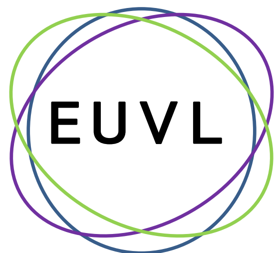
2014 June 26th EUVL Workshop in Maui

Overview of Actinic Mask Inspection System in NewSUBARU



University of Hyogo
Center for EUV Lithography
H. Kinoshita

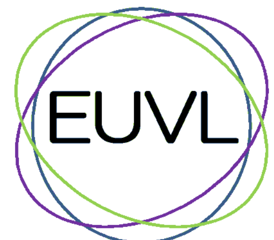
Outline

1. Introduction of CSM

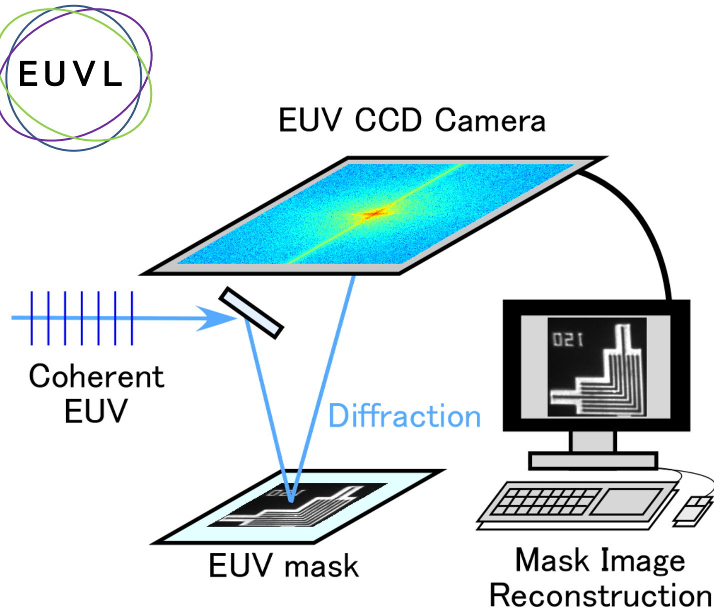
2. Defect inspection results using CSM

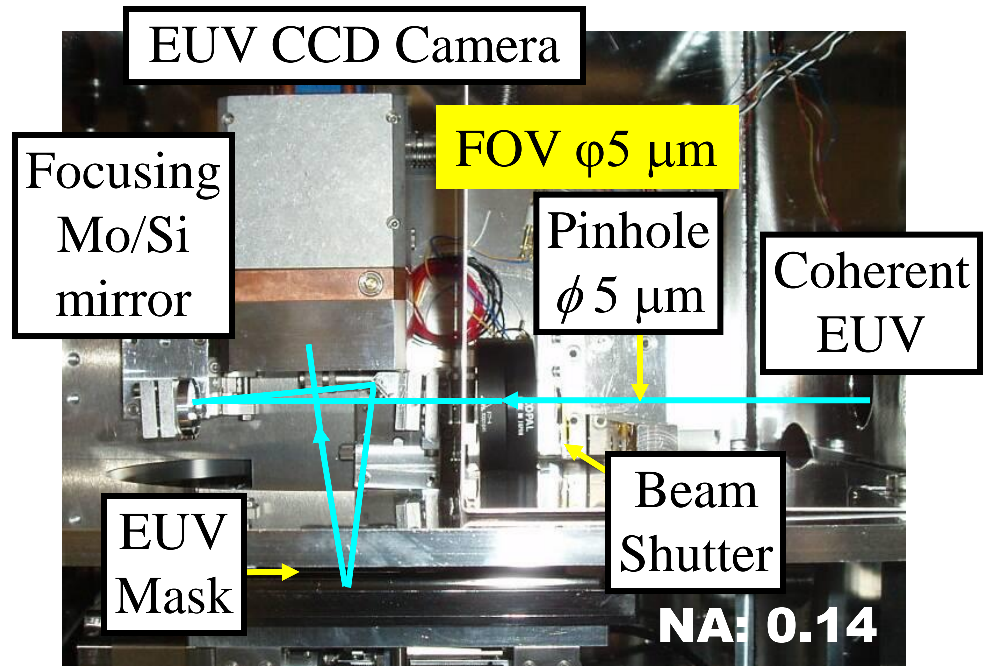
3. Experimental and Results of Micro-CSM

4. Summary



Coherent EUV Scatterometry Microscope (**CSM**)





