Defect Inspection of EUV Mask Blank Using Confocal Microscopy

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Introduction

- Defect management of mask blank is regarded as one of the most critical issues in commercializing EUV lithography technology.
- Limit of current confocal microscope needs to be established.
- Specification of confocal microscope is to be determined to detect the minimum printable defect.
- Modeling and simulation works of defect inspection are very informative to investigating mask defectivity and predicting the specification of inspection system.

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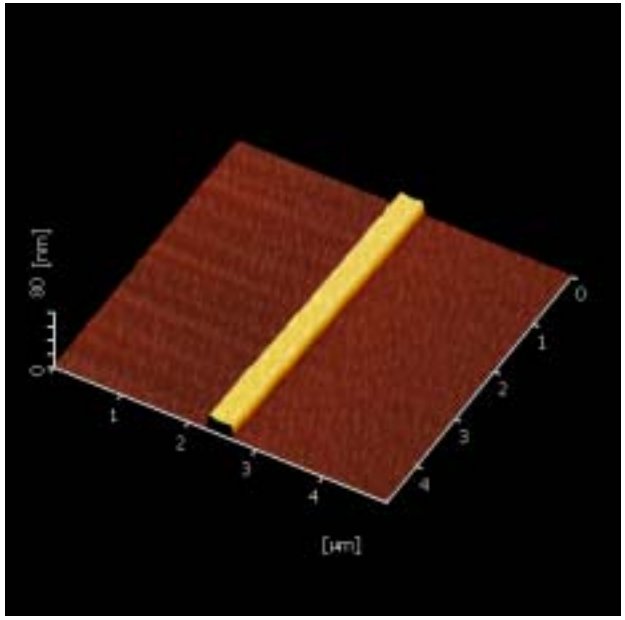
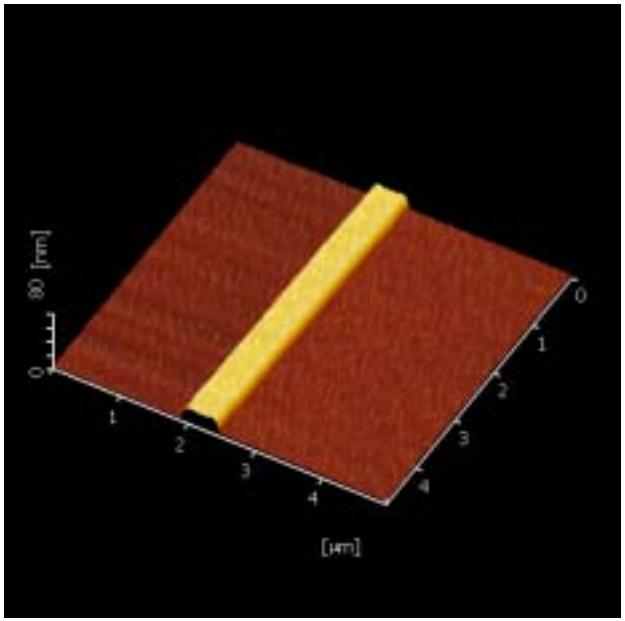
AFM Image of Phase defect

Before Multilayer Deposition



After Multilayer Deposition



- Programmed line defect of 42 nm-width and 17 nm-height is formed by e-beam.
- 40-pair of Mo/Si multilayer is deposited by ion-beam sputtering system.

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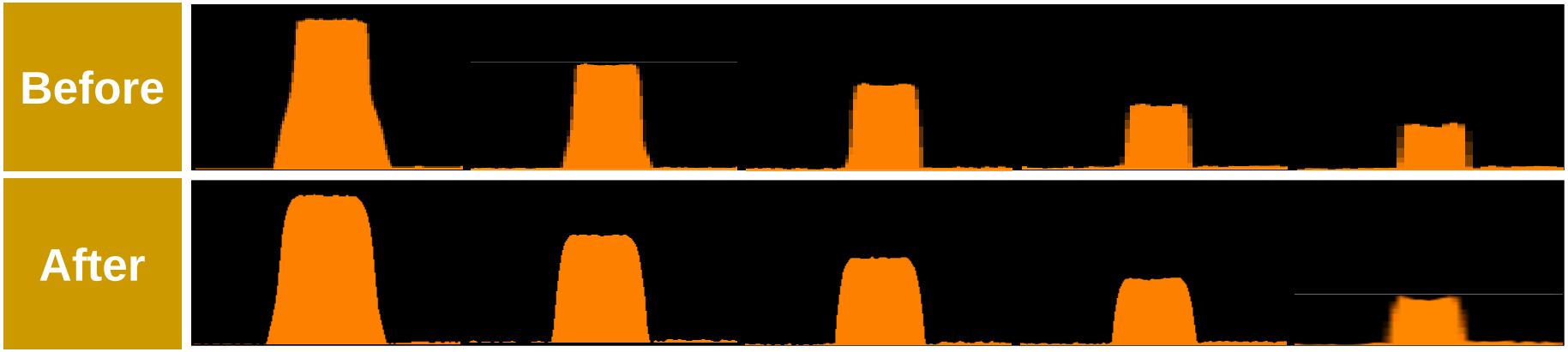
Defect Profile Before & After ML Deposition



