Asia Regional Update

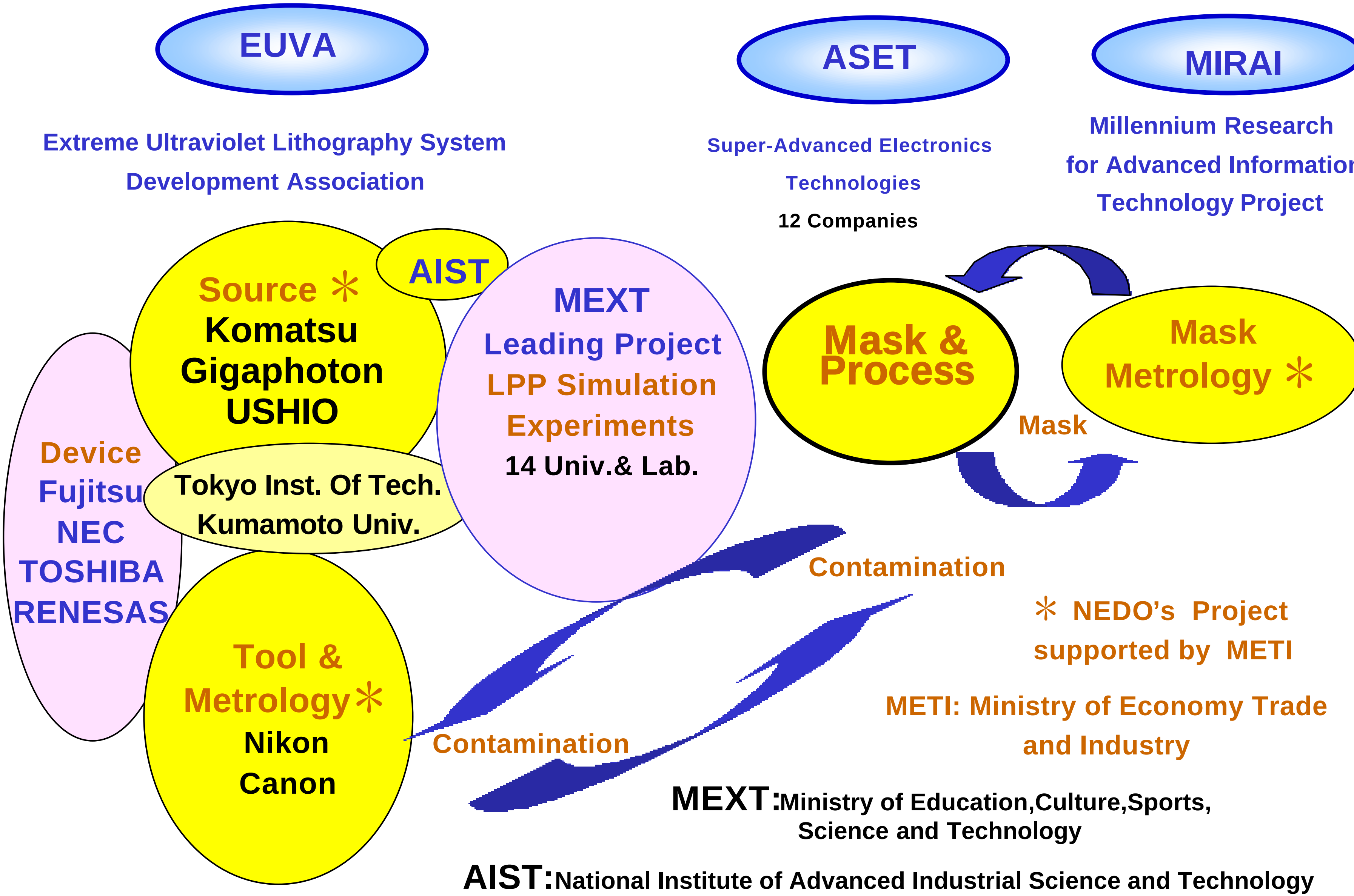
Extreme Ultraviolet Lithography

EUVA/ASET

Yasuhiro Horiike

(National Institute for Materials Science)

Japan EUVL Development



Leading Project on LPP EUV source development

MEXT's research group

Experimental group

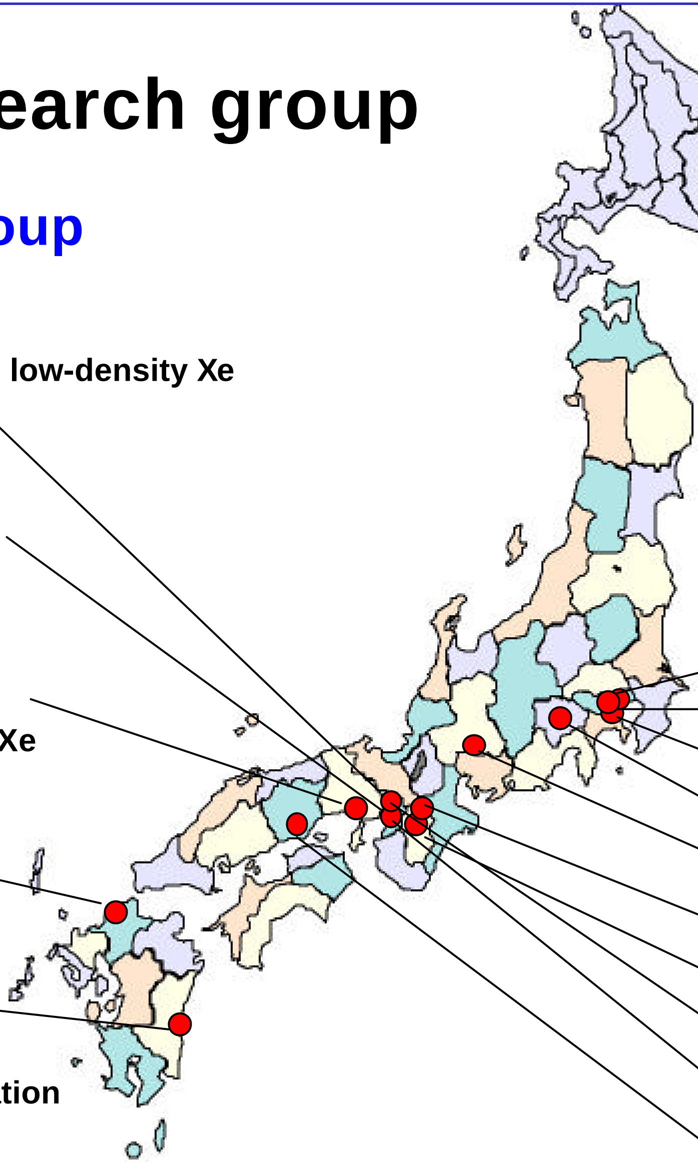
Osaka Univ.
Nd:YAG, low-density Sn and low-density Xe
Laser development

