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A Reliable Higher Power ArF Laser with Advanced Functionality for Immersion Lithography

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Gigaphoton Inc.

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- Focus Drilling
  - ✓ Issue of the Exposure Process
  - ✓ Approach for Focus Drilling by Laser Bandwidth Tuning
  - ✓ Requirements for Focus Drilling
  - ✓ Measurement Data
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- ArF (Immersion/Dry) Roadmap
- Summary

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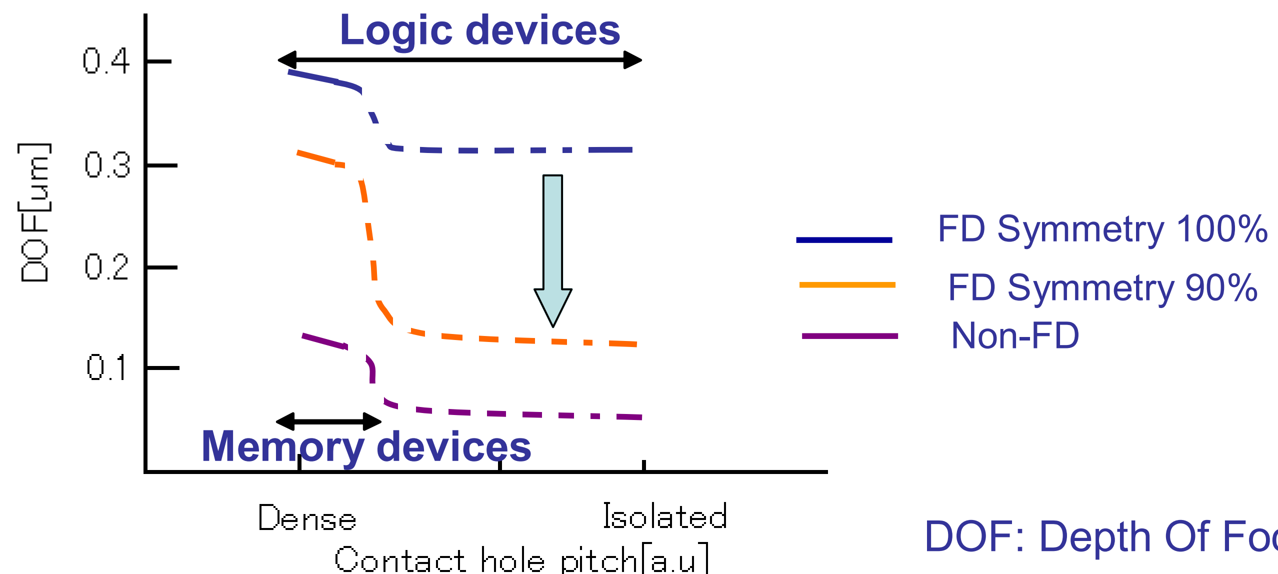
Issue of the Exposure Process

- **Lithographic Issue**
  - ✓ Rapid miniaturization of ULSI patterns resulting in:
  - ✓ Significant DOF erosion in isolated patterns, especially in contact hole layers

- **Solution: GPI's focus drilling by laser bandwidth tuning**
  - ✓ Sufficient focus margin for isolated features as well as dense features
  - ✓ Enabled by its unique technology to maintain spectral symmetry high



DOF: Depth Of Focus

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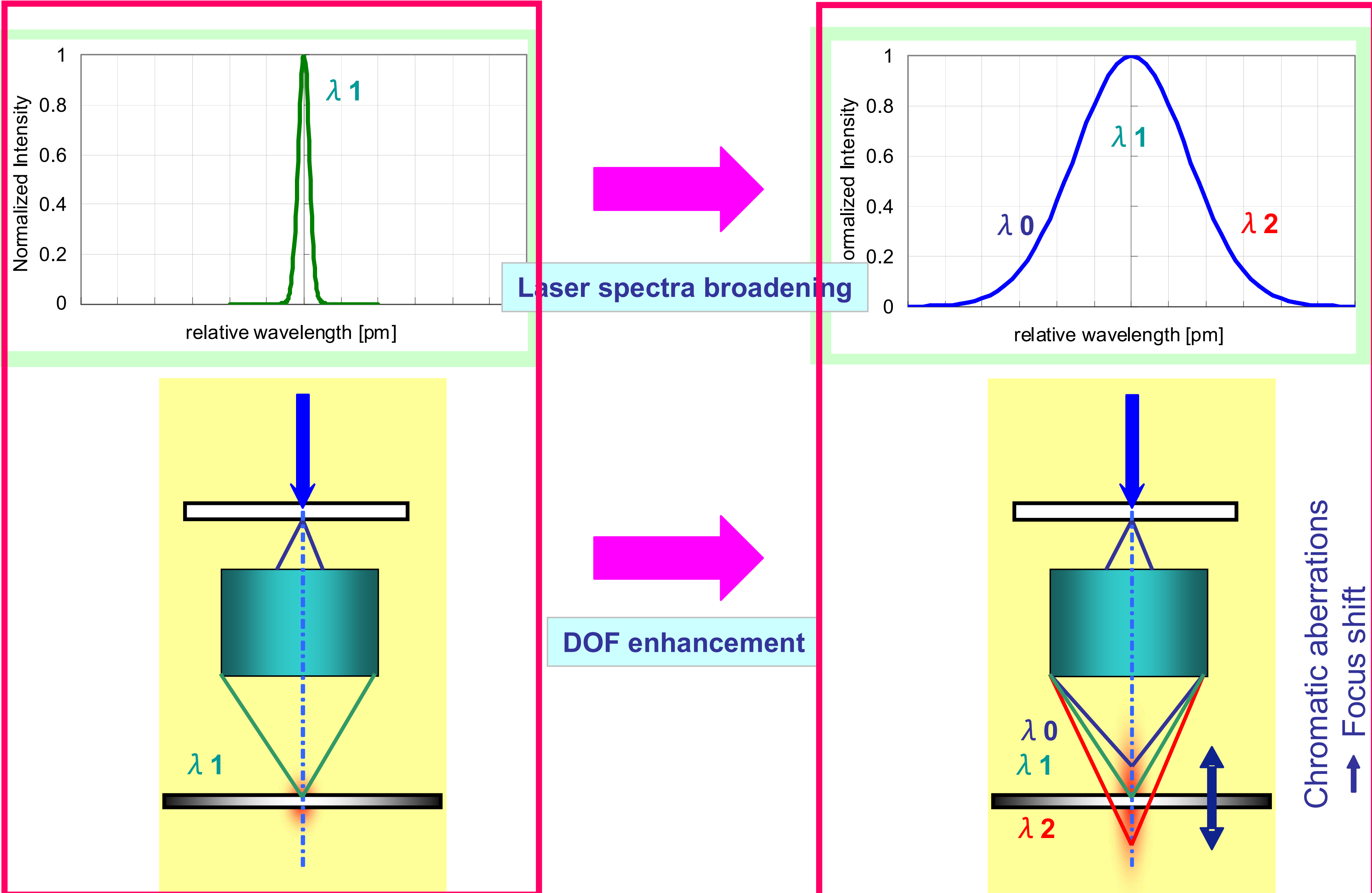
Approach for Focus Drilling by Laser Bandwidth Tuning