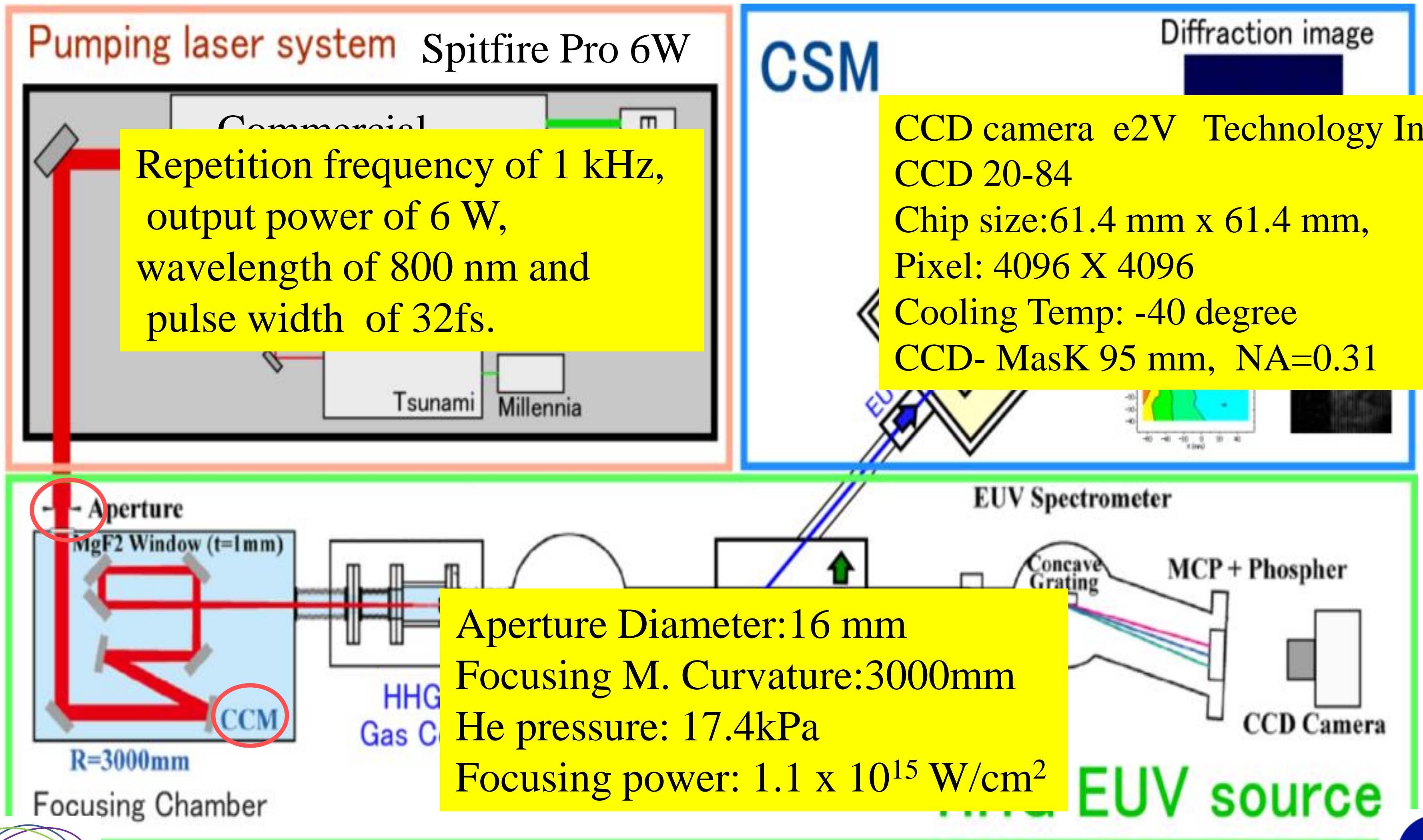
Lensless
Very simple
High resolution

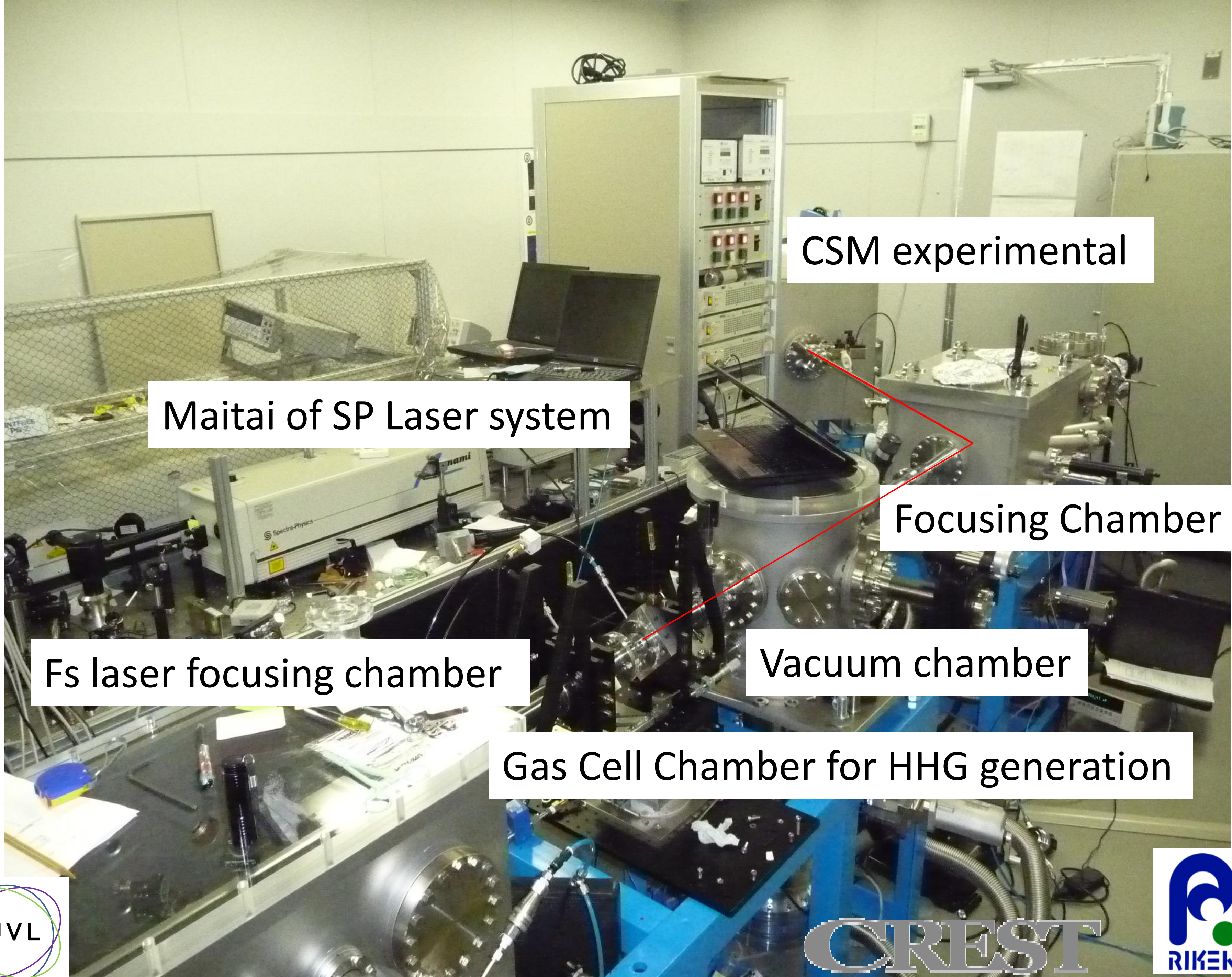
Imaging + **CD metrology**

- Coherent scatterometry microscopy is an ideal form of X-ray phase-contrast imaging, since there is no contrast degradation due to lenses.
- CSM inspect an amplitude defect, phase defect and and measure CD value.
- HHG light source for EUV (λ = 13.5 nm) that employs a femtosecond laser was developed in collaboration with RIKEN.