Inst. for Laser Tech.
Nd:Glass, mass-limited Sn

Univ. of Hyogo
Nd:YAG, rotating cryogenic Xe

Kyushu Univ.
CO_2 laser, Sn powder

Univ. of Miyazaki
Nd:YAG, Excimer,
EUV and debris characterization

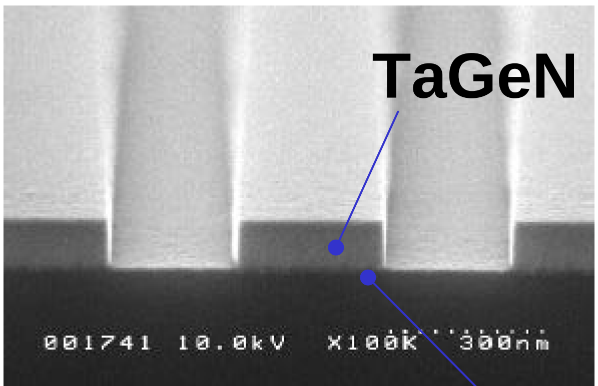


Theory & Simulation group

Tokyo metropolitan Univ.
Kitazato Univ.
Tokyo Inst. Tech.
Yamanashi Univ.
NIFS
APR, JAERI
Nara Women's Univ.
Osaka Univ.
Inst.for Laser Tech.
Okayama Univ.

Development EUVL mask

Ta based absorber mask



275nm L/S Cr

- Amorphous-like structure
- Good etching characteristic
- Stress stability
- DUV inspection contrast
- High EUV absorbance

Example of EUVL mask

Mask was fabricated in collaboration of DNP and ASET
Substrate :6025 glass

ASET

EUVA

Cleaning of carbon contamination by atomic hydrogen

- Atomic hydrogen cleaning was applied to carbon contamination on multilayer.
- Carbon contamination has been removed almost completely.
- Reflectivity was recovered by cleaning.
- Heat damage was suppressed by heat shield.

