# Dynamic scan operation of actinic EUVL mask blank inspection system with TDI mode

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Semiconductor Leading Edge Technologies, Inc.

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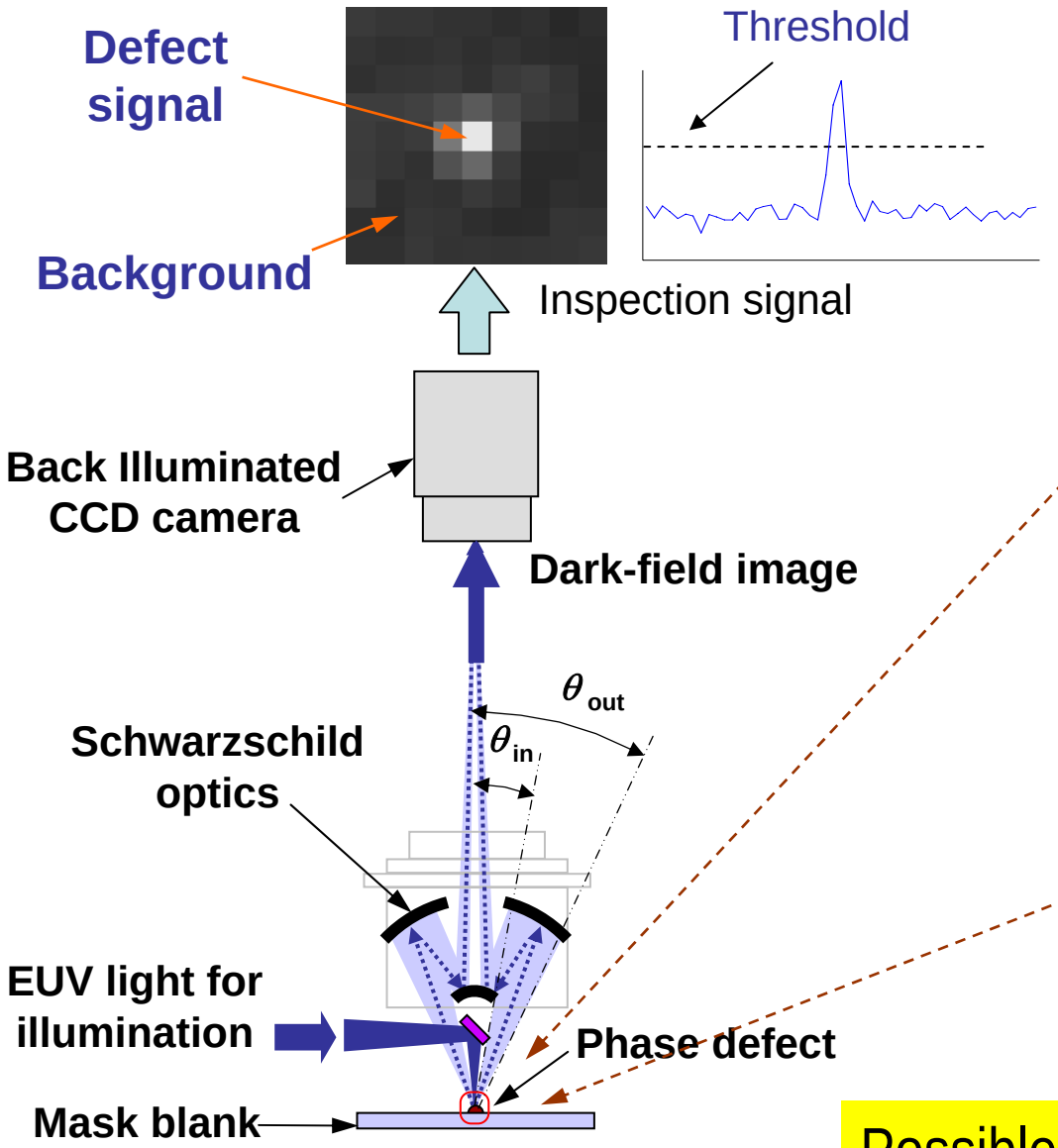
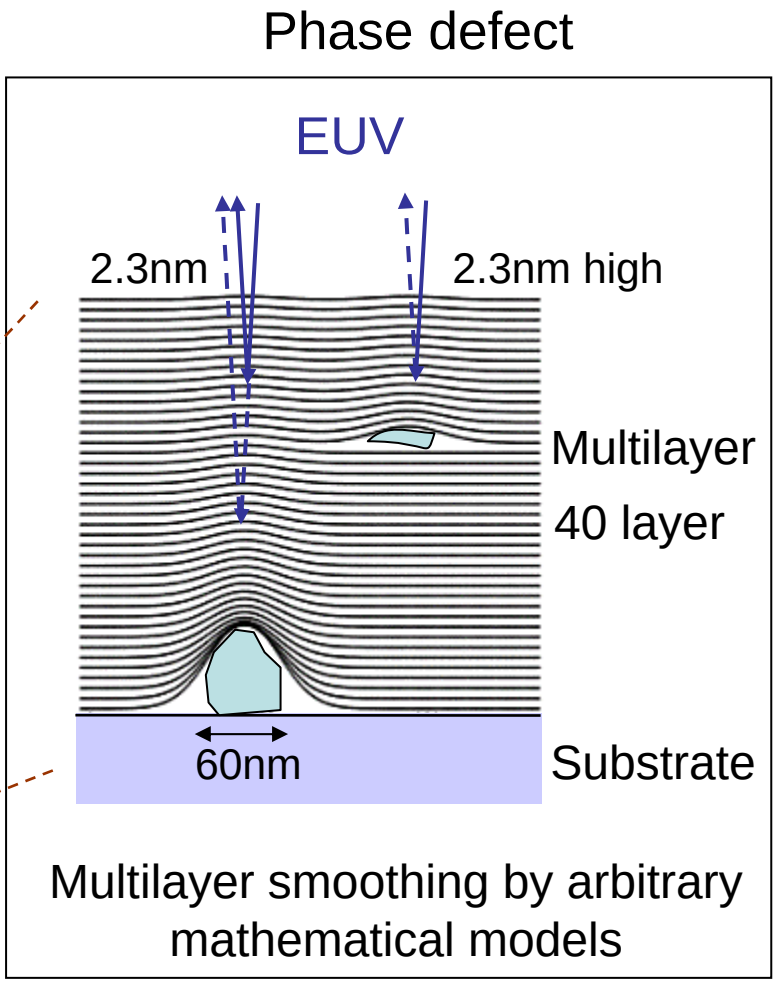
# Outline

1. Introduction
   - Dark field inspection
   - Positioning of Selete activity
2. Actinic mask blank inspection system design with Time Delay and Integration (TDI) mode.
3. Experimental of full-field phase defect detection
   - Programmed phase defect
   - Defect capture rate
4. Detection of Native defects and programmed phase defects among absorber patterns
5. Summary

# Dark-field actinic inspection




Possible needs for actinic defect detection

# Positioning of Selete activity

**MIRAI I and II (F.Y. 2001 ~)**

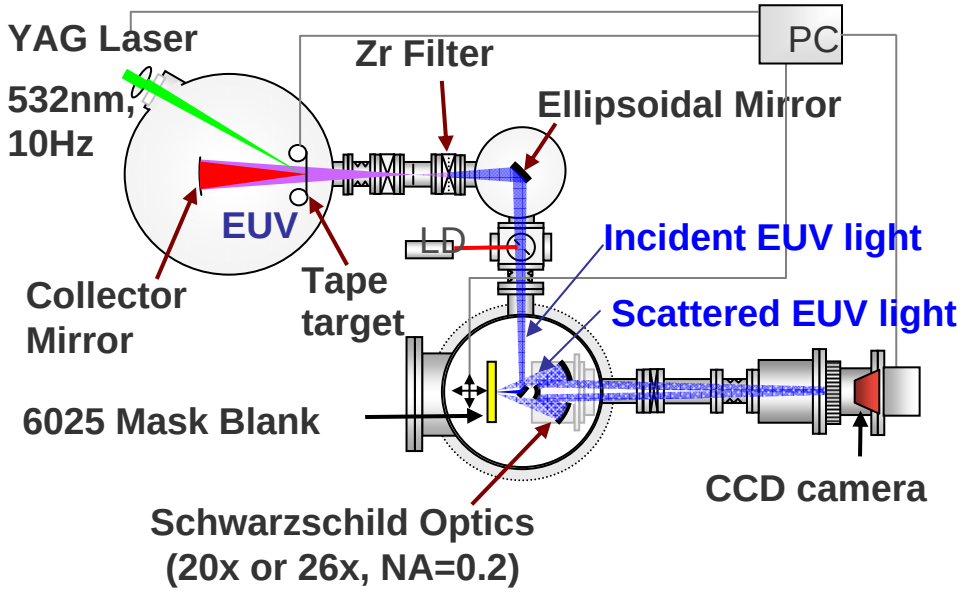
- Basic concept invented by AIST
- Proof of concept (POC) of actinic mask blank inspection tool with demonstration of minimum critical defect detection.
- Sensitivity limiting factor analysis and basic design completion of manufacturing ready prototype with accumulated experimental data.