- Defect profile remains almost same after 40-pair of Mo/Si multilayer deposition.
- Defect profile after ML deposition is supposed to be determined by the method and conditions of sputtering.

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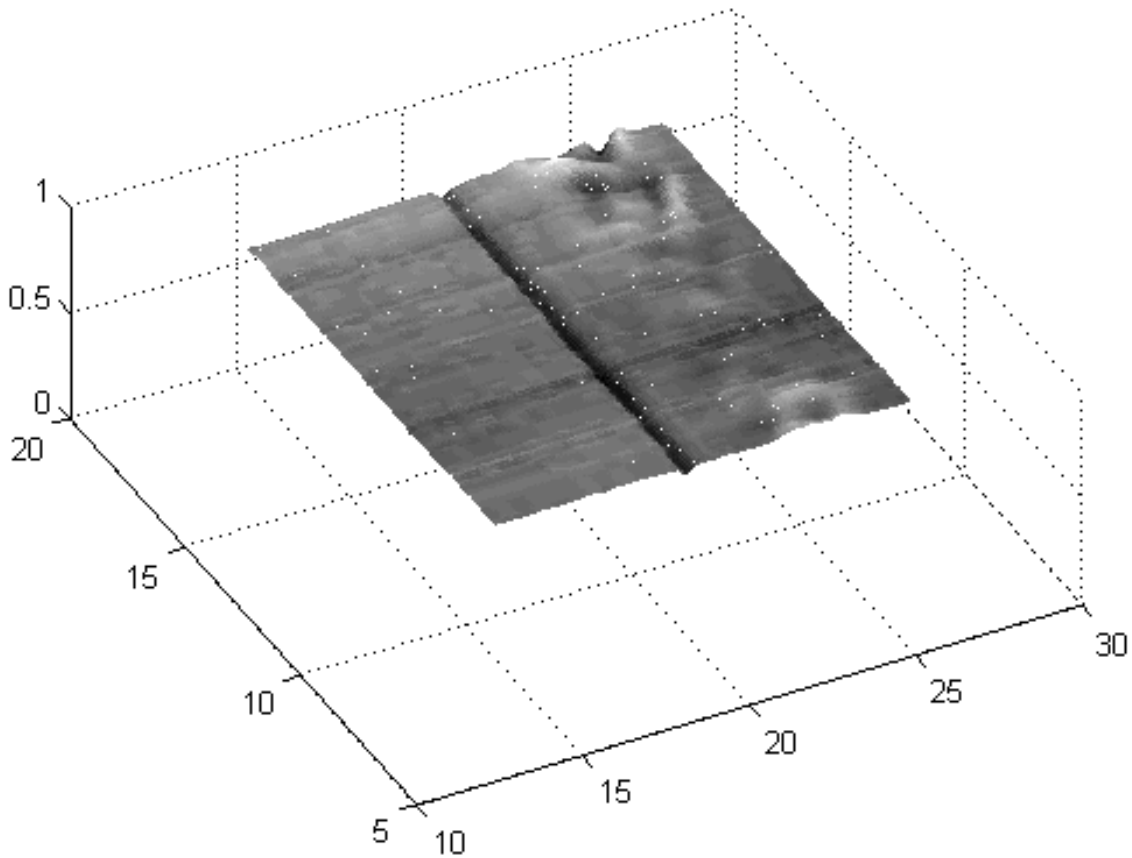
Confocal Microscopy Image of Line Defect

Scanned Data by Lasertec M2350 (λ = 488 nm, NA = 0.95)



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Flow Chart of Defect Inspection Simulator