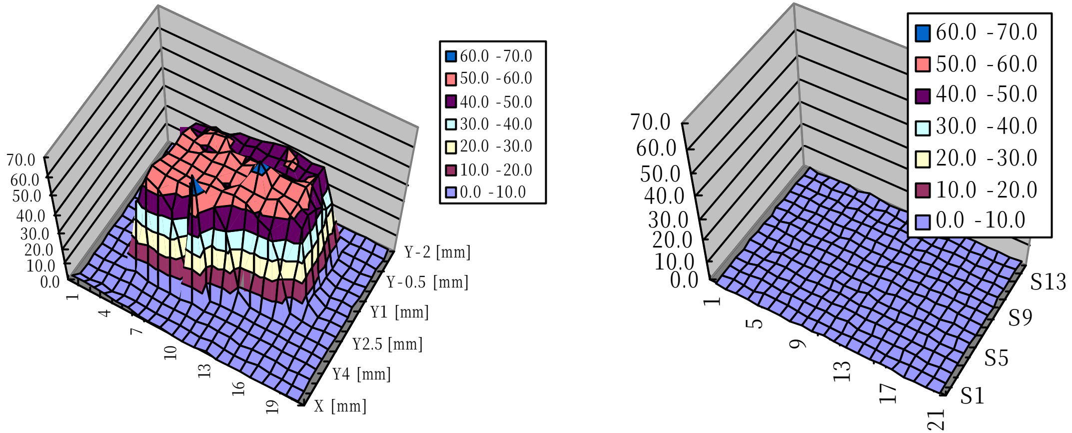
Hot-wire apparatus

Before cleaning

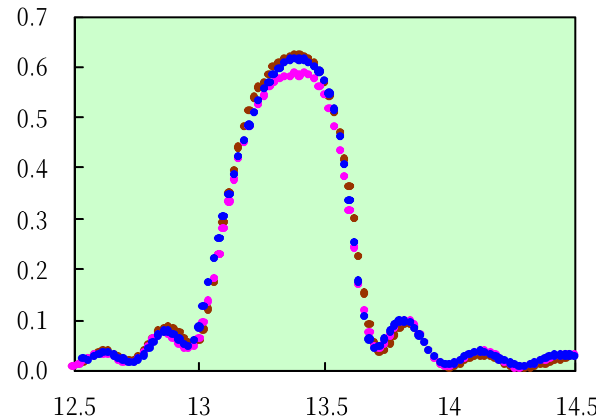
Thickness: 5.6 nm

After cleaning

Thickness: negligible

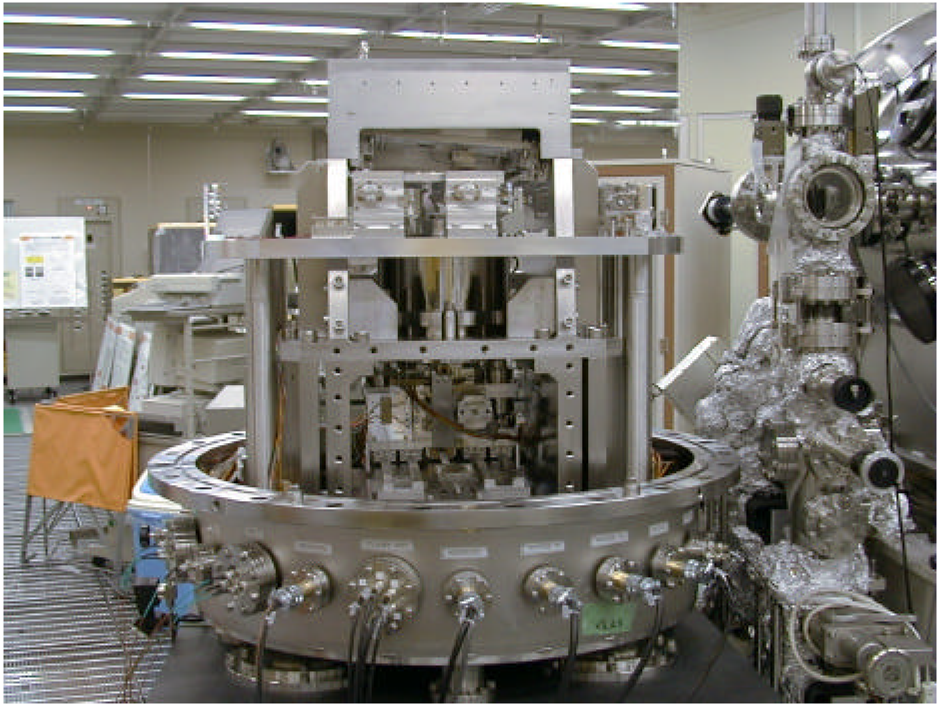


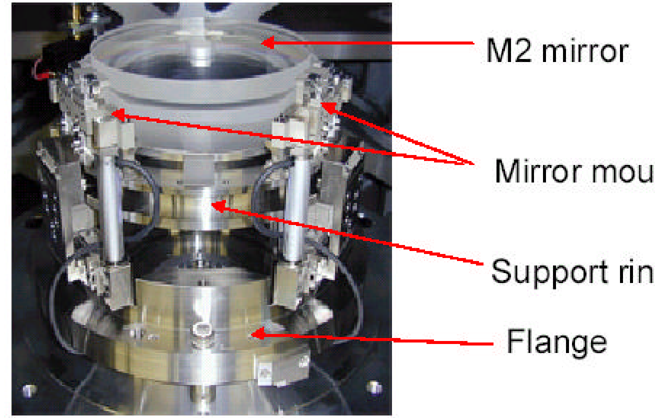
Removal of carbon contamination



Recovery of Reflectivity

HiNA Set-3 optics and Exposure Experiment

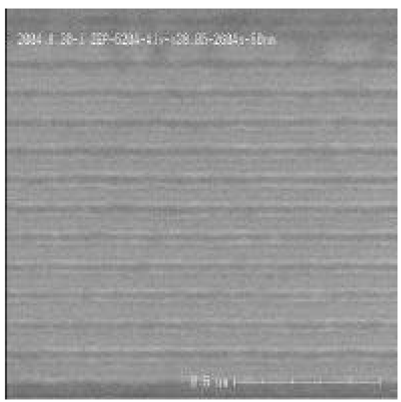




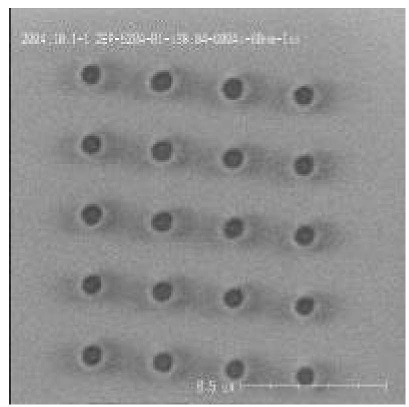
Final WFE: 0.91 nm rms (raw) and

0.75 nm rms (z36)

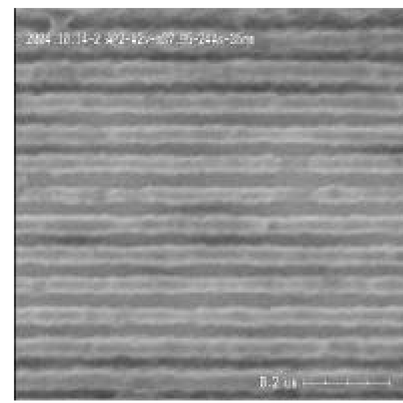
- **PO box in Atsugi-Lab. on June 18.**
- **Mask evaluation just has been started.**



50 nm L/S (σ =0.8)



60 nm Hole (σ =0.8)

