

Actinic EUV mask blank inspection with dark-field imaging using LPP EUV source and two-dimensional CCD camera

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1. Introduction

2. Phase defect detection

Basic concept of MIRAI POC tool

3. Experimental

Programmed defect

Detection signal

4. Throughput estimate

5. Summary

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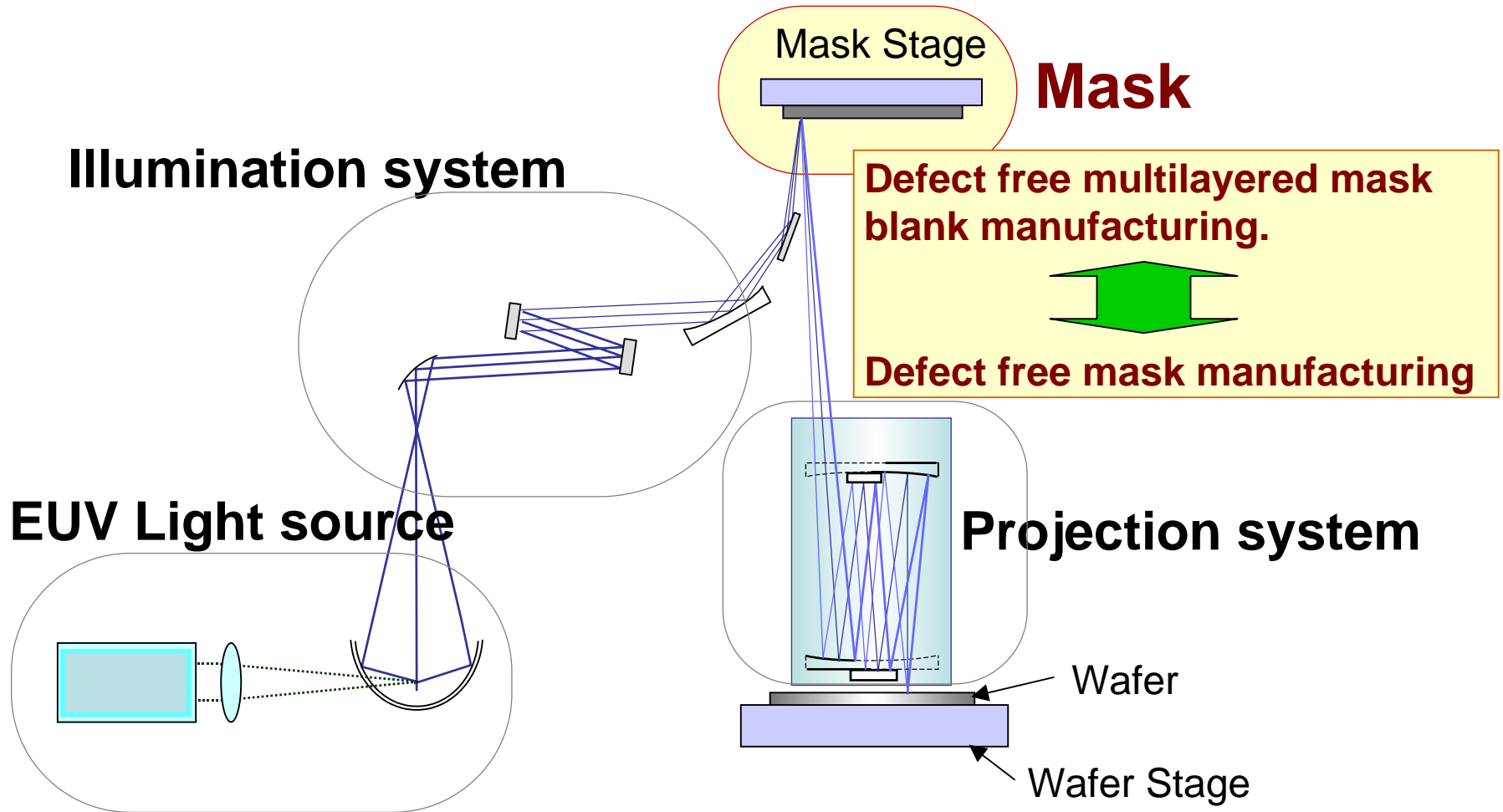
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EUV Lithography



~FY'03

Proof of concept of actinic mask blank inspection system.

Demonstration of minimum critical defect detection

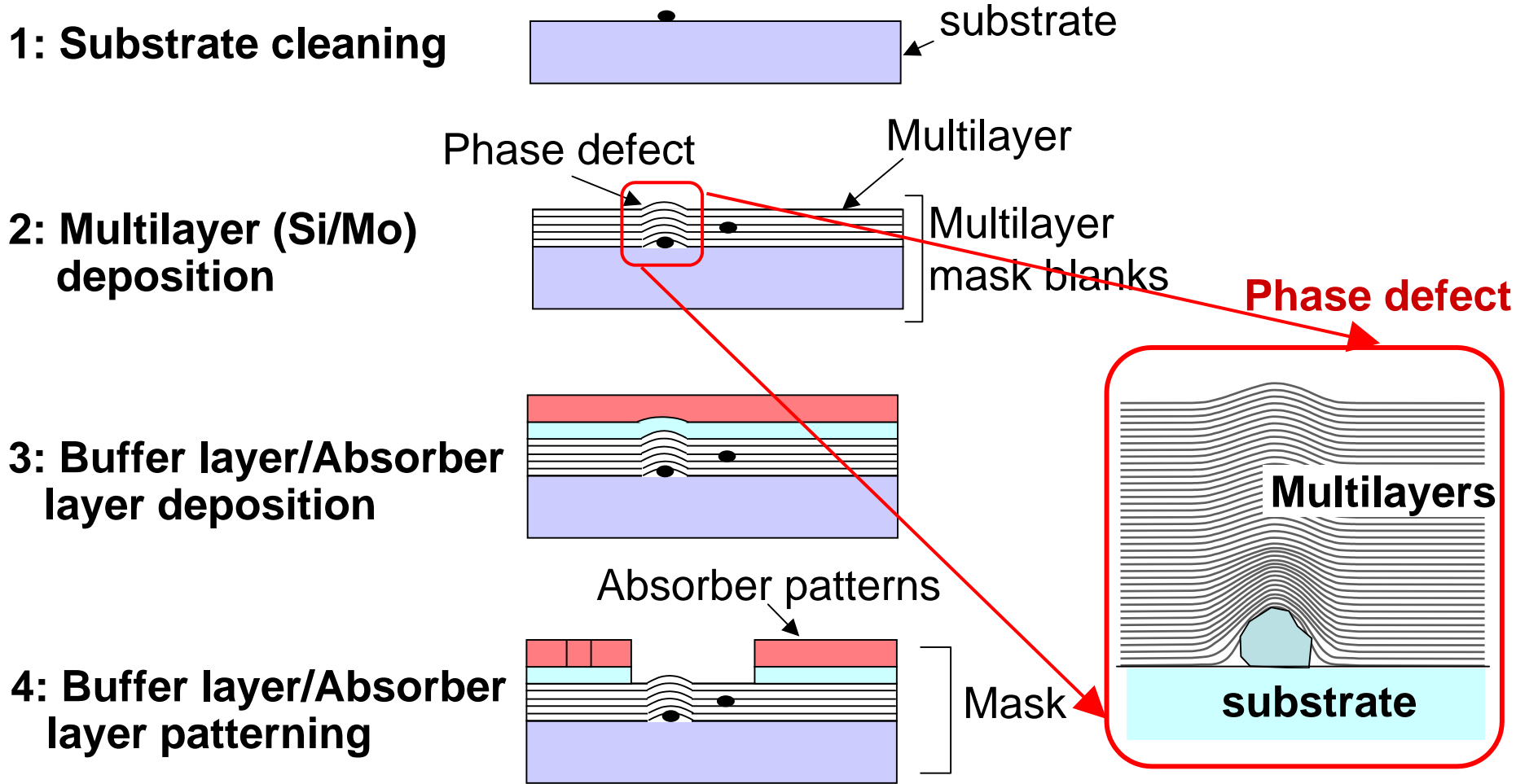
Data-driven estimate of reasonable throughput

 **Successfully Completed!**

~FY'05

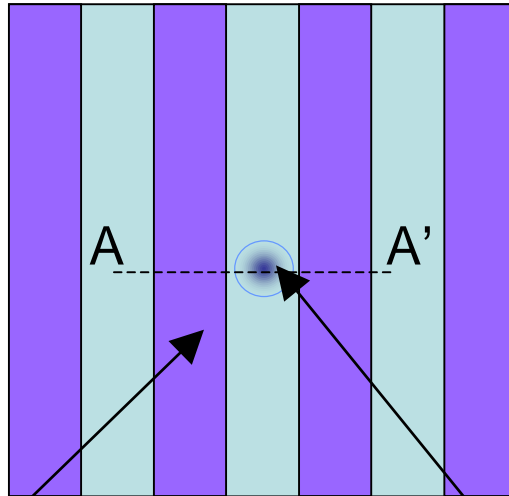
Design completion of manufacturing-ready prototype with accumulated experimental data.