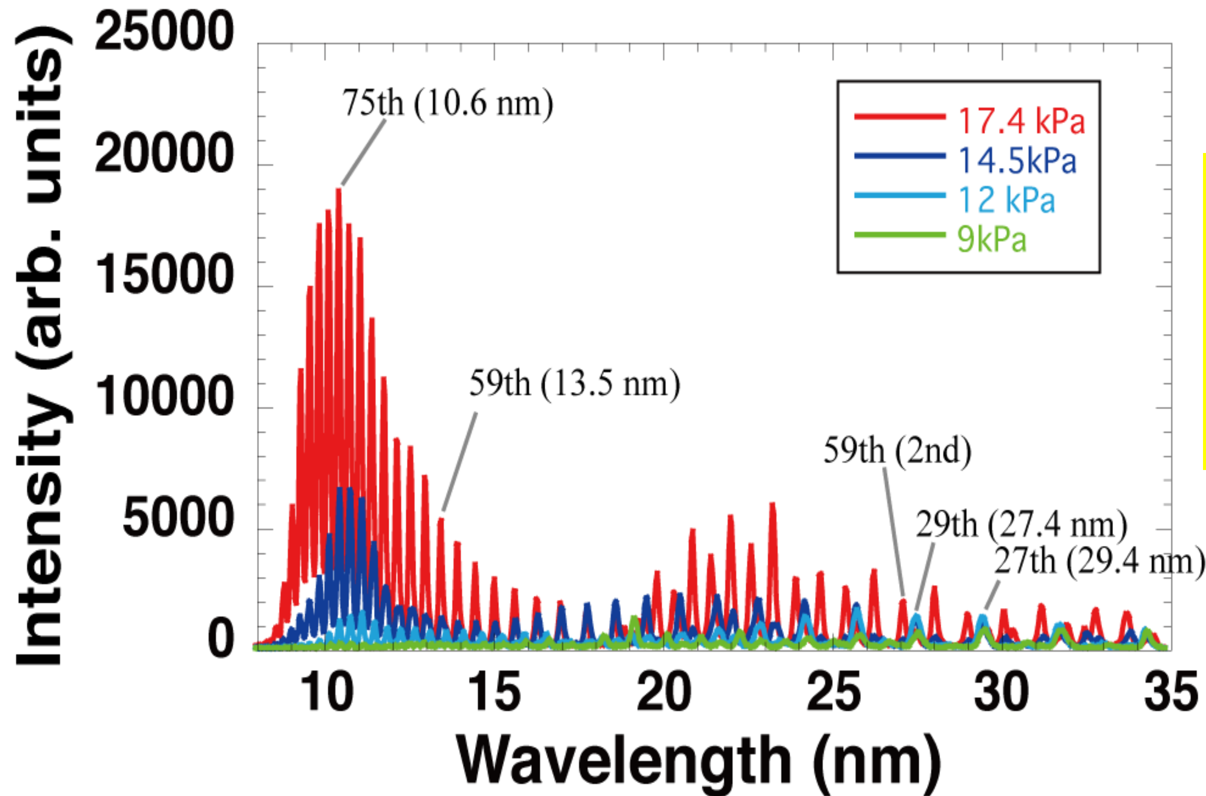
RIKEN

Schematic structure of HHG-CSM system.




CSM experimental
Maitai of SP Laser system
Focusing Chamber
Fs laser focusing chamber
Vacuum chamber
Gas Cell Chamber for HHG generation
EUVL
CREST
Core Research for Evolutional Science and Technology
RIKEN

Characteristic of HHG EUV light



- **Output EUV (59th)**
  1 μW
- **Divergence:**
  0.17 mrad

Coherent EUV power

SR × 1,000

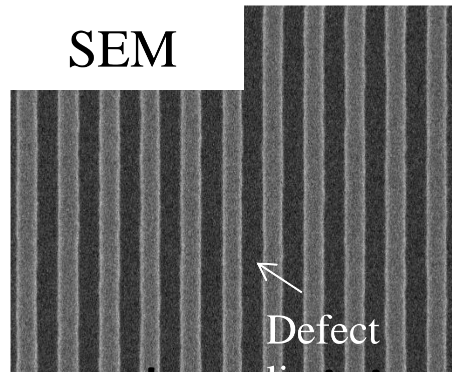
Spectral intensity distribution of He gas pressure.