Modeling of Phase Defect

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EUV Mask Near-field Calculation (RCWA)

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Confocal Microscopy Signal Calculation

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Defect Inspection Signal

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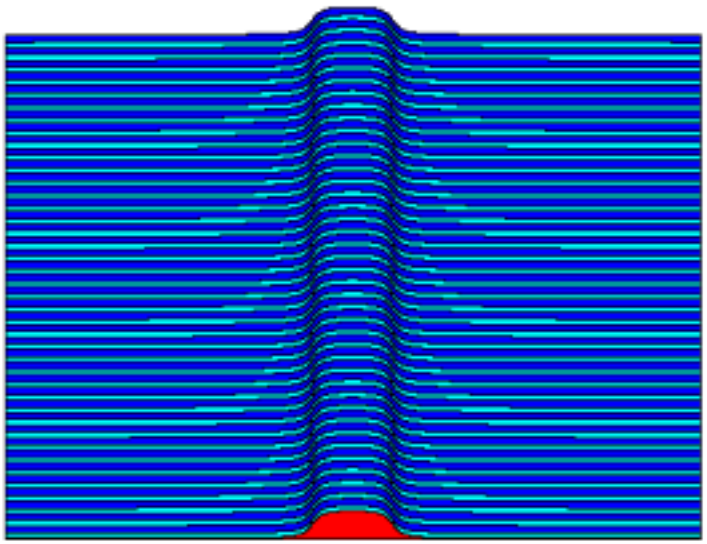
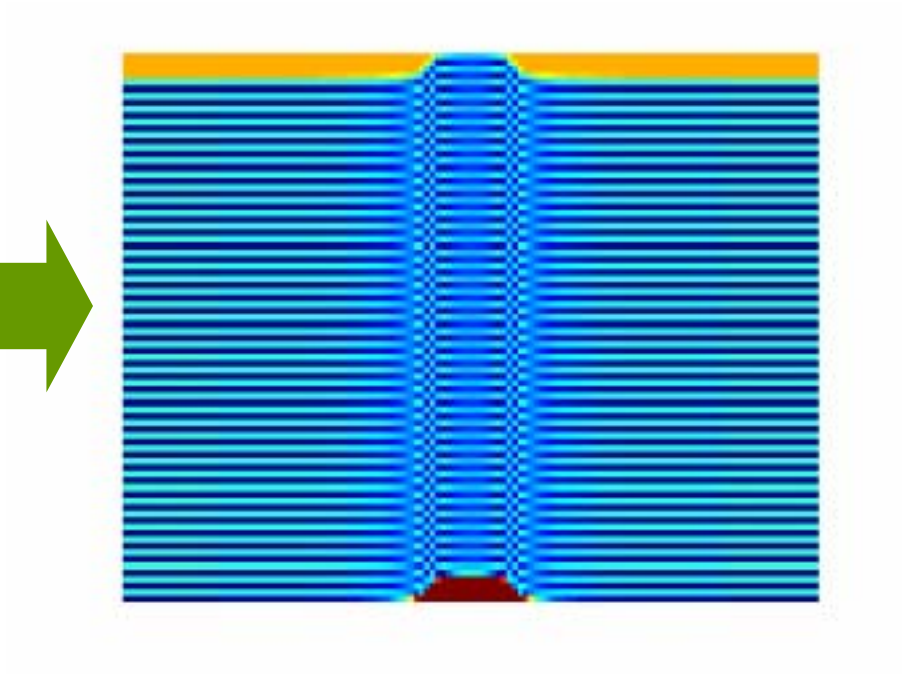
Modeling of Phase Defect

Phase Defect Embedded in ML



Phase Defect Embedded in ML



- Average dielectric constant model is applied to the defect and ML distorted by it.