EUV lithography mask



Effect of phase defect

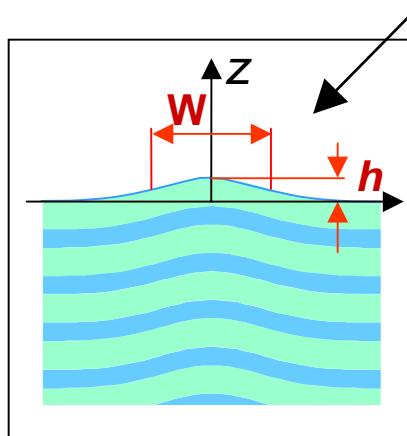
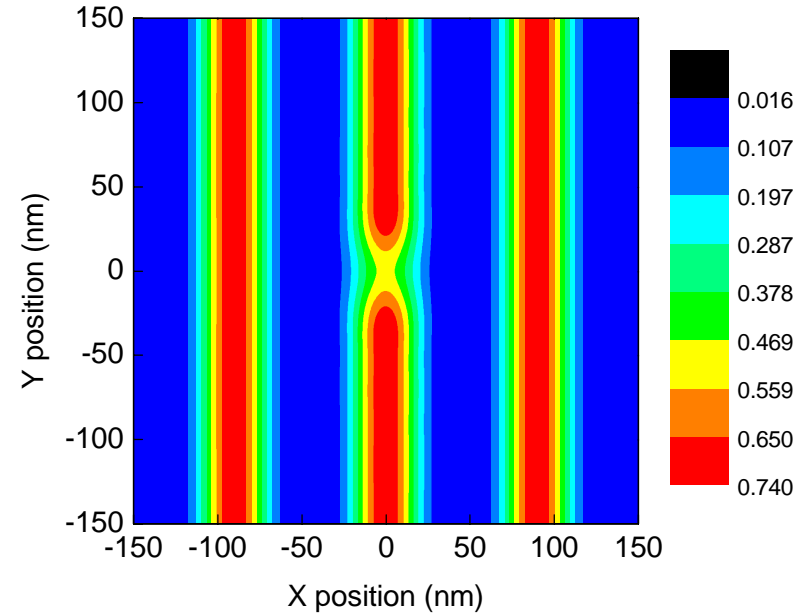
Mask



Absorber patterns

Phase defect

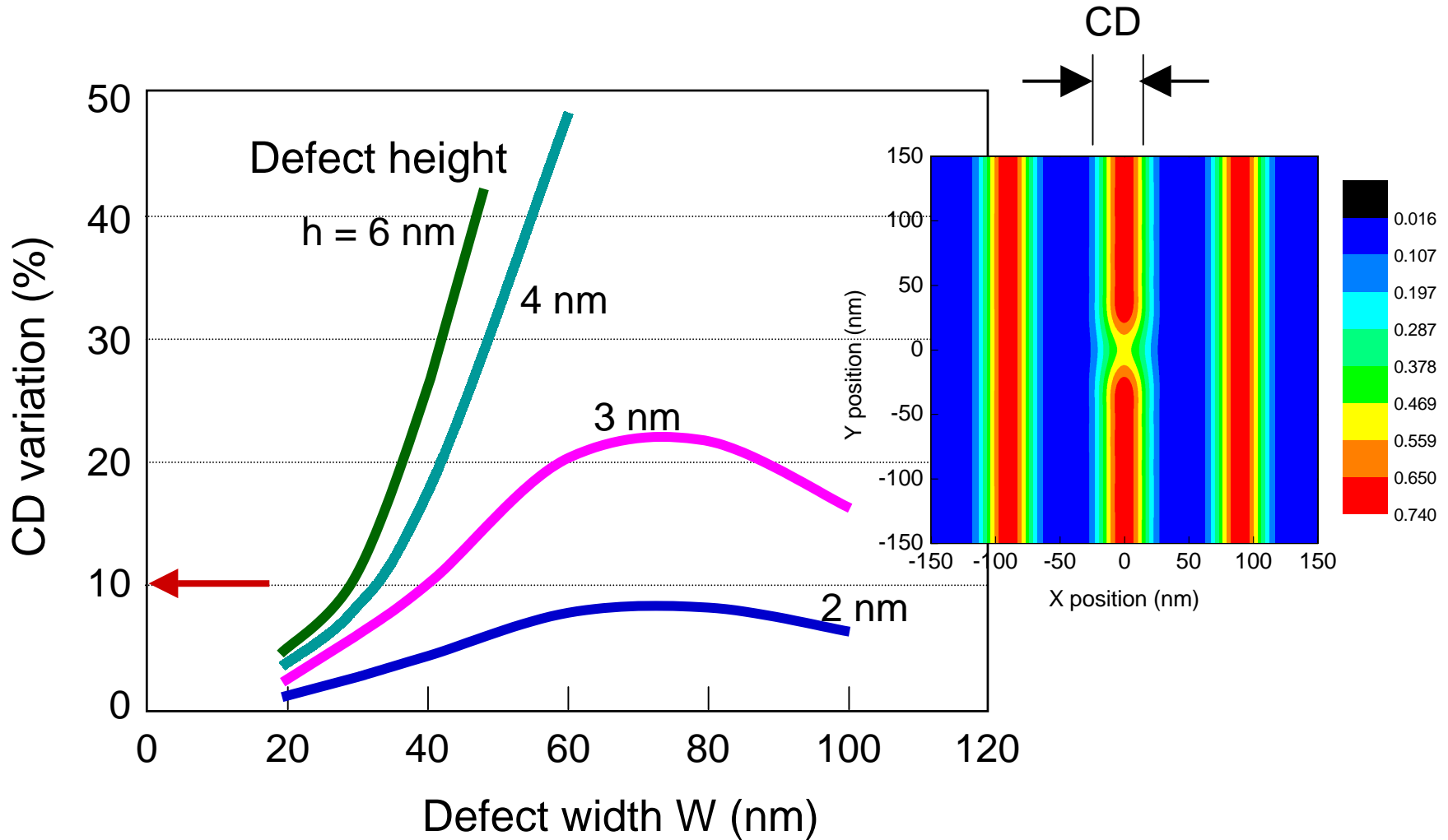
Projected image of 45 nm dense lines with phase defect



