www.gigaphoton.com

6520-75

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

Toru Suzuki*, Kouji Kakizaki**, Takashi Matsunaga*, Satoshi Tanaka**, Yasufumi Kawasuji*, Masashi Shimbori**, Masaya Yoshino**, Takahito Kumazaki*, Hiroshi Umeda*, Hitoshi Nagano**, Shinji Nagai*, Youichi Sasaki** and Hakaru Mizoguchi***
* Komatsu Ltd., ** Ushio Inc., ***Gigaphoton Inc.

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

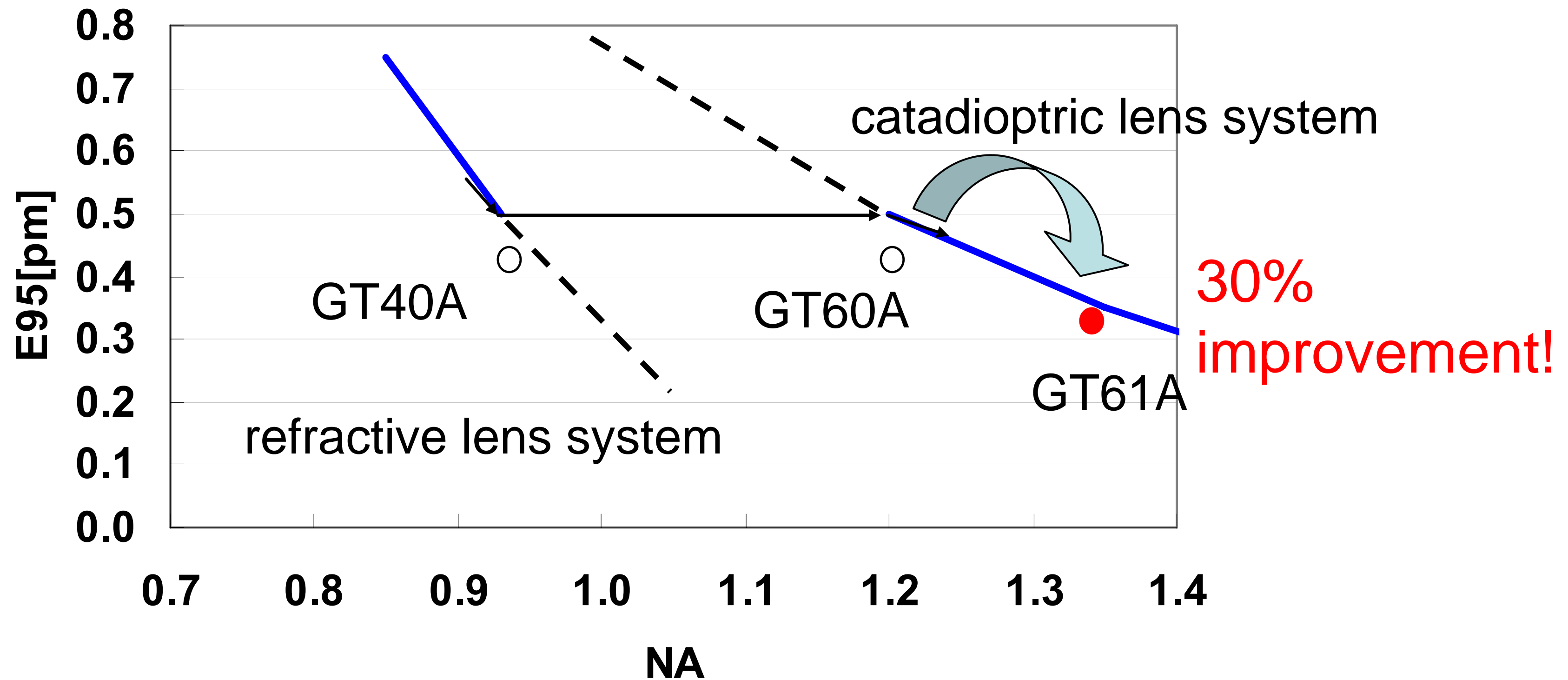
- Improved thermal design of LNM
- BCM

4. Conclusion

Copyright 2007 GIGAPHOTON INC. all rights reserved.

1. Introduction

1.1 E95 spec for hyper NA immersion lithography



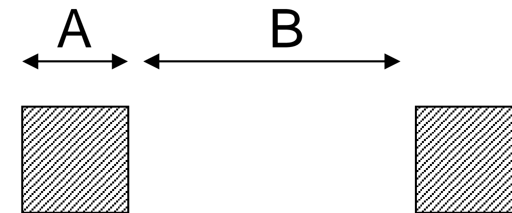
- E95 < 0.35pm required for hyper NA lithography

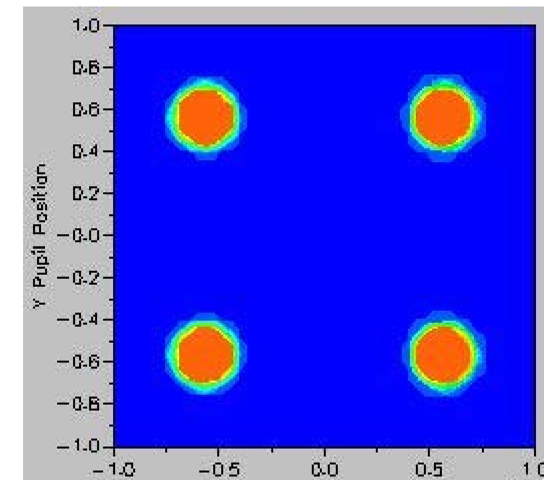
Copyright 2007 GIGAPHOTON INC. all rights reserved.