**MIRAI –Selete (MITAI III) (F.Y.2006 ~)**

- Implementation of full-field mask blank inspection with reasonable inspection speed using a Time Delay and Integration (TDI) mode.
- Collecting inspection data of multilayer native defects to support mask process improvement for achieving defect-free mask.

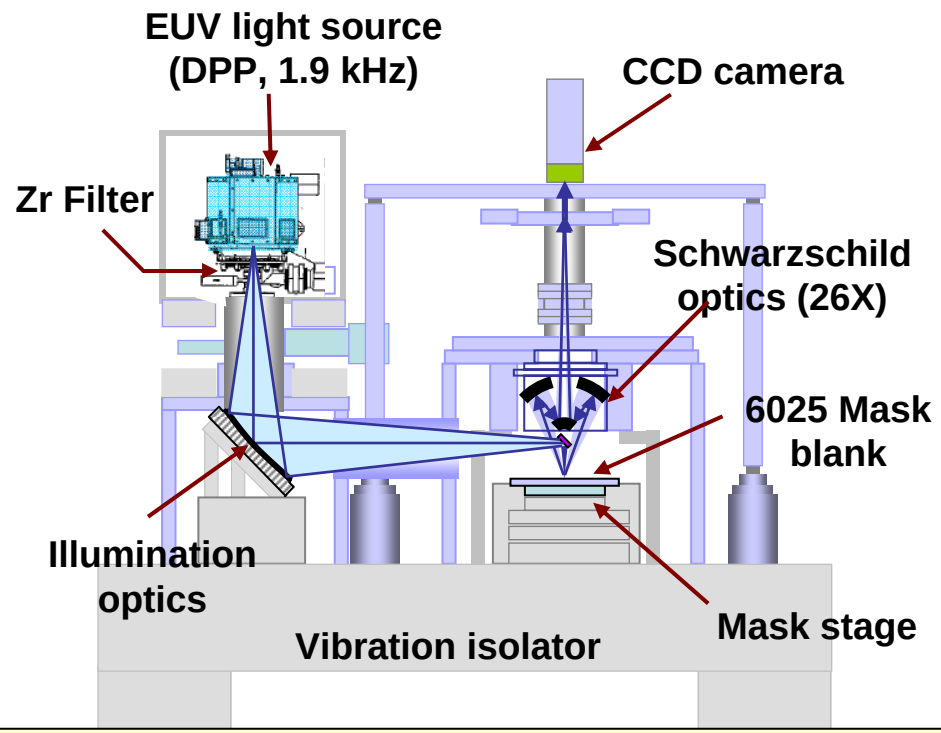
# Inspection tool design

## POC tool (MIRAI I and II)
### (Top view)



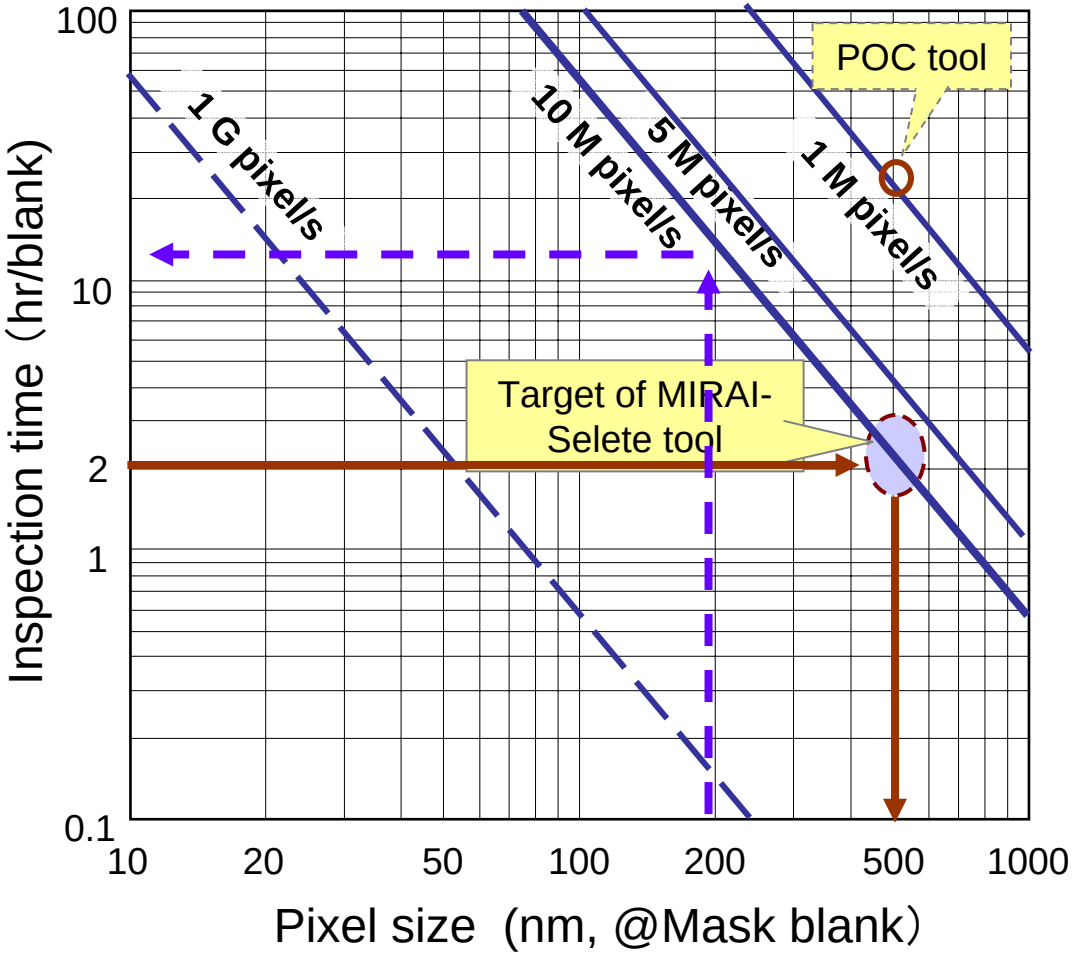

- In house LPP EUV light source (10 Hz)
- Mask stage stroke: X,Y: 10 mm,2 mm (Manual operation)
- Static imaging mode

## Full-field Inspection tool
### (Front view)

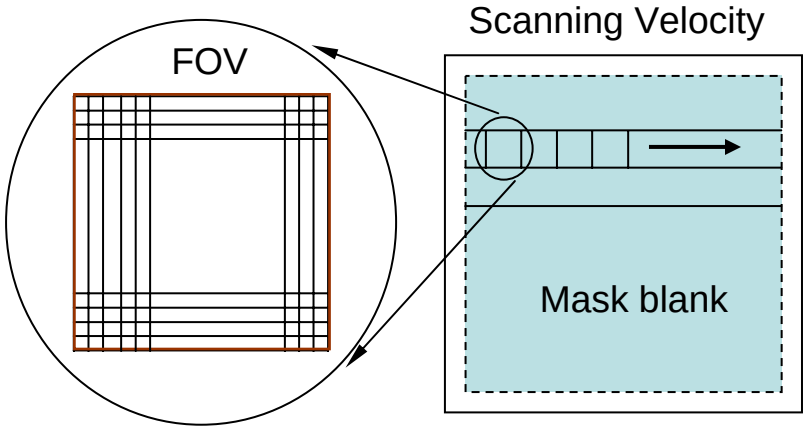



- Commercial available EUV source (1.9 kHz)
- Mask stage stroke: X,Y: 169 mm,169 mm (Automatic controlled)
- TDI mode & Static imaging mode