W: Full width at half maximum (FWHM)

h: Top height of Gaussian-shaped surface topography

CD variation due to phase defects



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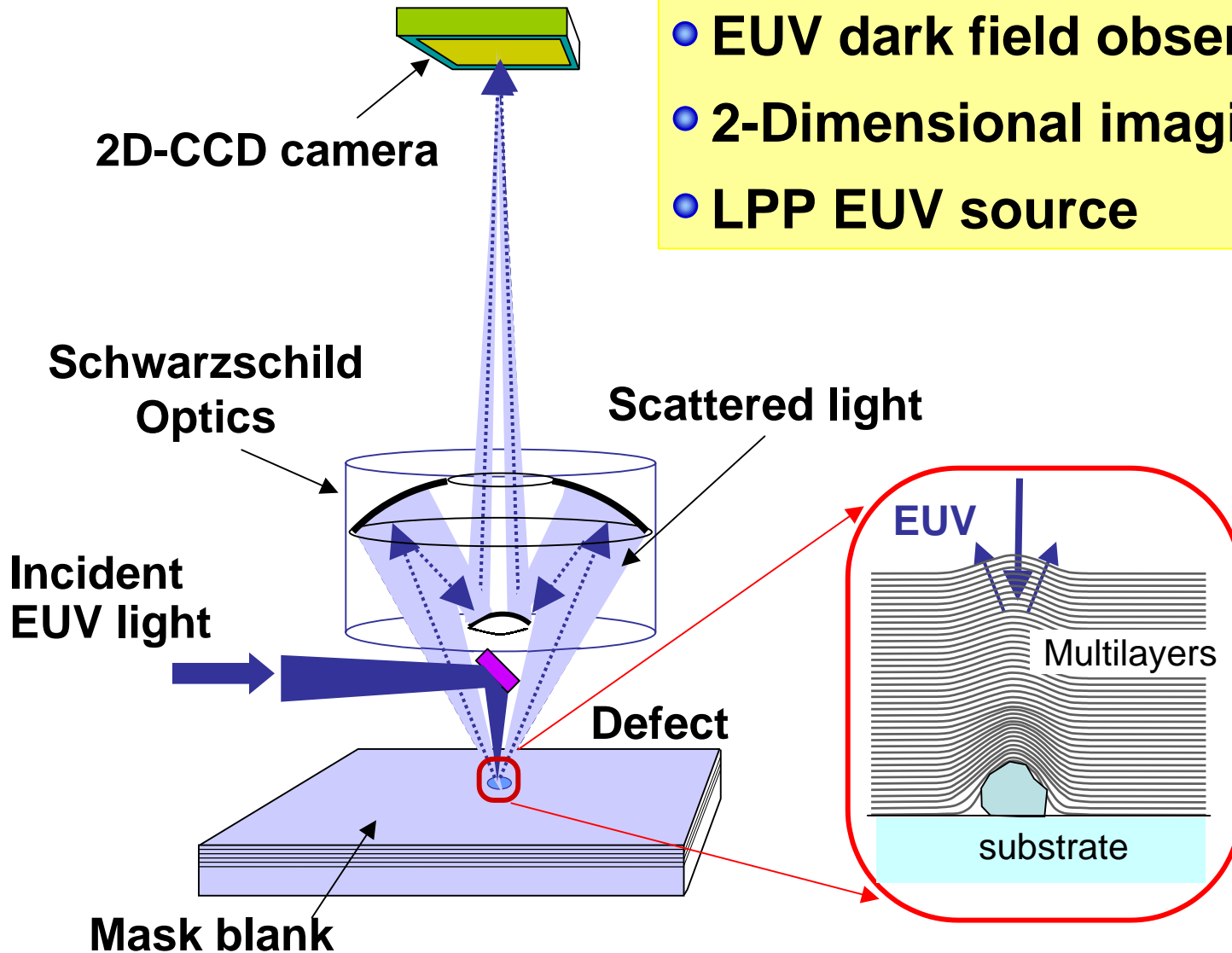
Detection signal

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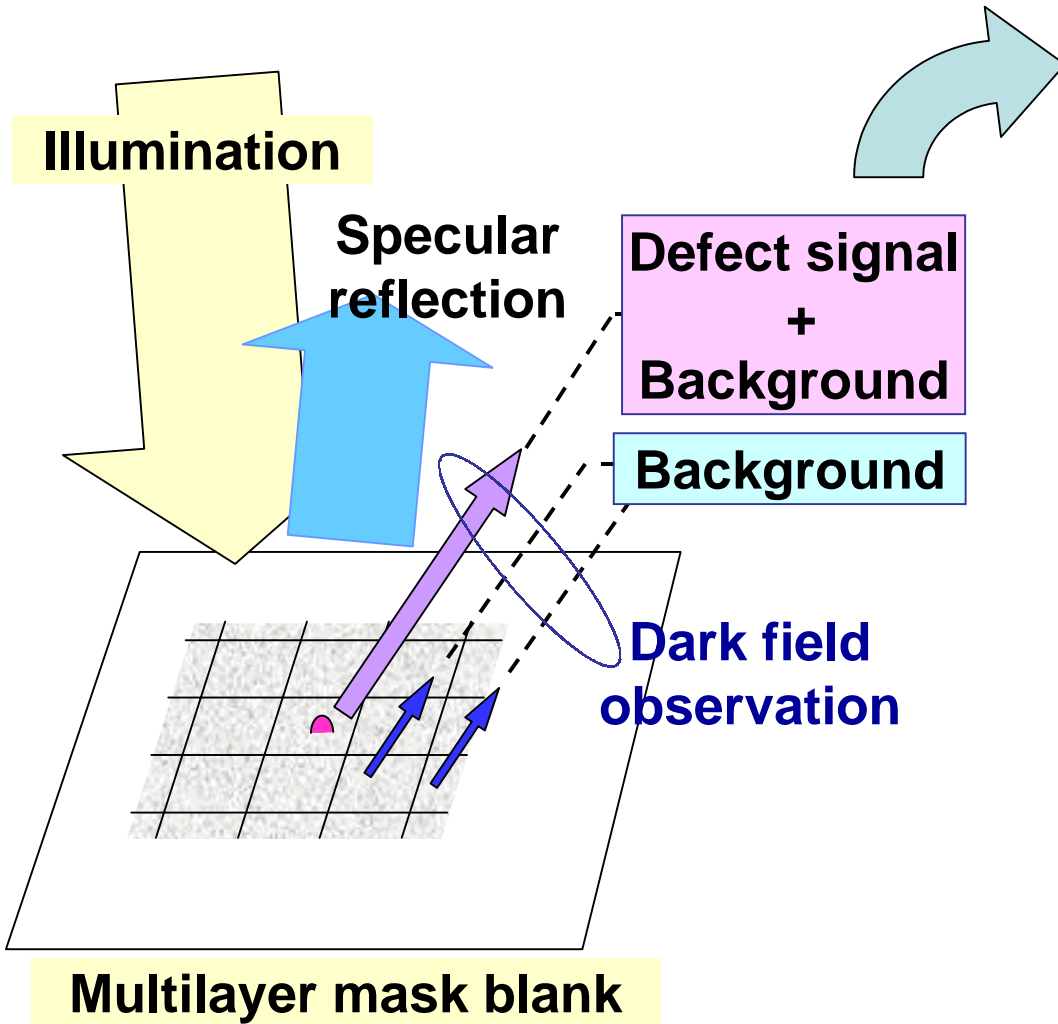
5. Summary

Concept of defect detection

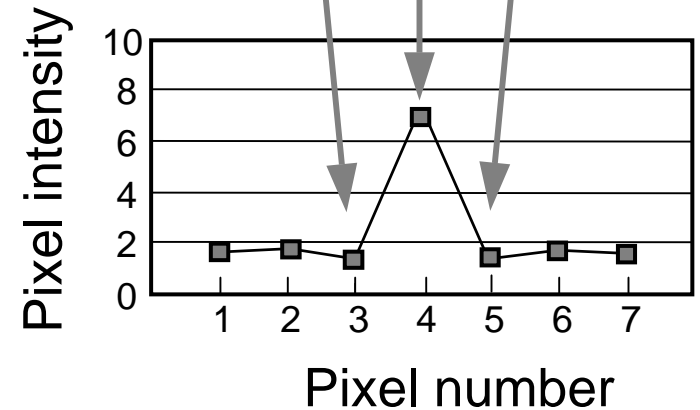
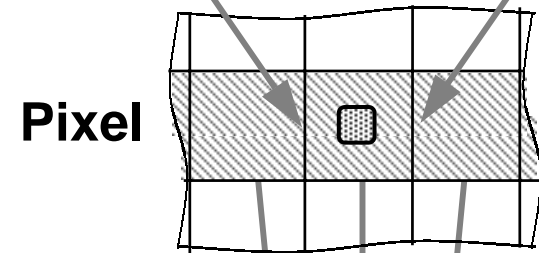
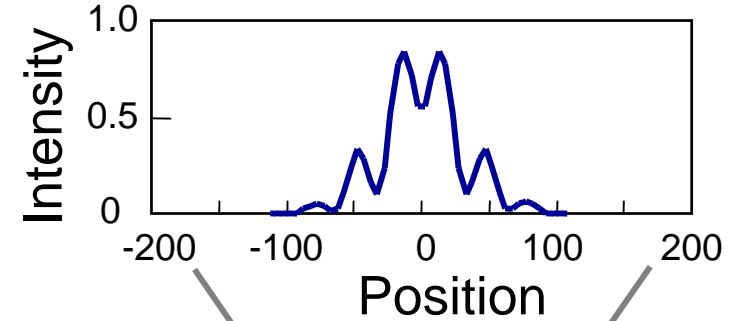
- EUV dark field observation
- 2-Dimensional imaging sensor
- LPP EUV source