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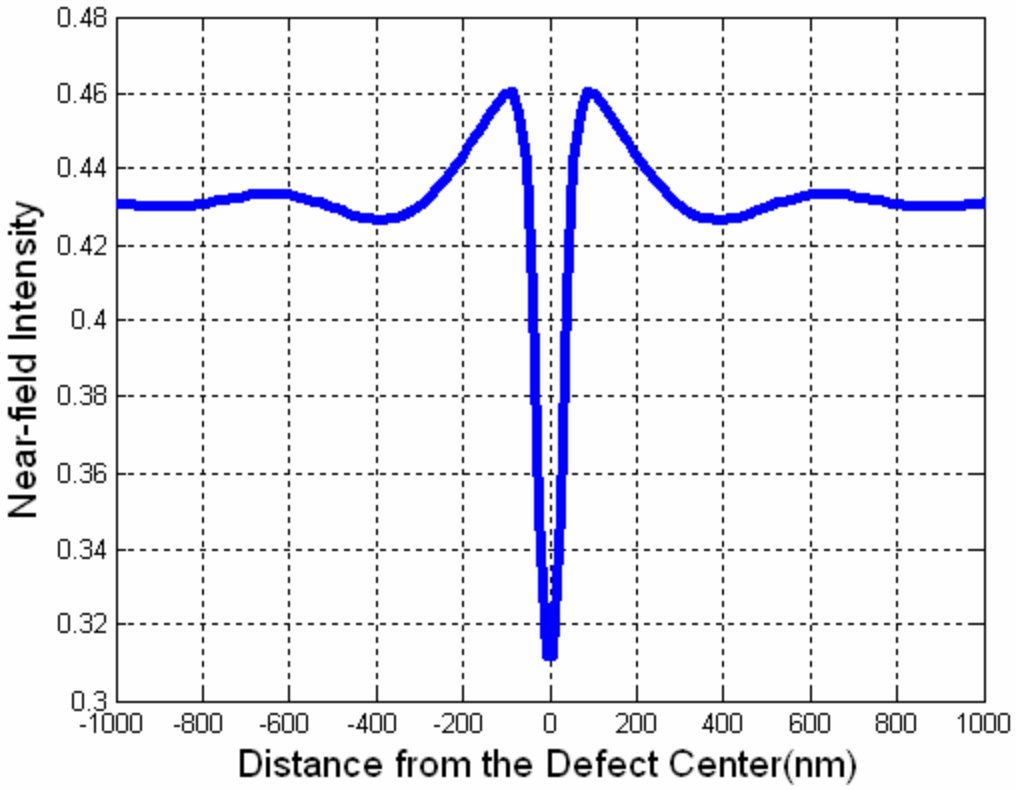
EUV Mask Near-field



- Mask near-field is calculated by RCWA.
- Contrast of mask near-field is about 27 %

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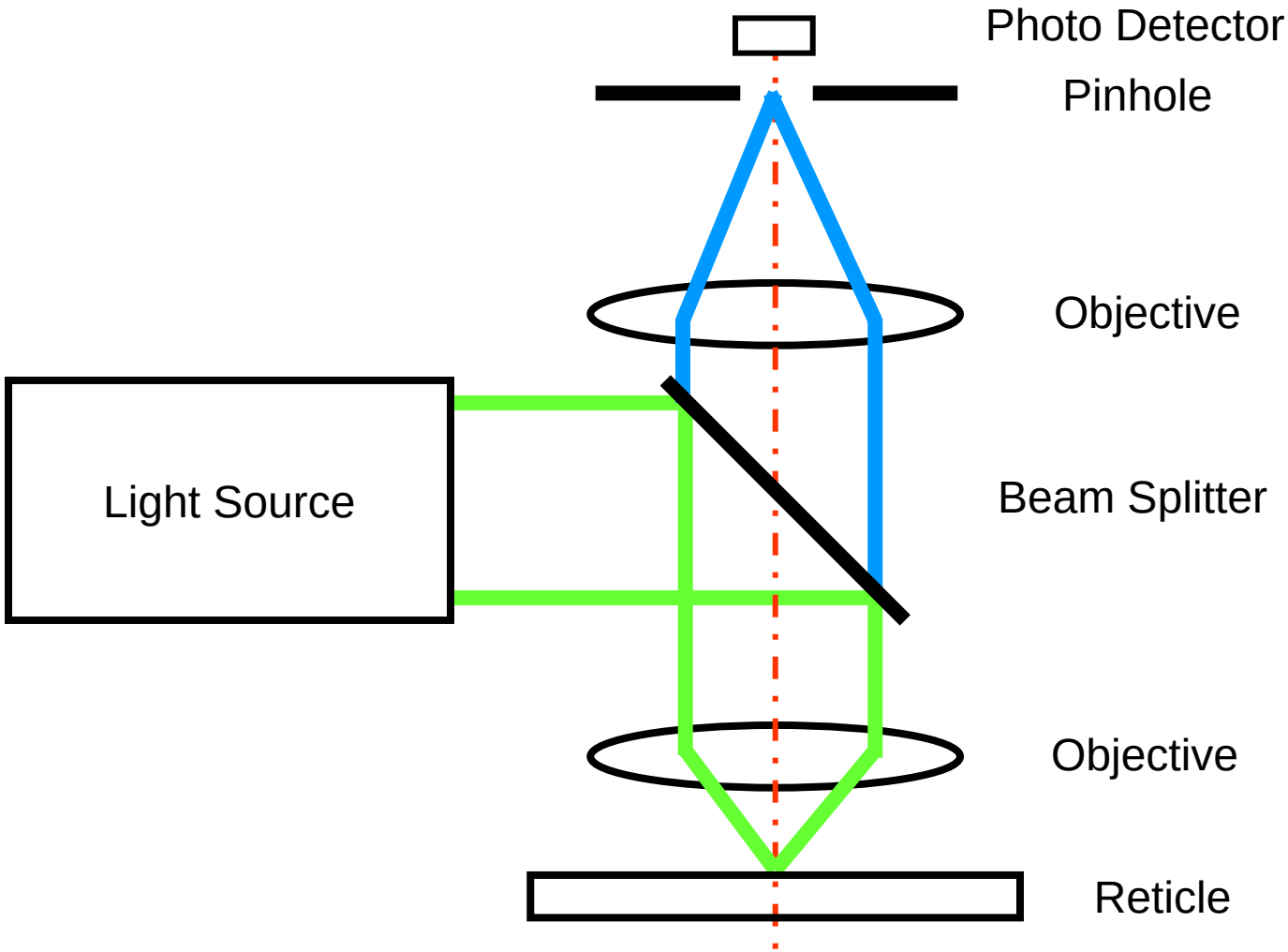
Schematic Diagram of Confocal Microscope



