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Ultra line narrowed injection lock laser light source for hyper NA ArF immersion lithography tool

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Outline

1. Introduction

- laser spectrum spec
- CD error sensitivity for E95
- E95 adjustability

2. Narrower spectrum

for Hyper NA lithography

- High resolution Line narrowing module (LNM)
- E95 fluctuation caused by acoustic wave

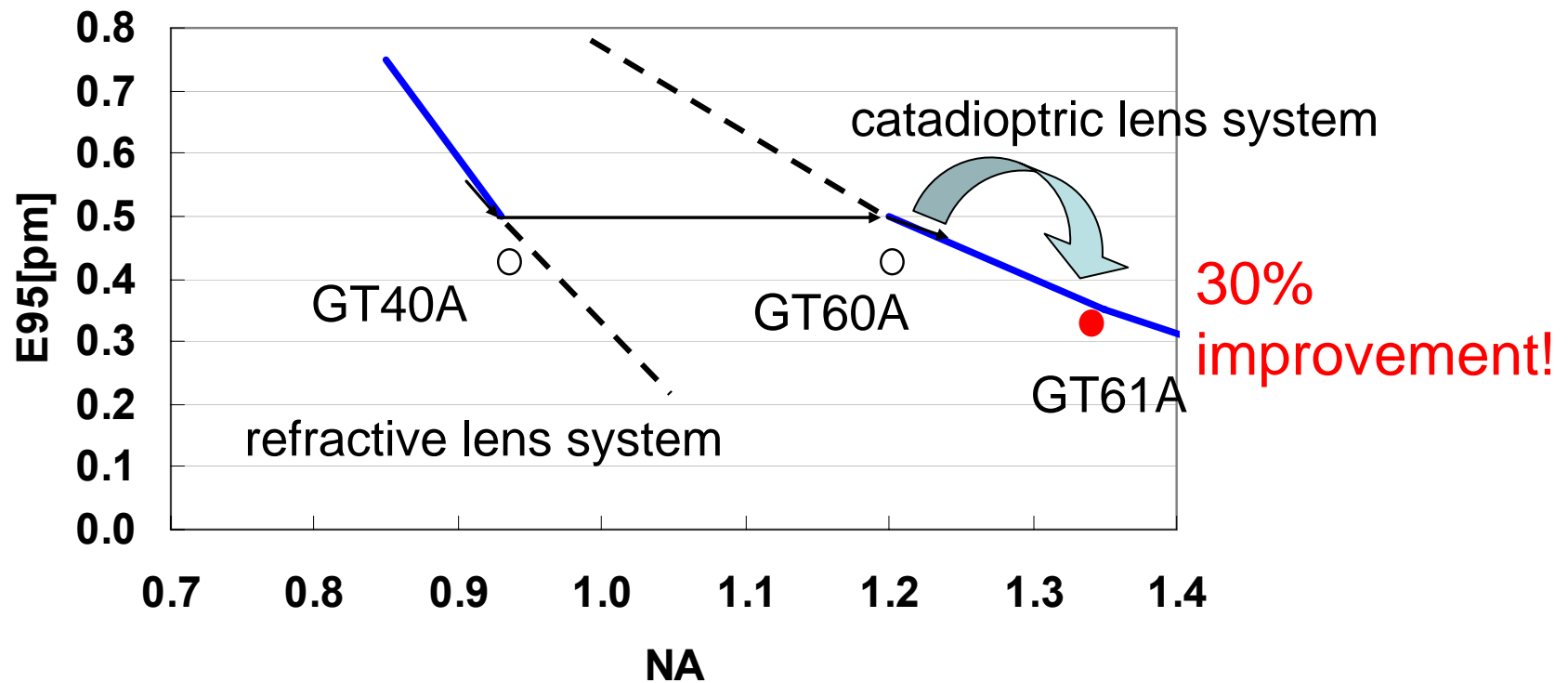
3. Stable spectrum for critical process

- Improved thermal design of LNM
- BCM

4. Conclusion

1. Introduction

1.1 E95 spec for hyper NA immersion lithography

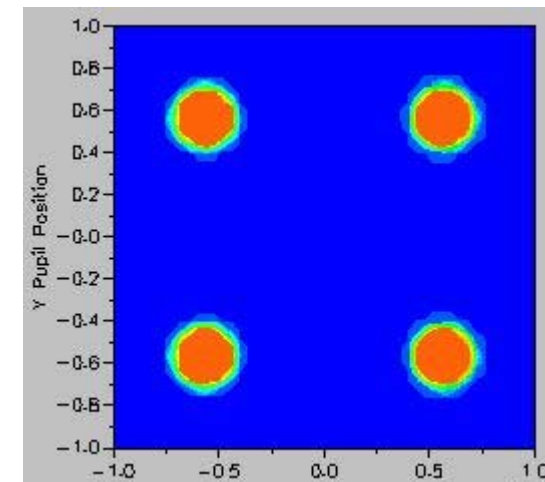
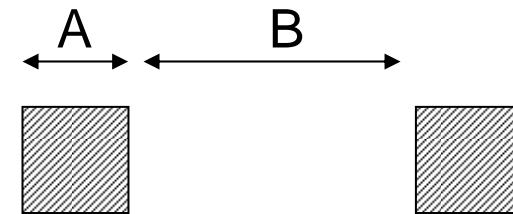