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



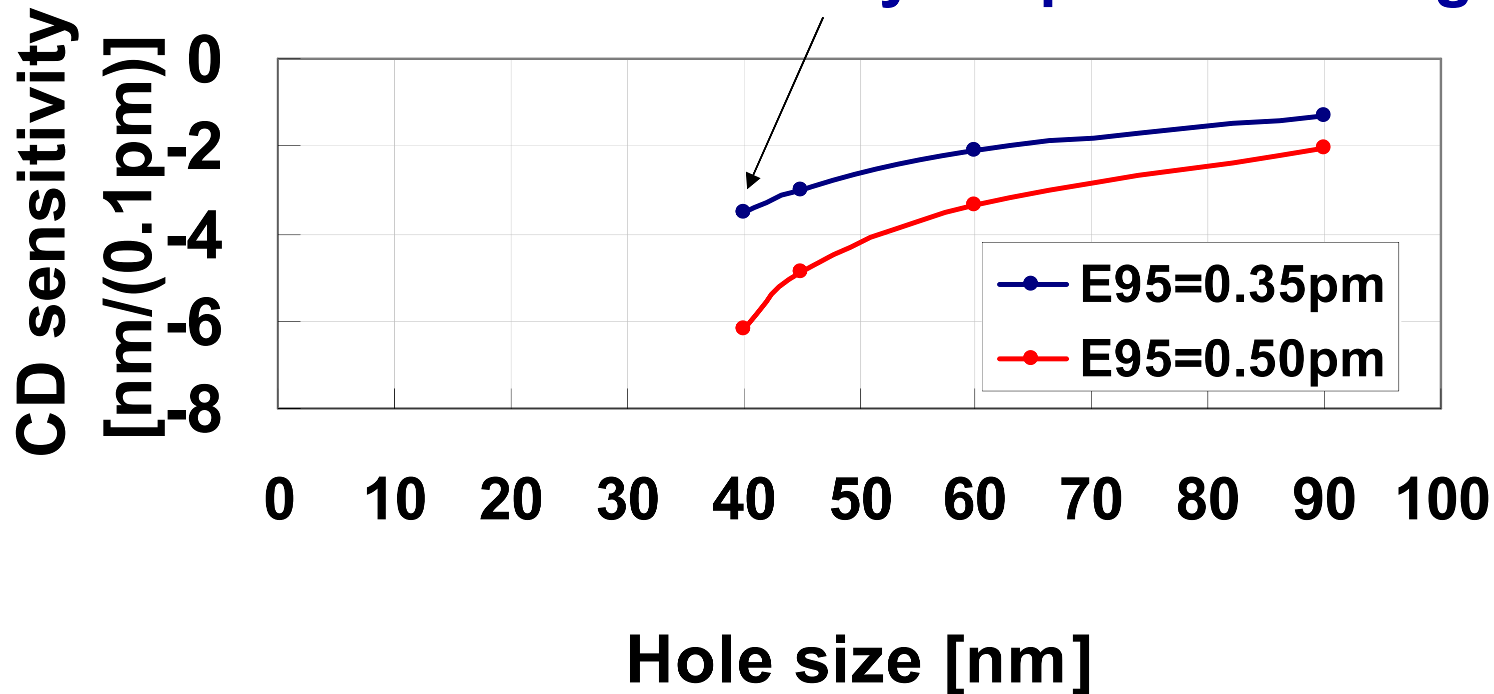


Copyright 2007 GIGAPHOTON INC. all rights reserved.

1.2 CD error sensitivity for E95 (2)

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

Simulation results

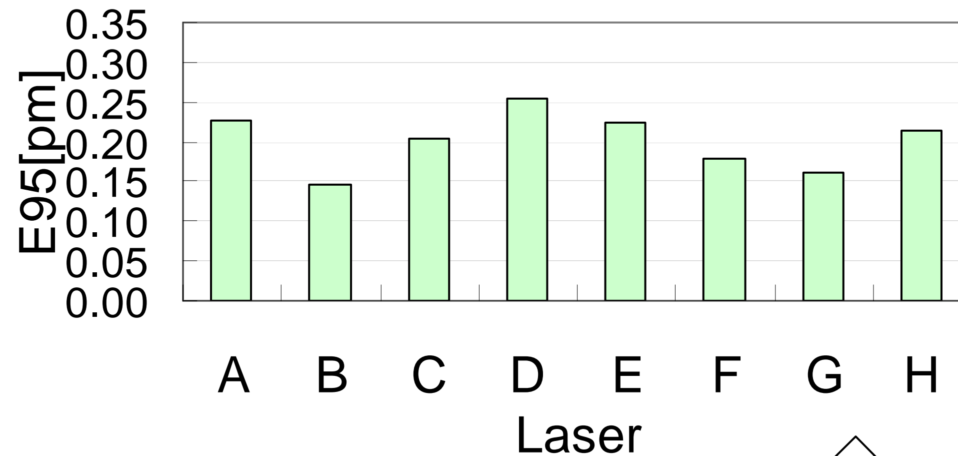


- Critical process need stable spectrum
- dE95 < 0.1pm design target

  introduce Bandwidth Control Module (BCM)

Copyright 2007 GIGAPHOTON INC. all rights reserved.

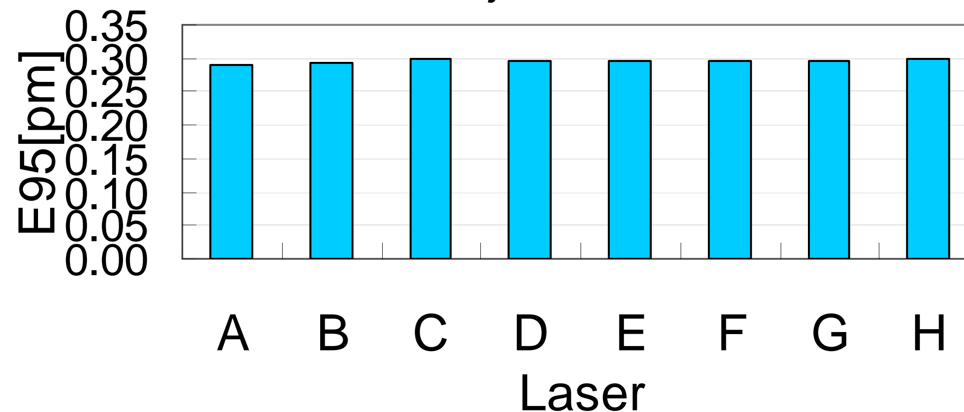
1.3 E95 adjustability



Tool to tool differences at shipping & after replacement of modules

Conventional data
dE95 < 0.15pm

➢ Need E95 adjustments for the exact replication of the process



Copyright 2007 GIGAPHOTON INC. all rights reserved.

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

Copyright 2007 GIGAPHOTON INC. all rights reserved.