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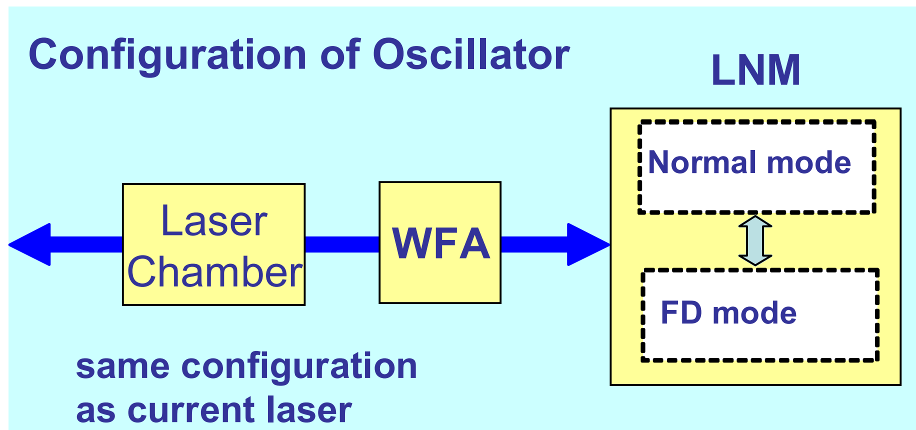
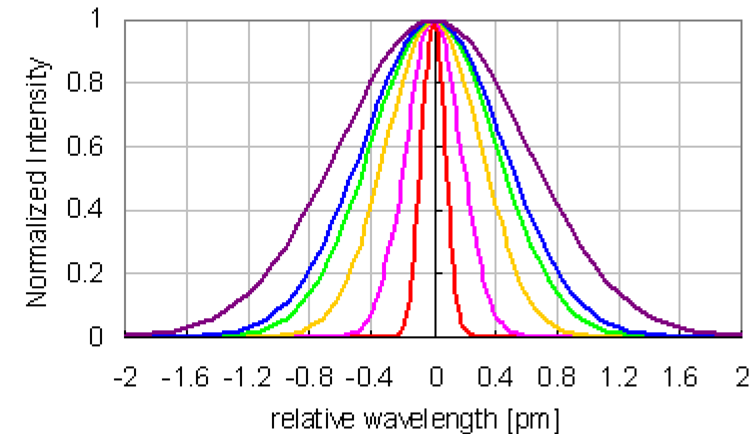
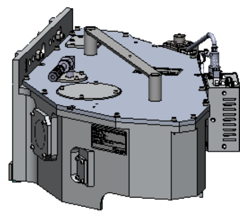
Approach for Focus Drilling by Laser Bandwidth Tuning

➢ New LNM has been developed for focus drilling

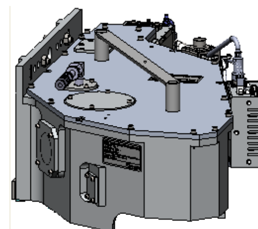
✓ Normal mode is switched to FD (Focus Drilling) mode to broaden the spectral bandwidth.







Current LNM
(Only Normal mode)



New LNM for Normal /FD mode

WFA : Wave Front Adjuster
LNM : Line Narrow Module

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Requirements for Focus Drilling

➢Focus drilling requirements based on simulation

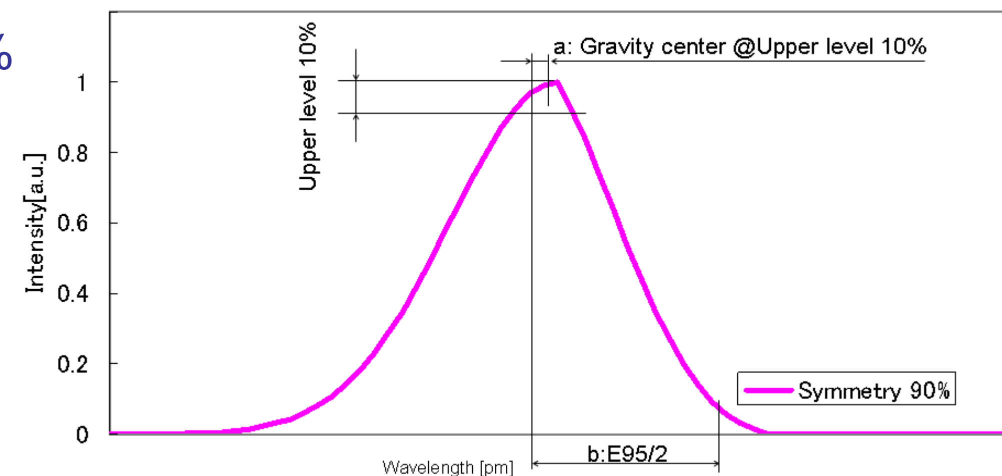
Item	Target value
Spectrum bandwidth(E95)	0.3 - 2.4pm
Symmetry of the spectrum For Isolated pattern @DOF >0.2um	>95%

➢Definition of the symmetry

Symmetry[%] = (1 - | a / b |) x 100

a : Gravity center of Upper level 10%

b : Spectrum width E95/2



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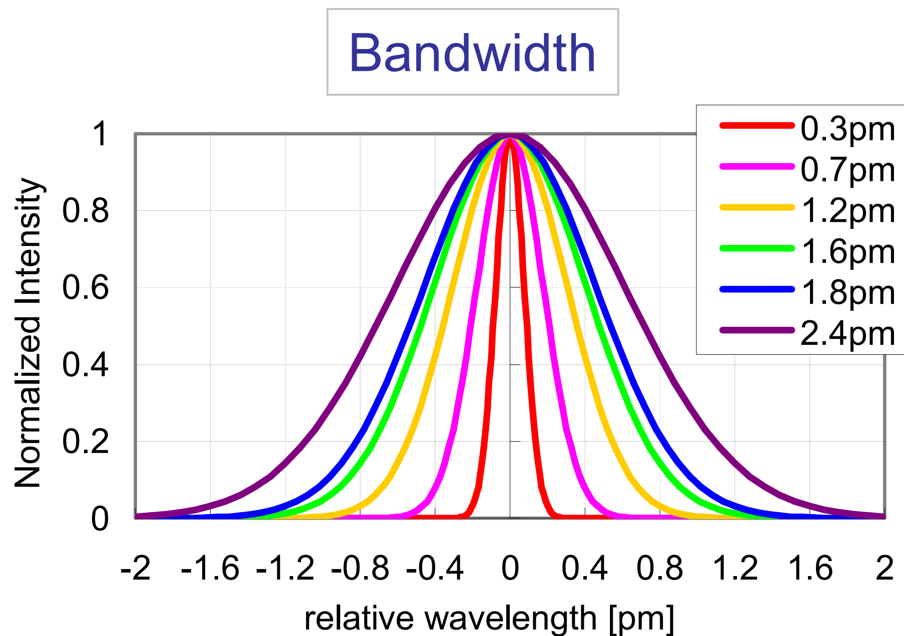
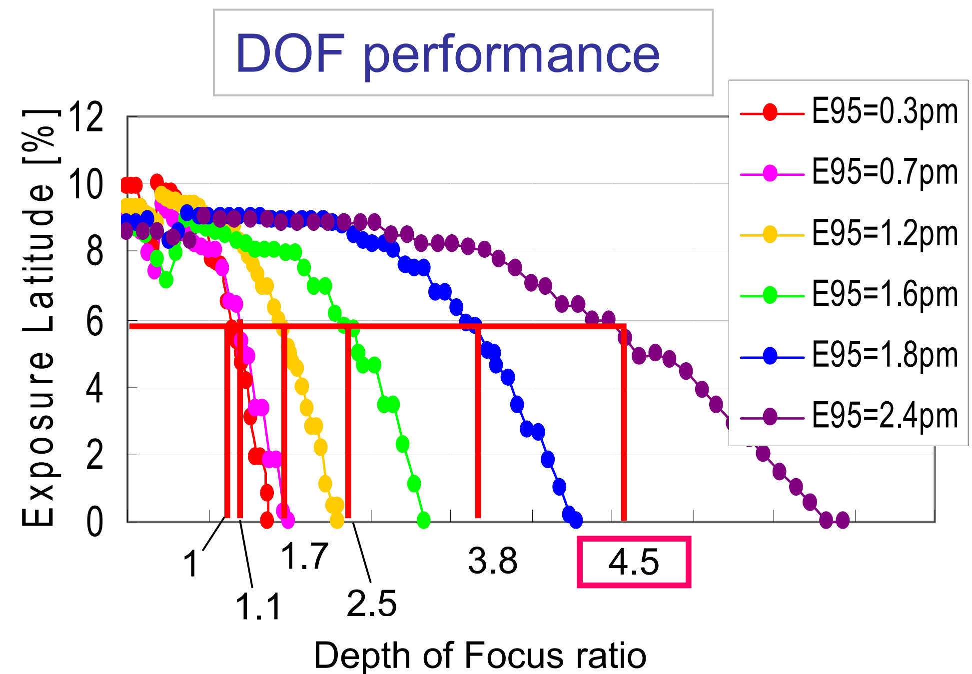
Requirements for Focus Drilling