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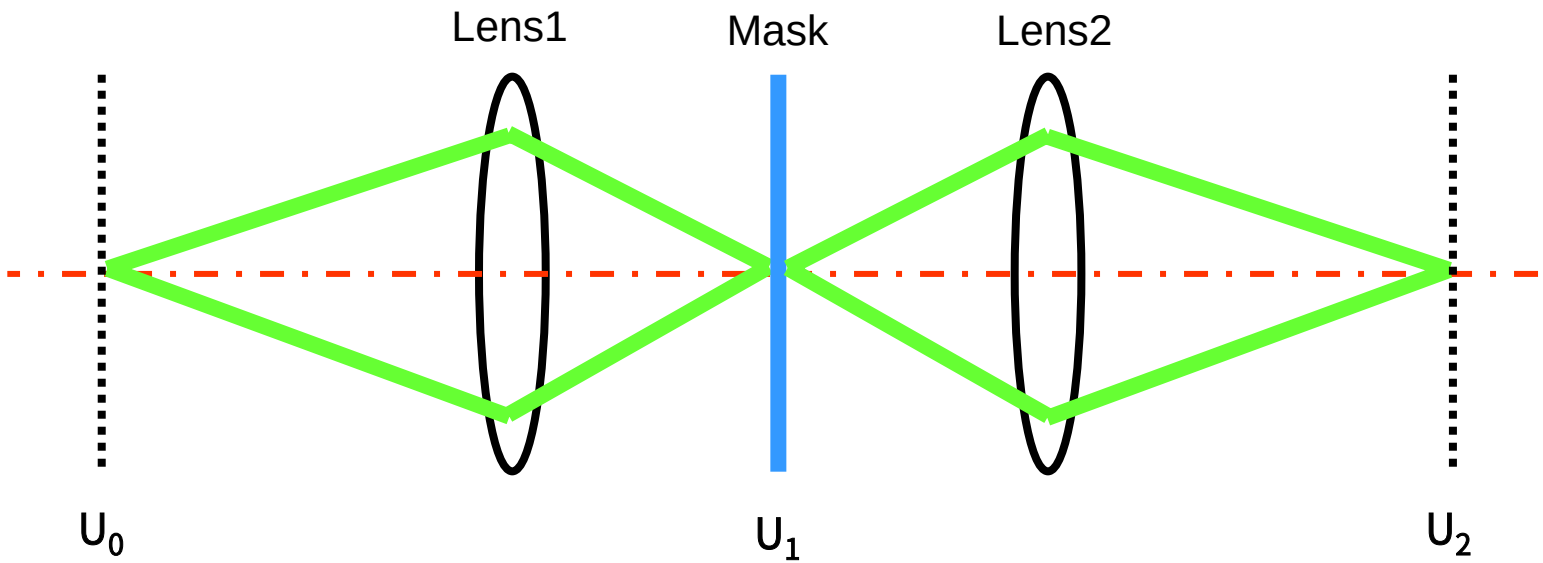
Modeling of Confocal Microscopy



$$U_1 = \frac{1}{\lambda^2 M_1 d_1^2} \Im^{-1}\{\Im(U_0)\cdot P_1 \cdot U_m\},\ U_2 = \frac{1}{\lambda^2 M_2 d_2^2} \Im^{-1}\{\Im(U_1)\cdot P_2\}$$

