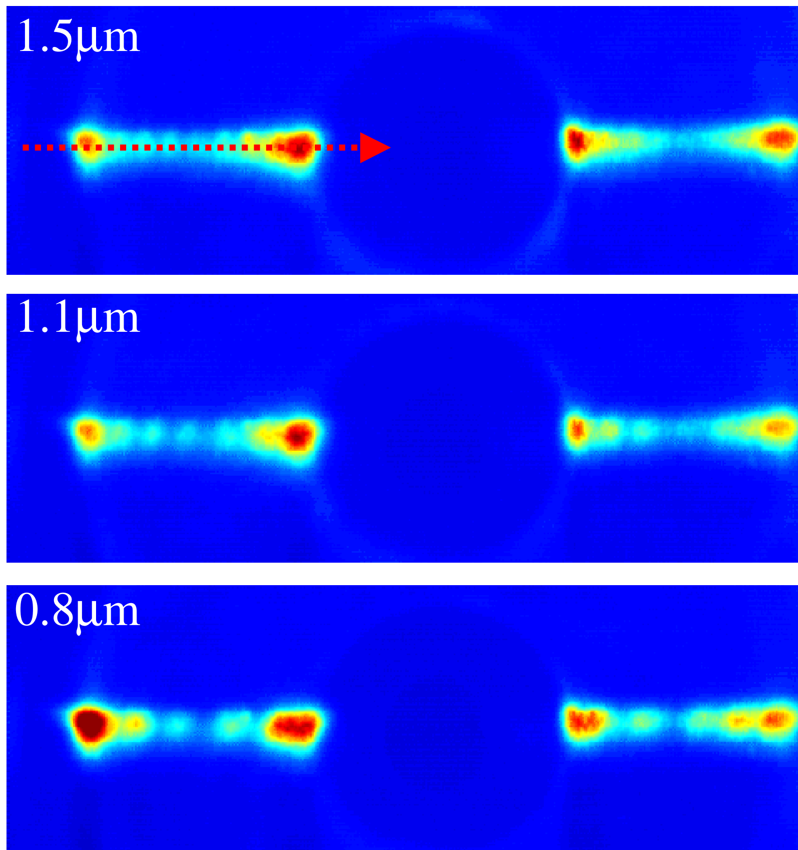
# Dark Field Diffraction Fringe patterns from different horizontal sizes of Opaque Defects

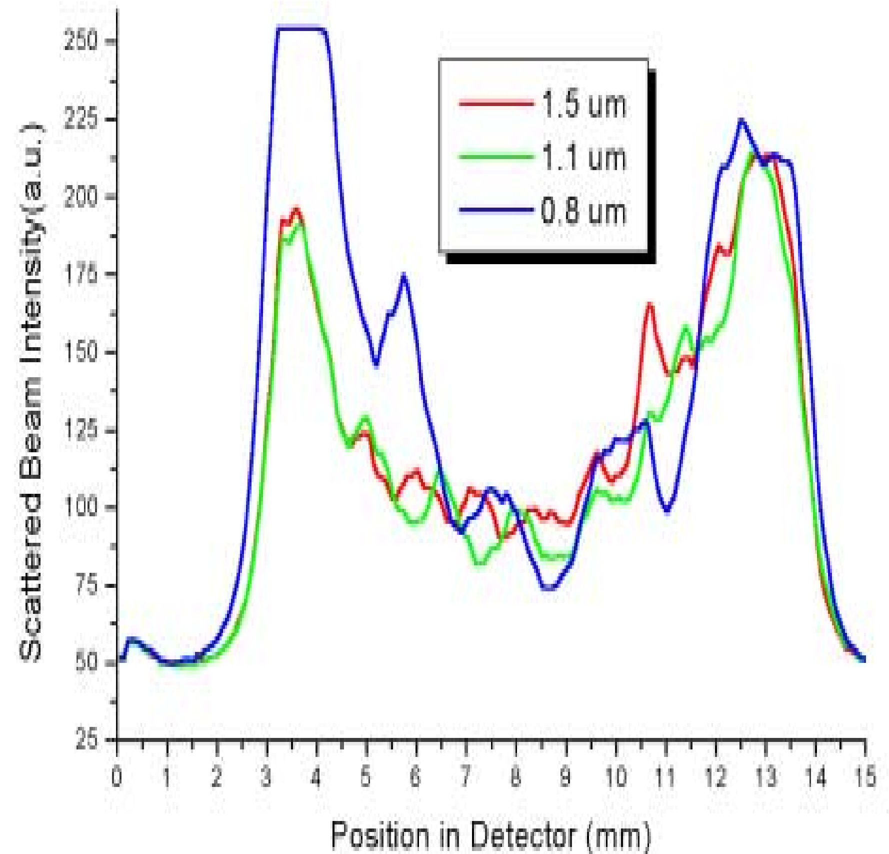



- Defects length is 8 microns.
- As the defect width is smaller, the fringe spacing is wider and the intensity is higher.

# Dark Field Diffraction Fringe patterns from different horizontal sizes of Phase Defects




- Fringe spacing was same at both opaque and phase defects for equal defect widths
- Fringe spacing : 1.5 μm → 1.03 mm, 1.1 μm → 1.47 mm, 0.8 μm → 1.764 mm.

# Summary

- Demonstration of EUVL mask blank defect classification

- Phase defects can be clearly distinguished from opaque defects in terms of the scattered intensity and scattered beam profiles

- Very distinct diffraction fringe pattern at the dark field observation of both of phase and opaque defects

- Future experiments:
    - Application to native EUVL mask blank defects