# Time Delay and Integration (TDI) mode

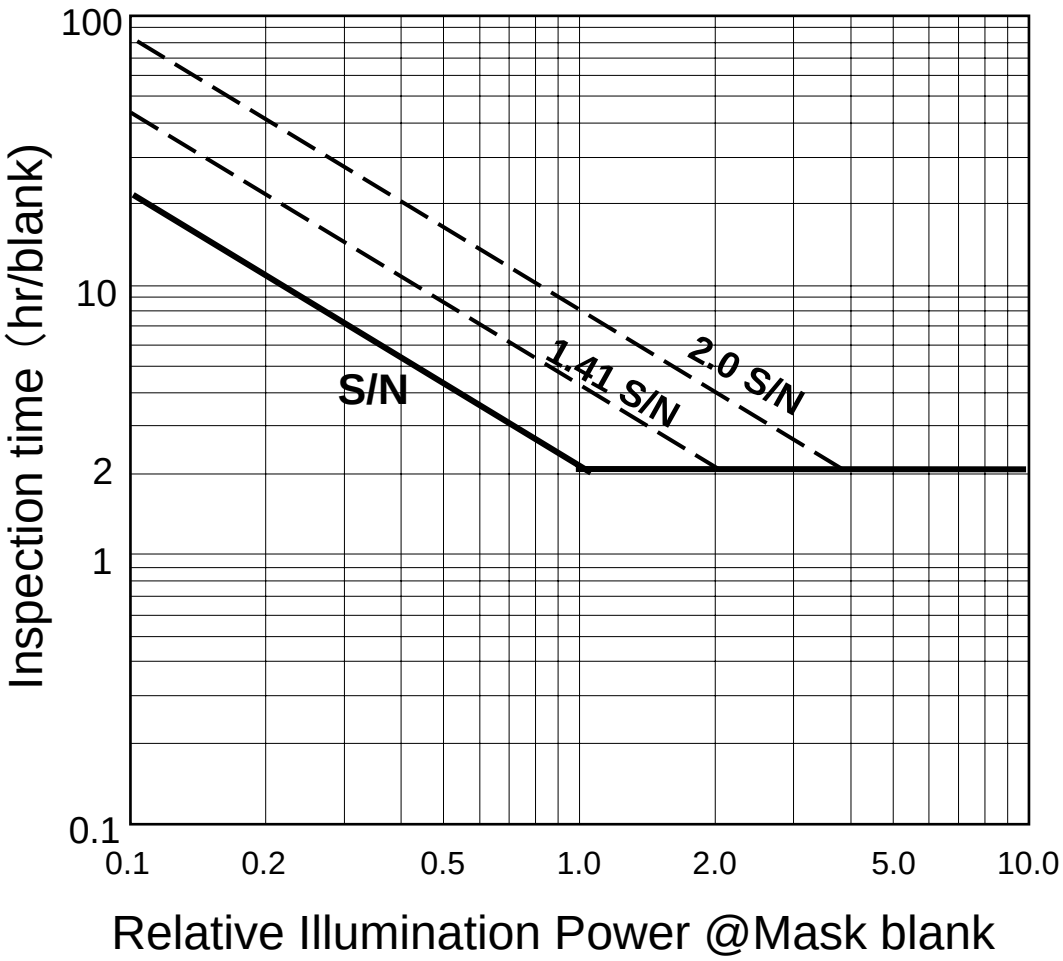



Assuming:
- Pixel size:500 nm
- Inspection Area: 140X140 $mm^2$




Fastest inspection speed is limited by CCD data transfer rate even if illumination power is sufficient .

# Time Delay and Integration (TDI) mode

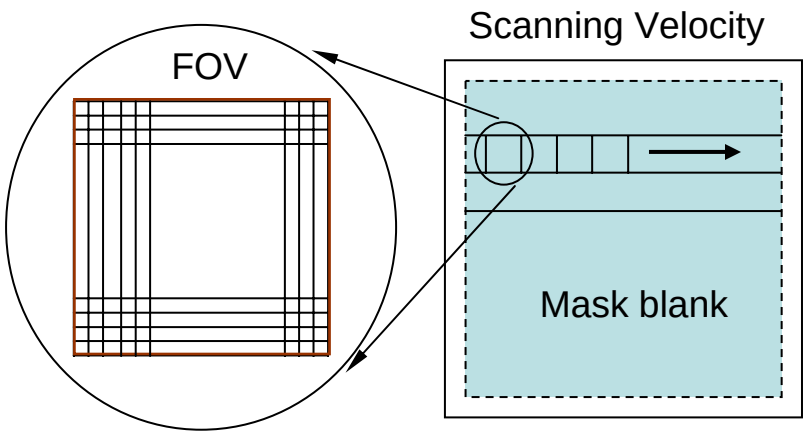



Only shot noise is assumed

Assuming:

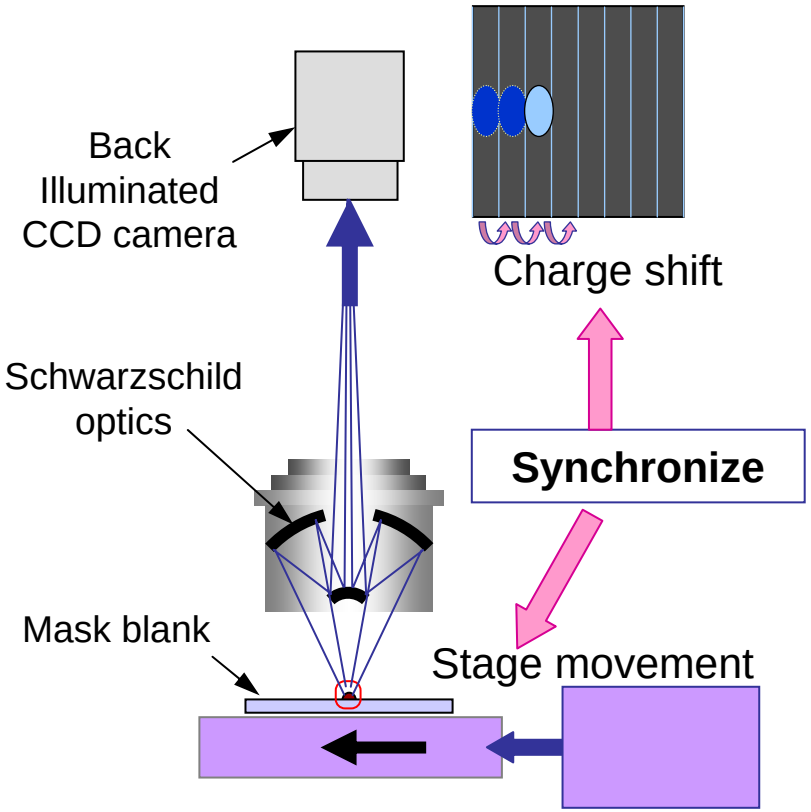
Pixel size:500 nm

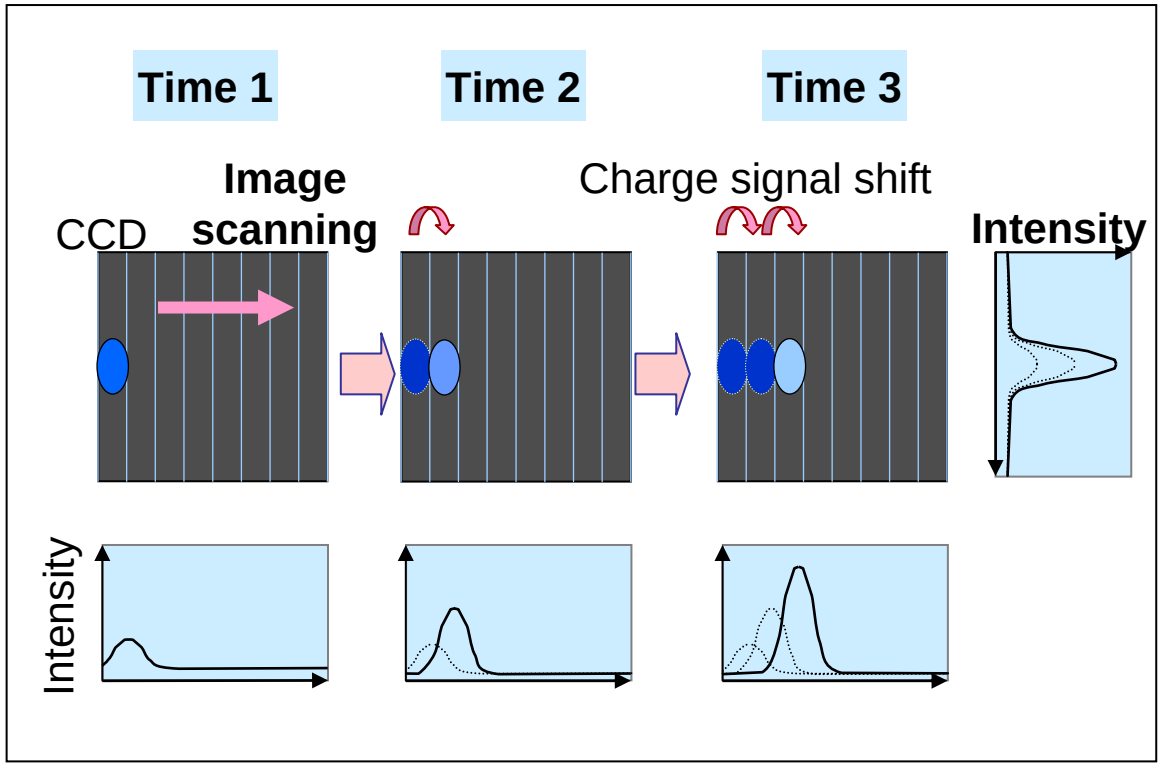
Inspection Area: 140X140 $mm^2$




Fastest inspection speed is limited by CCD data transfer rate even if illumination power is sufficient .