2. Narrower spectrum for Hyper NA lithography

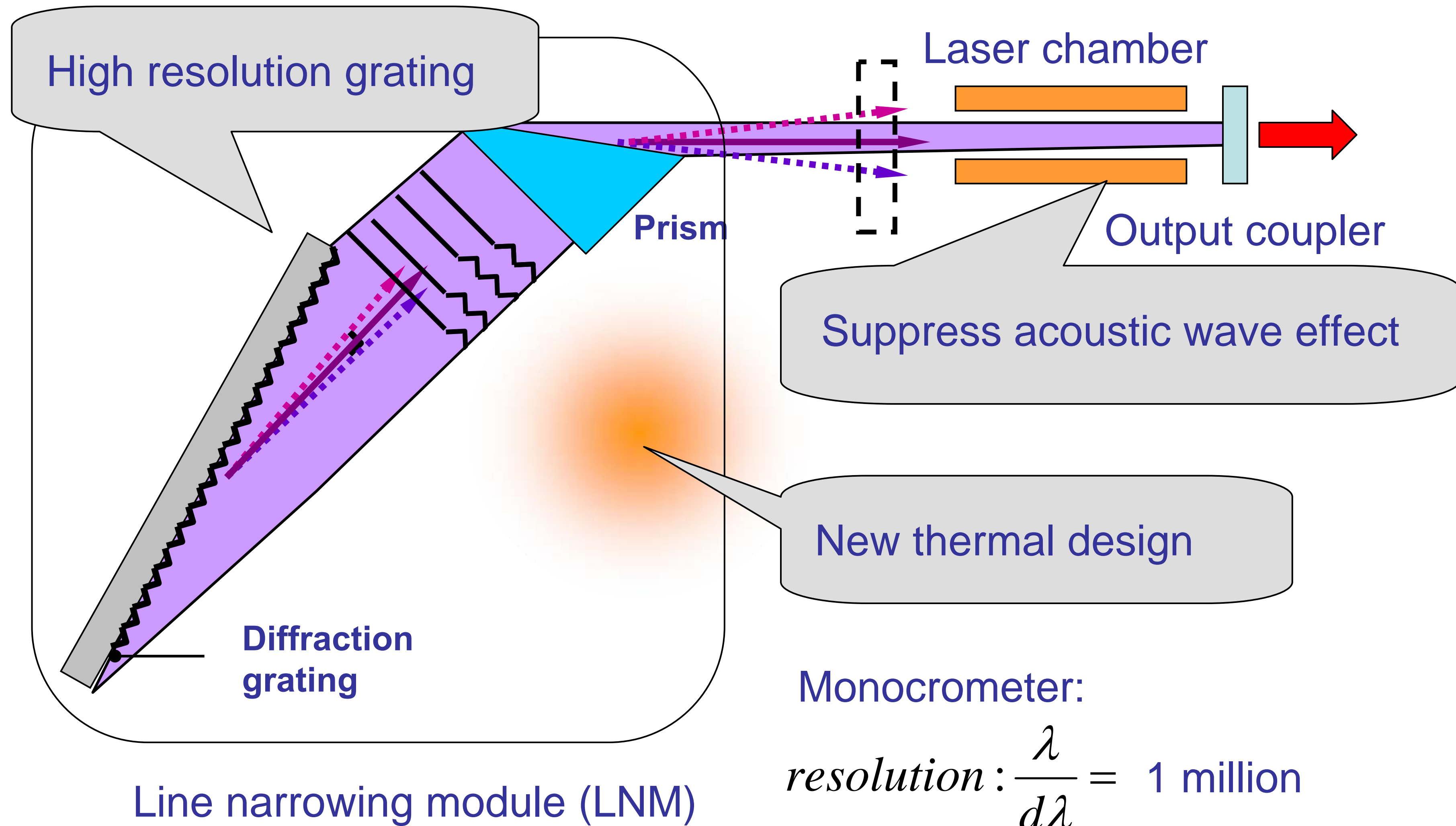
- ✓ E95 <0.35pm
  - High resolution Line narrowing module (LNM)
  - E95 fluctuation caused by acoustic wave

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

Copyright 2007 GIGAPHOTON INC. all rights reserved.

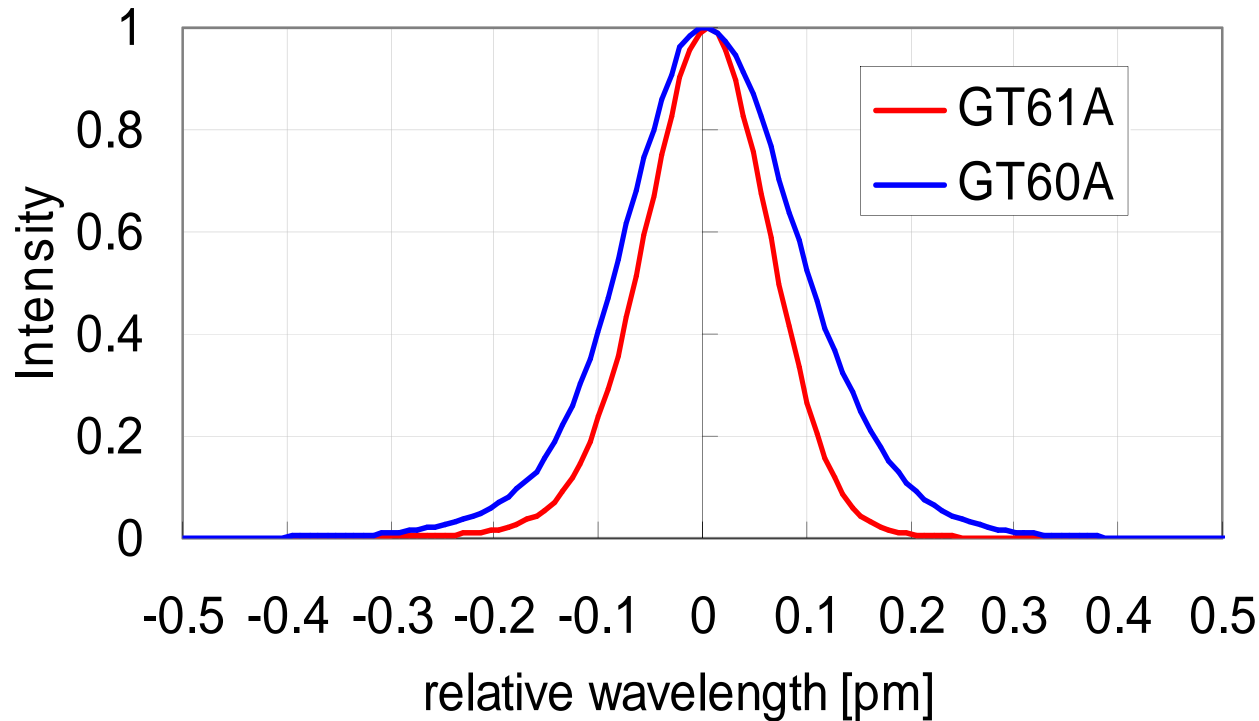
2-1 High resolution line narrowing module



$$resolution : \frac{\lambda}{d\lambda} = \text{ 1 million}$$

Copyright 2007 GIGAPHOTON INC. all rights reserved.