➢Spectral bandwidth by the simulation

- ✓DOF can be broadened by tuning spectral bandwidth.
- ✓4.5 times larger DOF at E95 = 2.4 pm compared to E95=0.3 pm





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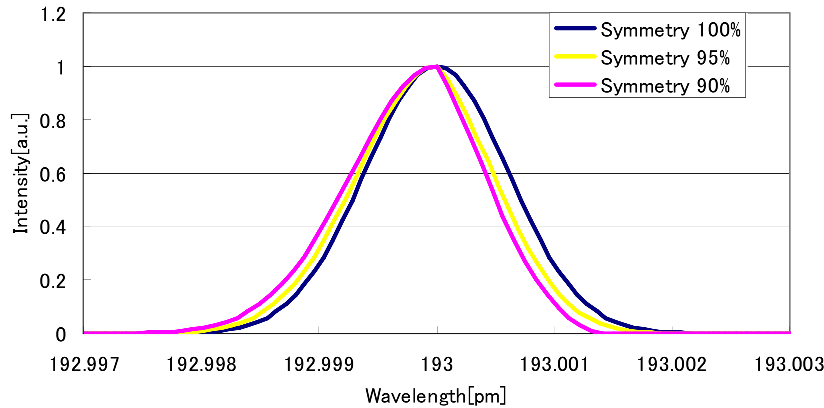
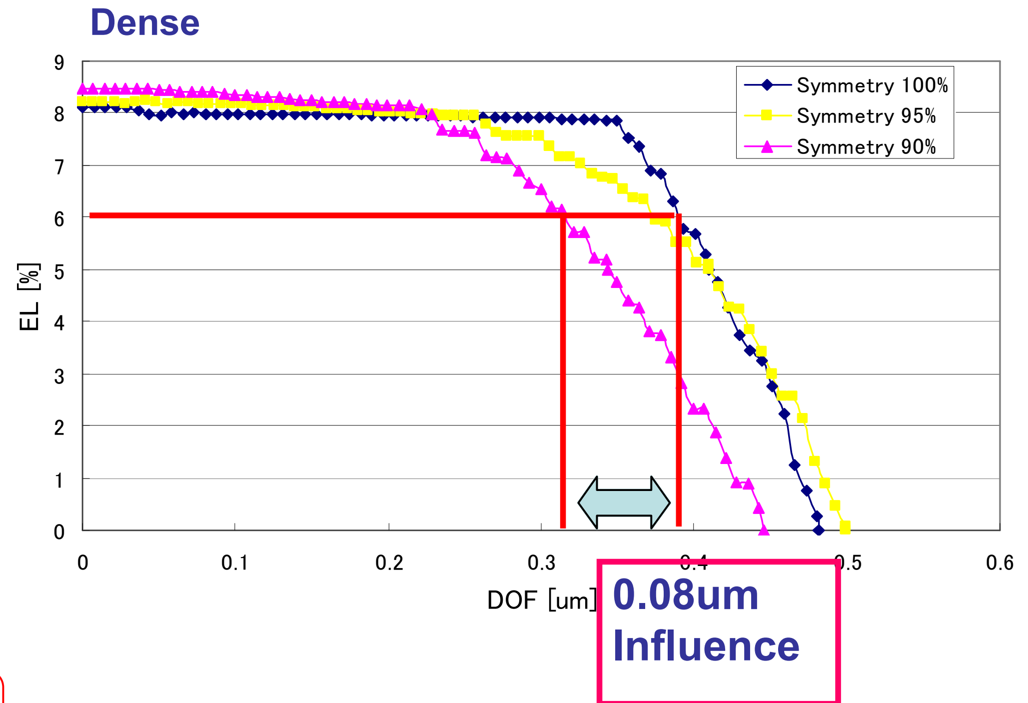
Requirements for Focus Drilling

➢Simulation for the spectral symmetry (Dense features)

Spectrum shape



Dense



Symmetry 100%: DOF 0.39um
Symmetry 95% : DOF 0.38um
Symmetry 90% : DOF 0.31um

Difference : 0.08um @ EL=6%

Conditions:

Illumination shape	Annular
Numerical Aperture	1.2
Spectrum E95	2.4 pm (all symmetry)≒CBW1.7
Dense patterns	Diameter/Pitch = 80 um / 160 um

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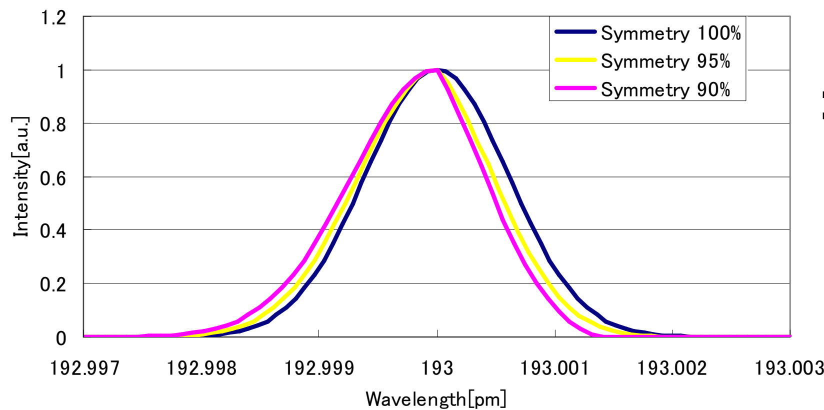
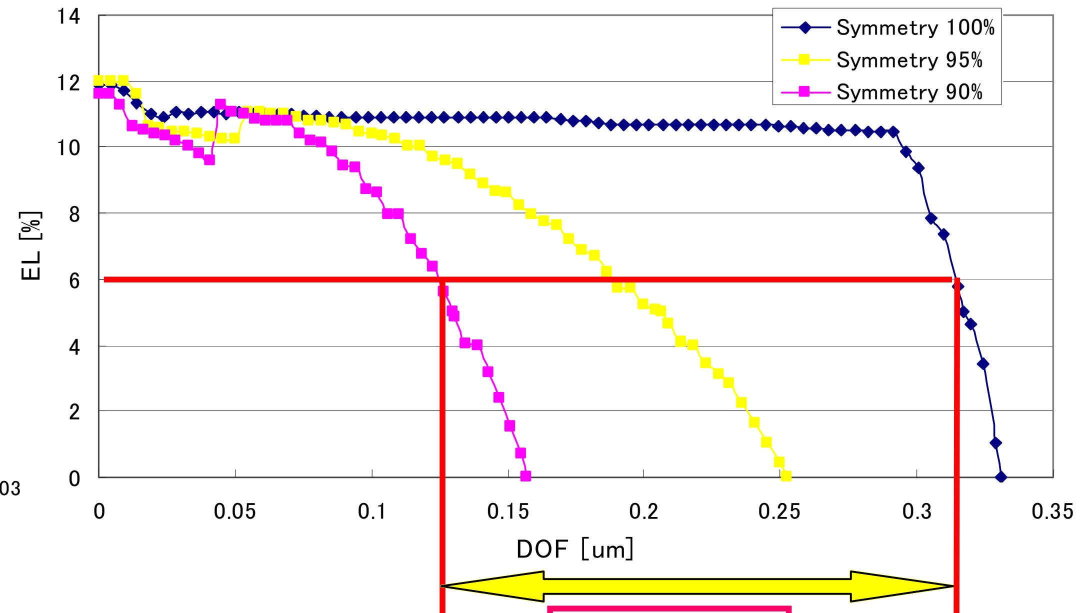
Requirements for Focus Drilling