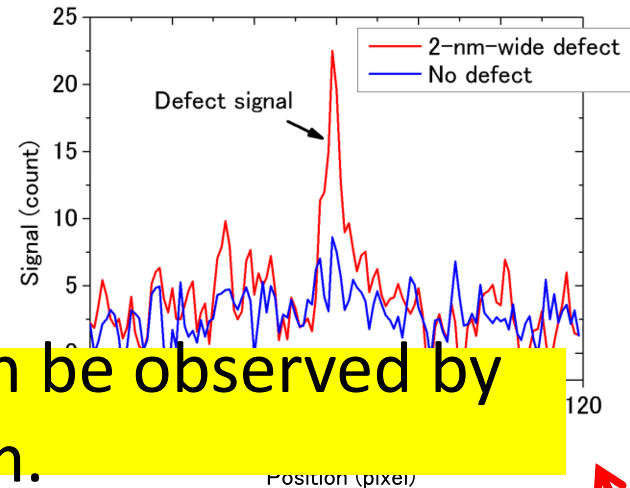
EUVL

RIKEN

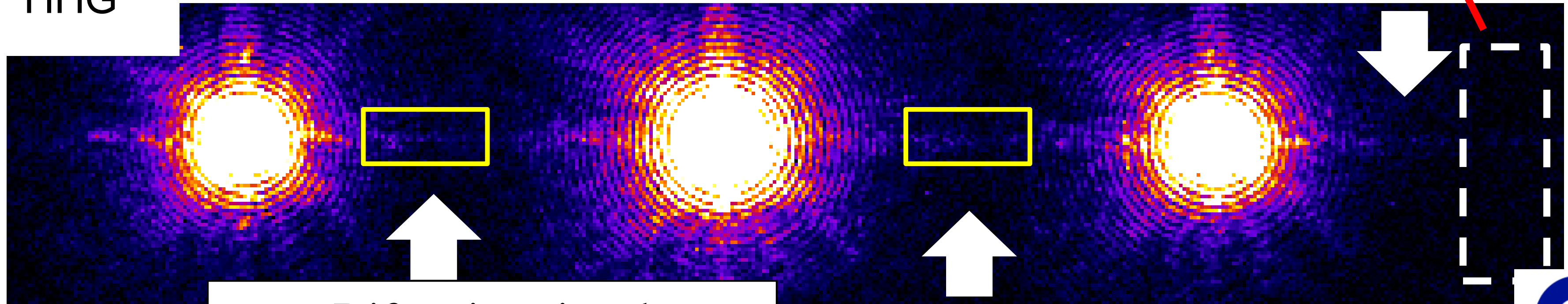
Detection of oversizing defect

hp 88 nm L/S pattern 2 nm oversizing defect
Exp. Time: 1000s





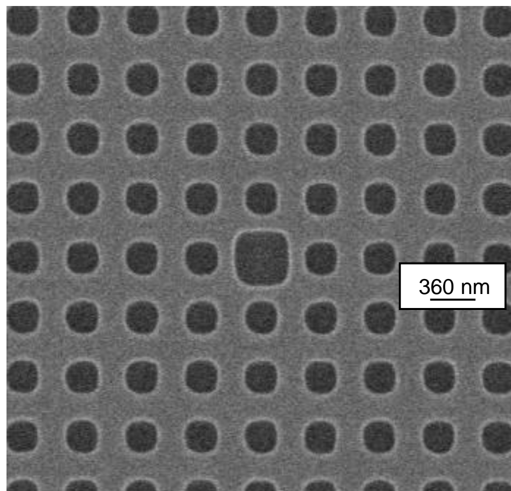
2nm downsizing defect can be observed by HHG system.



EUVL

RIKEN

Observation of larger hole pattern defect



hp45 hole pattern array
Center hole is bigger than other.
EXP.time:1000s

Hole defect was inspected. But it takes Long time.

Wit

EUVL

RIKEN

Problem of low beam flux

1) Beam fluctuation of Laser system

   ⇨ introduce beam lock mechanism 20X

2) Low efficient beam transfer optics

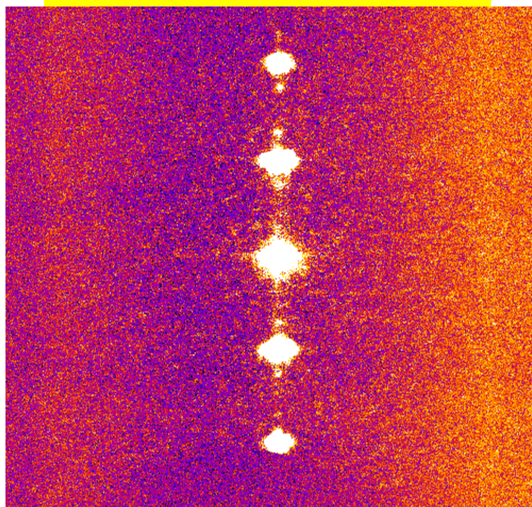
   ⇨ Optimization and reduce the optics

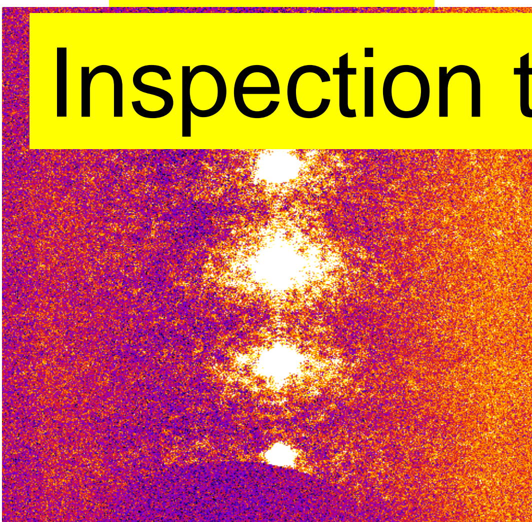
3) Effect of vibration and deformation of chamber in vacuum 4X

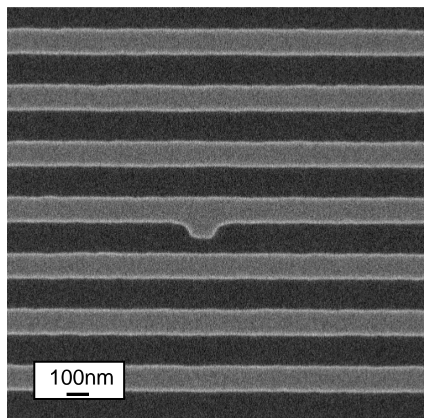
   ⇨ Isolate between chamber and optical board

After improvement, stability was up.

Point defect observation after improvement.