Typical spectrum profile of new LNM



Modified Lorenzian n=3

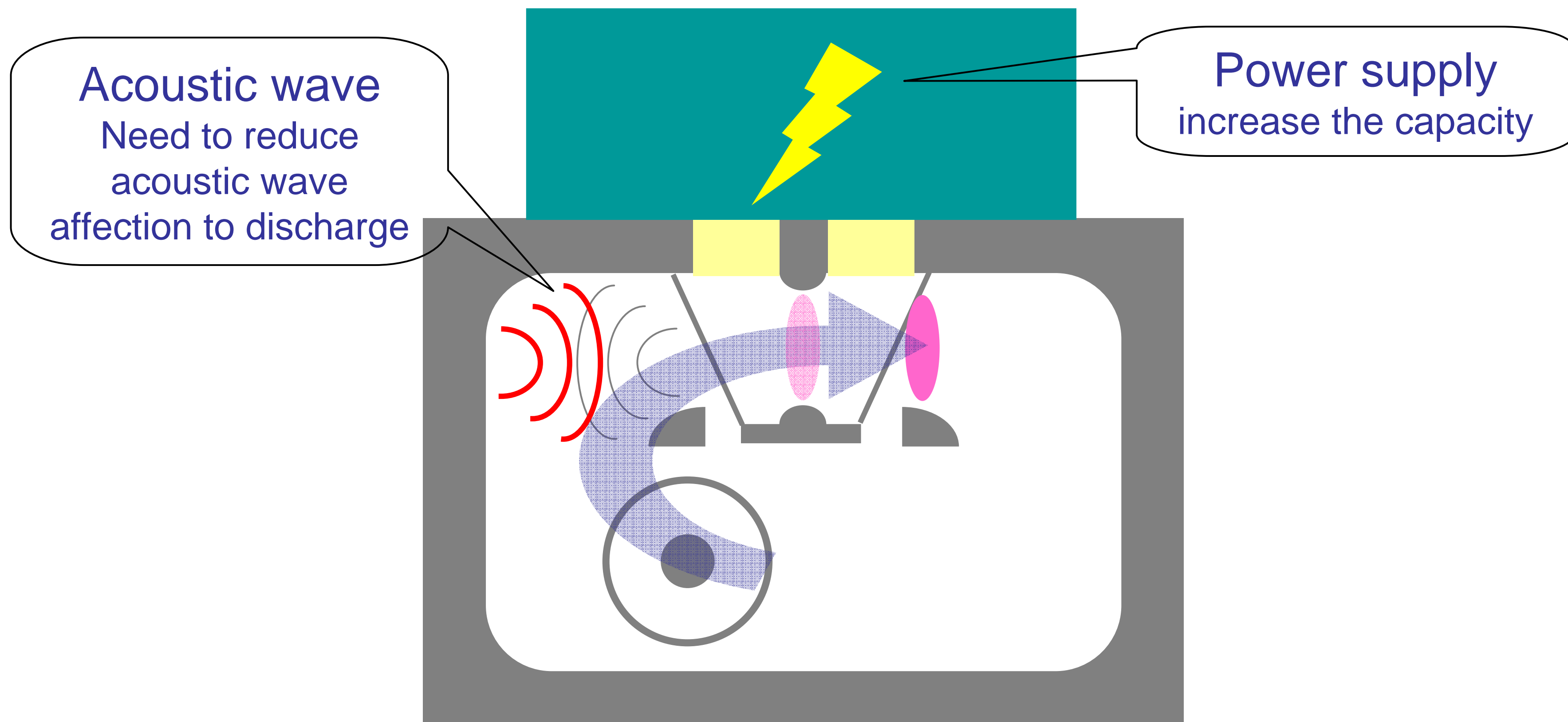
$$f(\lambda) = \frac{c^n}{c^n + (2\lambda)^n}$$

	E95
GT60A	0.35pm
GT61A	0.25pm

Copyright 2007 GIGAPHOTON INC. all rights reserved.

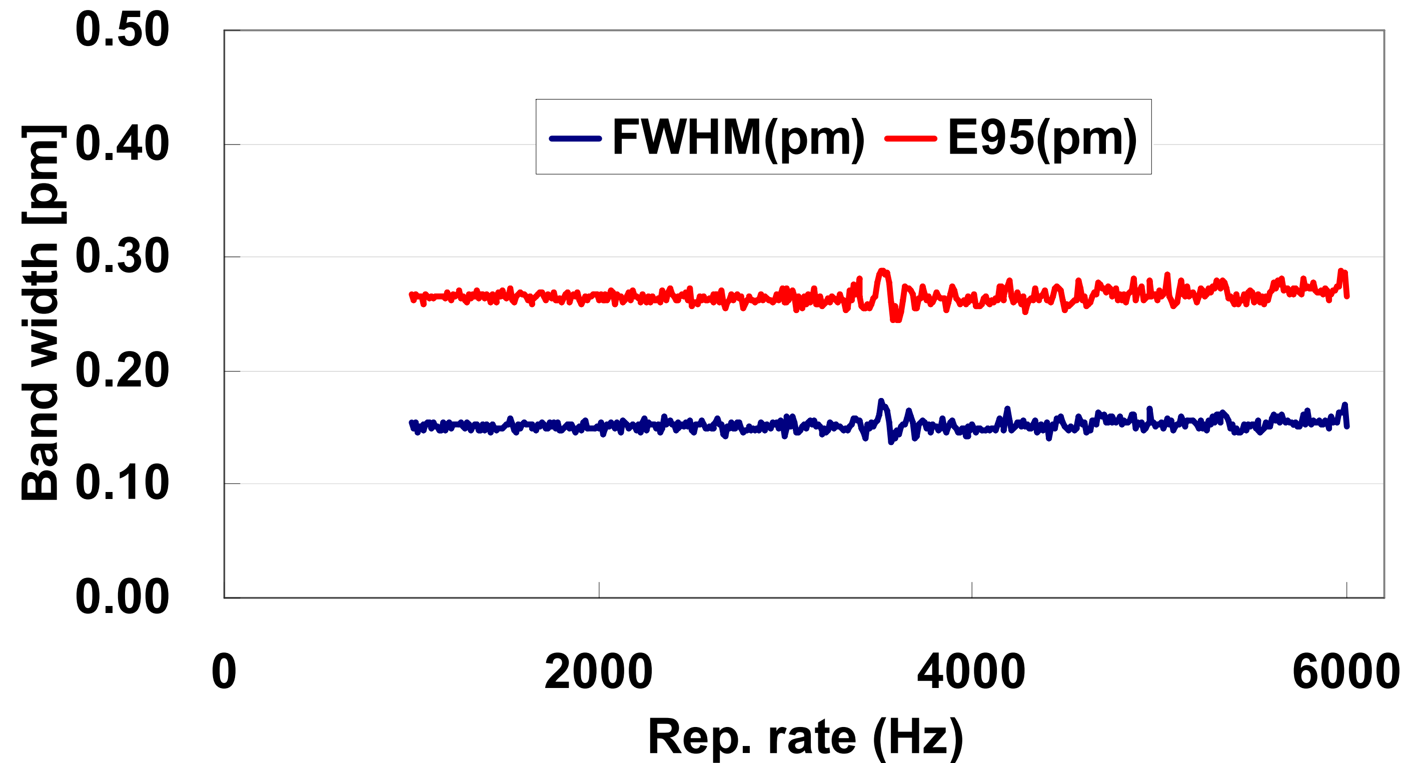
2-2 E95 fluctuation caused by acoustic wave

- Suppress the acoustic wave effect in the chamber



Copyright 2007 GIGAPHOTON INC. all rights reserved.

Repetition rate dependency of E95



No remarkable peak for all frequency

Copyright 2007 GIGAPHOTON INC. all rights reserved.

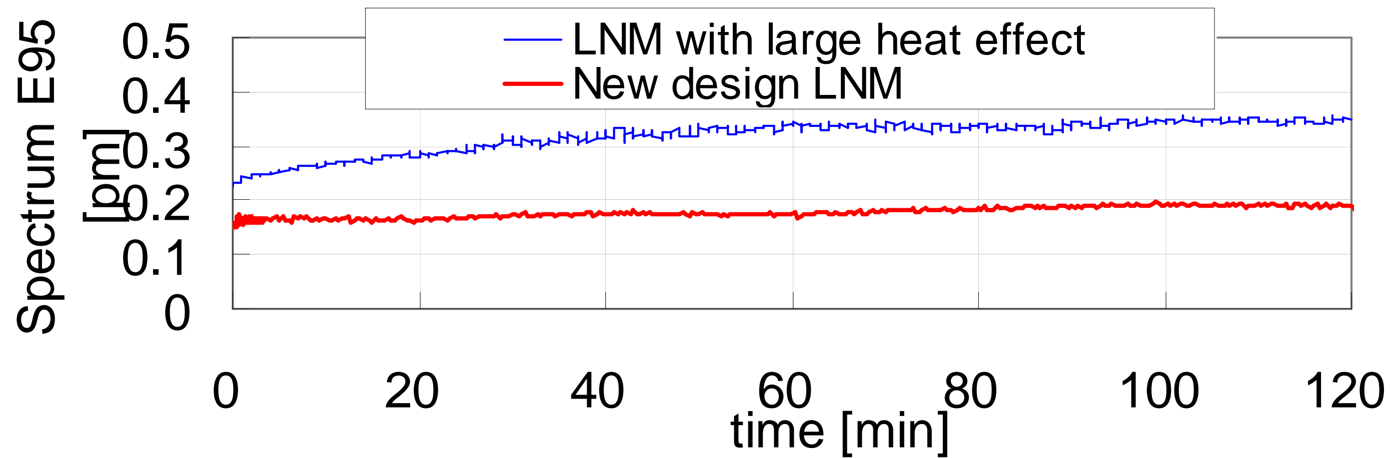
2. Narrower spectrum for Hyper NA lithography
   - ✓ E95 <0.35pm
     - High resolution Line narrowing module (LNM)
     - E95 fluctuation caused by acoustic wave