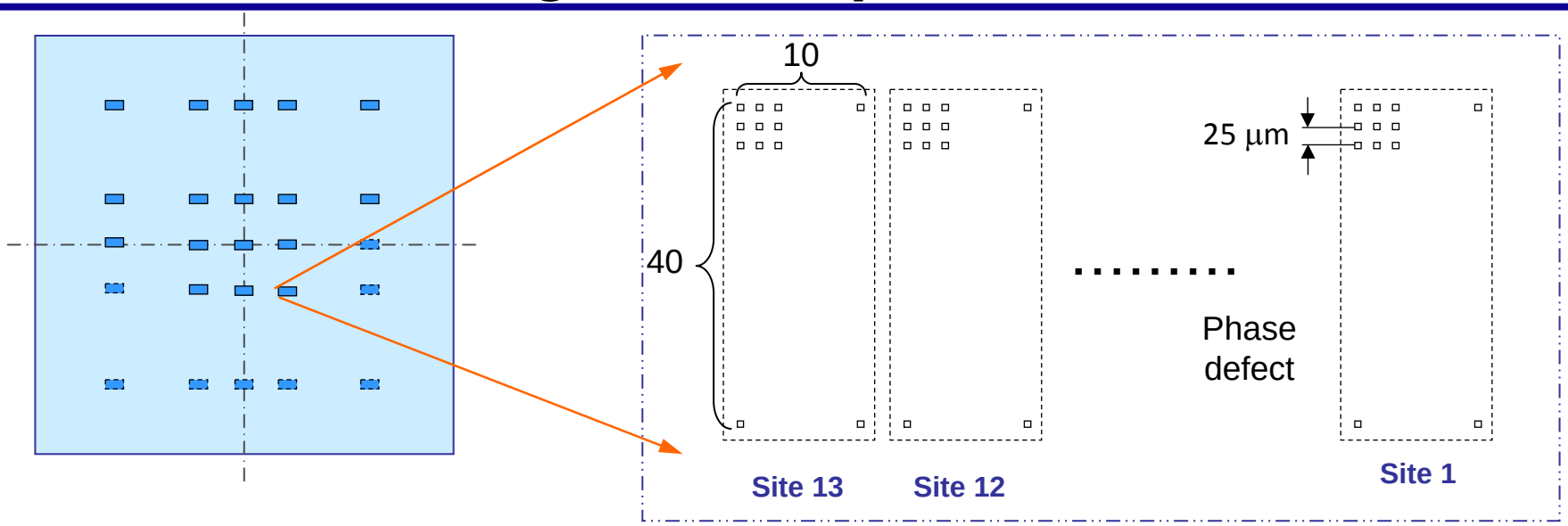
# Image charge shift for TDI mode



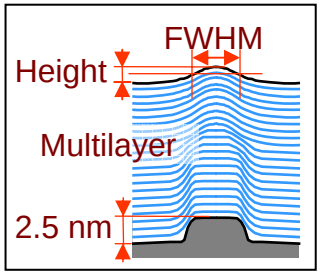



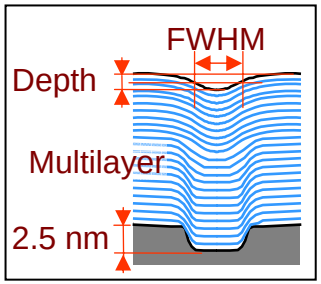

Charge shift is performed by the signal generated every 500 nm movement

# Programmed phase defect

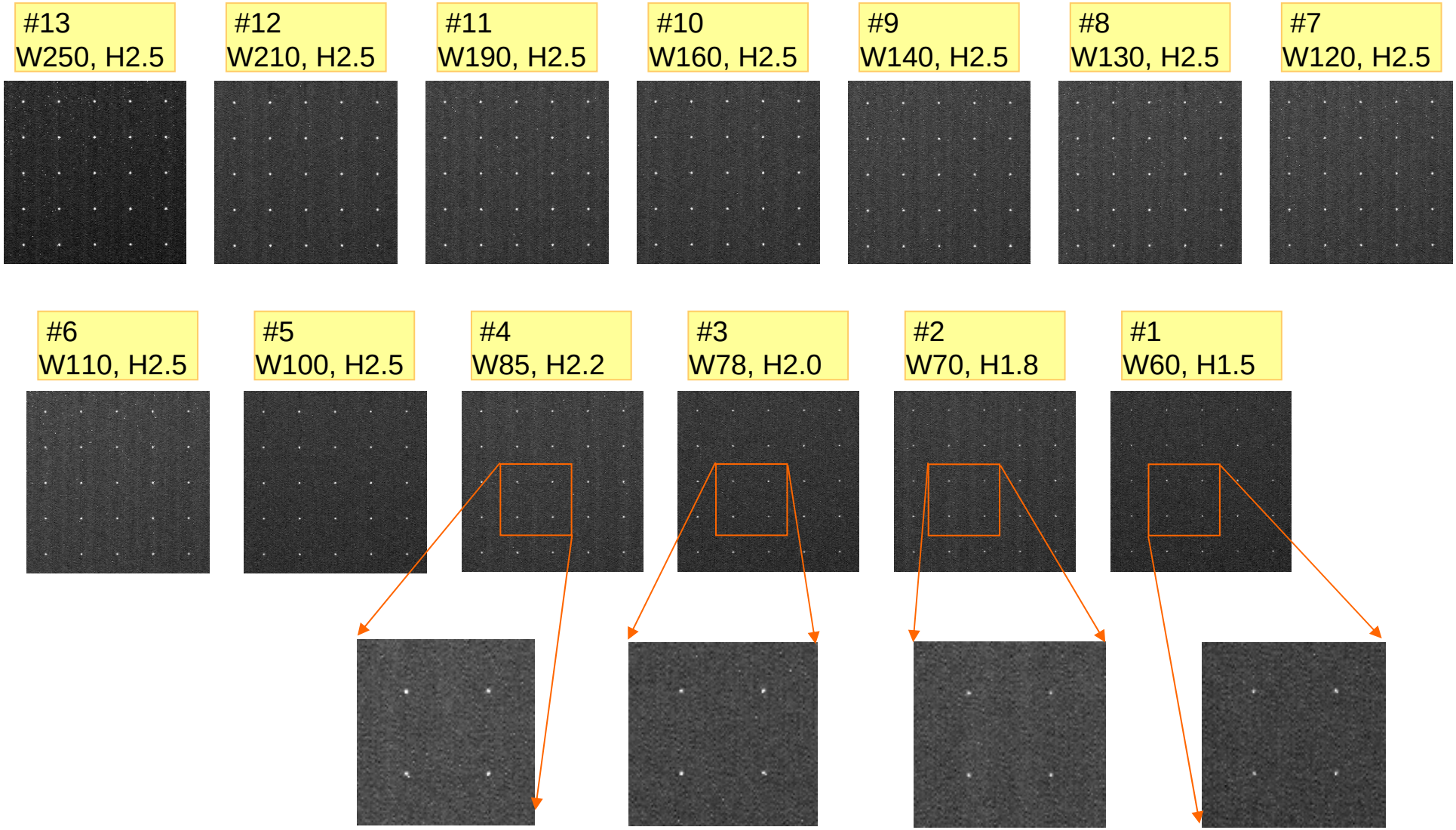



| Site Number | | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bump (a)** | FWHM (nm) | 60 | 70 | 78 | 85 | 100 | 110 | 120 | 130 | 140 | 160 | 190 | 210 | 250 |
| | Height (nm) | 1.5 | 1.8 | 2.0 | 2.2 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| **Bump (b)** | FWHM (nm) | 60 | 70 | 85 | 100 | 130 | 140 | 160 | 200 | 250 | 300 | 400 | 490 | 1000 |
| | Height (nm) | 1.5 | 1.8 | 2.2 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| **Pit** | FWHM (nm) | 120 | 190 | 230 | 250 | 270 | 300 | 320 | 360 | 420 | 460 | 520 | 760 | 1050 |
| | Depth (nm) | 2.3 | 2.5 | 2.5 | 2.2 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |



# Inspection optics performance

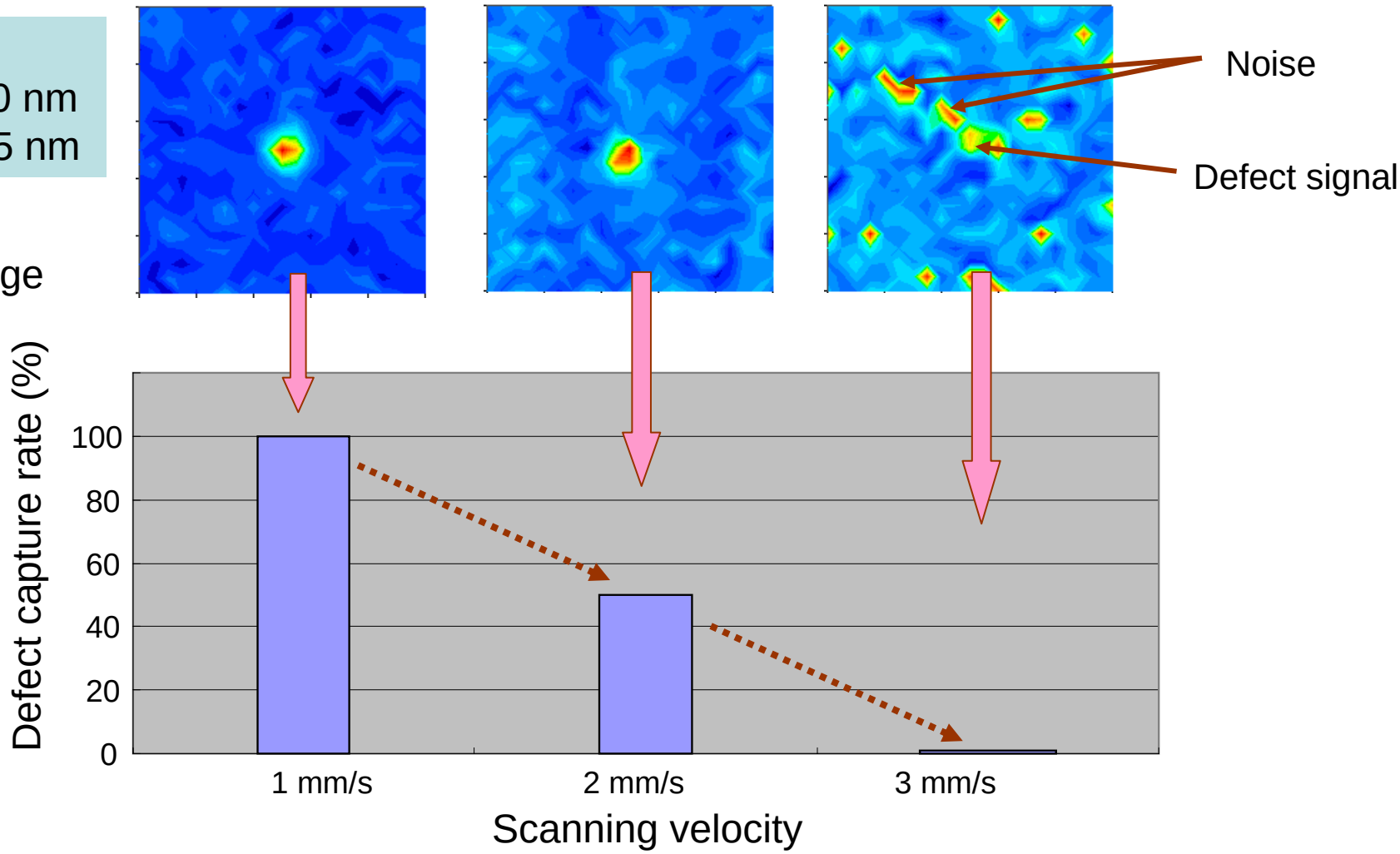



*T. Terasawa et al., SPIE Advanced Lithography 2009*

# Scanning velocity dependency

Defect:
Width: 100 nm
Height: 2.5 nm

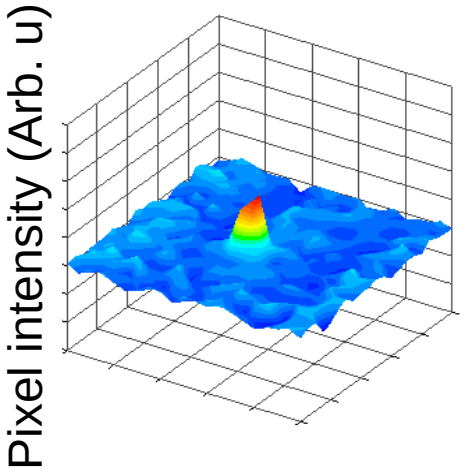
21X21
pixel image

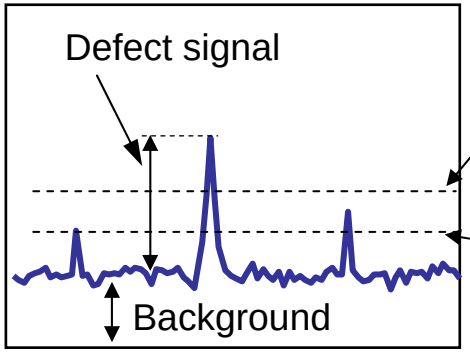



◆As stage velocity increased, an increase of noise signal was observed while scanning error was not observed.