- E95 < 0.35pm required for hyper NA lithography

1.2 CD error sensitivity for E95 (1)

➤ Simulation conditions

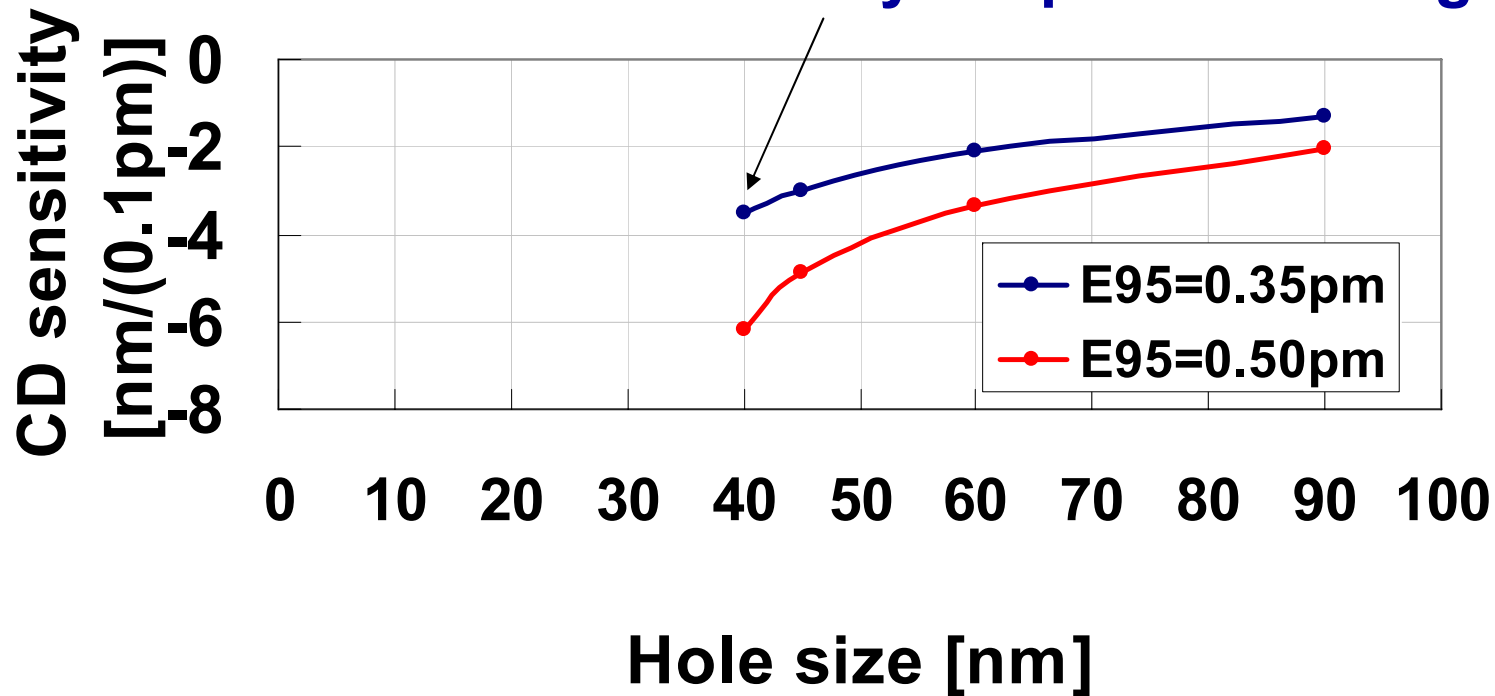
- ✓ 1D Binary – Contact hole
 - A = 40 ... 90 nm
 - B = 10 * A
- ✓ Illumination: quadrupole
sigma 0.8/0.15
- ✓ NA: 1.3 immersion
- ✓ Wavelength: 193nm
- ✓ E95: 0.35pm & 0.50pm
- ✓ Resist thickness: 165nm
- ✓ Simulator: prolith v9.3



1.2 CD error sensitivity for E95 (2)

Simulation results

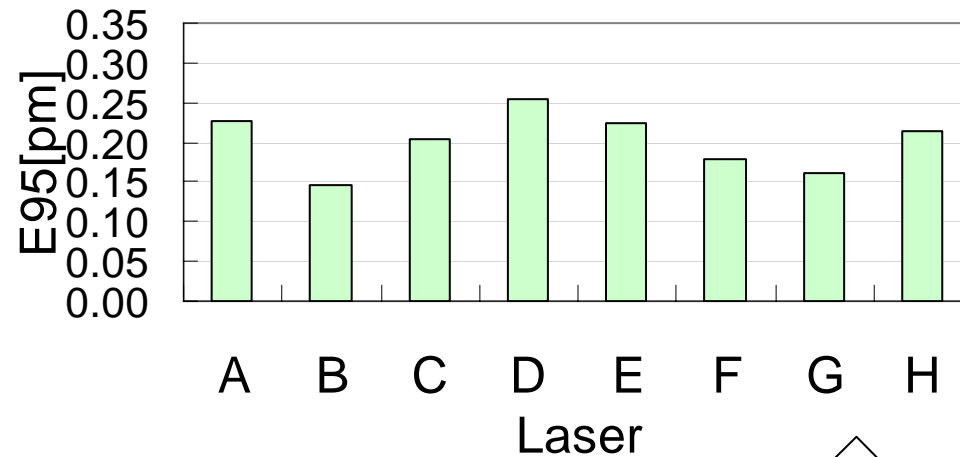
>3nm CD change is induced
by **0.1 pm** E95 change



- Critical process need stable spectrum
- $dE95 < 0.1\text{pm}$ design target
introduce **Bandwidth Control Module (BCM)**

1.3 E95 adjustability

Before adjustment

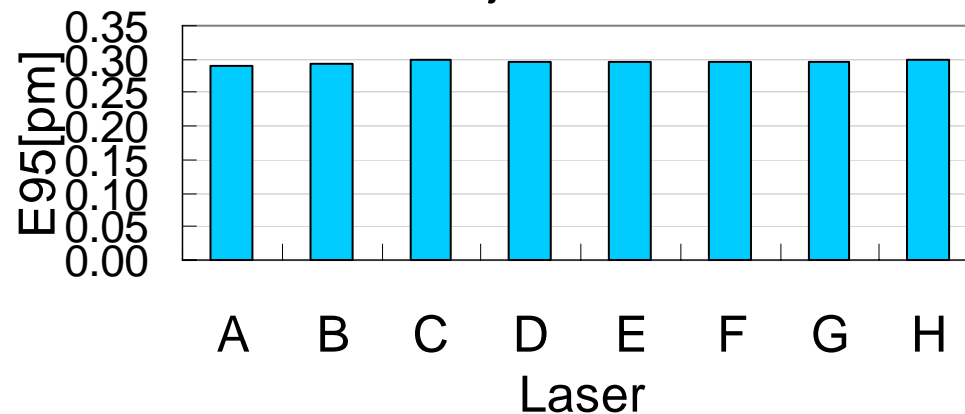


Tool to tool differences
at shipping & after
replacement of modules

Conventional data
 $dE95 < 0.15\text{pm}$

➤ Need E95 adjustments
for the exact replication of the
process

After adjustment



2. Narrower spectrum for Hyper NA lithography

✓ E95 < 0.35pm

- High resolution Line narrowing module (LNM)
- E95 fluctuation caused by acoustic wave

3. Stable spectrum for critical process

✓ dE95 < 0.1pm

- Improved thermal stabilization design of LNM
- BCM
 - No tool to tool spectrum differences for replication of the process
 - E95 stabilization by feedback system