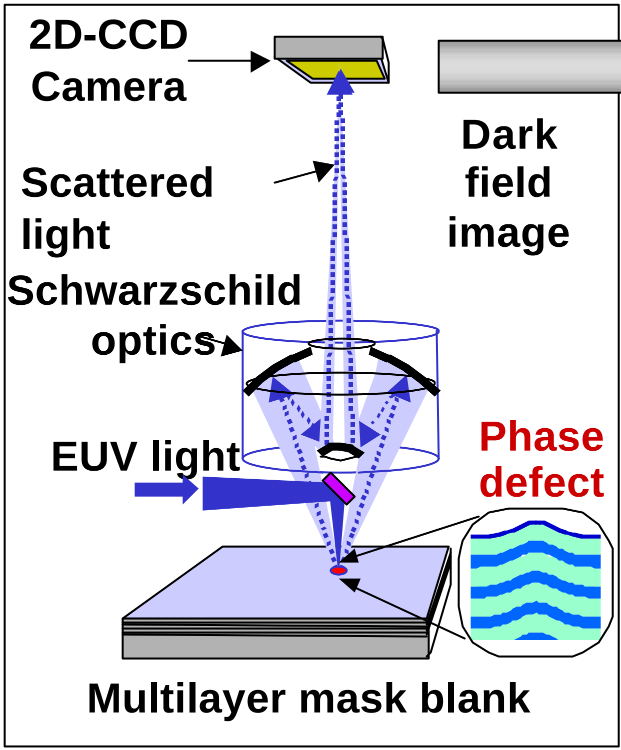


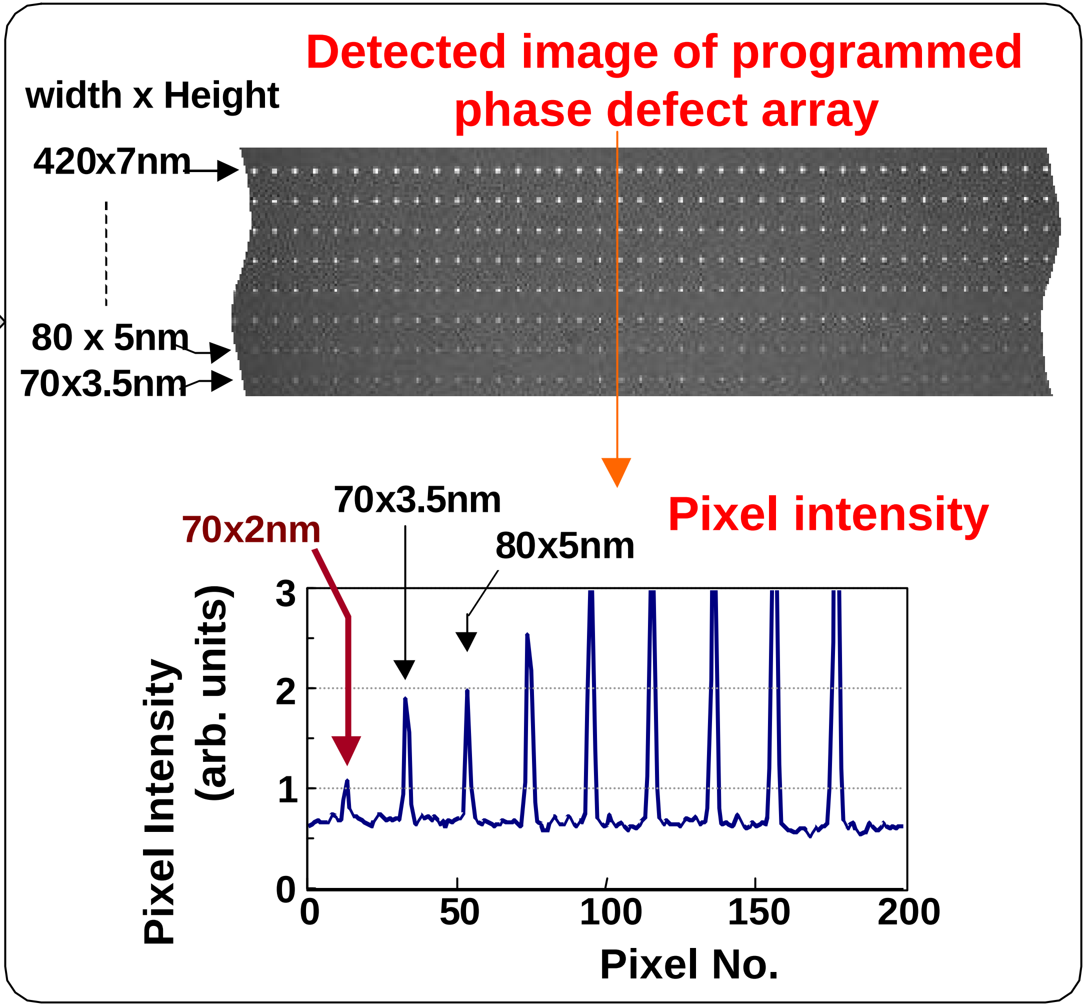
35 nm L/S (σ ~0)

Actinic inspection of EUVL mask blanks

MIRAI POC tool

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





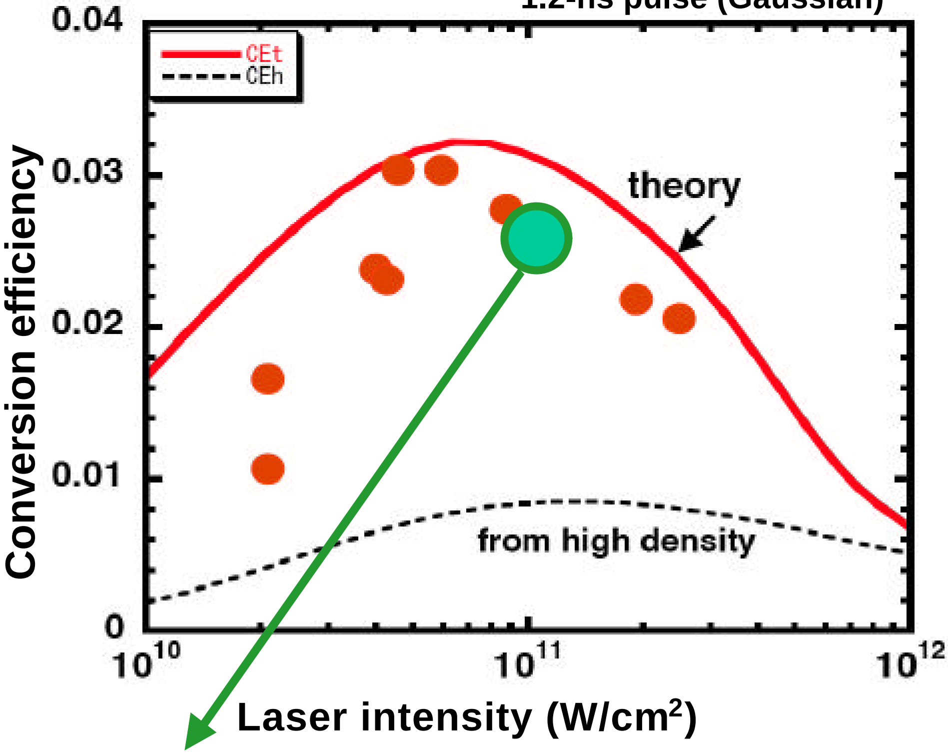
- Smallest phase defect with 70 nm in width and 2 nm in height was detected.
- Throughput estimate suggests 2 hours inspection per mask blank is feasible