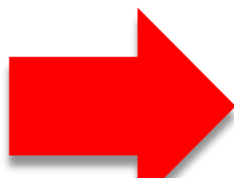


Point defect size

80 nm × 160 nm

128 nm L/S Pattern

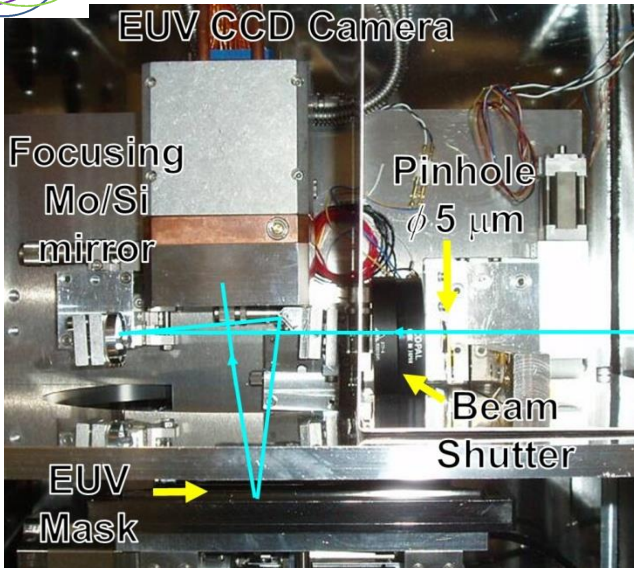
Exp. Time **1 s**



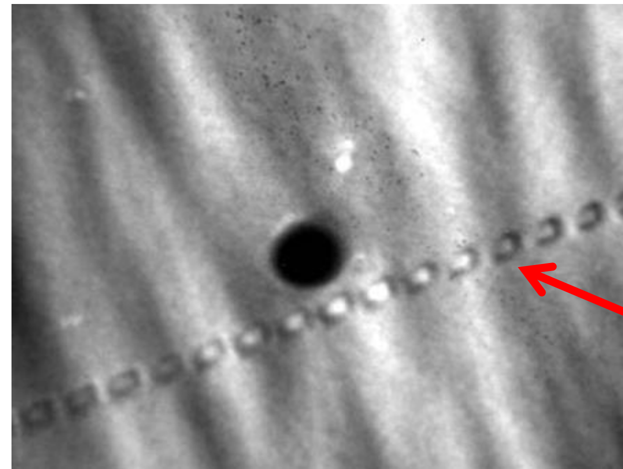
signal

Inspection time of 1 second was achieved.