λ: Wavelength

d_1 : Distance between light source and lens1, d_2 : Distance between mask and lens2

M_1,M_2 : Magnification of lens1 and lens2, respectively

P_1, P_2 : Pupil function of lens1 and lens2, respectively

U_m : Mask near-field

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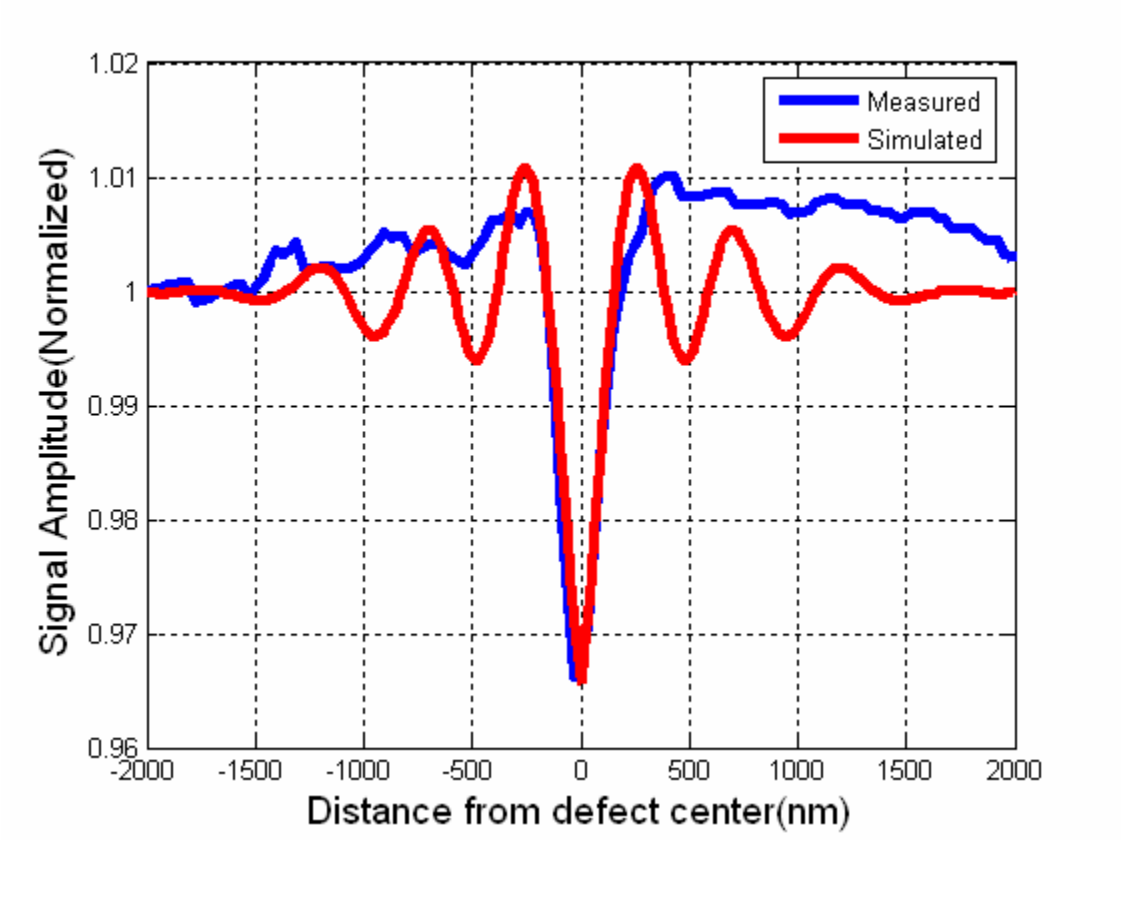
Measured and Simulated Signals



- Contrast of confocal microscope signal is about 3 % at λ = 488 nm.