2. Narrower spectrum for Hyper NA lithography

✓ E95 < 0.35pm

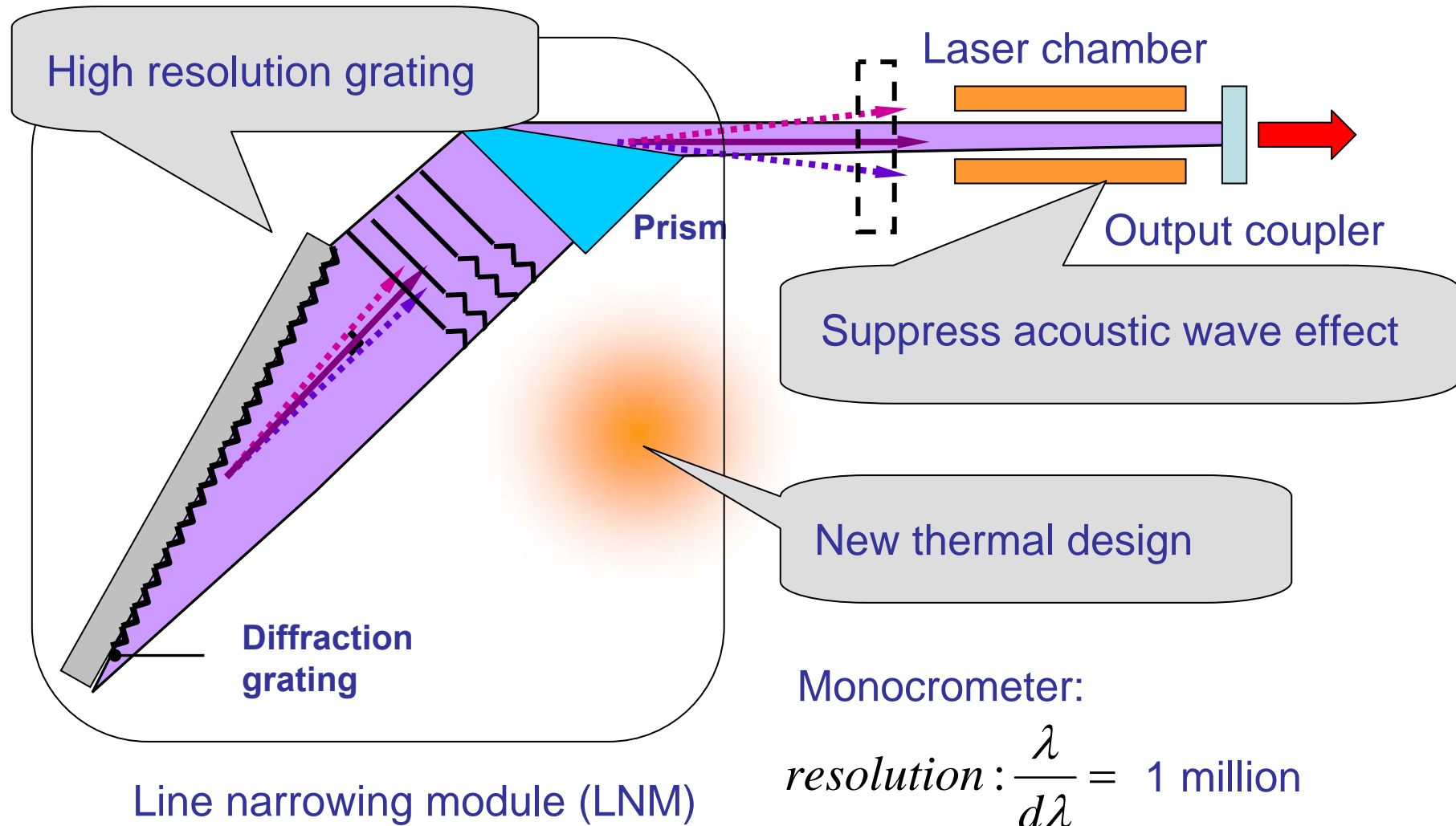
- High resolution Line narrowing module (LNM)
- E95 fluctuation caused by acoustic wave

3. Stable spectrum for critical process

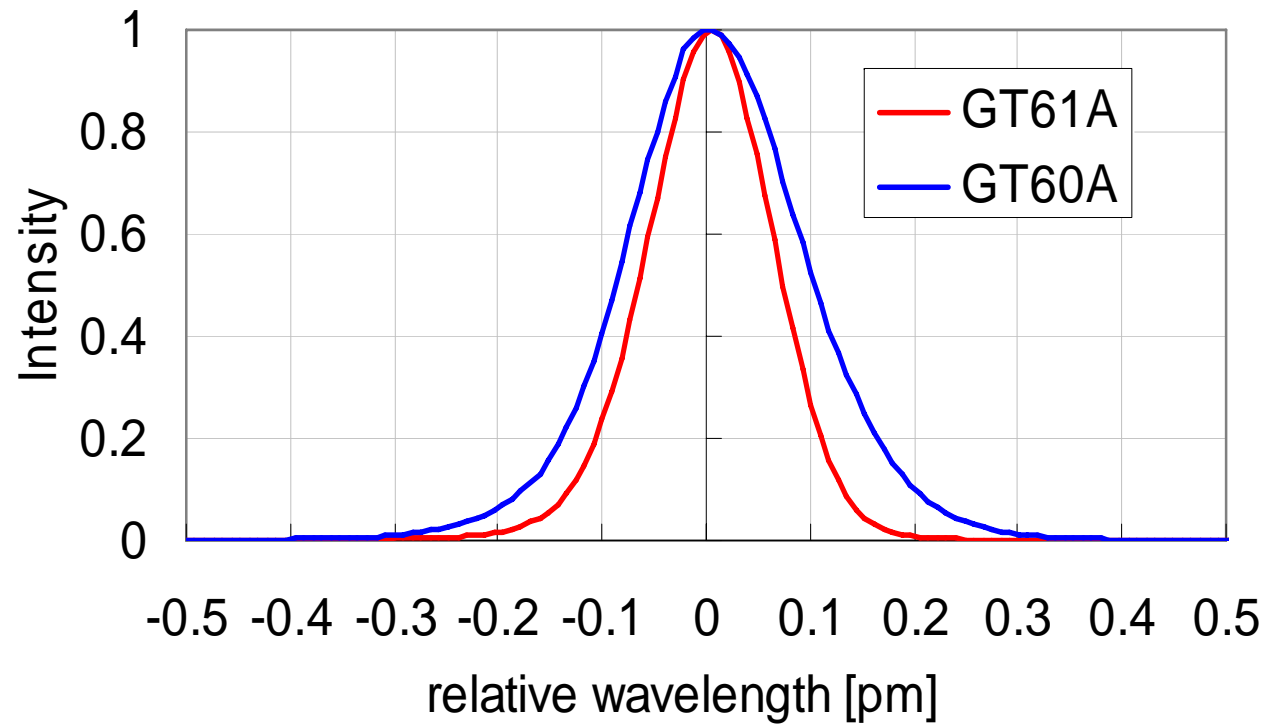
✓ dE95 < 0.1pm

- Improved thermal stabilization design of LNM
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 - E95 stabilization by feedback system