Feasibility demonstration of 250 W/2psr with Sn targets

EXT LP

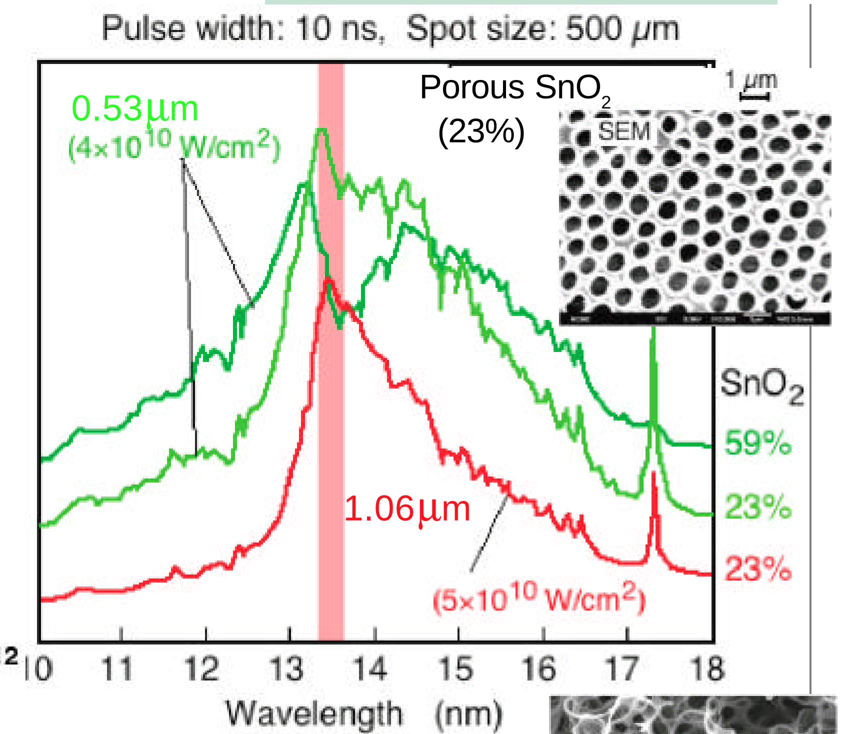
Laser intensity dependence

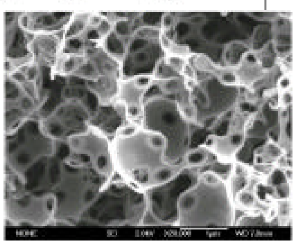
1.053-μ m laser
1.2-ns pulse (Gaussian)



Low-density Sn targets for the improvement of CE

Newly prepared Sn targets





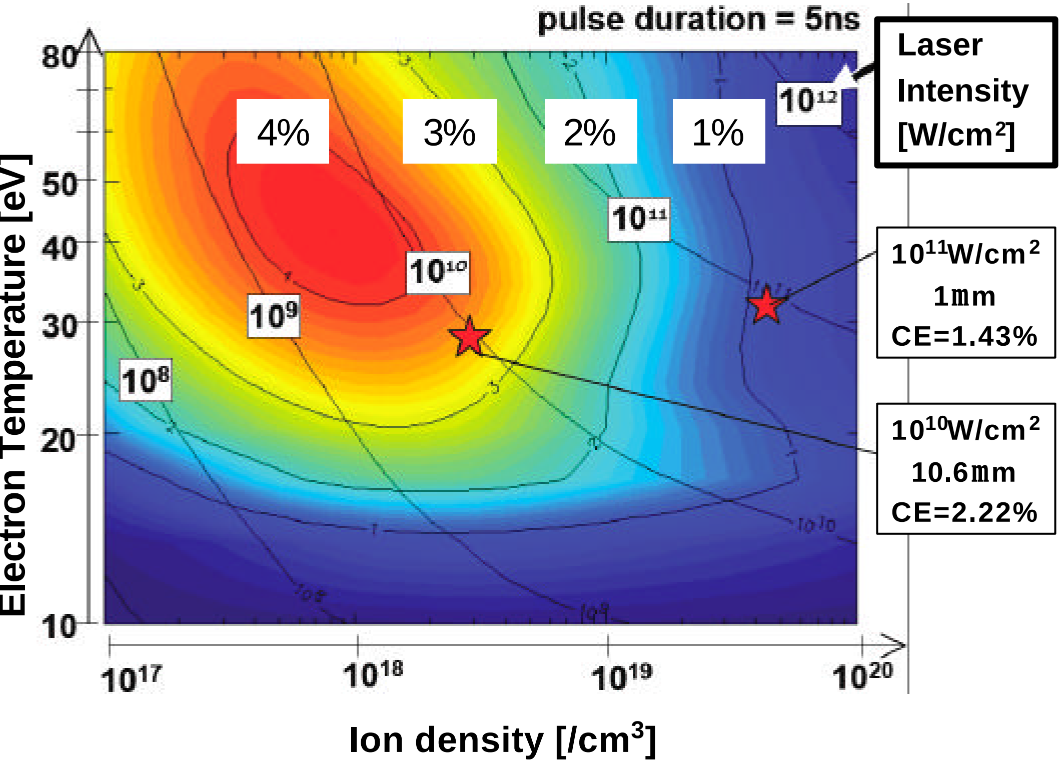
Density: 0.5 g/cc
(7% of Bulk)

250-W source (= 50/2 mJ/2psr (PE) x 10 kHz) **is feasible with a realistic laser pulse energy** (~2J)

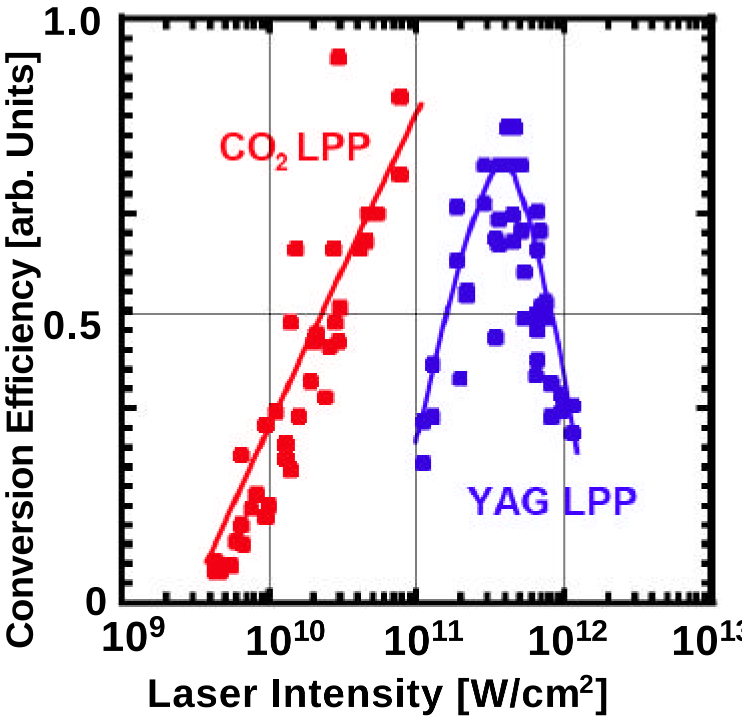
Wavelength dependence of conversion efficiency