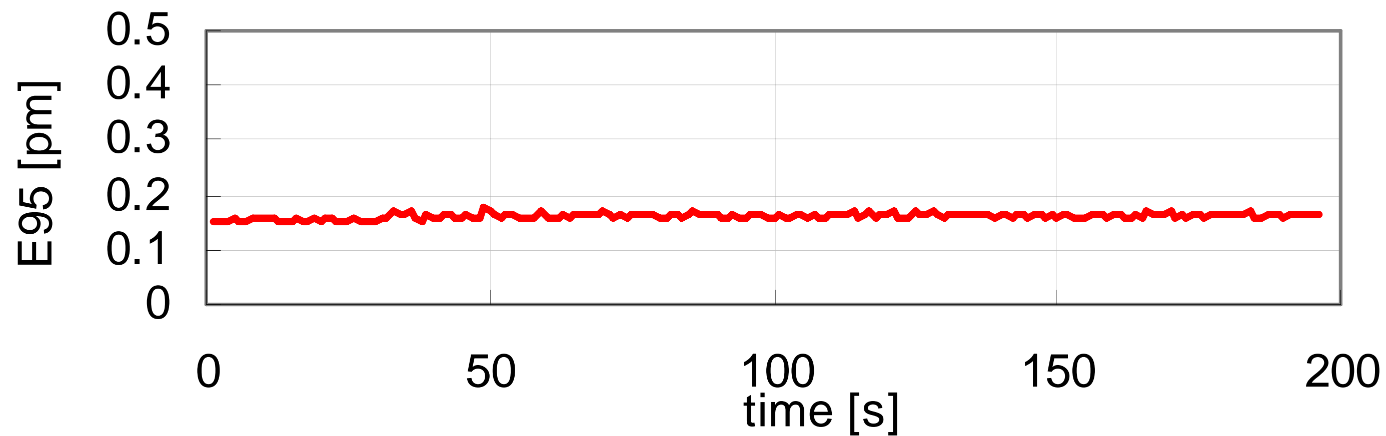
3. Stable spectrum for critical process
   - ✓ dE95 < 0.1pm
     - Improved thermal design of LNM
     - BCM
       - No tool to tool spectrum differences for replication of the process
       - E95 stabilization by feedback system

Copyright 2007 GIGAPHOTON INC. all rights reserved.

1) New thermal design of LNM

- Improved thermal stabilization design

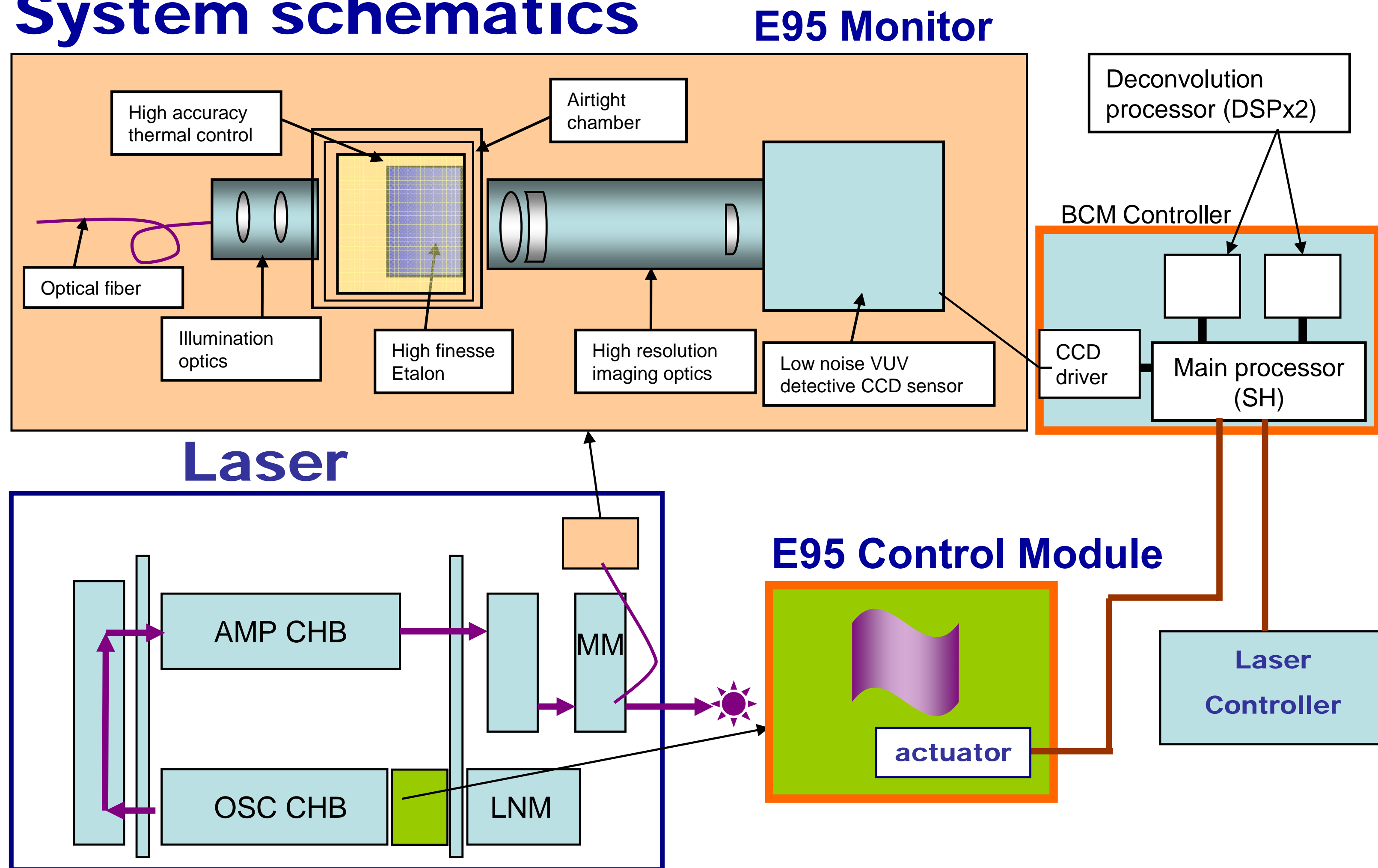




Copyright 2007 GIGAPHOTON INC. all rights reserved.