Phase defects observation by CSM



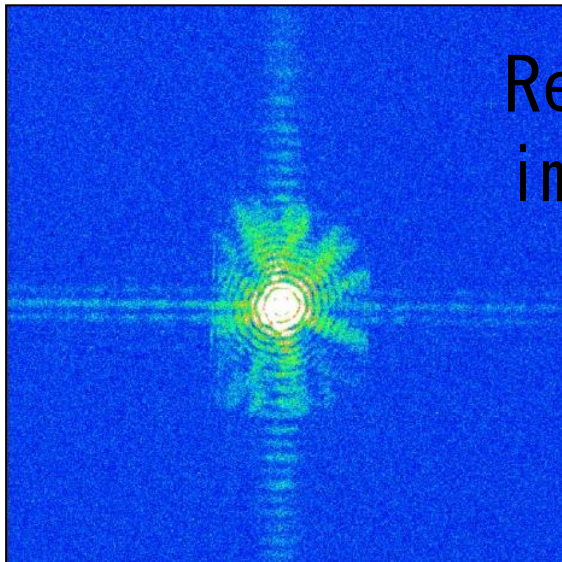
JST CREST . 2002～2007



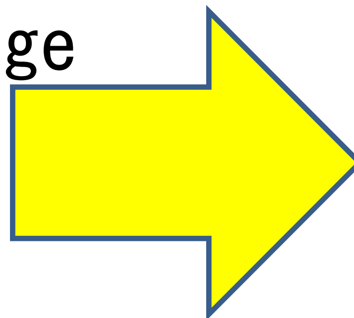
Bright field image of EUV Microscope

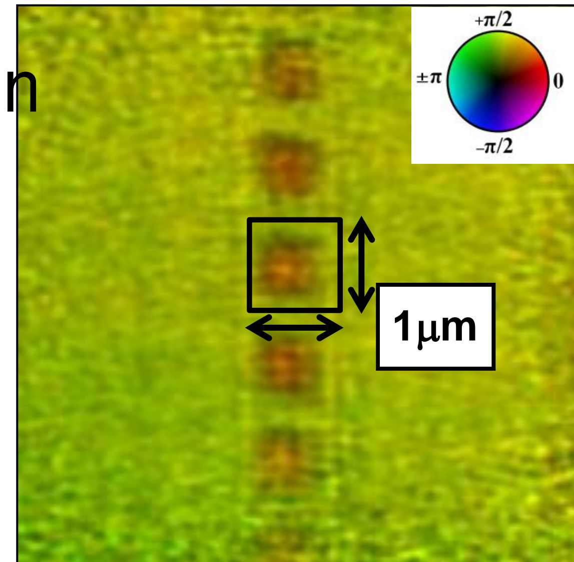
Programmed Phase defect

JST CREST . 2008～2013



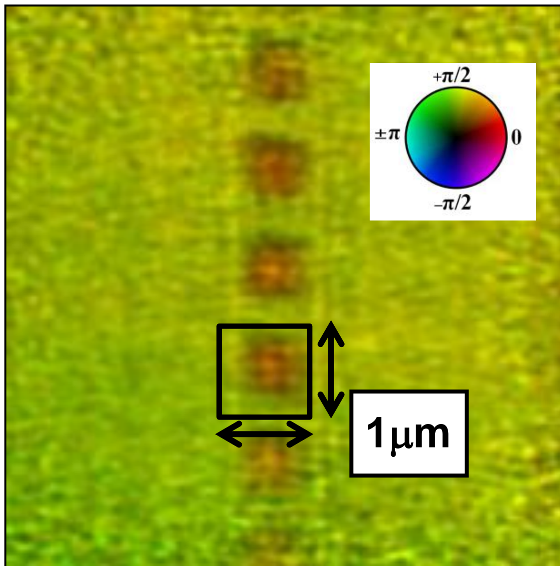
Diffraction pattern of phase defects



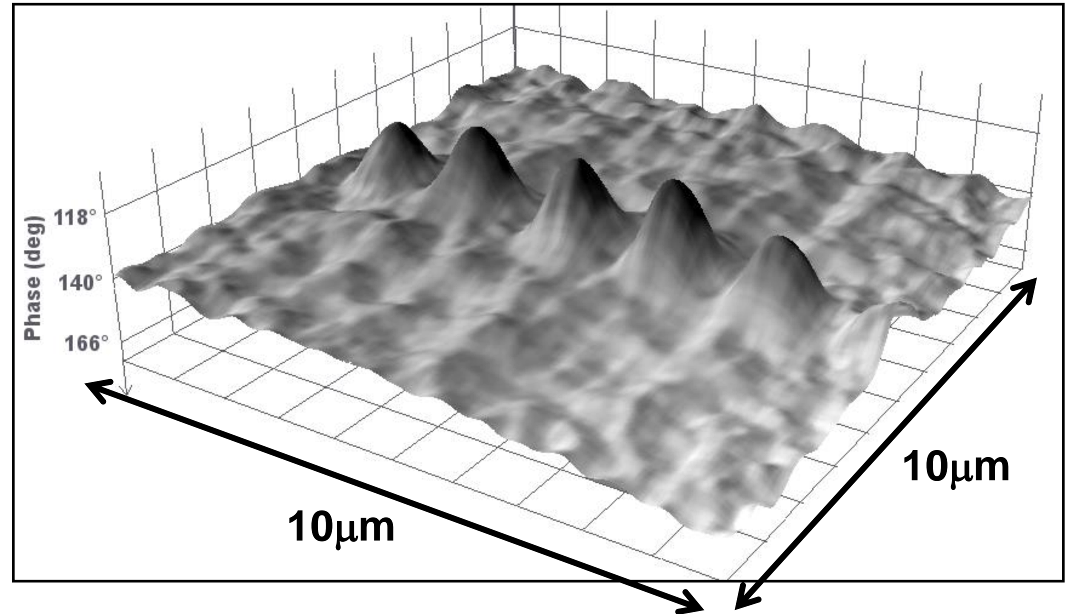


Intensity + Phase

Phase defect observation by CSM



Intensity + Phase

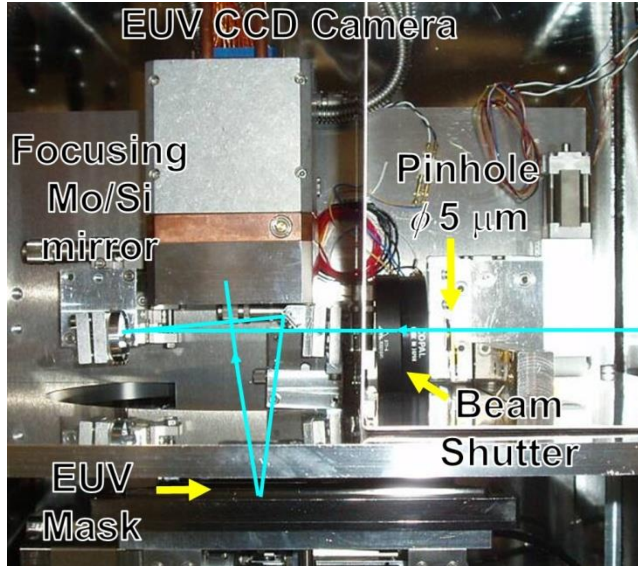


3-D image of phase defect

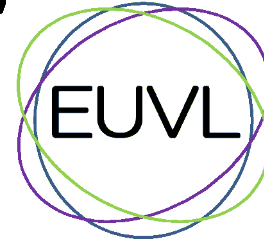
Height is estimated to be 6.1 nm using phase, which correspond with AFM Value of 6.2 nm.

EUVL

Observation of phase defect by CSM



NewSUBARU BL-3

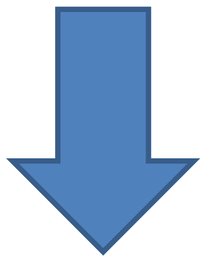


Lensless Actinic Microscope

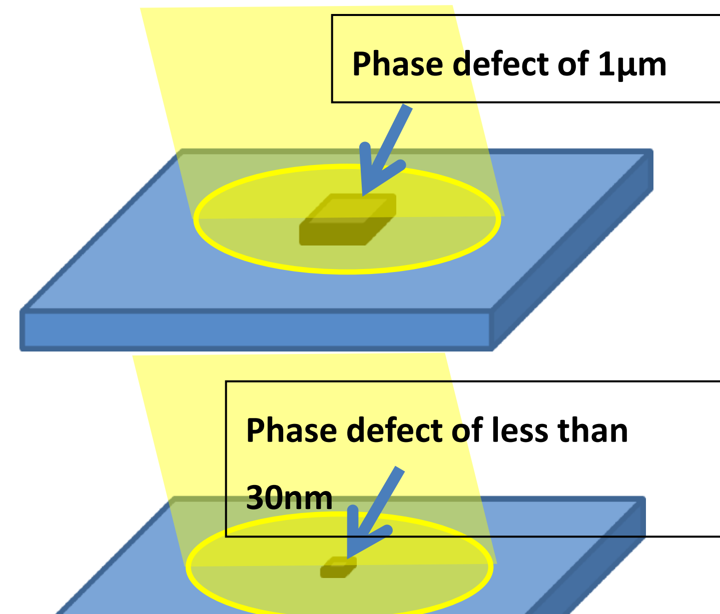
Coherent Scatterometry Microscope

JST CREST 2008～2013

Demonstrate the figure of phase defect less than 30 nm



Improve the defect signal



Defect signal become to be so low.

Principle of μCSM

Off-Axis FZP

EUV CCD Camera

EUV

Aperture

EUV Mask (Blank)

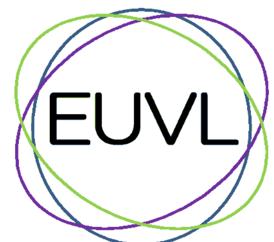
Phase Defect

NewSUBARU BL-10

Vacuum cond. : 10^{-5} Pa
NA of FZP : 0.08
NA to CCD camera : Max. 0.27
Number of pixel : 2048 x 2048 pixel

Focus size of ϕ200 nm

Off-Axis FZP focused the SR beam and the intensity of the diffraction signal was improved enough to detect the fine phase defects.