MEXT LP

Density-temperature map of 13.5-nm EUV conversion efficiency

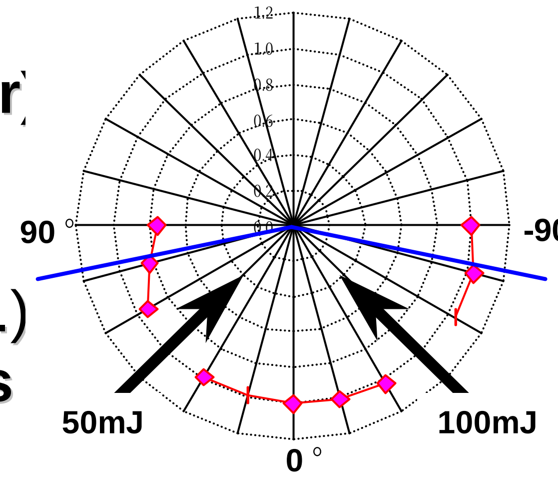


CO_2 LPP vs YAG LPP



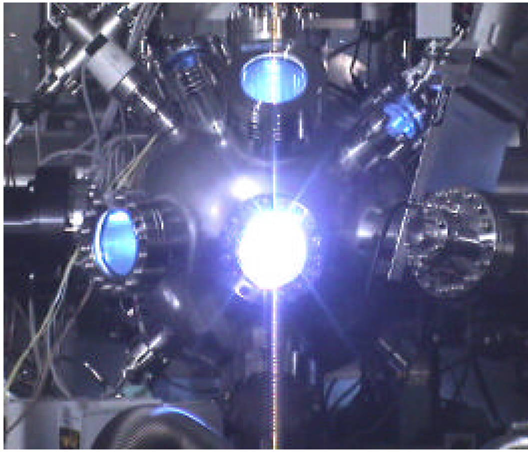
LPP; 1.5kW YAG, 9.1W@ Primary, 4W@IF

- •EUV Power at Source : **9.1 W** (2%BW/2π sr)
  at I.F. : **4W** (Calculated)
- •Conversion Efficiency : 0.61 %
- •EUV Energy Stability : 1.3% (50-pulse ave.)
- •Laser Power : 1500W@10kHz, 6ns
- •Target : Liquid Xenon jet

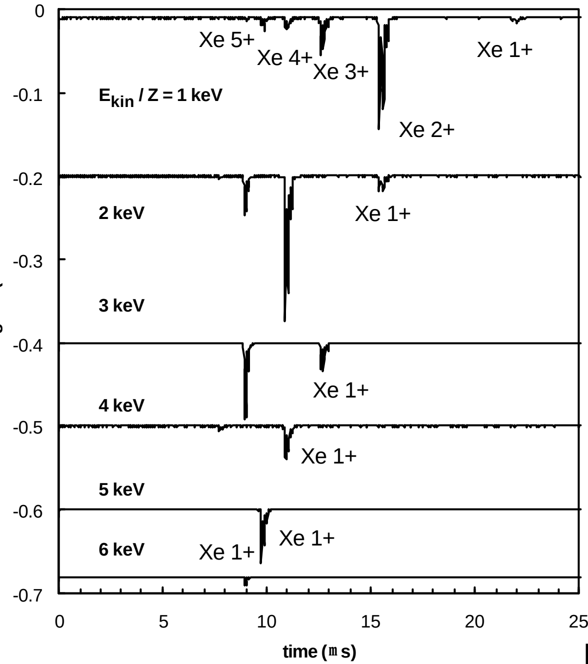


Angular distribution :6.9 %

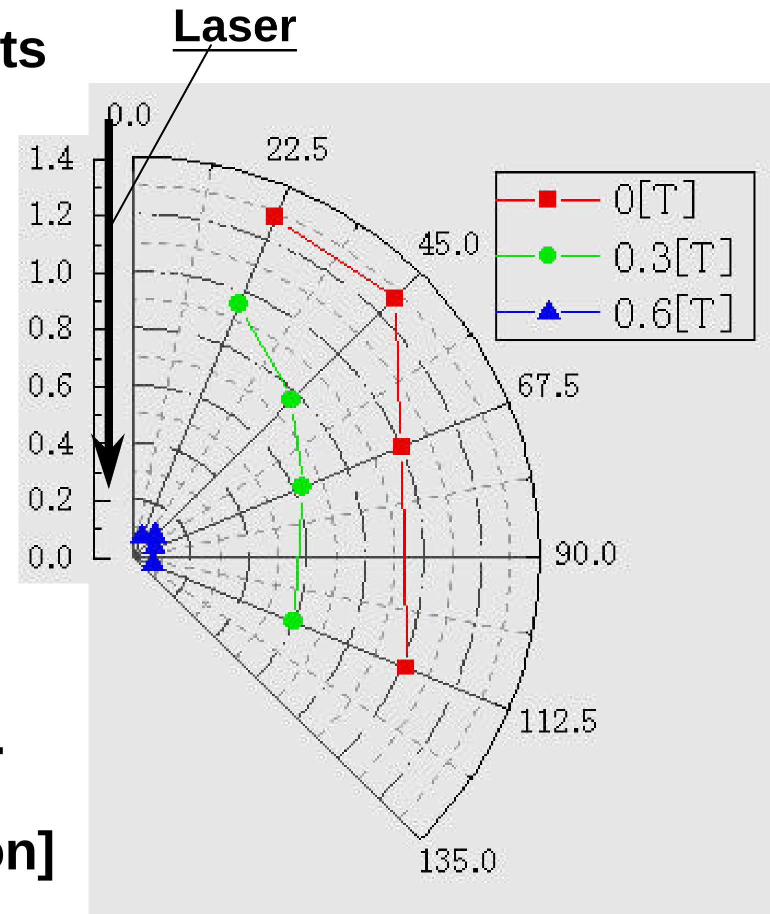
	Jun 2003	Aug 2003	Sep 2003	Nov 2003	Jun 2004	Today
In-band EUV power (2π sr)	0.6W	1.0W	2.2W	4.0W	7.2W	9.1W
EUV energy stability (1σ , 50-pulse ave.)	--	1.44%	0.72%	0.53%	1.2%	1.3%
Conversion efficiency	0.14%	0.33%	0.33%	0.44%	0.55%	0.61%
Average laser power	420W	300W	600W	900W	1300W	1500W
Repetition rate	10kHz	10kHz	10kHz	10kHz	10kHz	10kHz
Laser pulse duration	32ns	6ns	6ns	6ns	6ns	6ns