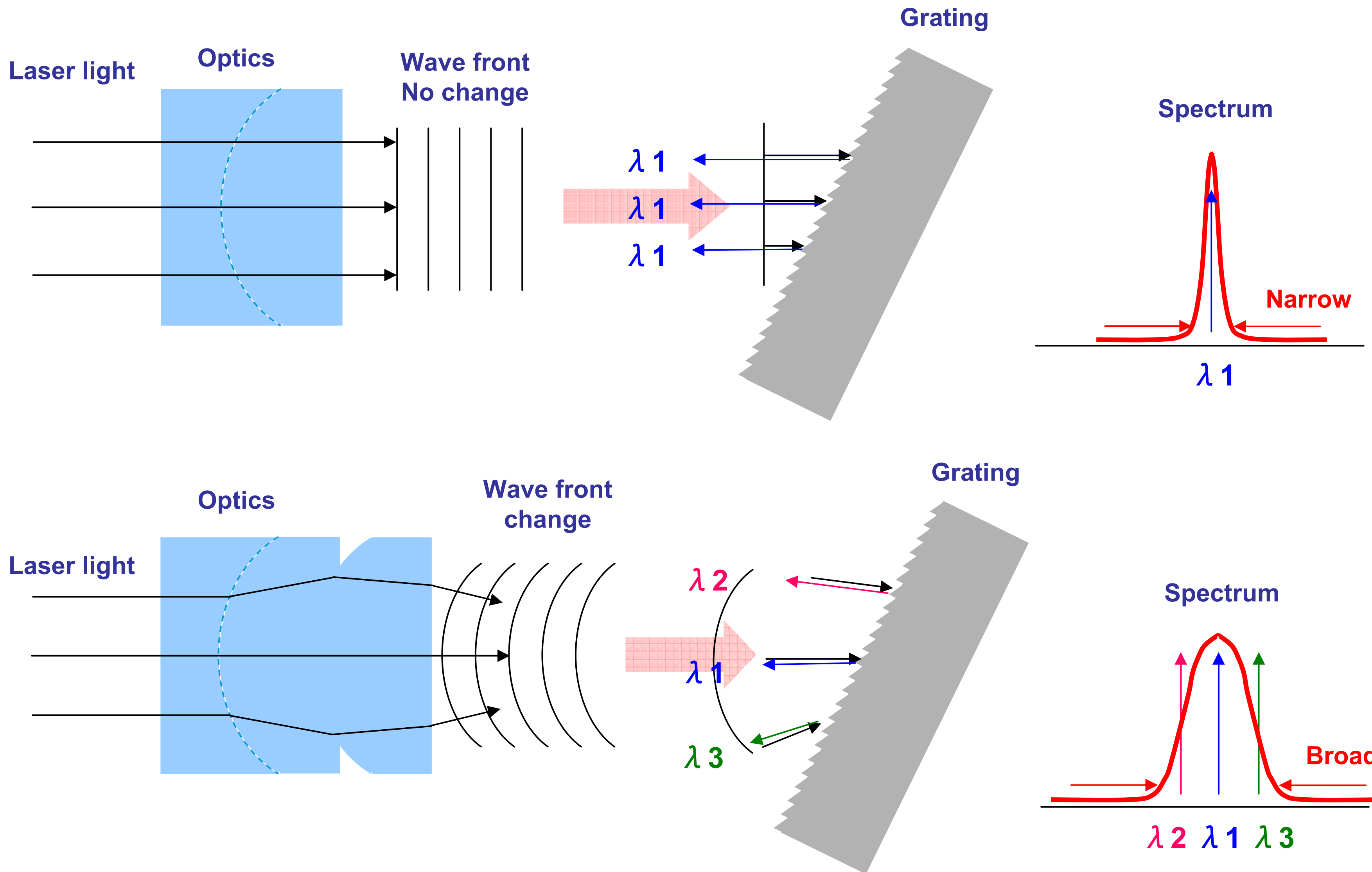
2) E95 feedback control system

BCM (bandwidth control module)



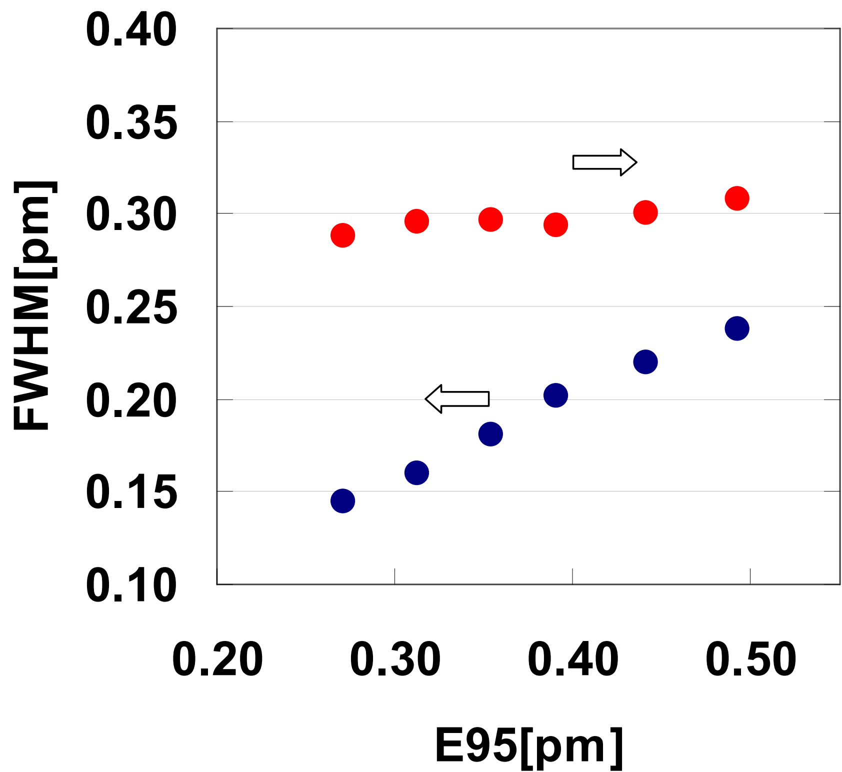
Copyright 2007 GIGAPHOTON INC. all rights reserved.