2-1 High resolution line narrowing module



Typical spectrum profile of new LNM



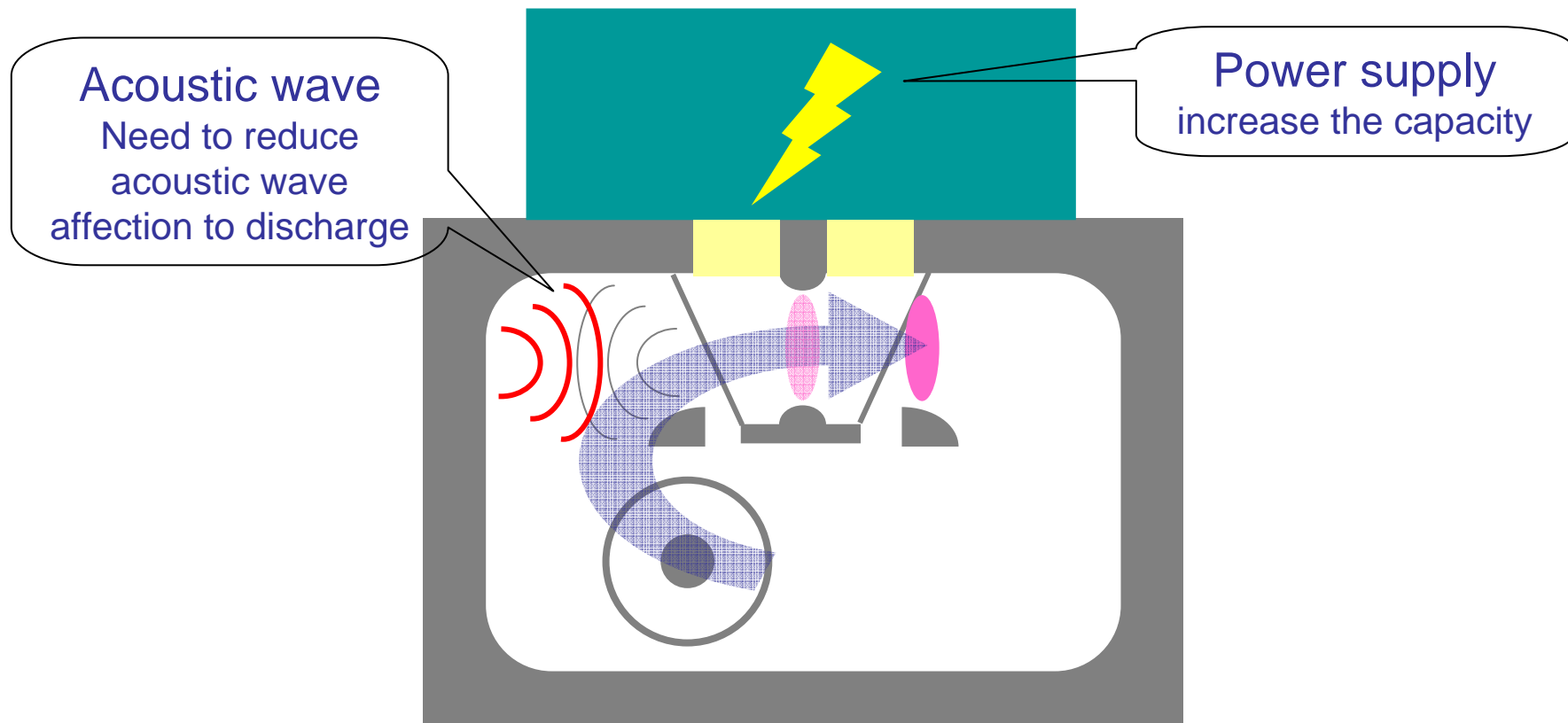
Modified Lorentzian n=3

$$f(\lambda) = \frac{c^n}{c^n + (2\lambda)^n}$$

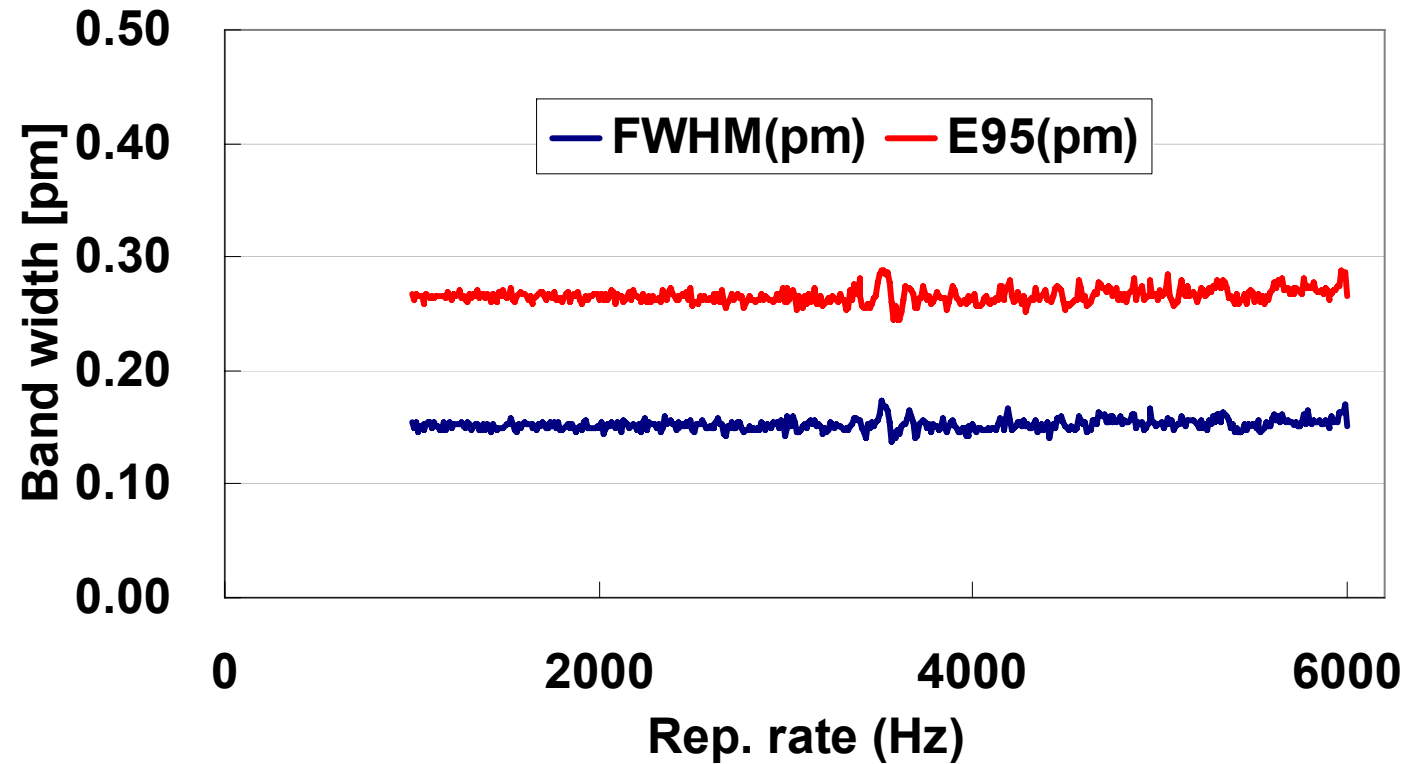
	E95
GT60A	0.35pm
GT61A	0.25pm

2-2 E95 fluctuation caused by acoustic wave

- Suppress the acoustic wave effect in the chamber



Repetition rate dependency of E95



No remarkable peak for all frequency

2. Narrower spectrum for Hyper NA lithography

✓ E95 < 0.35pm

- High resolution Line narrowing module (LNM)
- E95 fluctuation caused by acoustic wave