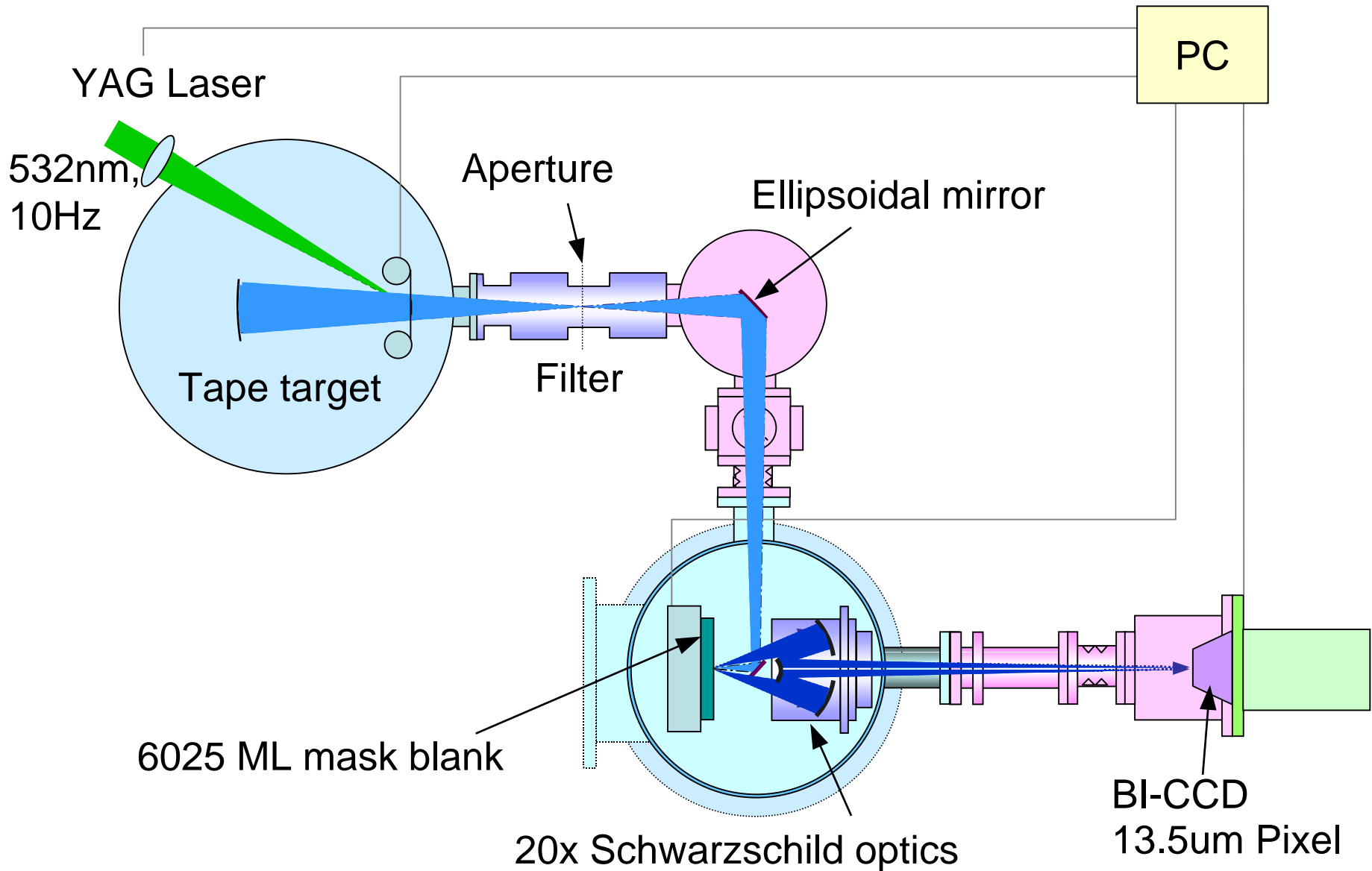
Detection data acquisition



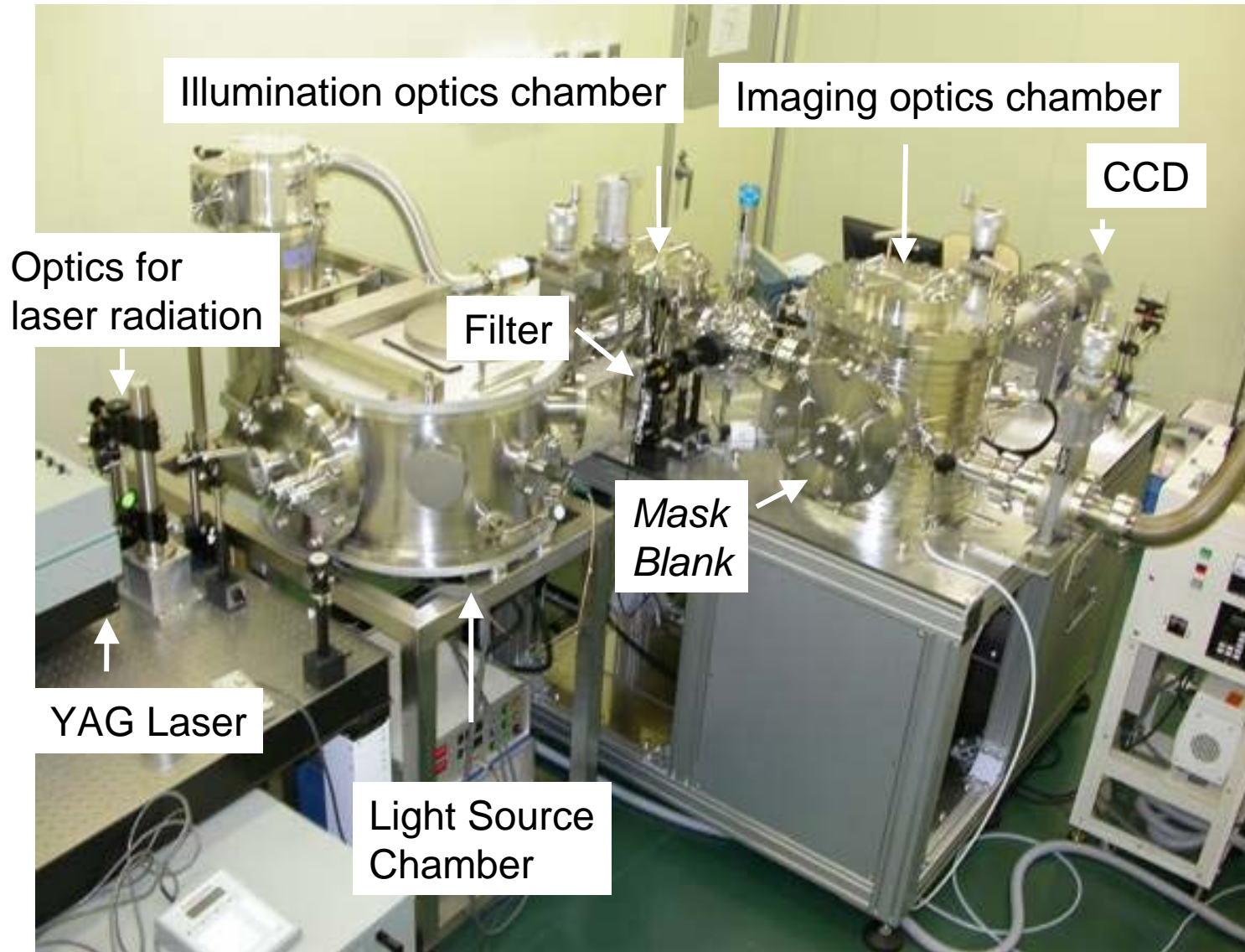
Dark-field image intensity



Top view of MIRAI POC tool



POC Set up



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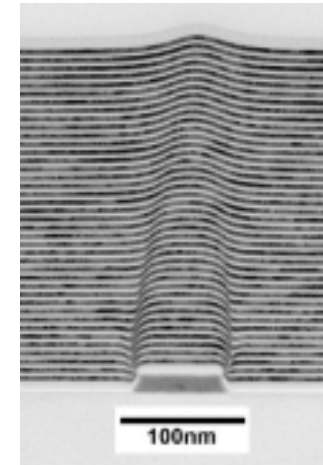
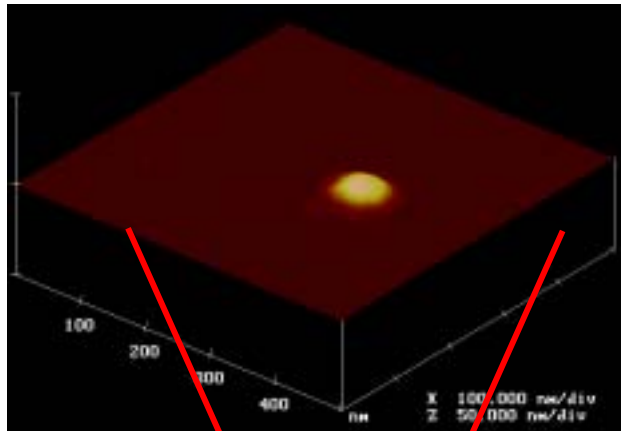
Programmed defect