➢Simulation for the spectral symmetry (Isolated features)

Spectrum shape



Isolated



0.19um Influence

Symmetry 100% : 0.31um
Symmetry 95% : 0.19um
Symmetry 90% : 0.12um

Difference : 0.19 um @ EL=6%

Isolated / Dense =
0.19 / 0.08 um = 2.4

Conditions:

Illumination shape	Annular
Numerical Aperture	1.2
Spectrum E95	2.4 pm (all symmetry)≒CBW1.7
Dense patterns	Diameter/Pitch = 80 um / 720 um

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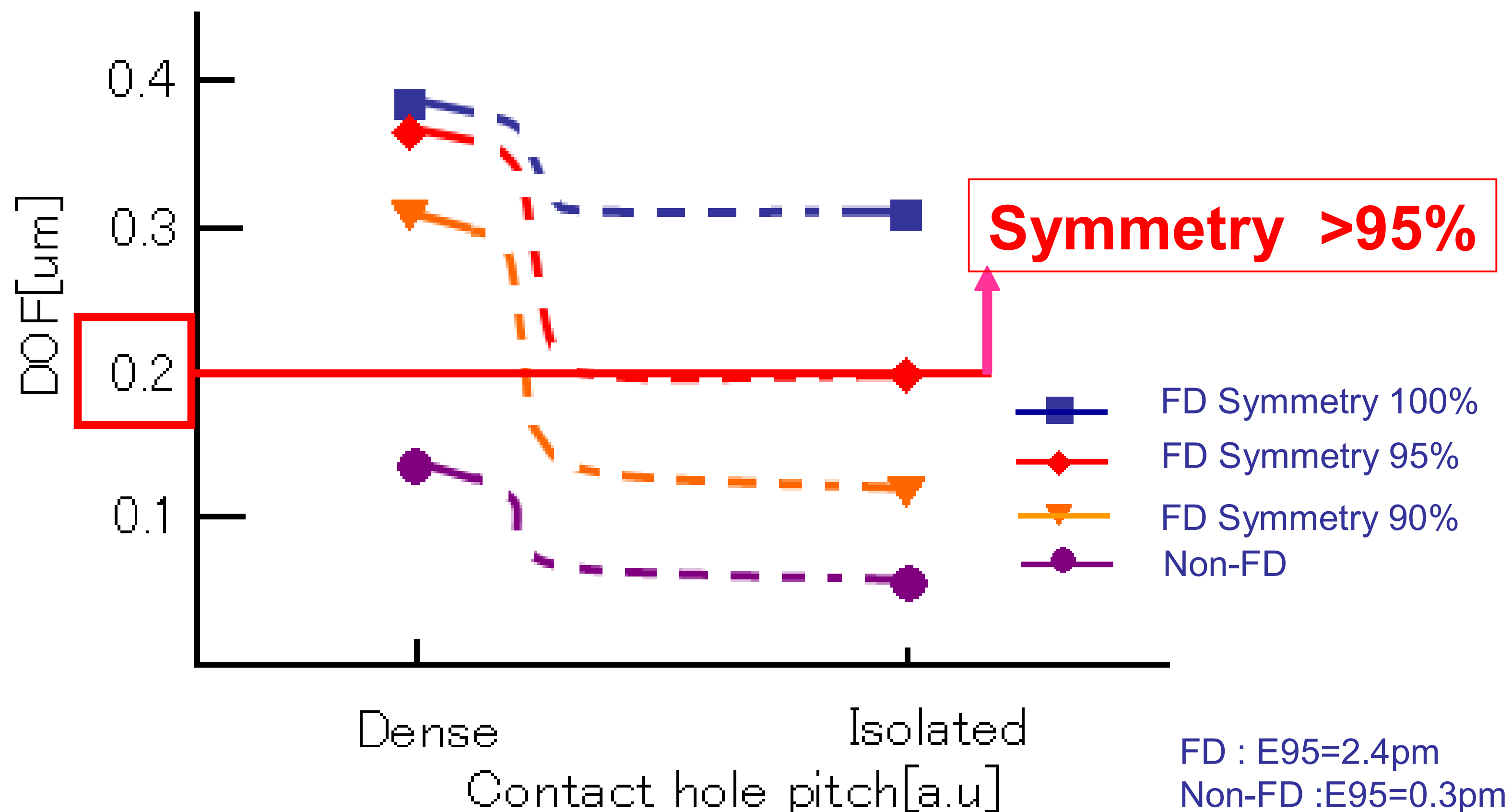
Requirements for Focus Drilling

- **The simulation result of the symmetry**
  - ✓The spectral symmetry impacts DOF.
  - ✓The more symmetric = larger DOF
- **> 0.2 um DOF = >95% symmetry needed for spectrum**