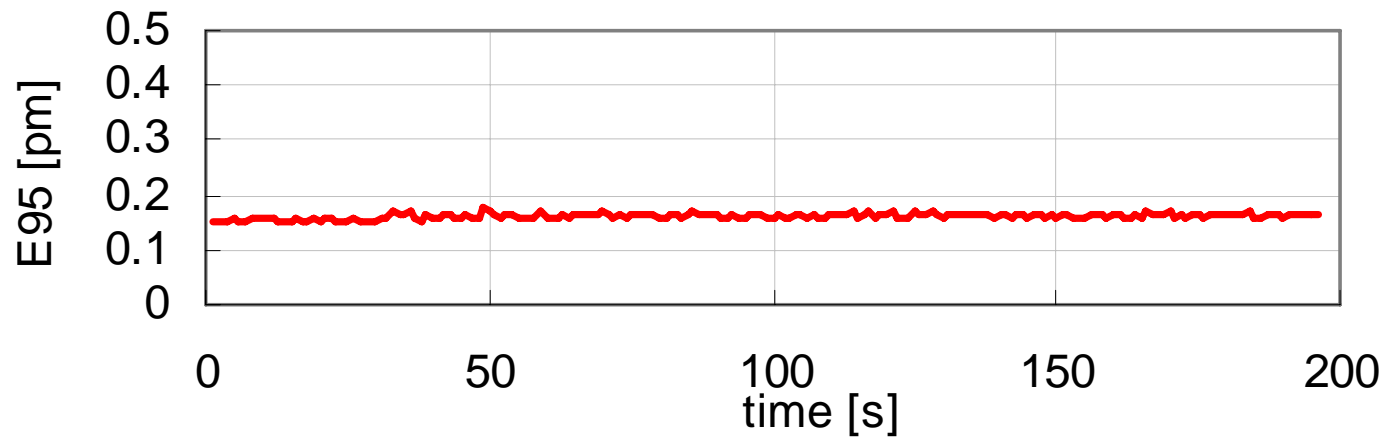
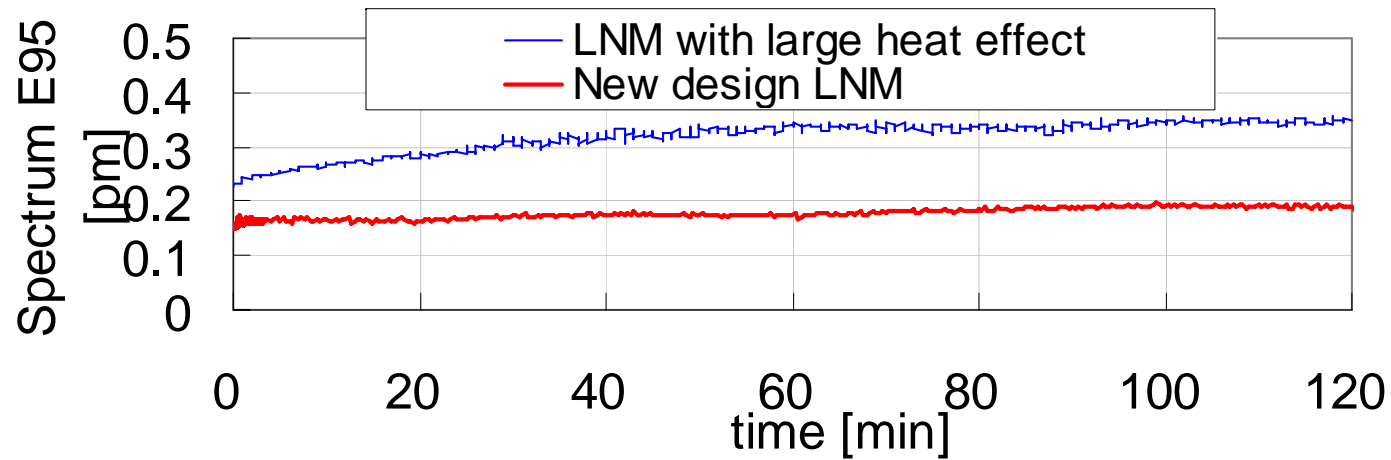
3. Stable spectrum for critical process

✓ dE95 < 0.1pm

- Improved thermal design of LNM
- BCM
 - No tool to tool spectrum differences for replication of the process
 - E95 stabilization by feedback system