Detection signal

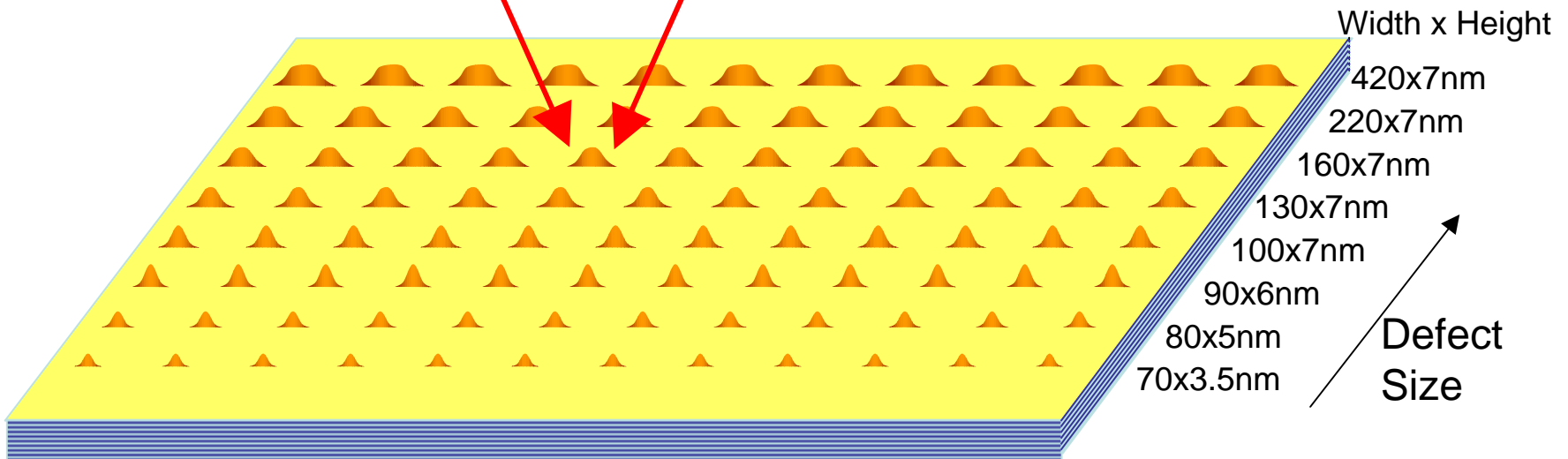
4. Throughput estimate

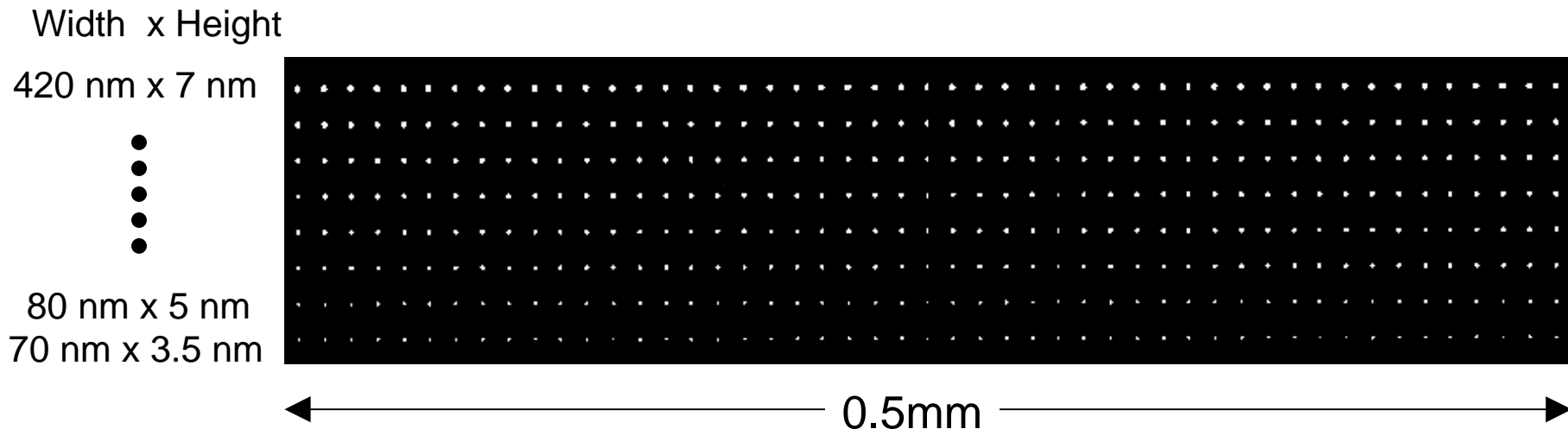
5. Summary

Programmed phase defect array



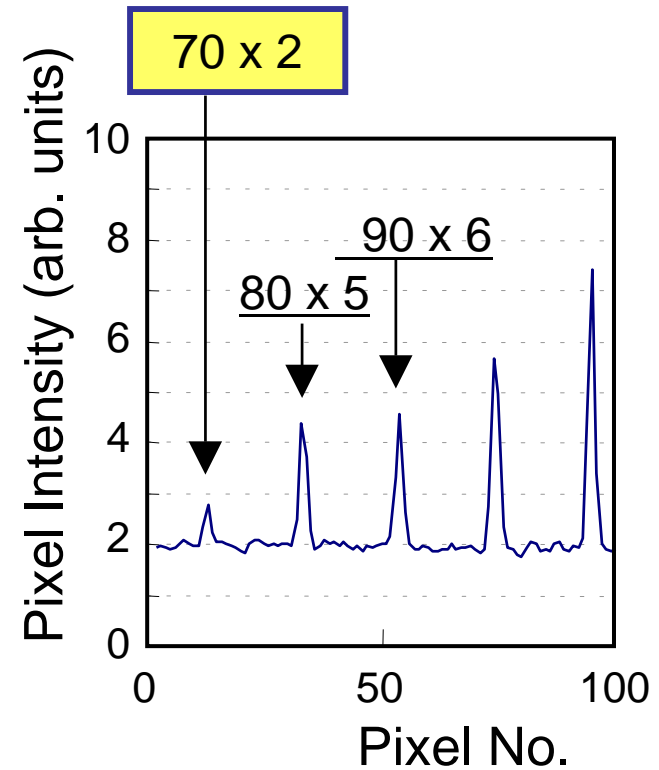