FD : E95=2.4pm
Non-FD :E95=0.3pm

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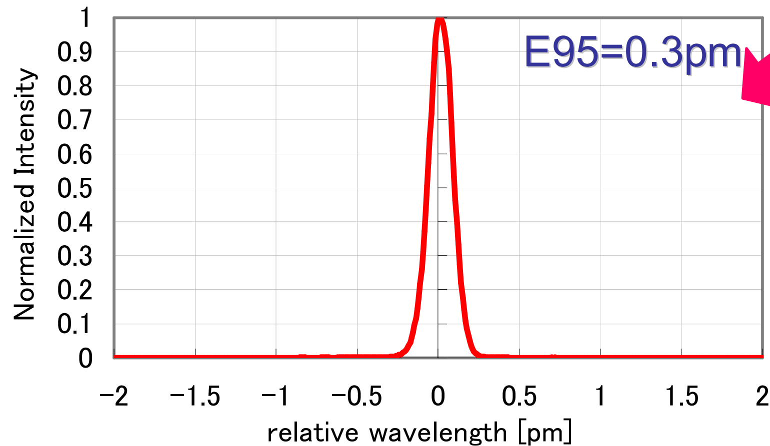
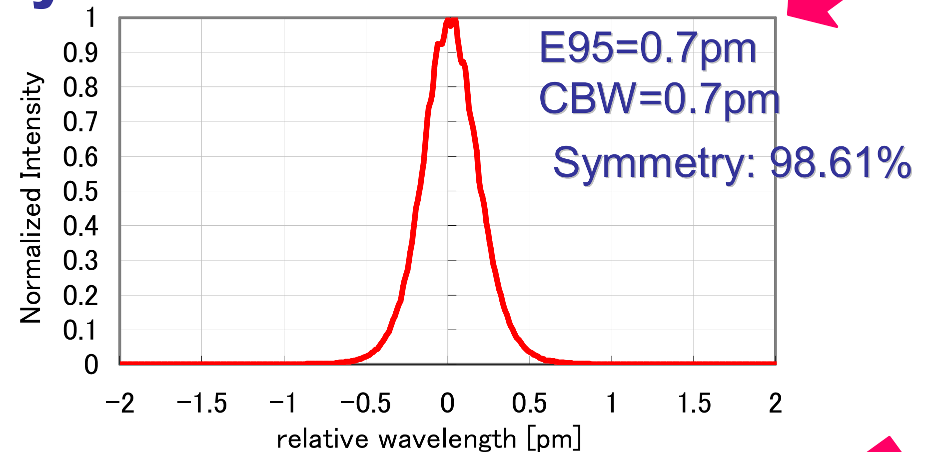
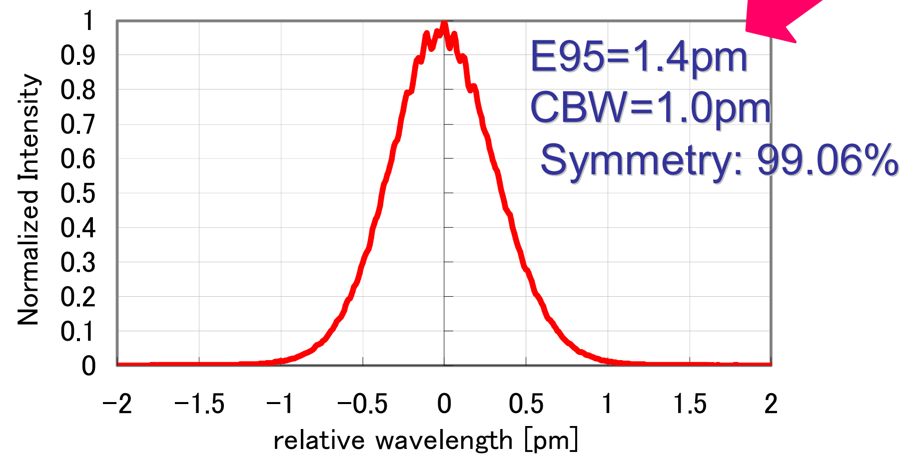
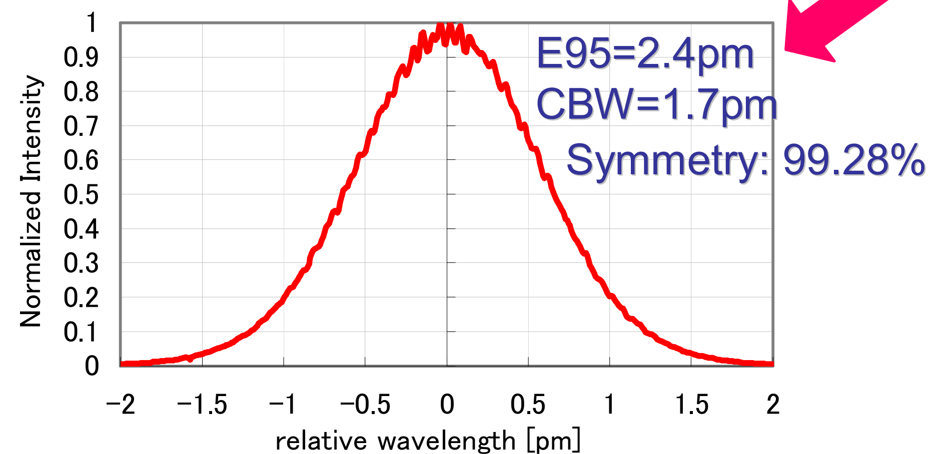
Measurement data : Spectral Bandwidth

- **The bandwidth is broadened by the new LNM**









CBW : Convoluted bandwidth

Ref: Proc. SPIE Optical Microlithography XXIV 7973, 28
"Focus Drilling for Increased Process Latitude in High-NA Immersion Lithography"

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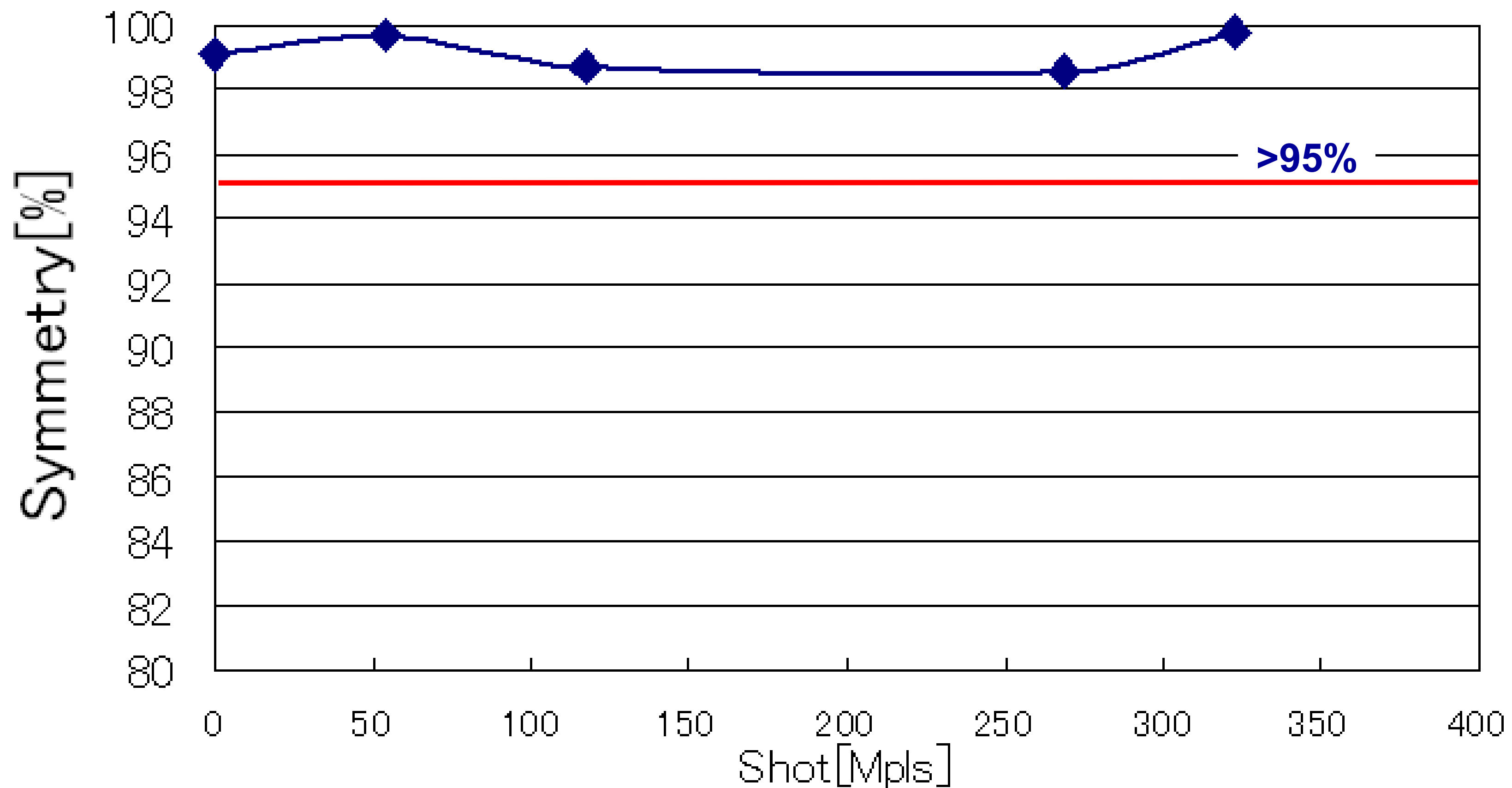
Measurement data : The Spectral Symmetry –Middle Term

The spectral symmetry is stable for 330 million pulses (3 days)