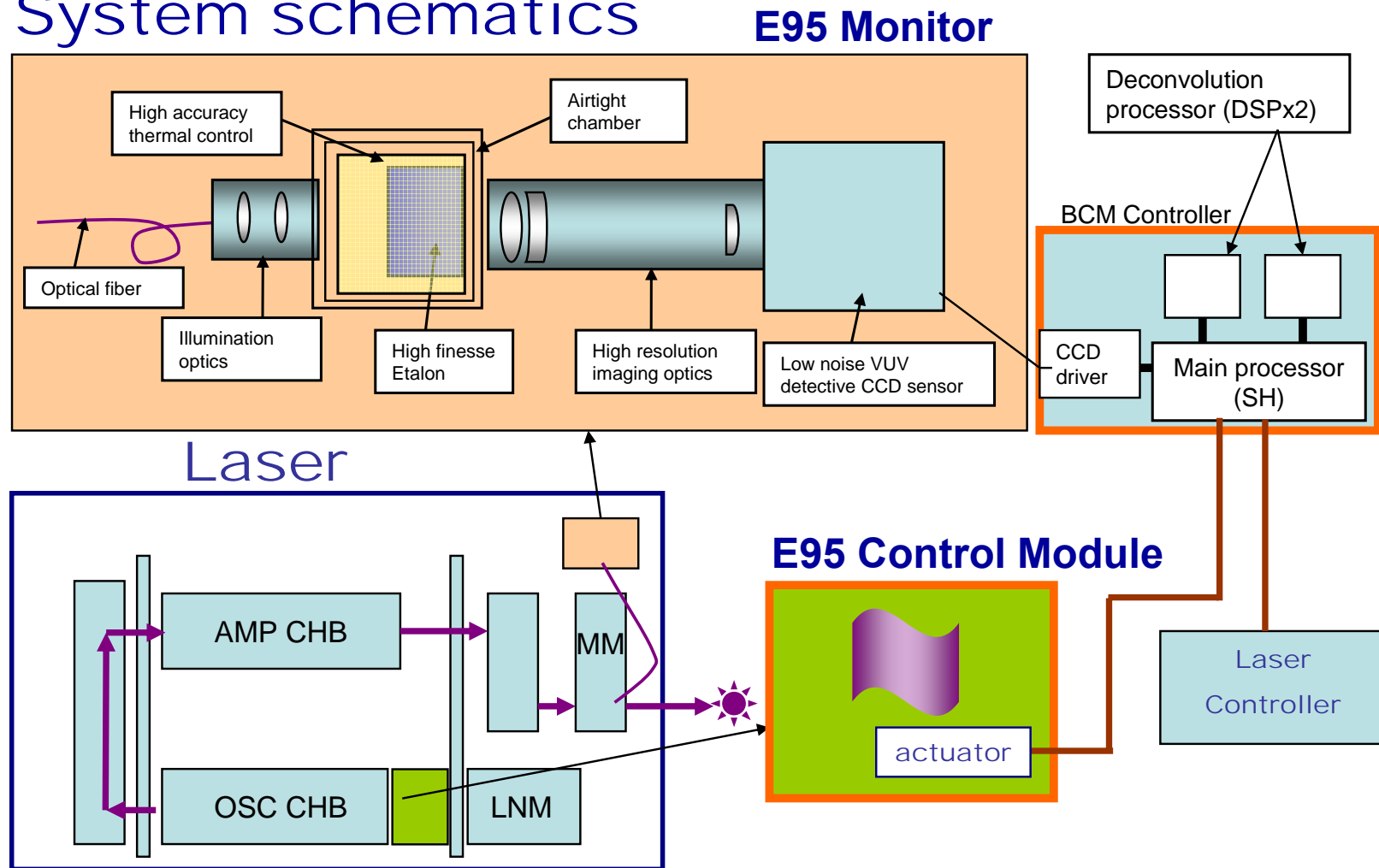
1) New thermal design of LNM

➤ Improved thermal stabilization design

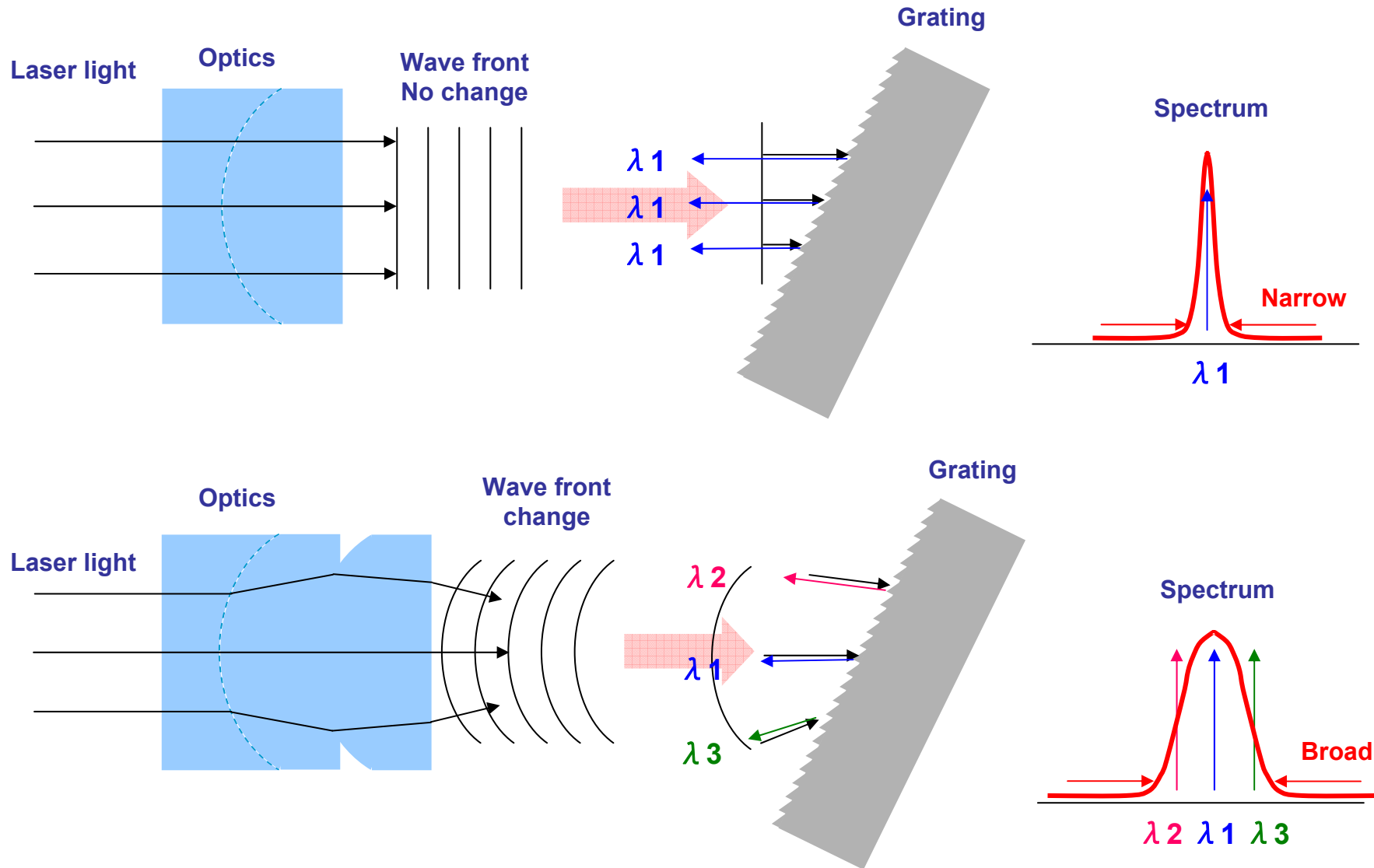


2) E95 feedback control system BCM (bandwidth control module)

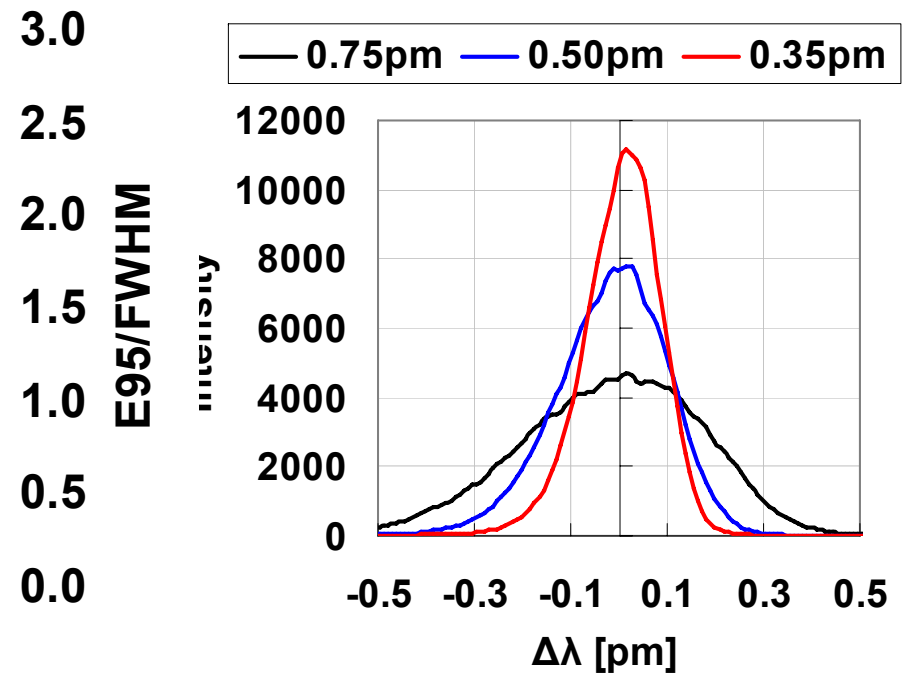
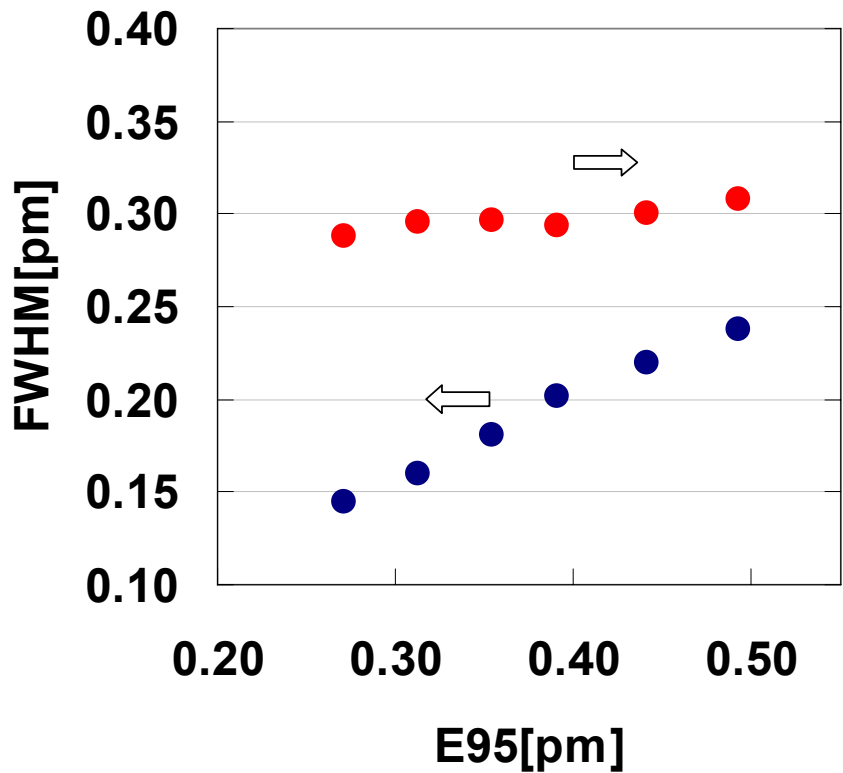
System schematics