# Threshold level for little false defects

Defect detection signal profile



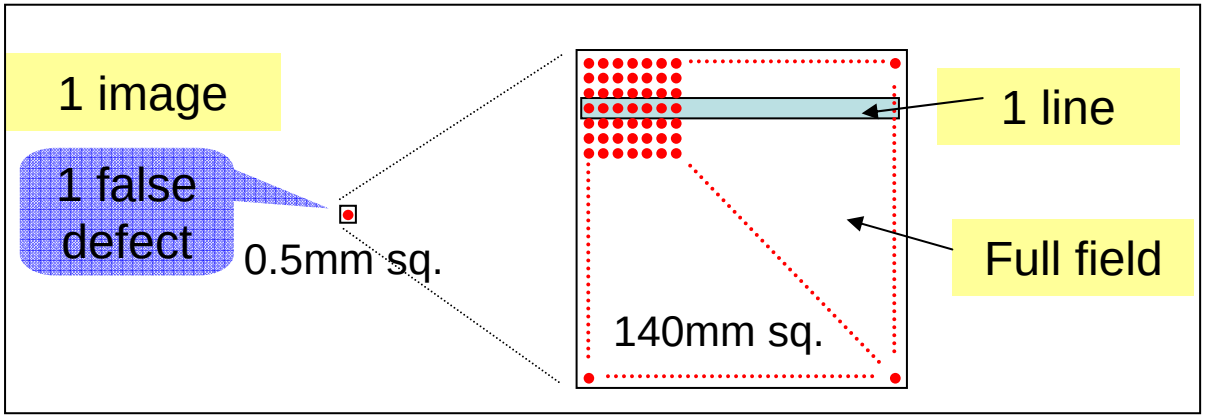




**High threshold**

Little occurrence of false defect

**Low threshold**

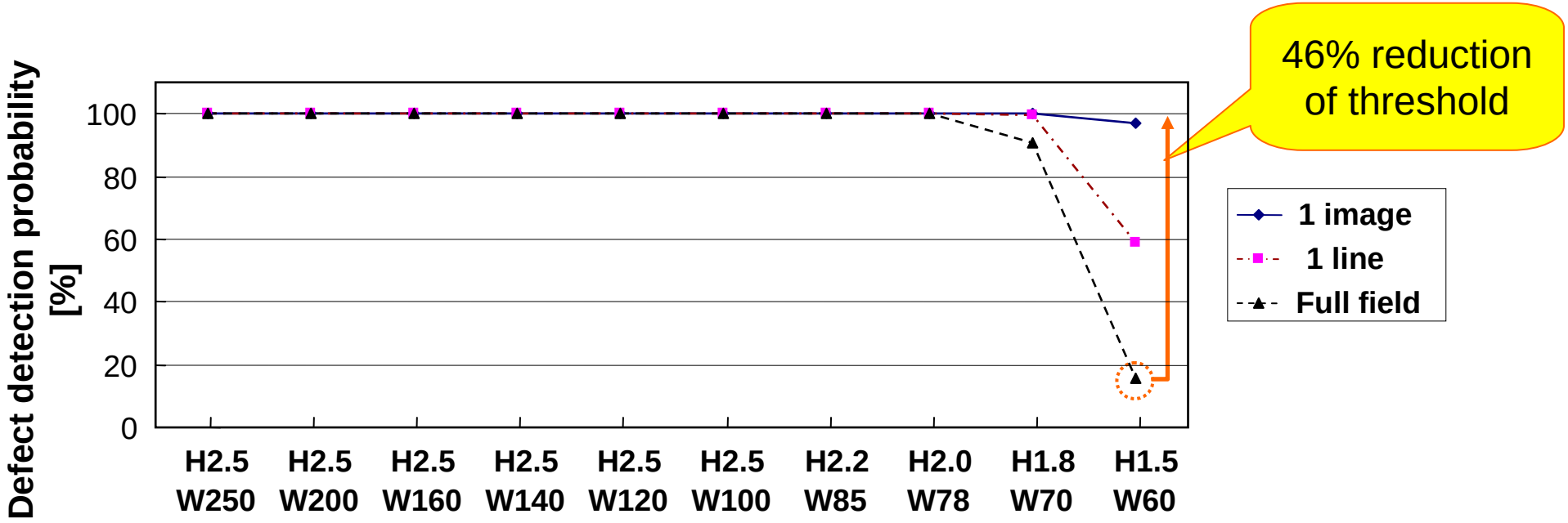
High probability of defect detection




Relative threshold level for false defect number less than 1 for current MIRAI tool

| 1 image | 1 line | Full-field |
|---|---|---|
| 0.67 | 0.86 | 1.0 |

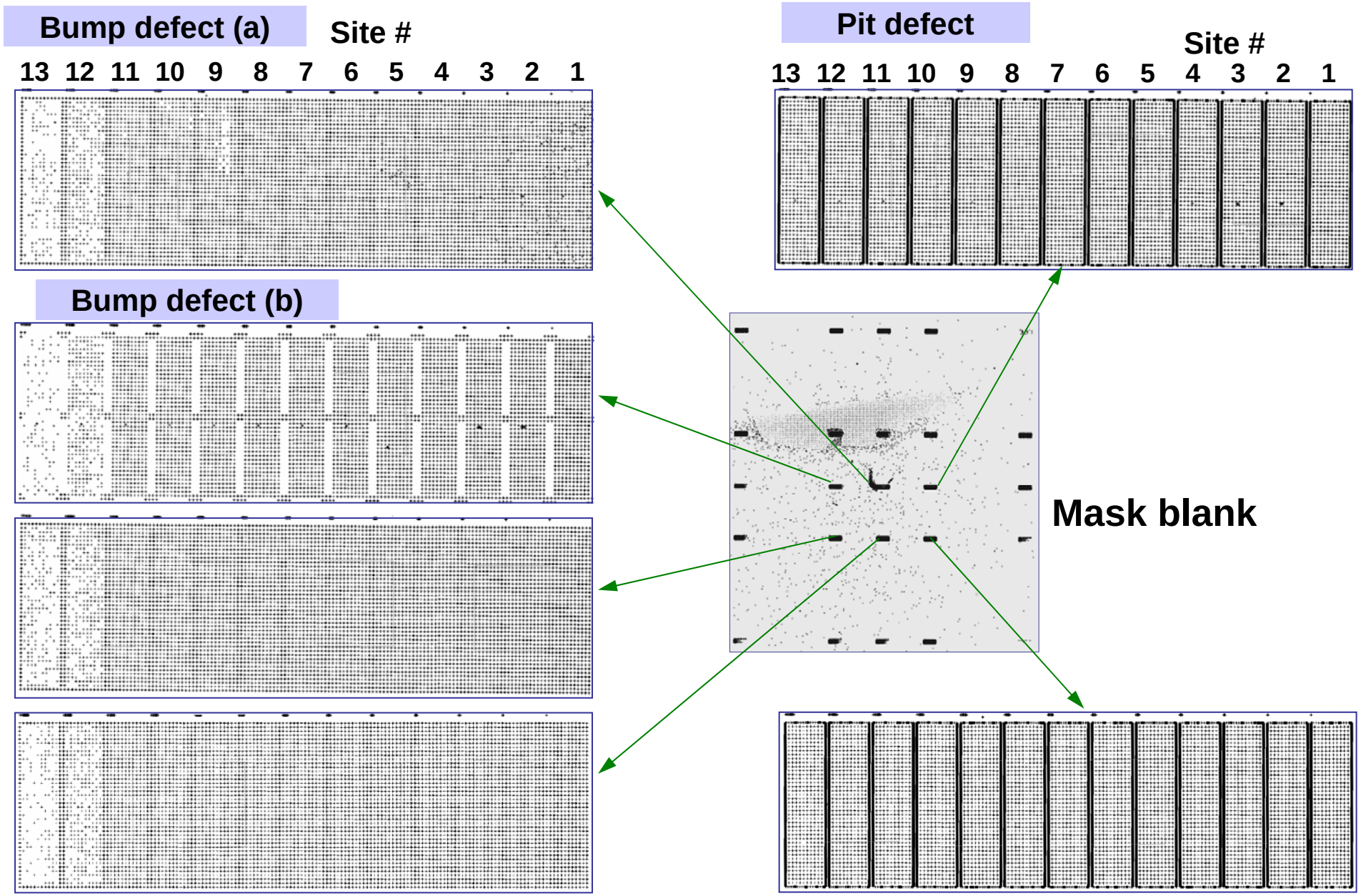
# Defect detection probability




◆100% detection with no false defect at full field is achieved for defects larger than H2.0nm W78nm.

◆For 100% detection of H1.5nm W60nm defect, 46% reduction of threshold will be needed. Signal noise reduction will be performed

# Full field inspection

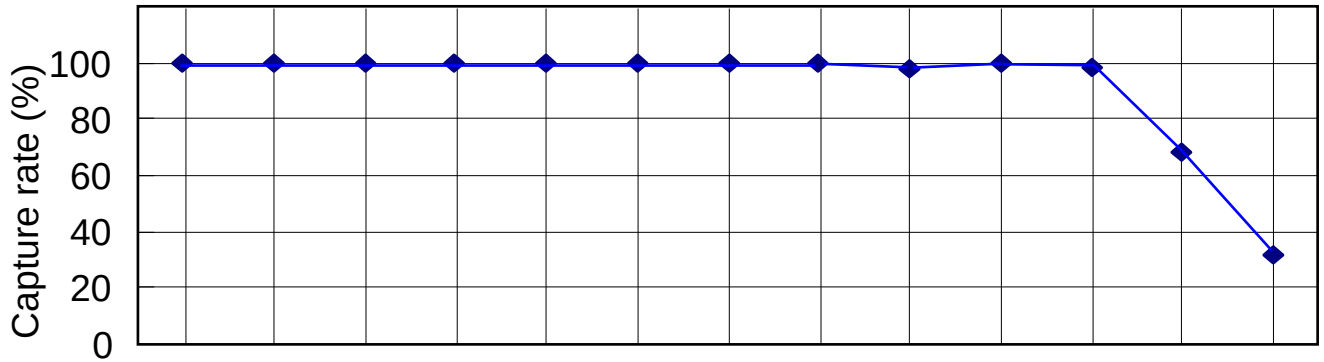


# Defect capture rate

$$\text{Defect capture rate} = \frac{\text{Number of detected defects in one site}}{\text{Number of programmed defects in one site (=400)}}$$

Threshold : Full-field

Bump defect (a)