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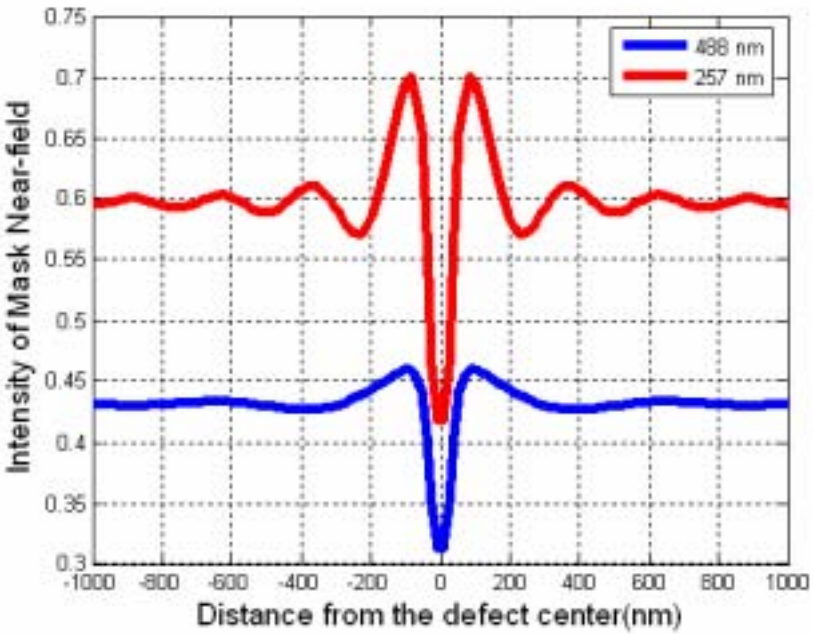
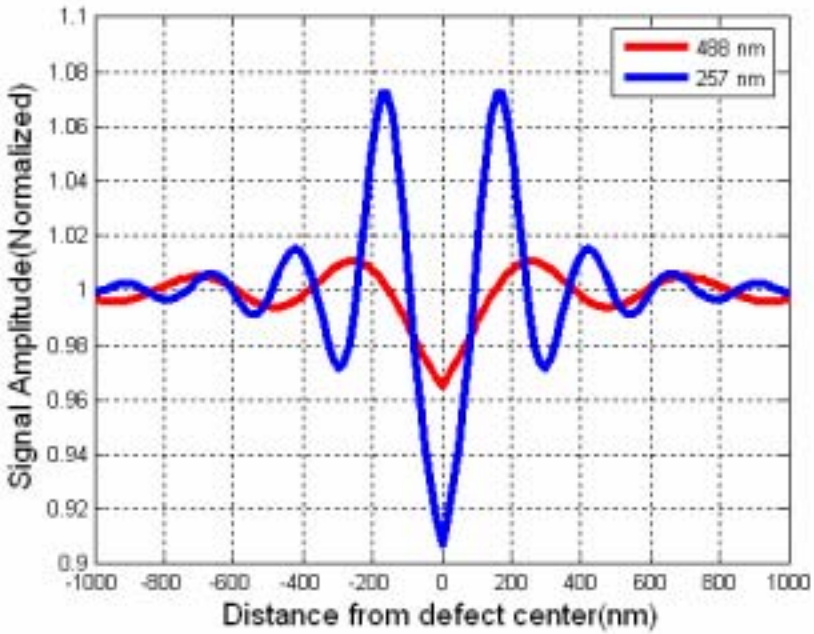
Signals with λ = 488 nm and 257 nm

Mask Near-field



Confocal Microscope Signal



- Contrast of confocal microscope signal increases from 3 % to 9 %, if wavelength is changed from 488 nm to 257 nm.