3) Bandwidth control module feature

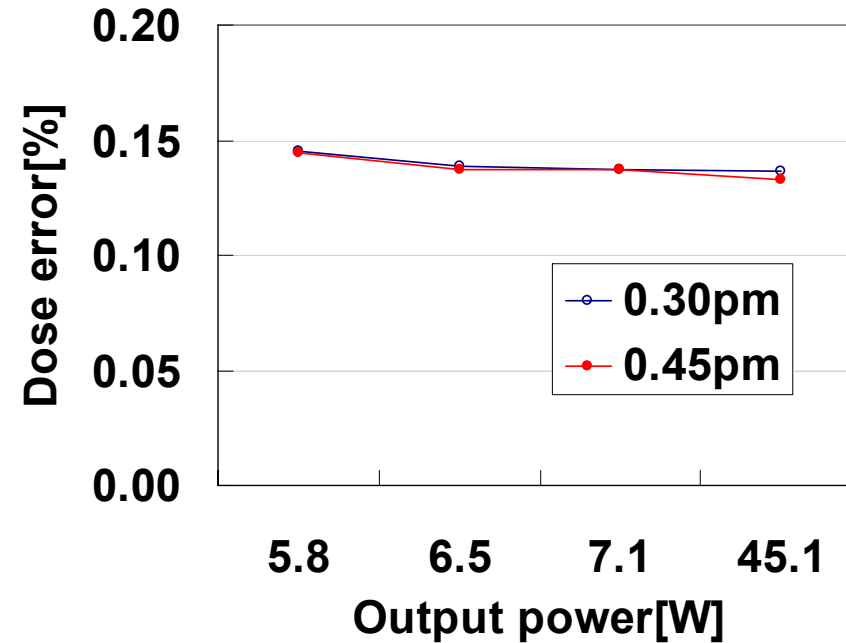
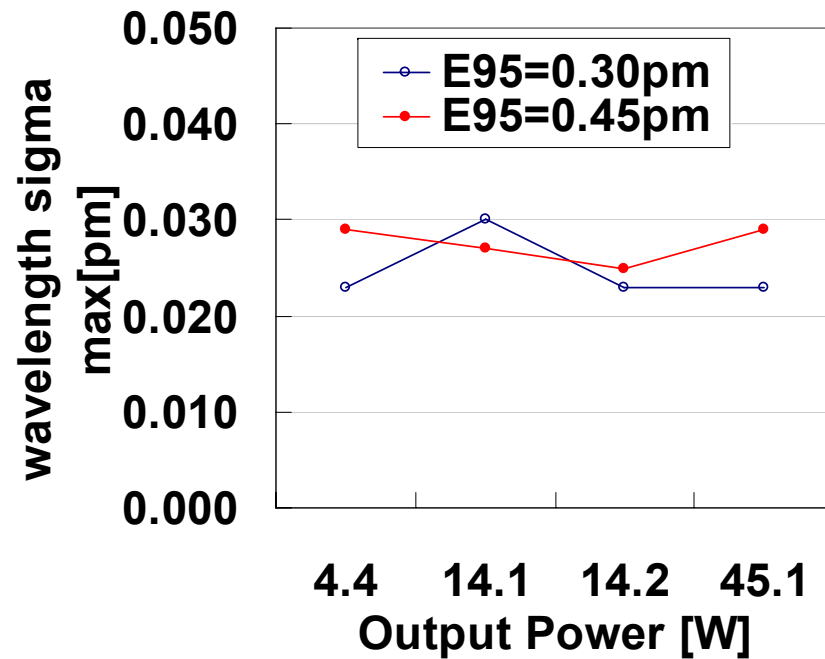


1) spectrum profile stability



BCM (bandwidth control module) enables to adjust the spectrum bandwidth
 No spectrum profile change by adjusting E95

2) Laser performance stability

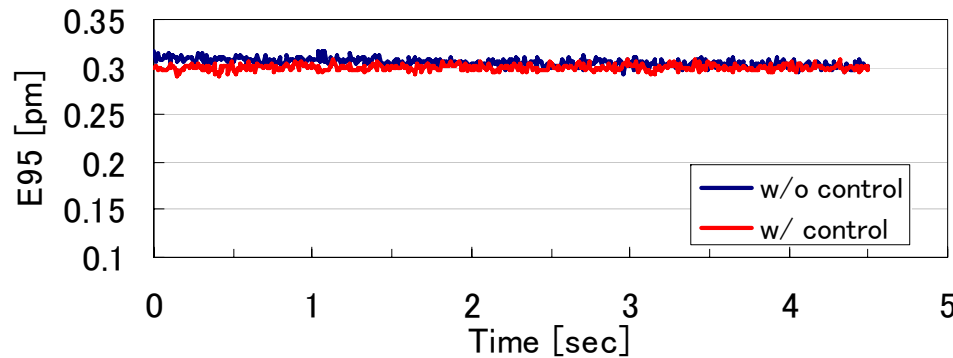


Wavelength and dose performance do not change by adjusting E95

3) E95 feedback control performances (1)

a) Short term (4sec) : die to die

Target E95 = 0.3pm

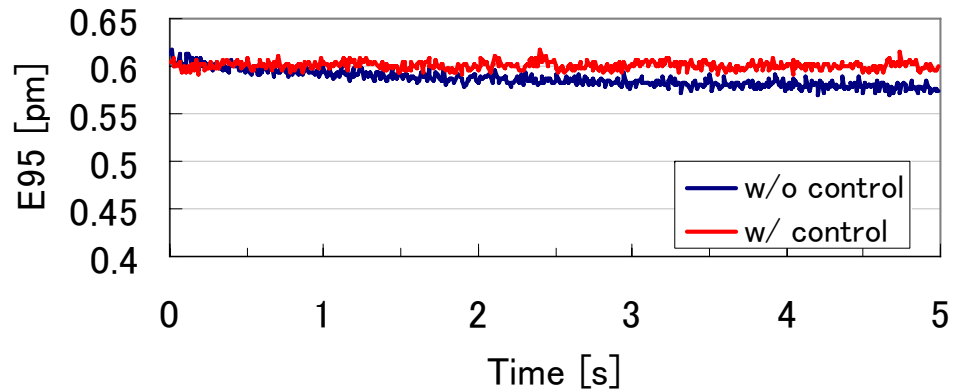


Variation (Peak to Valley)

w/ control 0.02pm

w/o control 0.03pm

Target E95 = 0.6pm



Variation (Peak to Valley)