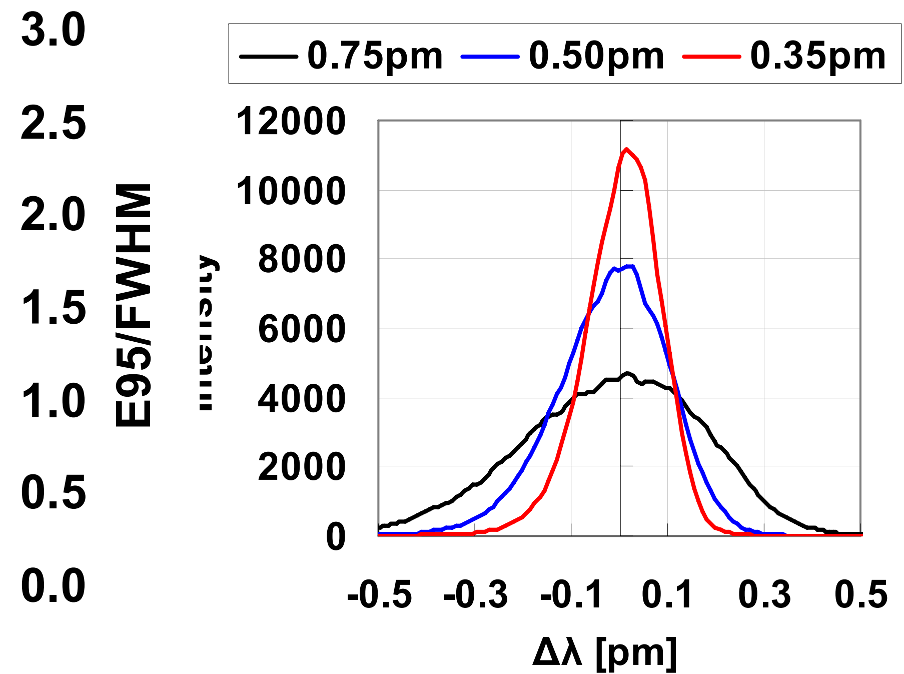
3) Bandwidth control module feature



Copyright 2007 GIGAPHOTON INC. all rights reserved.

1) spectrum profile stability



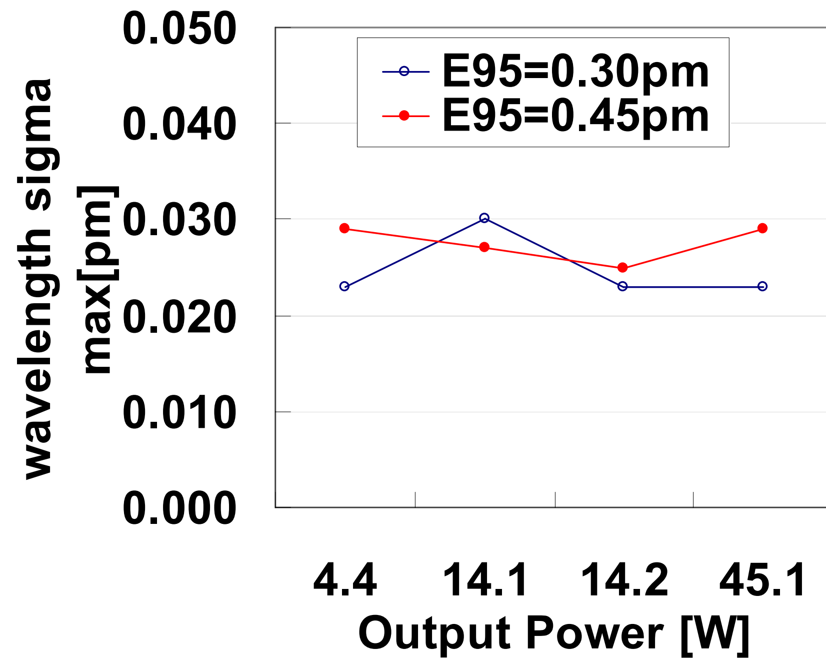


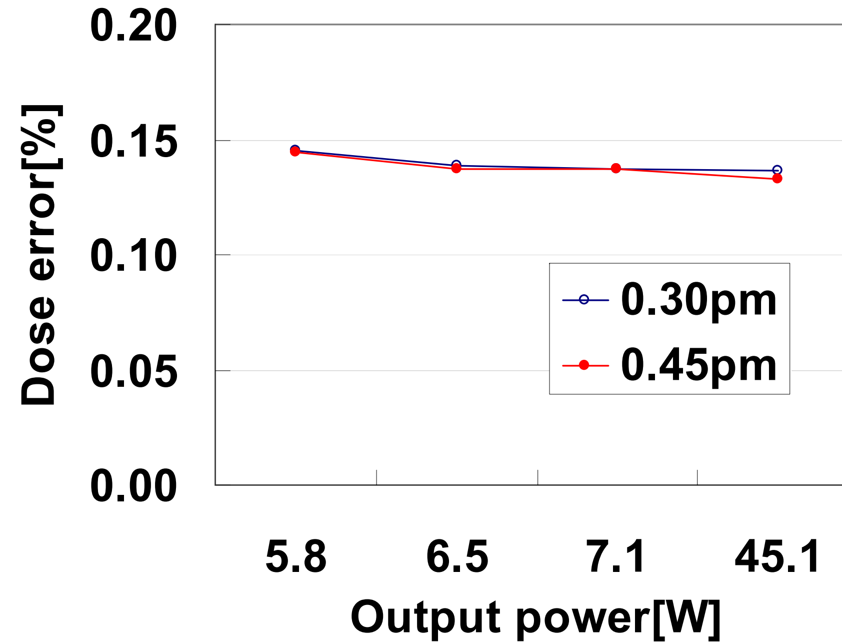
BCM (bandwidth control module) enables to adjust the spectrum bandwidth

No spectrum profile change by adjusting E95

Copyright 2007 GIGAPHOTON INC. all rights reserved.

2) Laser performance stability





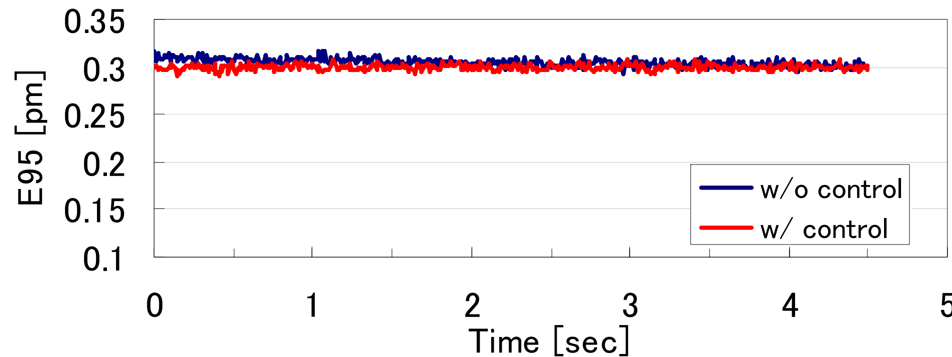
Wavelength and dose performance do not change by adjusting E95

Copyright 2007 GIGAPHOTON INC. all rights reserved.