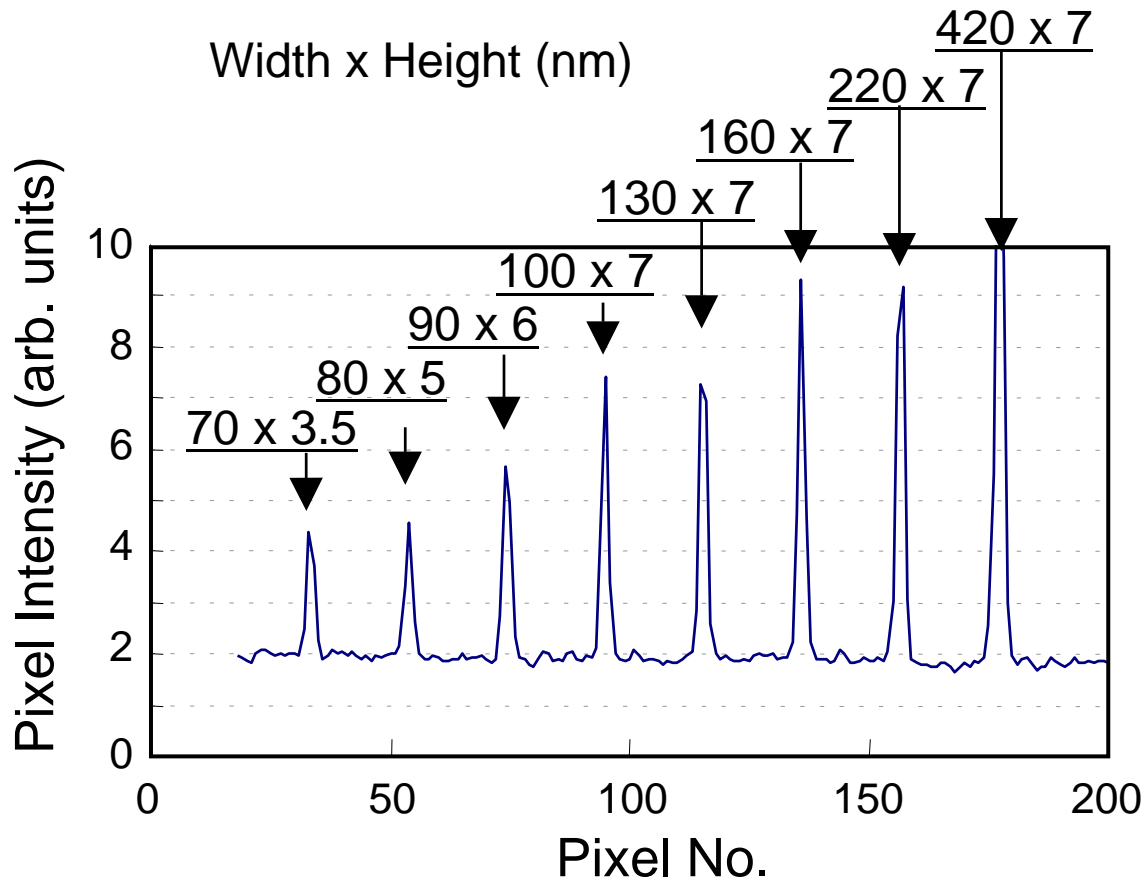
Courtesy of HOYA



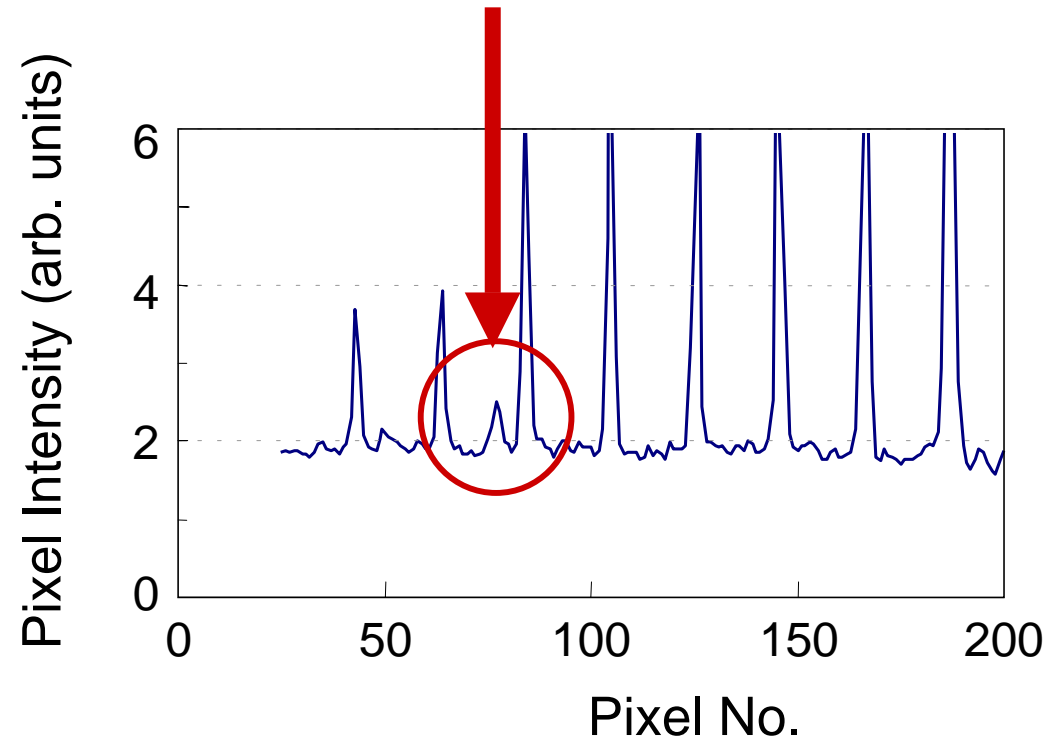
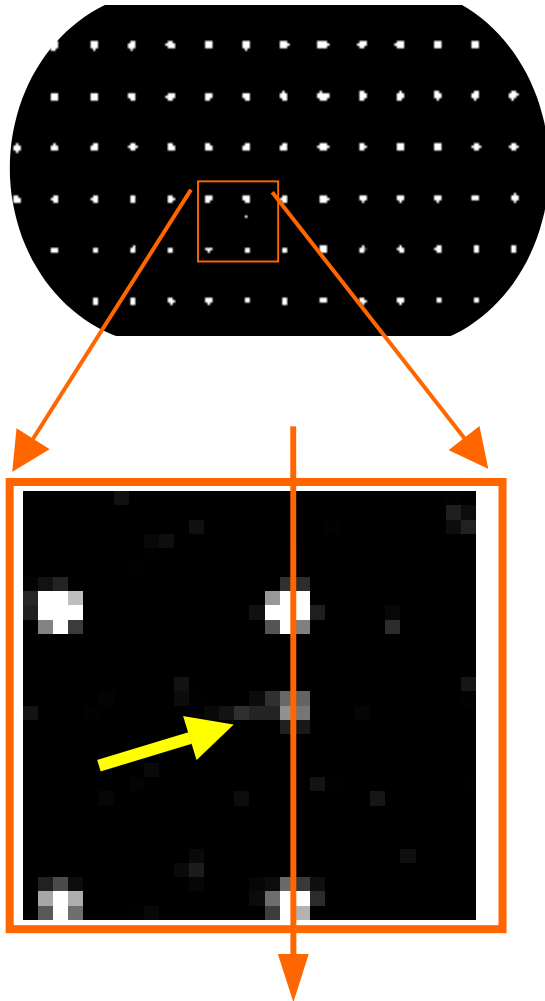


Images of 0.5mm area at mask blanks were obtained by CCD camera.