- ✓ Symmetry : Worst : 98.5%
  Average : 99.2% stability :+/-0.64%



Target E95 :2.4pm =CBW:1.7 pm

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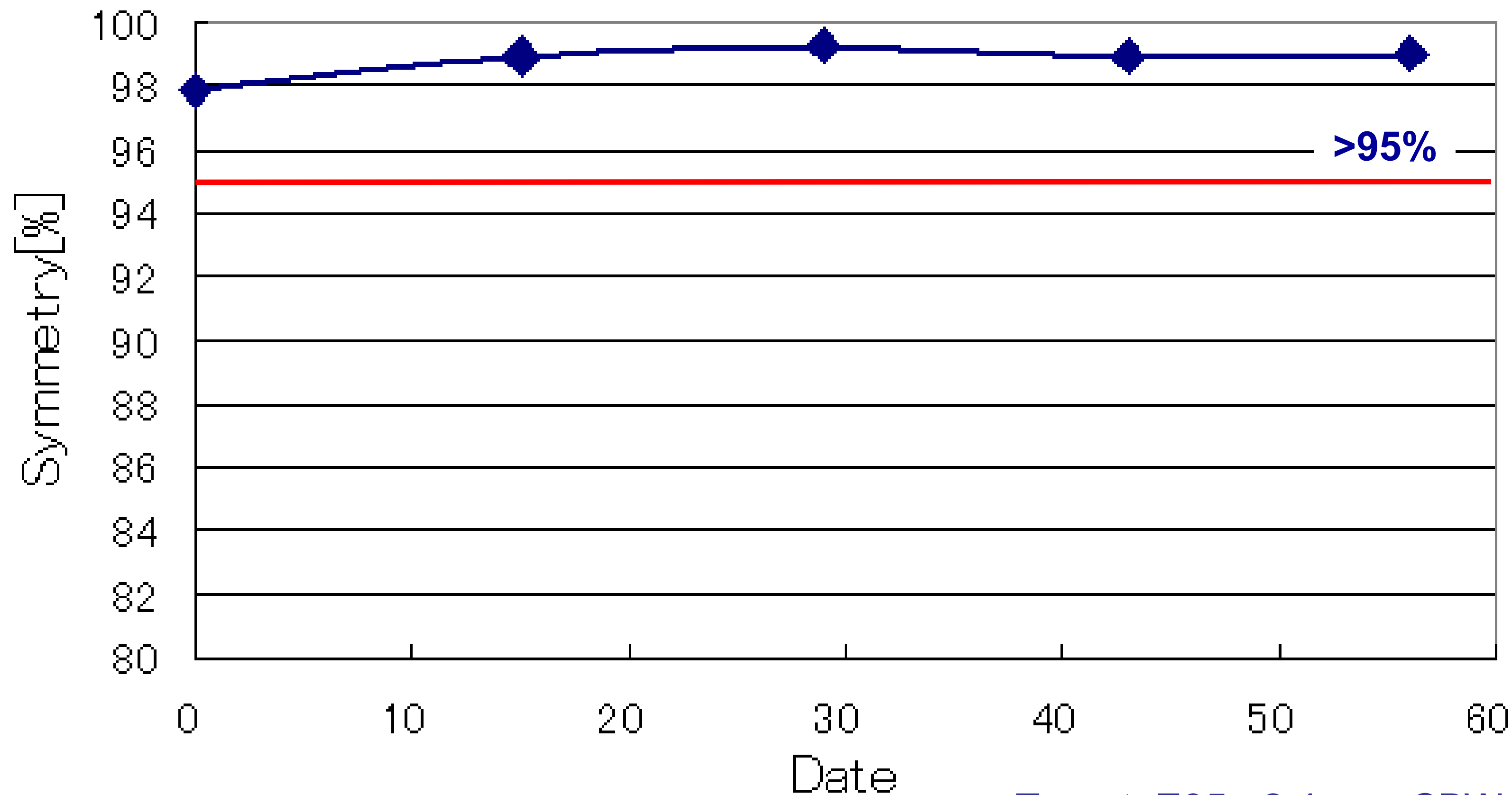
Measurement data : The Spectral Symmetry - Long Term

- **The spectral symmetry is stable over 50 days.**
  - ✓ **Symmetry Worst : 97.8%**
    Average : 98.7% stability:+/-0.93%



Target E95 :2.4pm =CBW:1.7 pm

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Measurement data : Spectral Bandwidth / Symmetry

➢Summary of the measurement result

Item	Target value	Result	Judge
Spectrum bandwidth(E95)	0.3 to 2.4pm	0.3 to 2.4pm	OK
Symmetry of the spectrum For Isolated pattern	>95%	97.8 to 99.7%	OK

➢ The actual performances meet the design target

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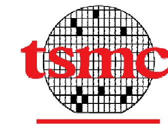

Field data

- **Report of the actual exposure result in the field**

✓DOF changes when change a spectrum (CBW)

✓Confirmed proximity matching

- ✓Process window
- ✓Critical Dimension (CD)

EFESE_HR is ASML's product name (GPI Focus drilling function by bandwidth tuning)
EFESE_Rx is ASML's product name (ASML Focus drilling function by stage tilt)

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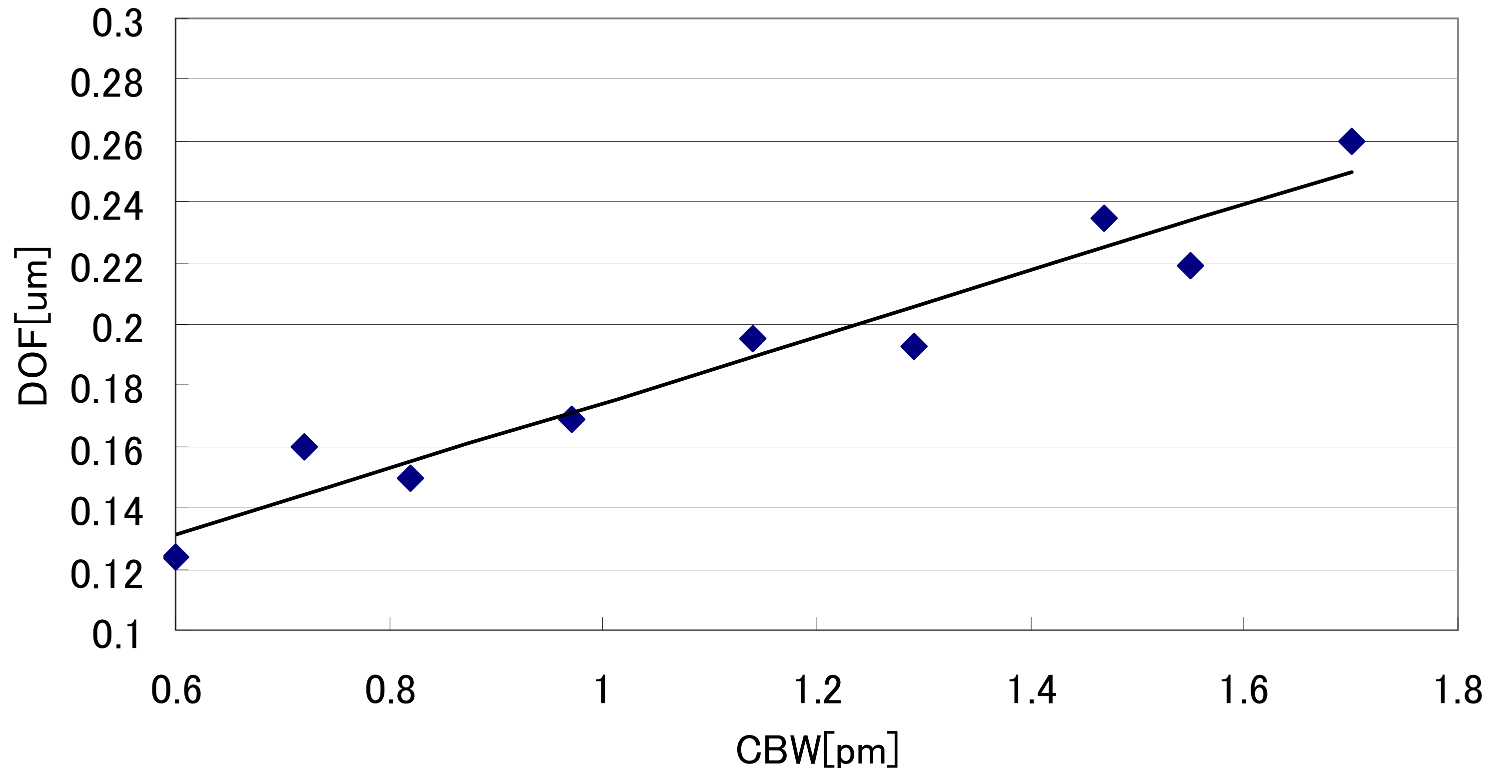
Field data : Actual exposure result Expand DOF