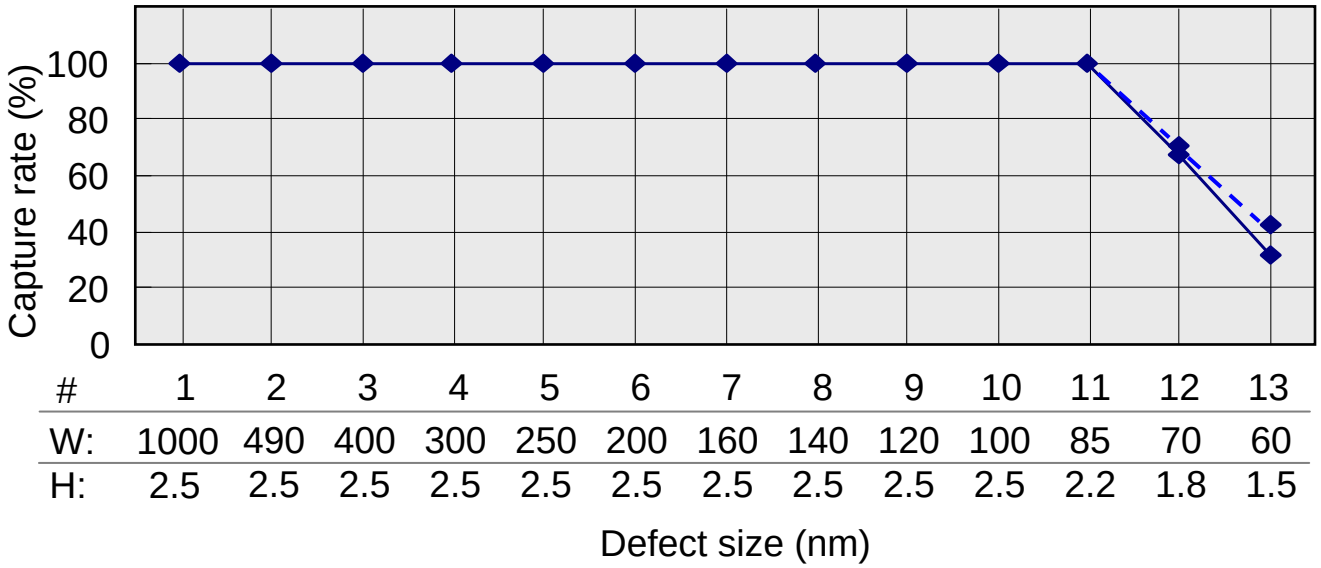



| # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W: | 250 | 210 | 190 | 160 | 140 | 130 | 120 | 110 | 100 | 85 | 78 | 70 | 60 |
| H: | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.2 | 2.0 | 1.8 | 1.5 |

Defect size (nm)

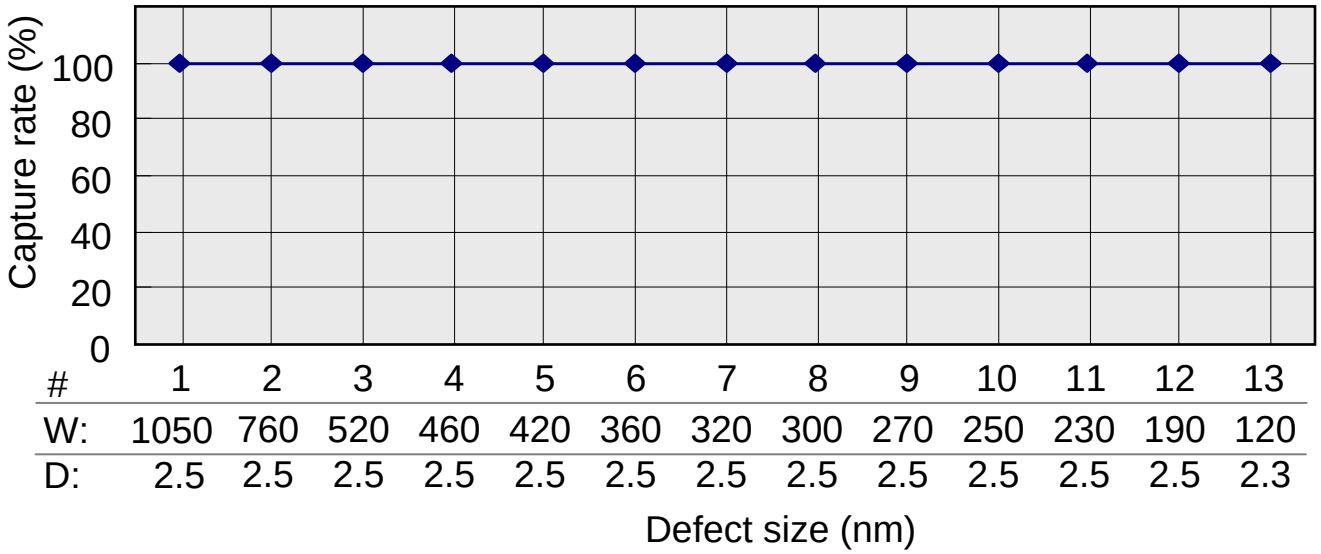
# Defect capture rate

Bump defect (b)




| # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W: | 1000 | 490 | 400 | 300 | 250 | 200 | 160 | 140 | 120 | 100 | 85 | 70 | 60 |
| H: | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.2 | 1.8 | 1.5 |

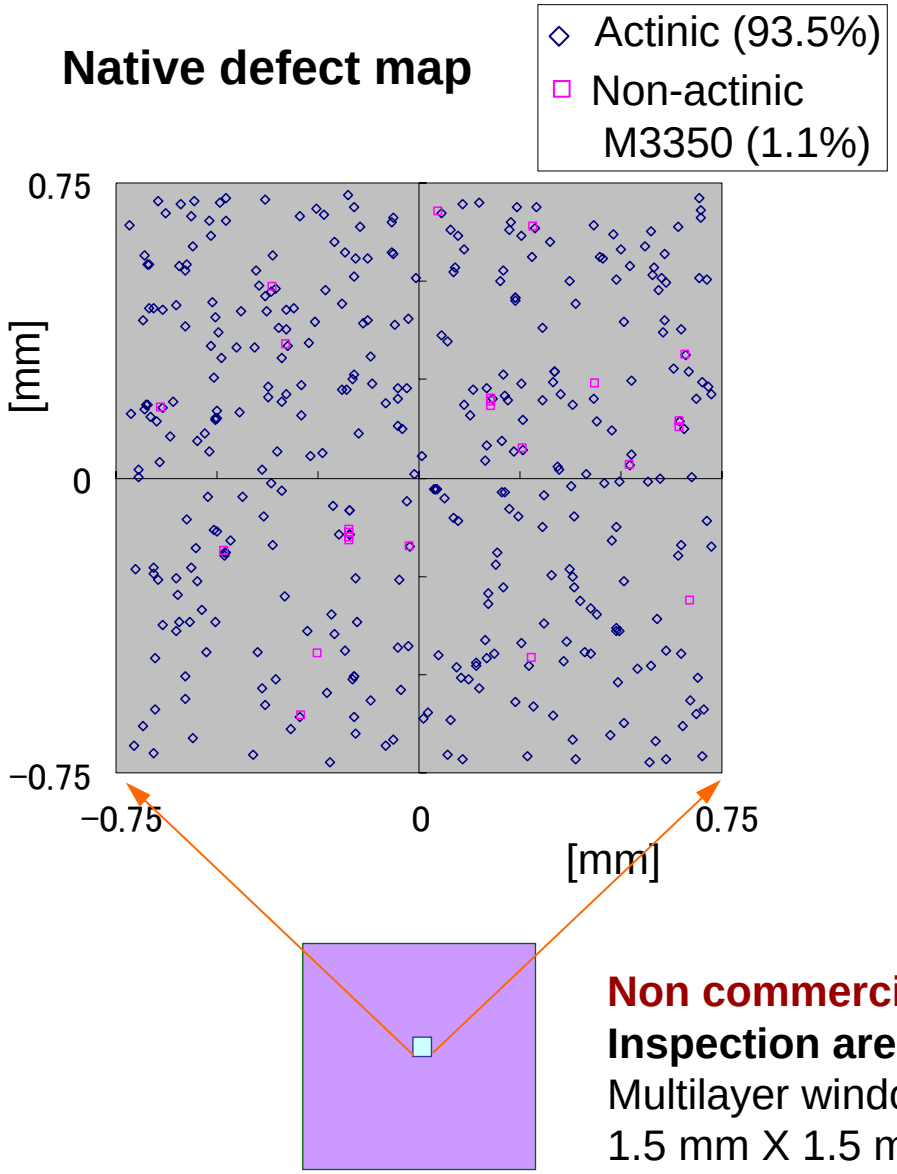
Pit defect




| # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W: | 1050 | 760 | 520 | 460 | 420 | 360 | 320 | 300 | 270 | 250 | 230 | 190 | 120 |
| D: | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.3 |