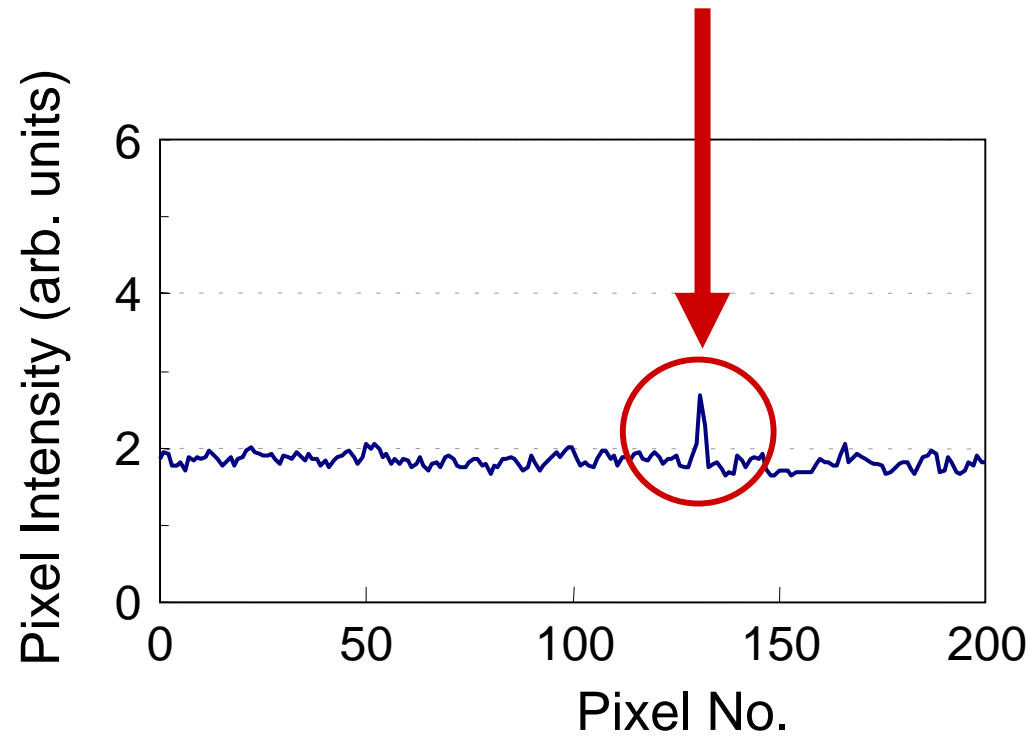
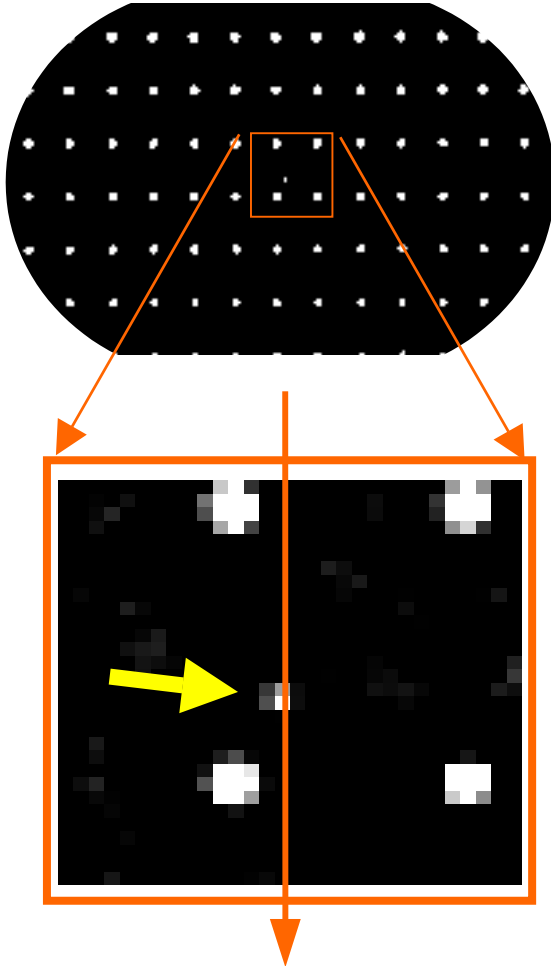
Pixel intensity

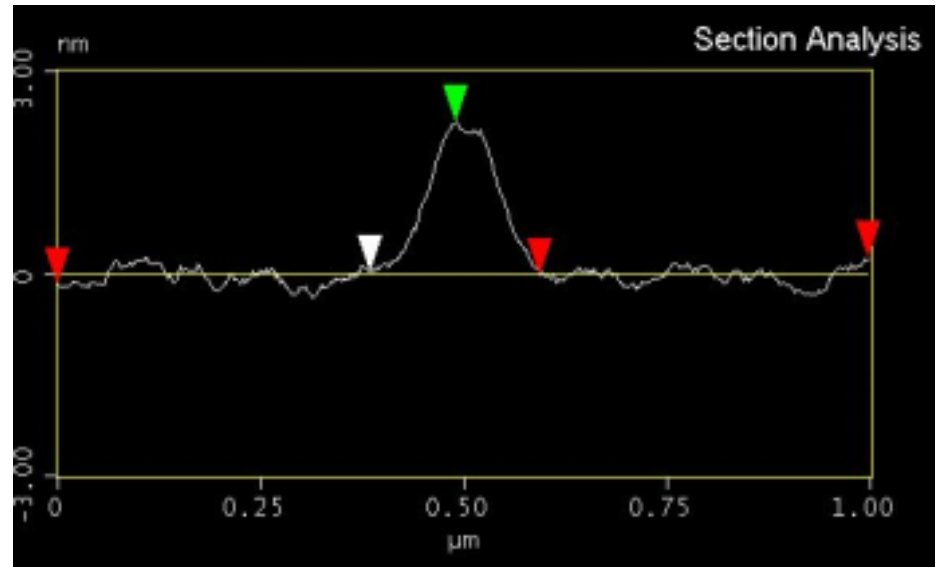
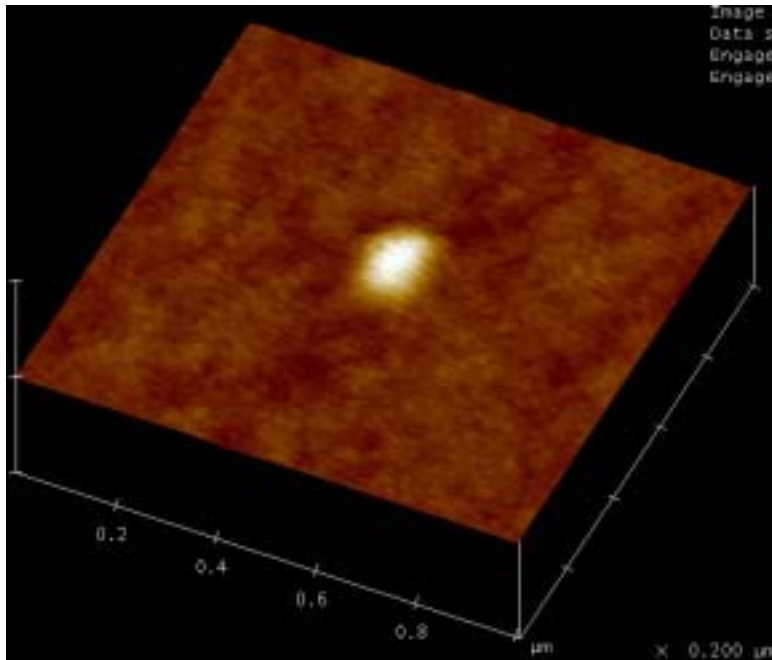