- The analysis of Focus-Exposure-Matrix (FEM) wafers exposed at different CBW values has been performed for the semi-iso with
  - ・target CD of 85 nm,
  - ・pitch=365 nm
  - ・annular illumination settings with NA=1.2

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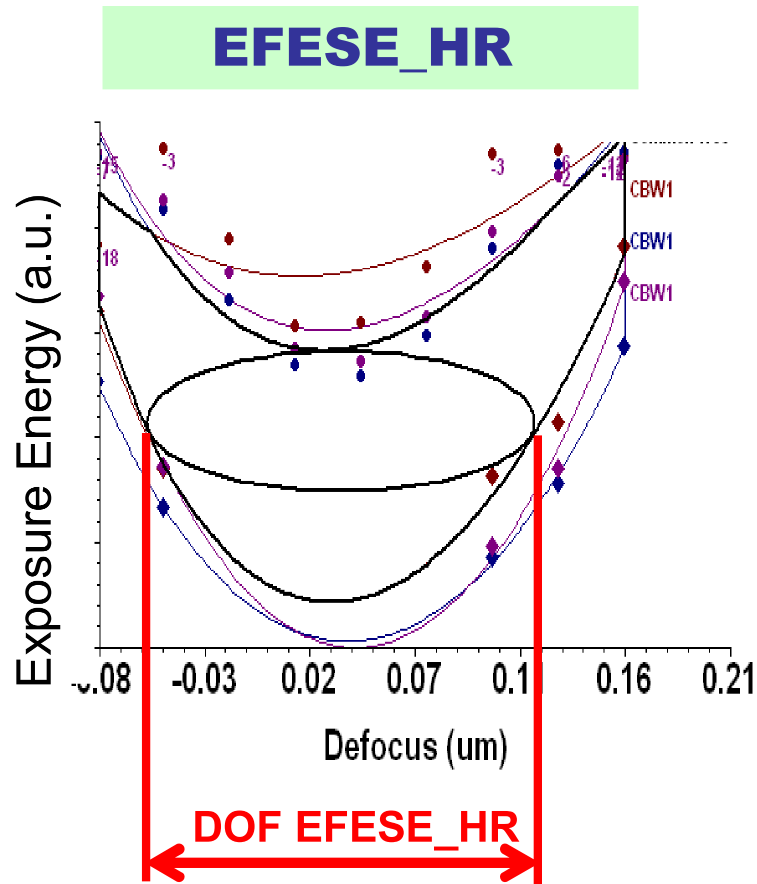
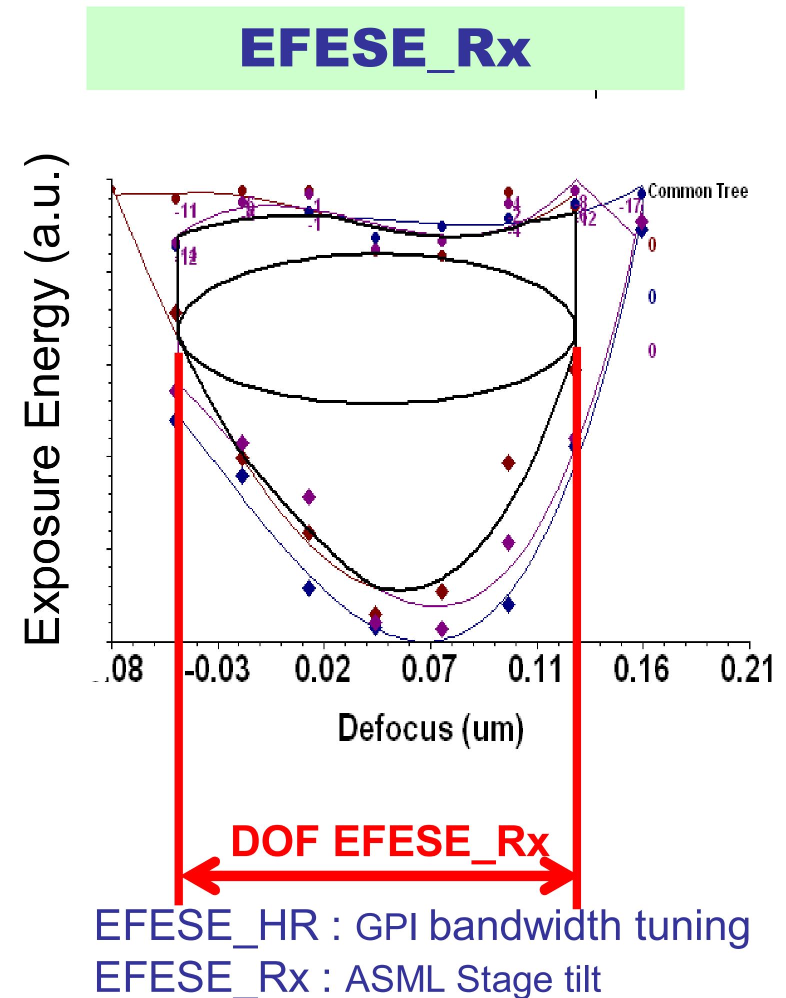
Field data: Process window

- DOF by EFESE_HR is substantially same as that by EFESE_Rx.