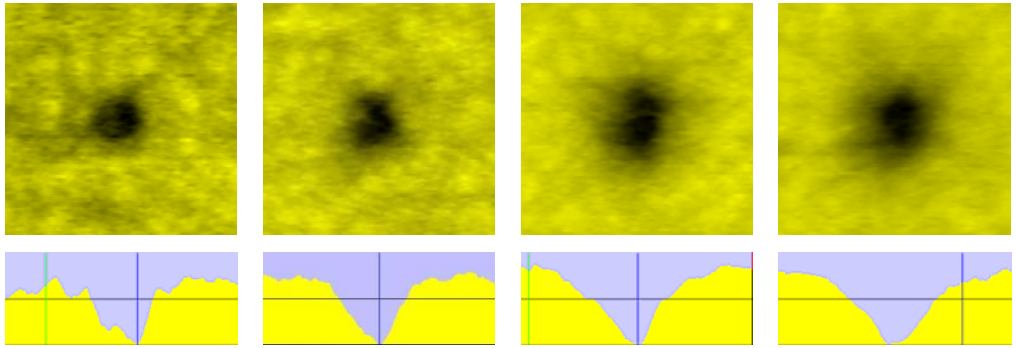
# Native defect detection

## Native defect map



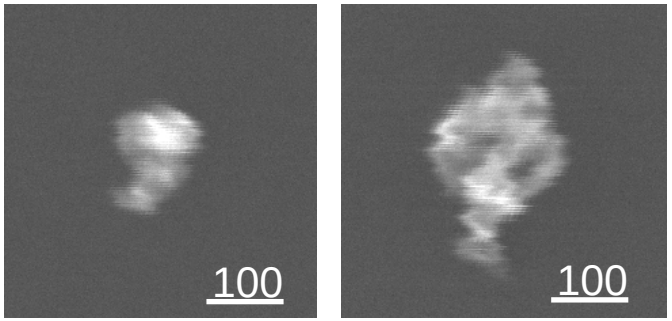

**Non commercial Mask**
**Inspection area:**
Multilayer window of
1.5 mm X 1.5 mm area

**Phase defects smaller than 100 nm were detected only by the actinic system.**

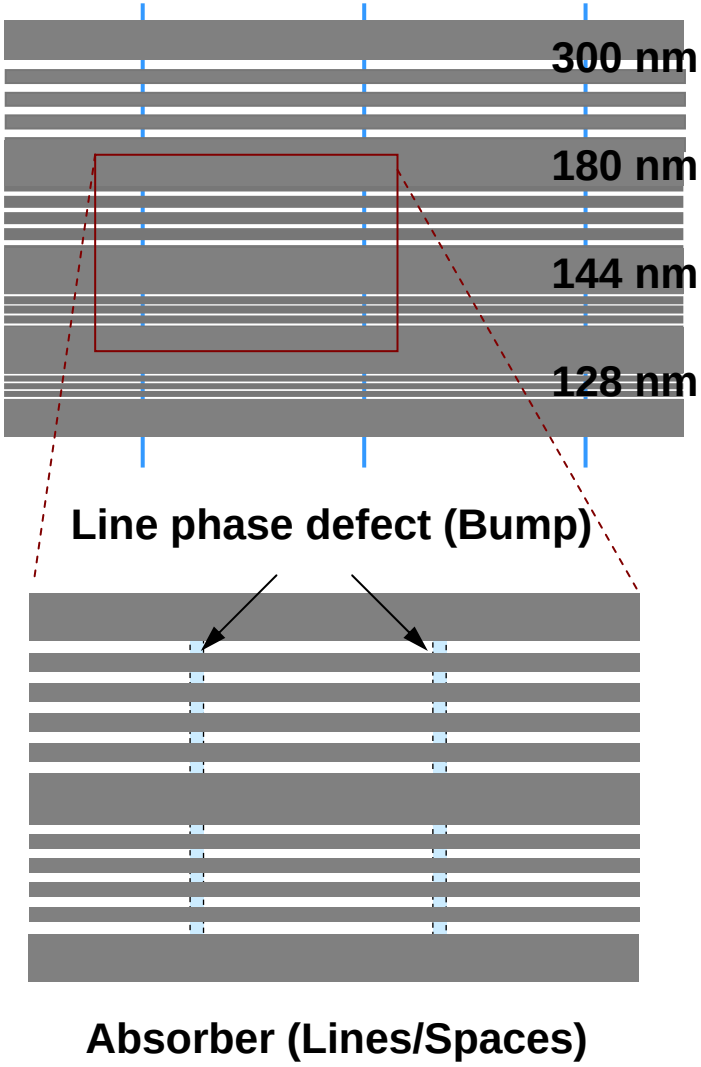


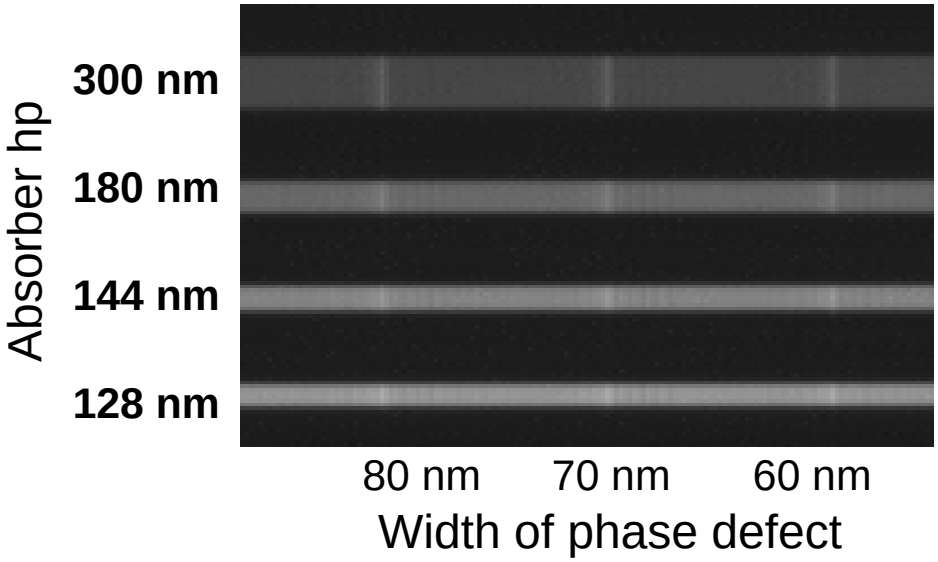
| D 2.5nm, W 66nm | D 3.5nm, W 68nm | D 5.7nm, W 96nm | D 6.8nm, W 93nm |
|---|---|---|---|

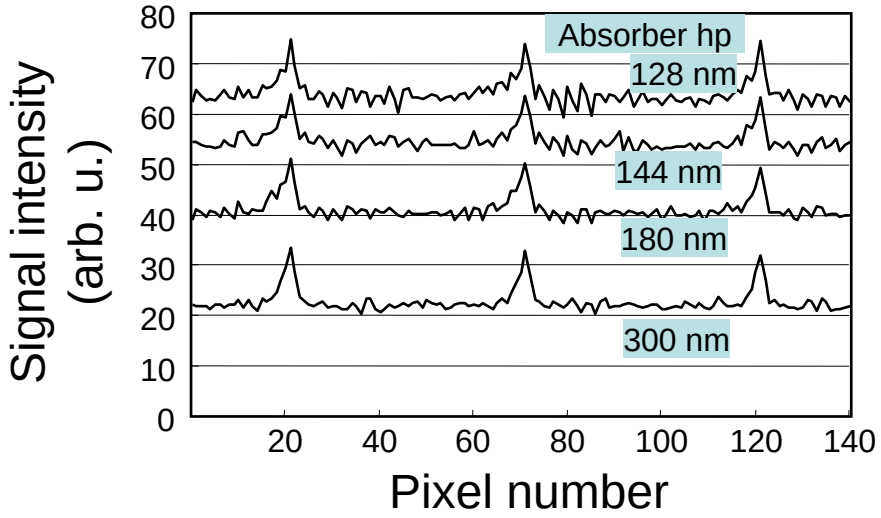
**Small particles were detected only with the Non-actinic system.**



# Phase defect under the absorber L/S




Signal intensity distribution along the spaces

# Summary

1. Actinic dark-field mask blank inspection tool with Time Delay and Integration (TDI) mode was achieved.
2. Threshold method is used to identify phase defects. Sensitivity of detecting small defect such as 1.5 nm in height and 60 nm in width was confirmed, but capture rate must be improved.
3. Inspection results were compared with non-actinic tool. Defects detected only with the actinic system were mostly pit phase defects smaller than 100 nm while small particles were detected only with non-actinic tool.
4. Possibility of detecting phase defects on a mask with absorber patterns was demonstrated.

## Activities planned:

1. Inspection signal noise reduction for fast TDI operation.
2. Collect /compile inspection data of multilayer native defects.

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**( Inspection optics )**

**-T. Shoki, K. Yamashiro, and Y. Usui of HOYA Corporation.**
**( Programmed defect mask blank)**

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