Natural defect - 1



Natural defect - 2



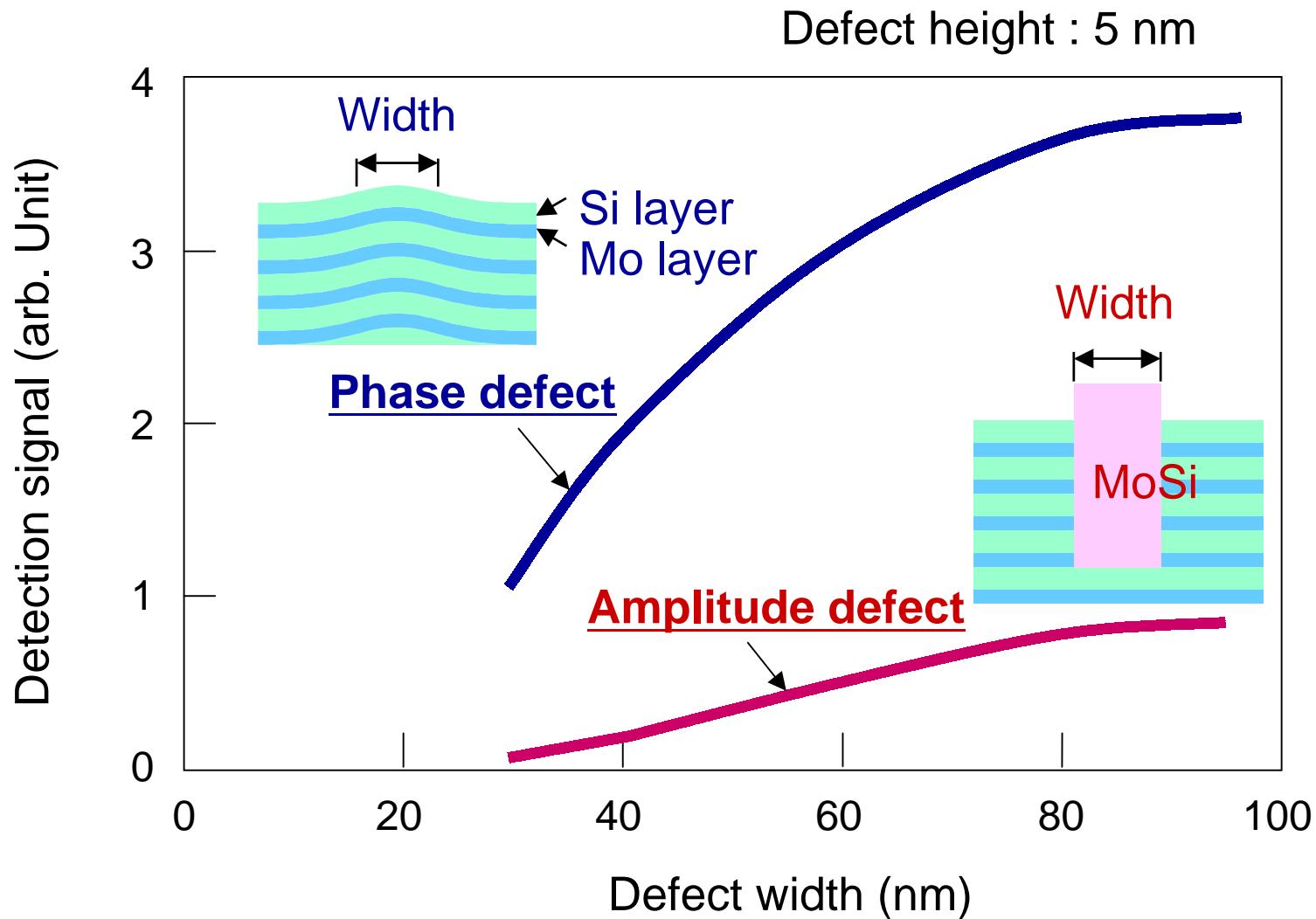


Defect width (FWHM) : $\sim 90 \text{ nm}$

Defect height : 2.2 nm

Natural phase defect

Prediction of detection signal



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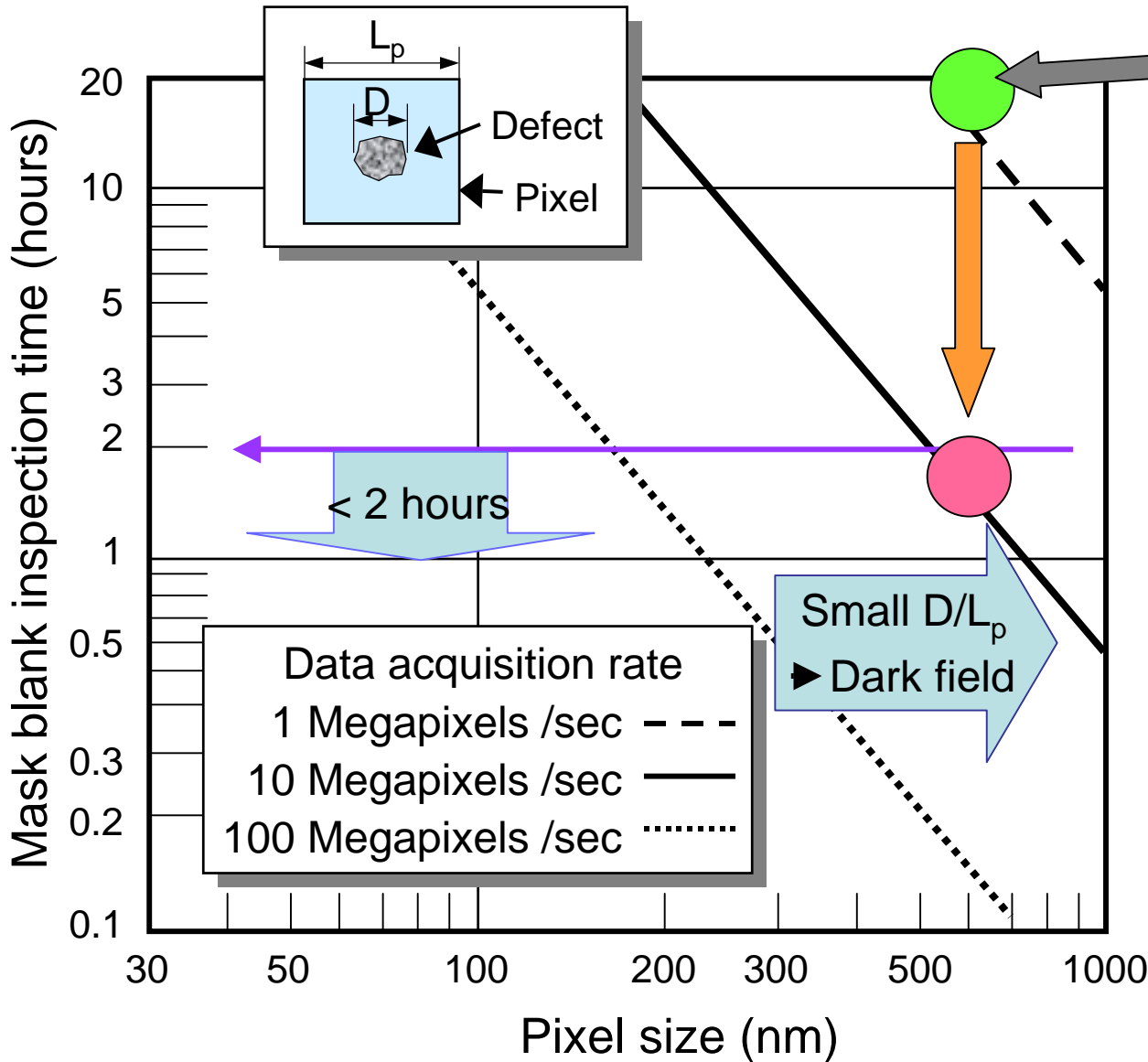
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Predicted inspection time



Inspection time in the first test
 $2\text{sec}/(0.5\text{ mm sqr.})$
 $800\text{ sec}/\text{cm}^2$

CCD data transfer
 $1\text{M pixel/s (current)}$
 $\rightarrow 12\text{hrs}$

$10\text{M pixel/s (planned)}$
 $\rightarrow 75\text{min}$

@ Light source power
 $\sim 2\text{mW}$

$2\text{ hrs}/\text{mask blank}$ is well within reach

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Summary

- **MIRAI successfully demonstrated actinic multilayer defect detection using dark-field imaging and LPP light source.**
- **Programmed defects down to $70\text{nm}^w \times 2\text{nm}^h$ were detected without any false defect detection.**
- **Natural defects were also observed by actinic detection signal and their topographies were measured by AFM. Further investigation of characterization is needed.**
- **Experimental inspection speed equivalent to $800 \text{ sec}/\text{cm}^2$ has been demonstrated, and further throughput estimate suggests that 2 hours per mask blank is feasible.**

•Please visit our poster presentation MeP12.

Acknowledgments

- The authors are grateful to Drs. Nagarekawa, Shoki, Yamashiro, and Takehana of HOYA Corporation for their fabrication of programmed defect mask blank.



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