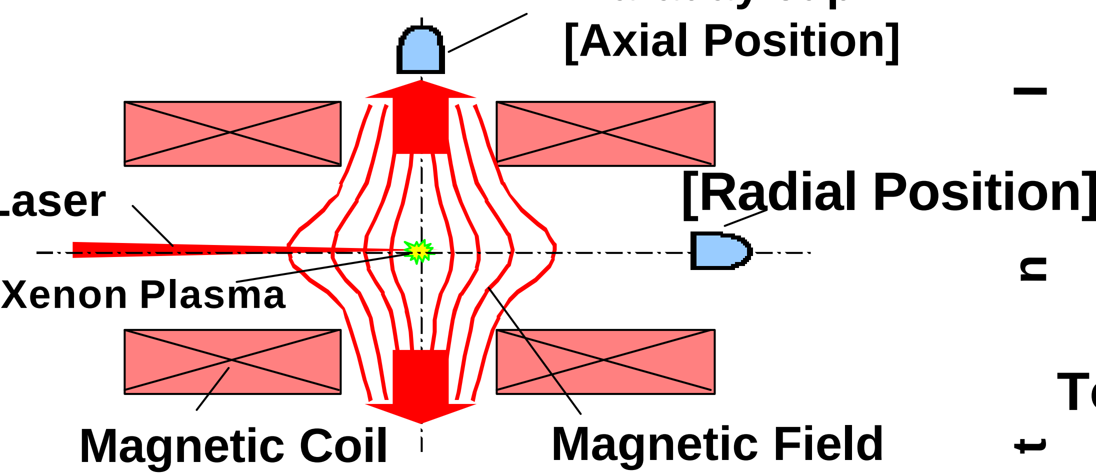


Magnetic Ion Mitigation for Xenon Plasma



TOF Measurements of fast ions from Xe laser plasma

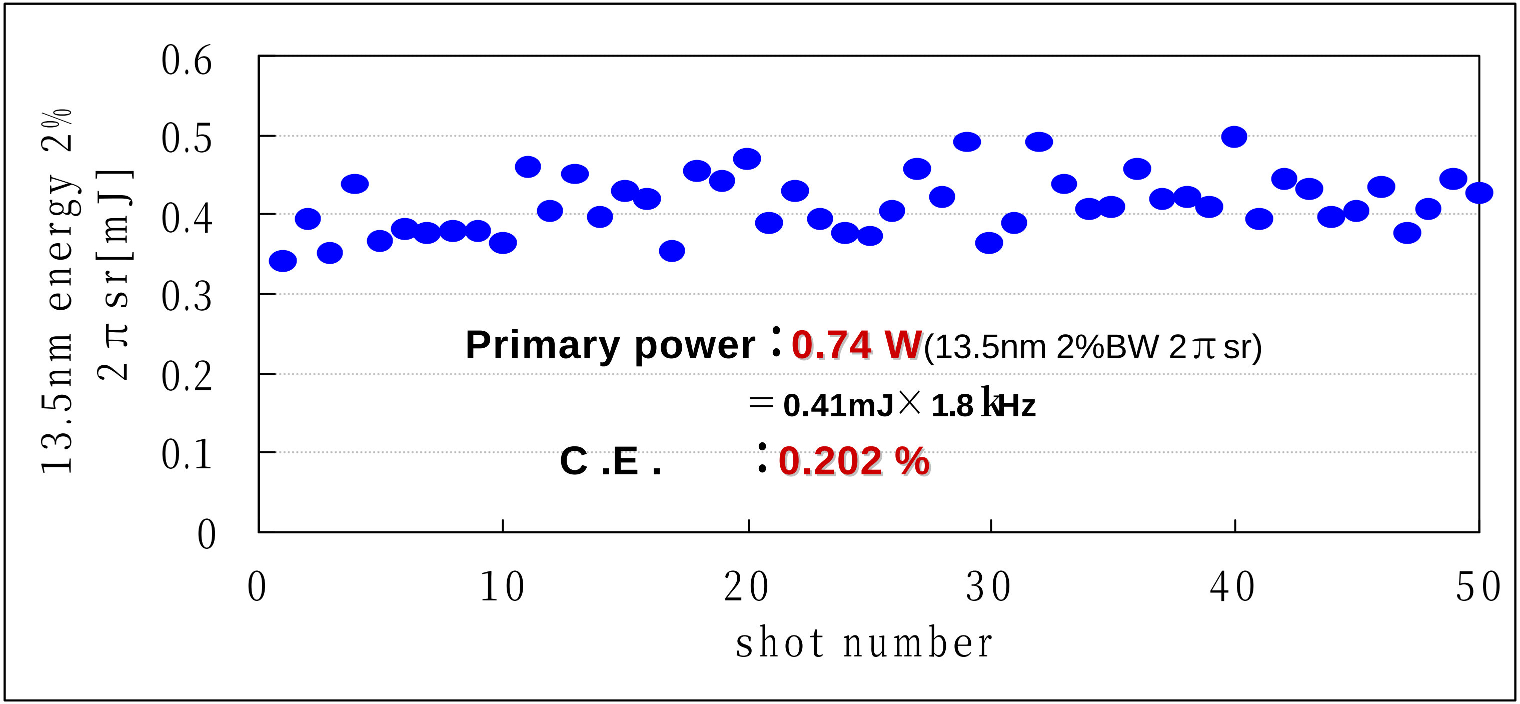




Angular dependence of Total charge of Faraday cup (Radial Position)

EUV emission with high repetition CO_2 laser

CO_2 laser power ：360W = 200mJ × 1.8 kHz



- 0.7 W is the early level of EUV power with YAG laser
  (EUV 0.6W **with** YAG 420W, 2003/6)
- **Hereafter high CE and high power by CO_2 laser development**