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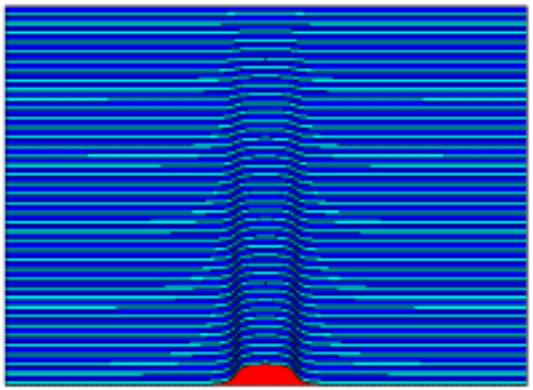
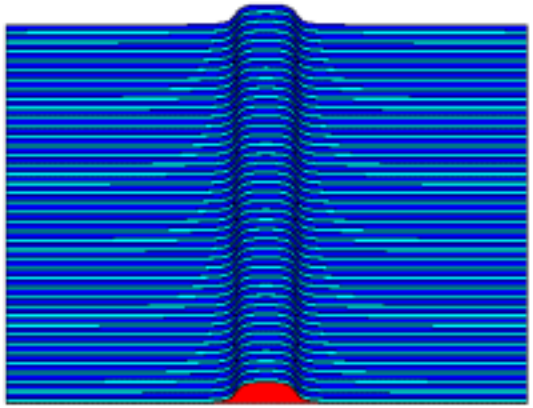
Signals from defect with Flat and Swelled Surface

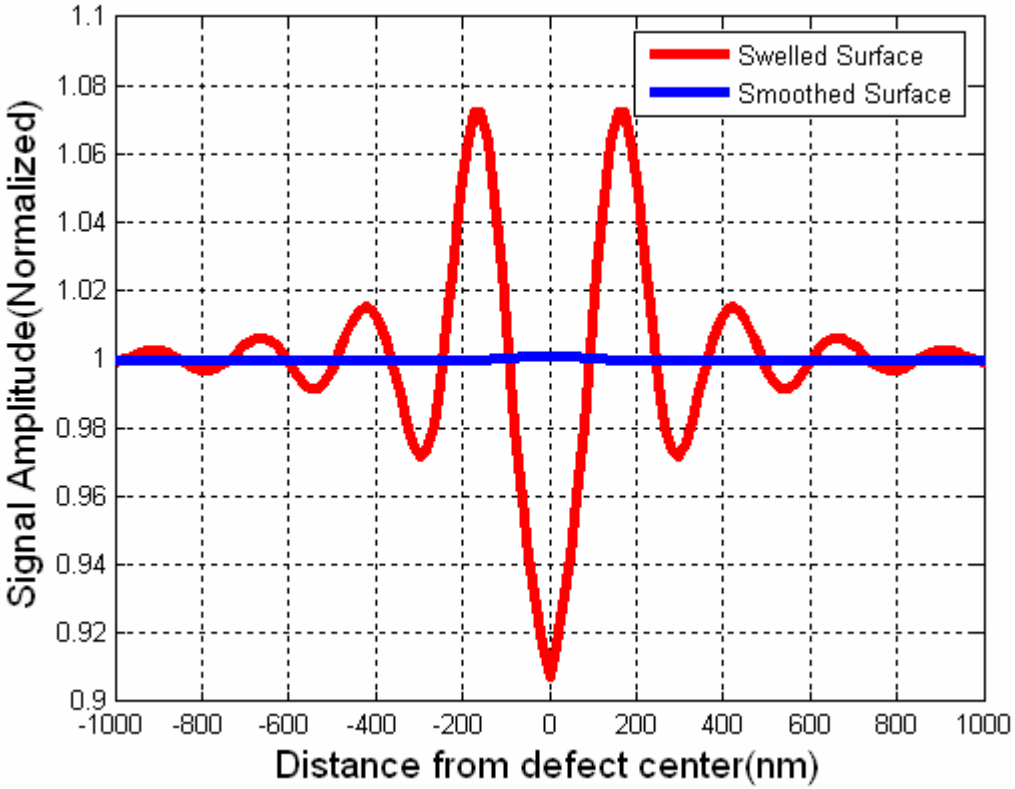
Smoothed Surface



Swelled Surface



Confocal Microscope Signal



- **Phase defect with smoothed surface is extremely difficult to detect with confocal microscope.**

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Summary

- Programmed line defect over-coated with 40-pair of Mo/Si multilayer is prepared and confocal microscope signal is detected by Lasertec M2350.
- Near-field of EUV mask and confocal microscopy signal are calculated by rigorous coupled-wave analysis(RCWA) and scalar diffraction theory, respectively, and compared with experimental data.
- Theoretical results are confirmed to coincide well with experimental ones and the confocal microscopy signal contrast of the line defect of 42 nm-width and 17 nm-height is around 3 %.
- Contrast of confocal microscope signal increases about 3 times as the wavelength reduces from 488 nm to 257 nm.
- Phase defect with smoothed surface is expected to be extremely difficult to detect by confocal microscopy even with 257 nm-wavelength.

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