Capacitive Sensor (Z)

EUV CCD Camera

Turning Mirror

EUV

Shutter

FZP

Mask

PZT Stage (XYZ)

Z Stage

Laser Interferometer ×2 (XY)

Ceramic

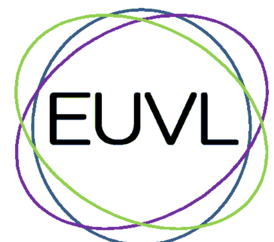
Y Stage

X Stage

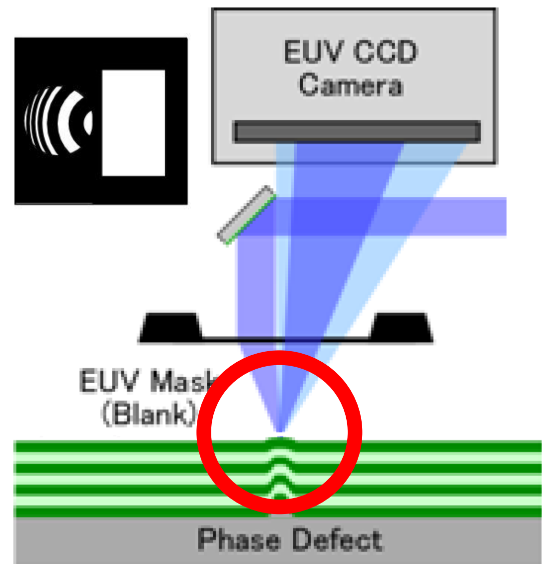
Ceramic

Super Inver Frame

Isolated from Chamber



Recoding image of CCD camara



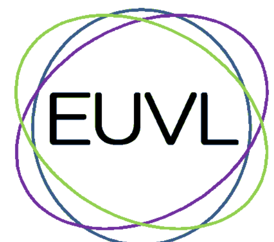
Capture angle of ±16°

Capture angle of ±16°

With phase defects

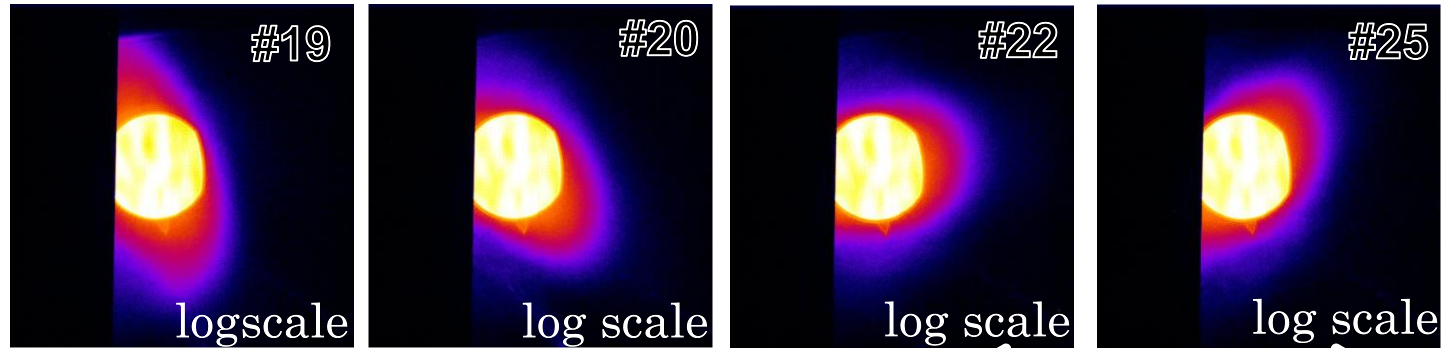
Pupil of F

Diffraction signal of phase defect

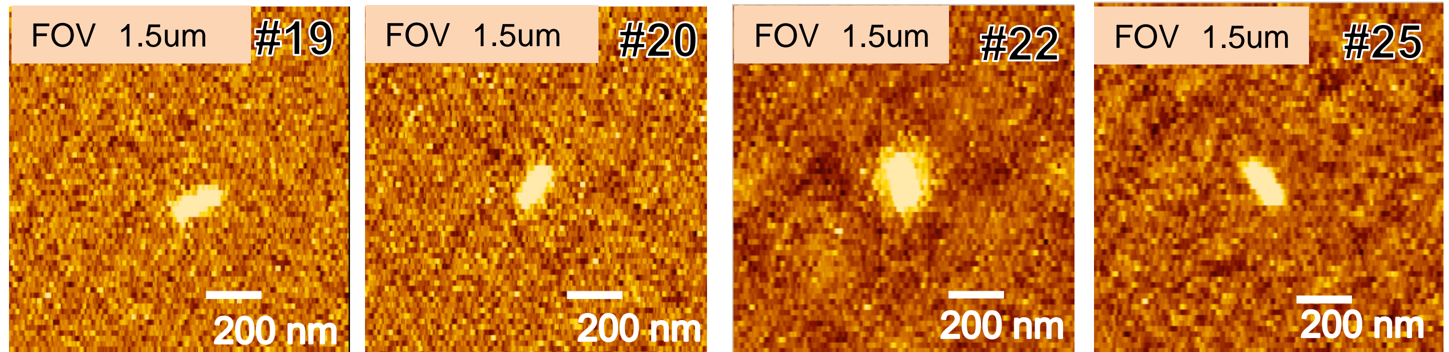


Diffraction patterns to various figures

Micro-CSM



AFM



Minor axis of diffraction signal correspond to major axis of figure by AFM.

Diffraction signal correspond to pattern was obtained.