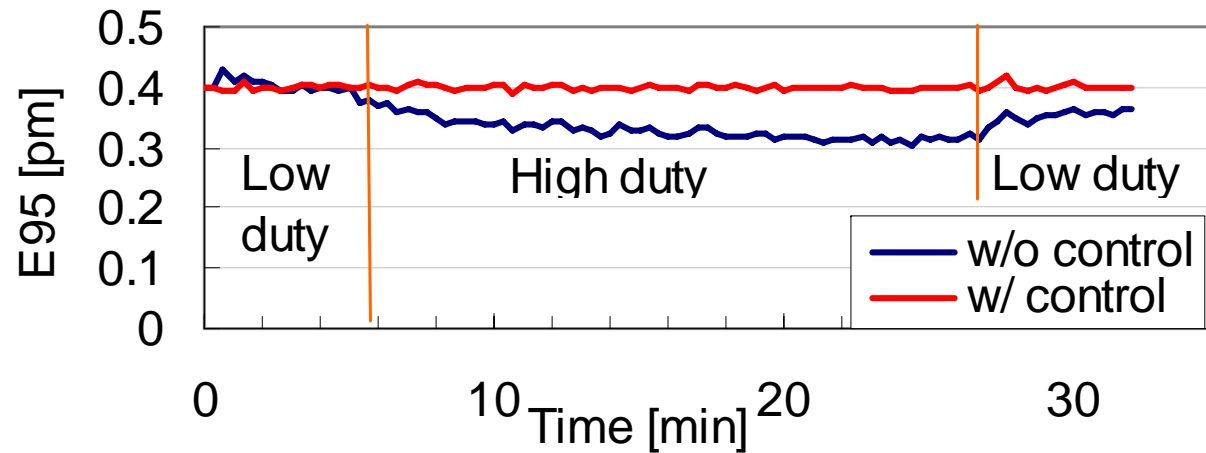
w/ control 0.03pm

w/o control 0.05pm

3) E95 feedback control performances (2)

b) Middle term (30min) : wafer to wafer

Target E95 = 0.4pm



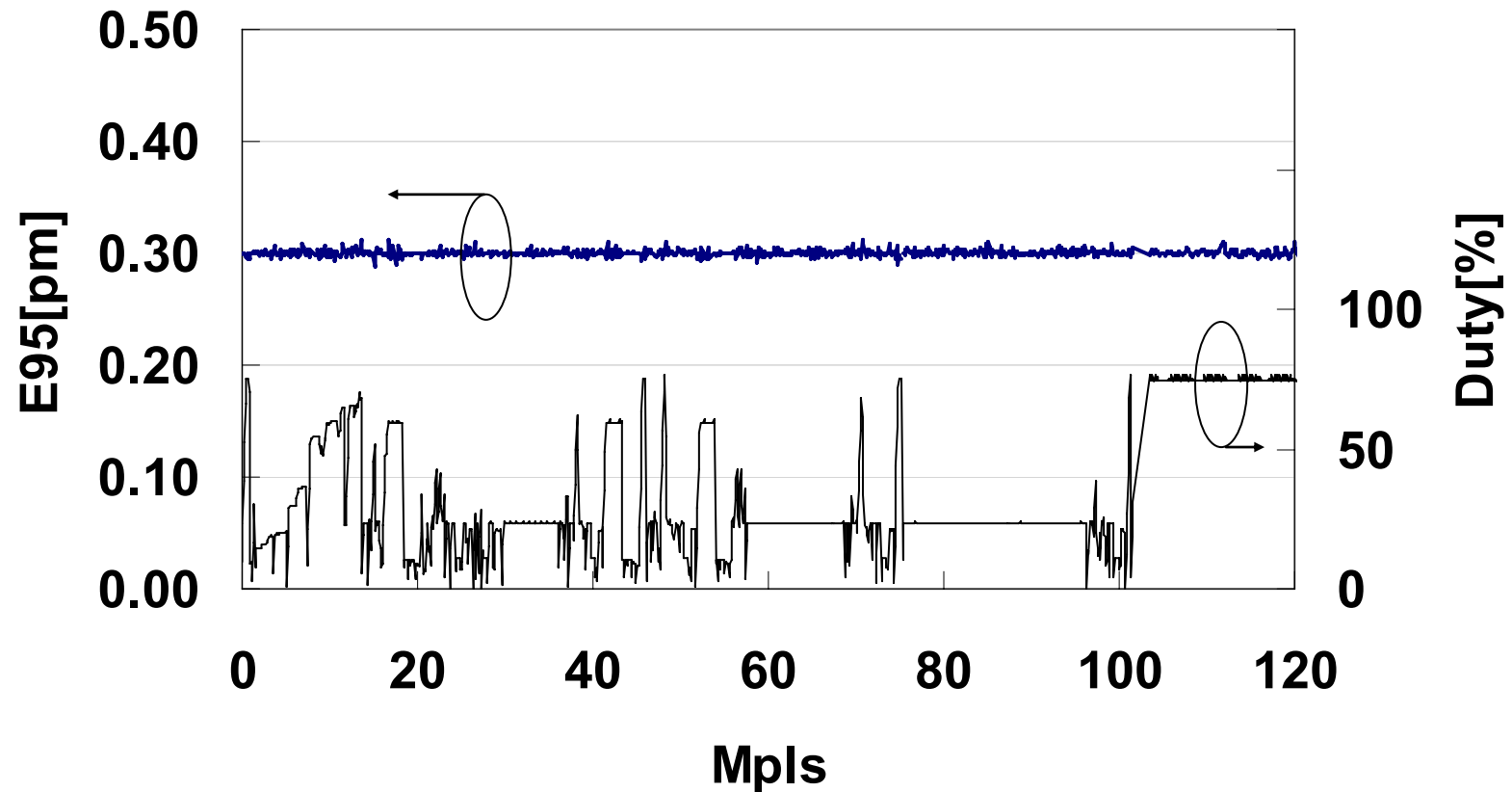
Variation (Peak to Valley)

w/ control 0.03pm

w/o control 0.13pm

3) E95 feedback control performances (3)

c) Long term (3 days) : lot to lot



3. Conclusion

- 1) CD error, properly related to laser spectrum for Hyper NA (>1.3) immersion lens, is characterized by numerical simulations.
- 2) We decide the tight E95 and dE95 design target. We innovated new line narrowing module, chamber and BCM to achieve the tight target.
- 3) New line narrowing module achieved E95 $< 0.35\text{pm}$.
- 4) New Bandwidth Control Module (BCM) makes stable E95 (dE95 $< 0.1\text{pm}$) which is required for critical process.
- 5) Adjustable E95 enables exact replication of the process.
- 6) ArF light source GT61A for Hyper NA immersion lithography is successfully developed.



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