3) E95 feedback control performances (1)

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

Target E95 = 0.3pm

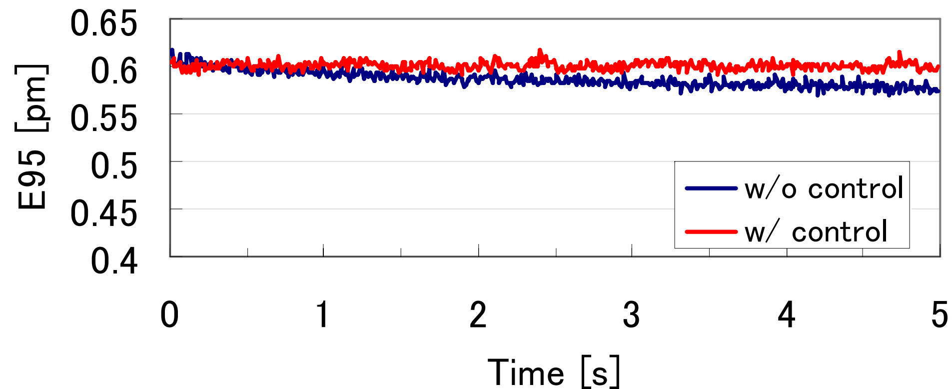


Variation (Peak to Valley)

w/ control 0.02pm

w/o control 0.03pm

Target E95 = 0.6pm



Variation (Peak to Valley)

w/ control 0.03pm

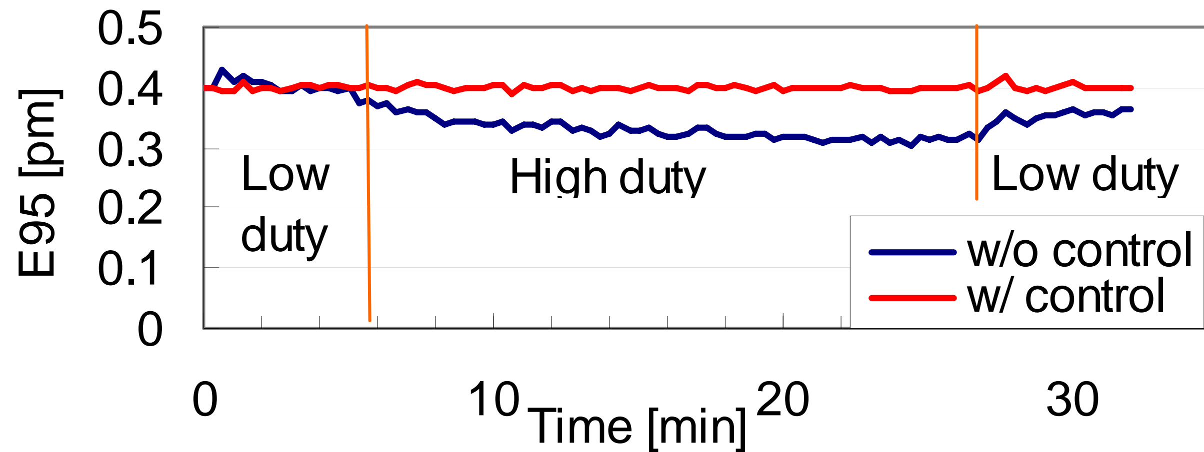
w/o control 0.05pm

Copyright 2007 GIGAPHOTON INC. all rights reserved.

3) E95 feedback control performances (2)

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

Target E95 = 0.4pm



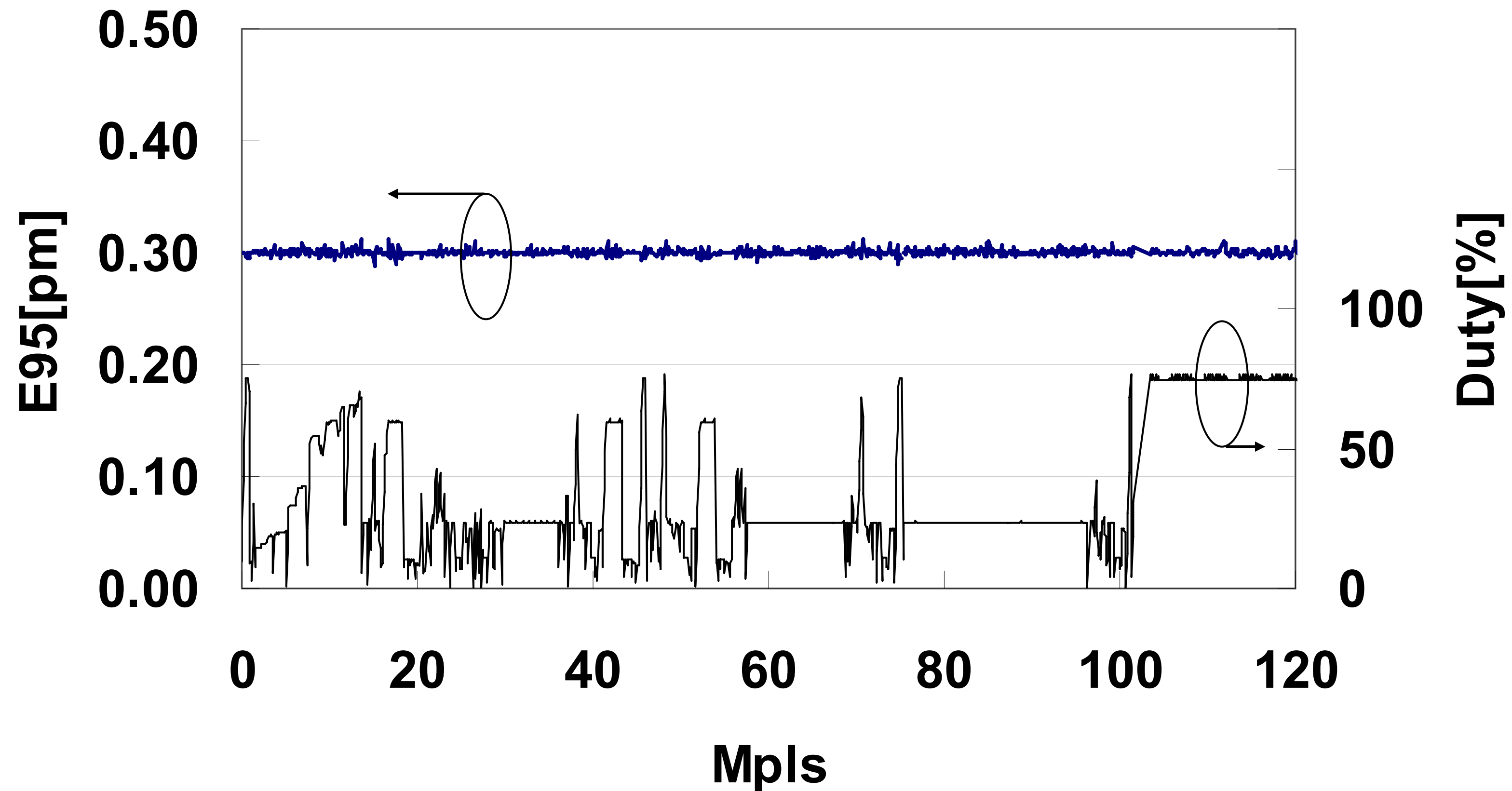
Variation (Peak to Valley)

w/ control	0.03pm
w/o control	0.13pm

Copyright 2007 GIGAPHOTON INC. all rights reserved.

3) E95 feedback control performances (3)

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



Copyright 2007 GIGAPHOTON INC. all rights reserved.

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 < 0.35pm.
4) New Bandwidth Control Module (BCM) makes stable E95 (dE95 < 0.1pm) 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.

Copyright 2007 GIGAPHOTON INC. all rights reserved.

http://www.gigaphoton.com/