Resolution of phase defect inspection

散乱信号と基板ノイズの解析

S/N ratio (dB)

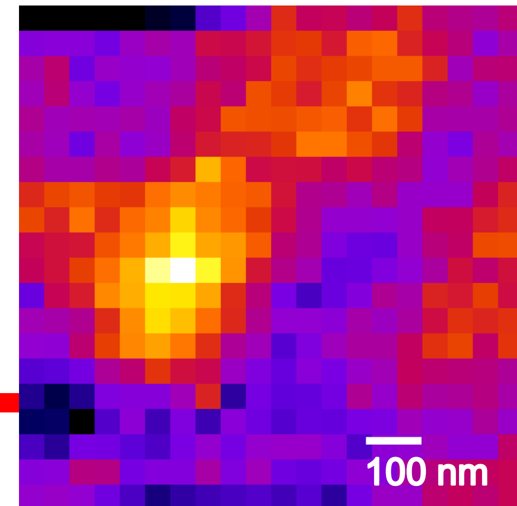
60
50
40
30
20
10

20 30 40 50 60 70 80 90 100 110

Defect width (nm)

The relation between S/N and defect size

Defect image



Mapping image

Up to now, defect size of 25.5 nm width and 1.4 nm height was detected.

3-D image reconstruction by the diffraction signal

CSM

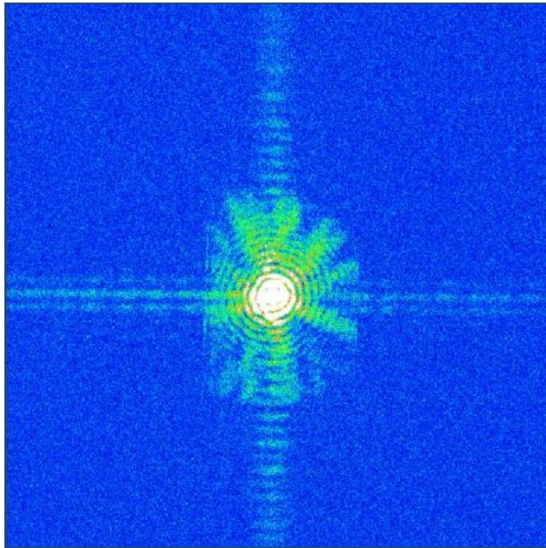
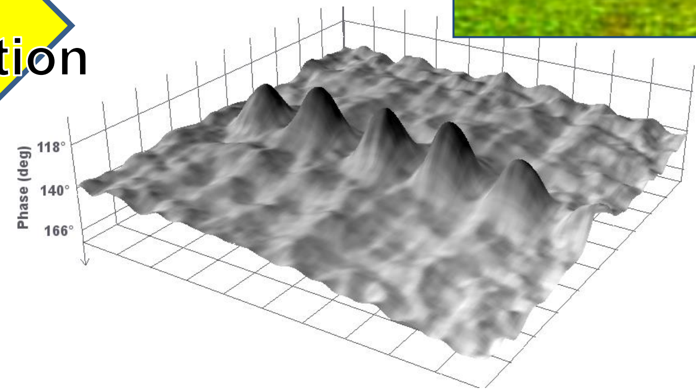
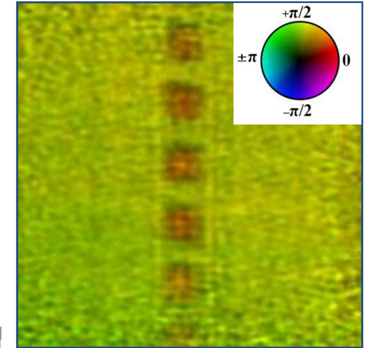


Image Reconstruction





Micro CSM

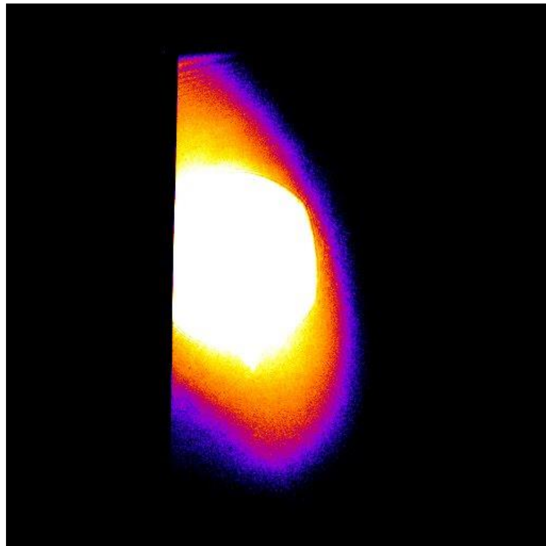
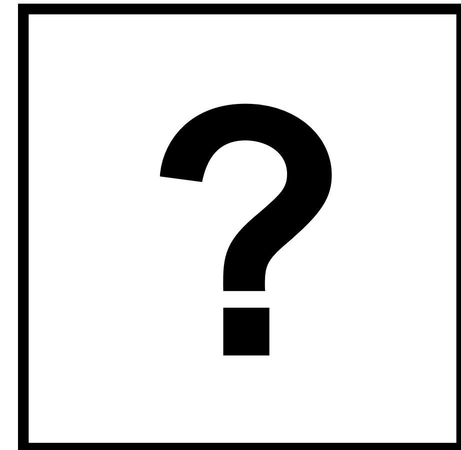


Image Reconstruction



Intensity + Phase

Summary

- We have developed the lensless microscope of HHG-CSM for **ACTINIC** observation of EUV mask patterns.
- Up to now, 1uW of EUV full coherent light of 13.5 nm light source was obtained. And divergence of light is 0.17mrad, which is the smallest data in the published paper.
- Defects such as downsizing, hole missing, bridge pattern, were inspected. Downsizing of 2nm can be observed.
- Construct the micro CSM in NewSUBARU BL-10
- Diffraction signal that depends on the shape of the defect was obtained. That show the possibility of 3-D image of phase defect.
- Up to now, the smallest phase defect of 25.5 nm width and 1.4 nm height can be observed.