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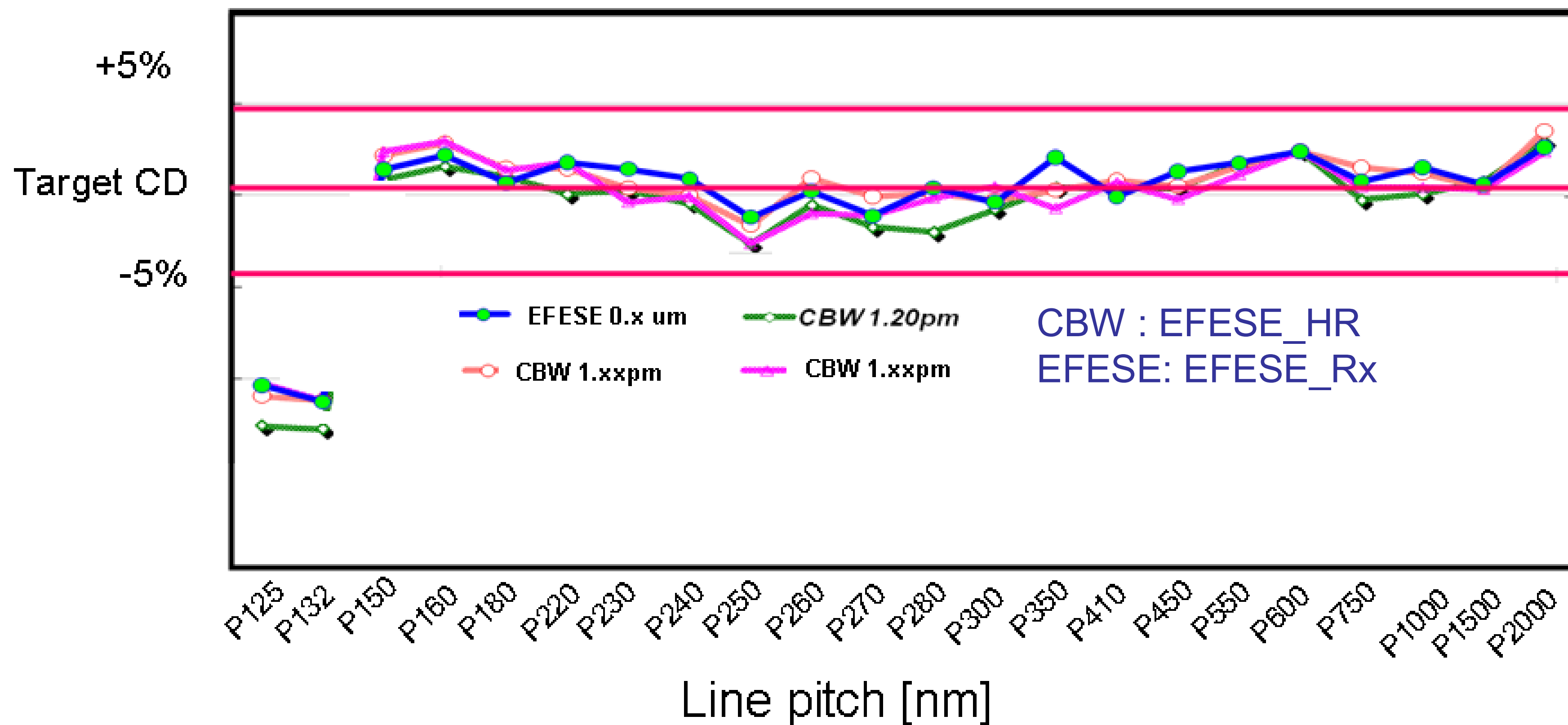
Field data: Critical Dimension(CD)

➢ **Line pitches by EFESE_HR are substantially the same as those by EFESE_Rx .**



EFESE_HR : GPI bandwidth tuning
EFESE_Rx : ASML Stage tilt

CD : Process less than 80 nm

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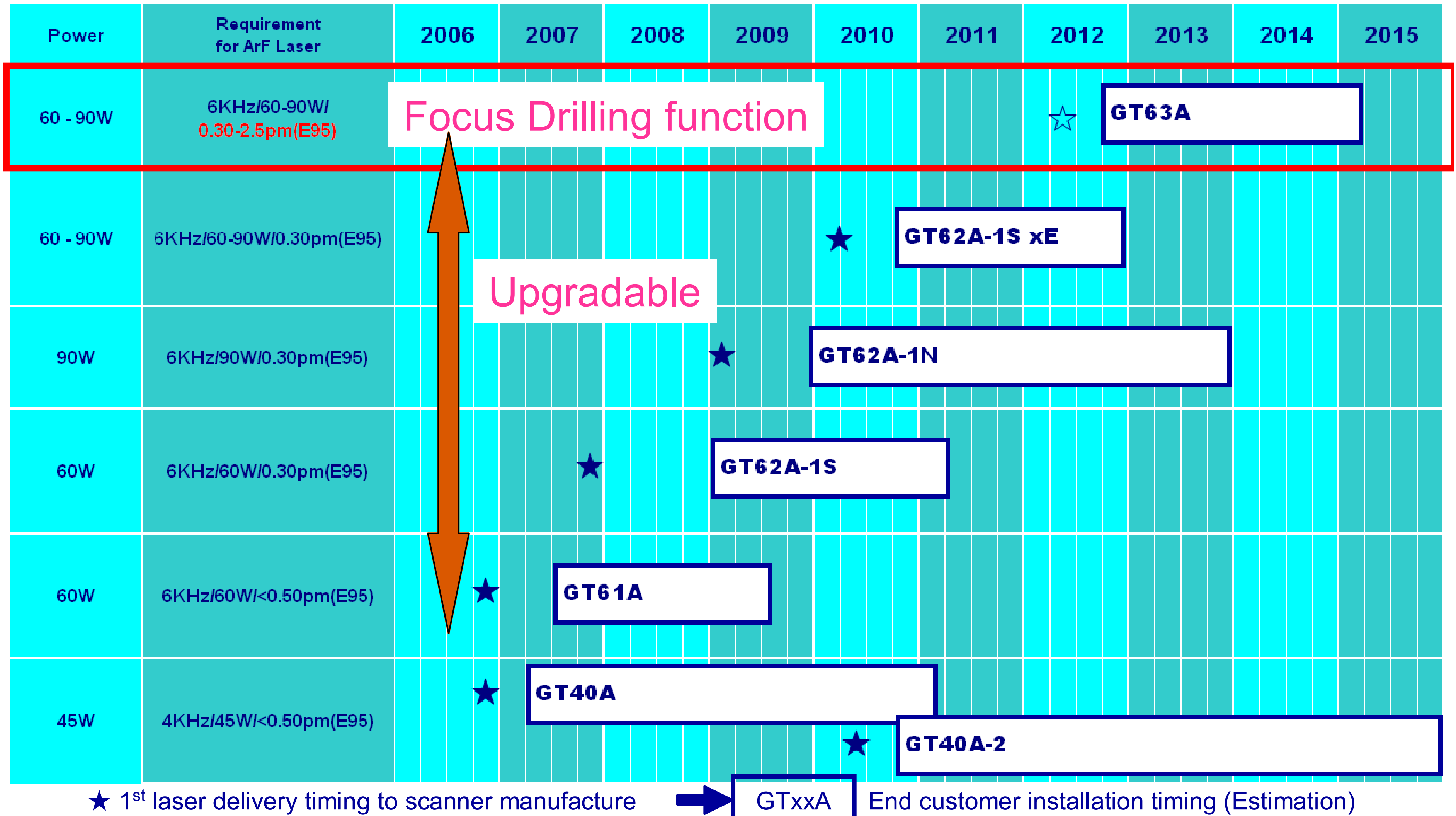
ArF (Immersion/Dry) Roadmap



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New product

ArF (Immersion/Dry) Roadmap

GPI will release new ArF laser GT63A

- **GT63A**
  - ✓ **Based on GT62A-1SxE**
- **Features**
  - ✓ **New functionality and benefit**
    - Focus drilling LNM* : Enable FD
    - Gas refill free : Shorter downtime
    - 60B pulse New Laser chamber : Lower cost & Shorter downtime
    - New Monitoring : Higher reliability (REDeeM piece, FDC)
- **First shipment of GT63A**
  - ✓ **Q2 2012 to litho tool manufacturer (TBD)**
- **New development HW and SW are applicable to install base lasers**
  - ✓ **GT61A / GT62A-1S / GT62A-1SxE**

* LNM hardware is not standard.
It is commercial option

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Summary

- **Focus drilling**
  - ✓ DOF enhancement by laser spectrum broadening
    - ✓ Symmetry is the key for isolated features
  - ✓ GPI's new technology offers DOF enhancement with very high symmetric spectrum, with stability verified for middle and long term
  - ✓ The solution has been verified to be equivalent to stage tilting solution(EFESE_Rx) under chip making environment

- **ArF (Immersion/Dry) roadmap**
  - ✓ Focus Drilling function is commercial option for GT63A.
  - ✓ Applicable for existing product lines down to GT61A

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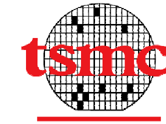
R.C.Peng, Tony Wu, Edward Huang



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