GDPP; 8.4 W @IF. Using total source system

Low Inductance ·7KHz Pulse Power Supply

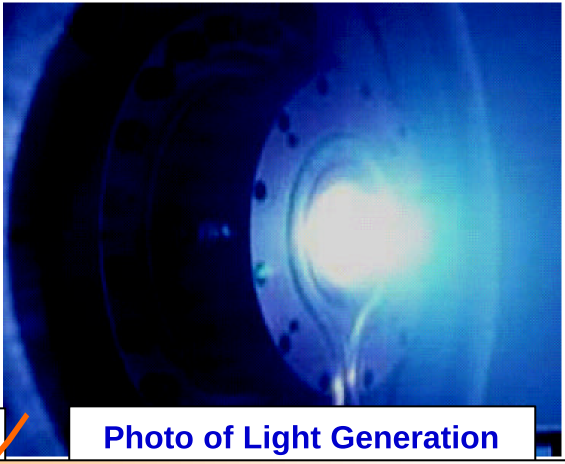
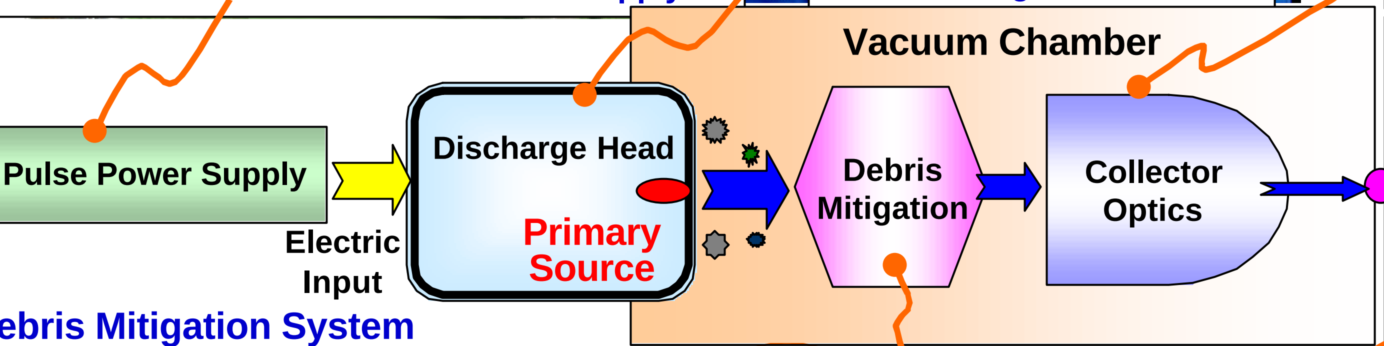
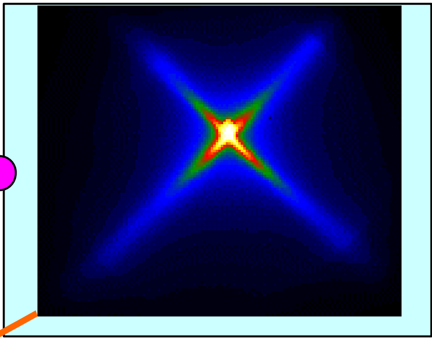


Photo of Light Generation

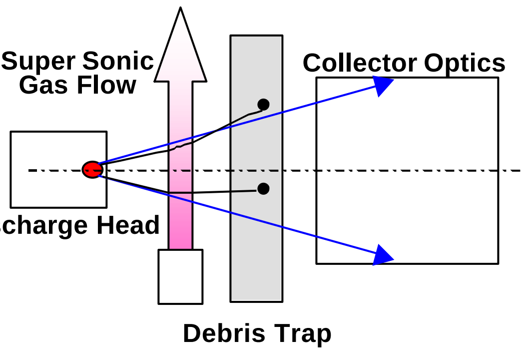
Collector Optics





EUV Light Image at I

ebris Mitigation System



Debris Mitigation System

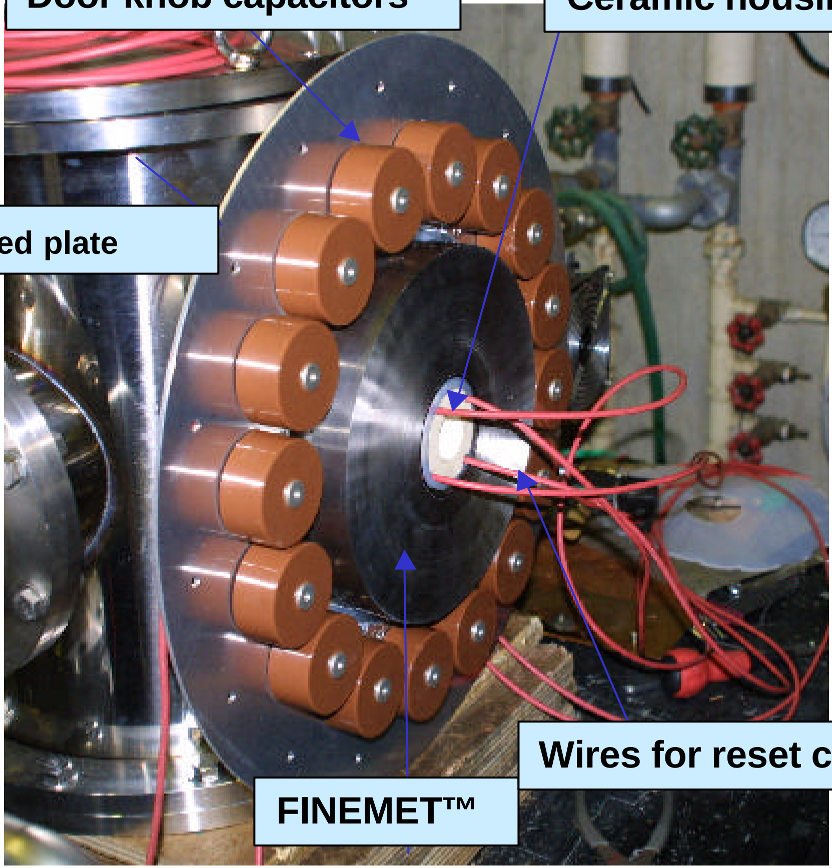
Slit for debris mitigation

Primary power: 59W

Low inductance power source

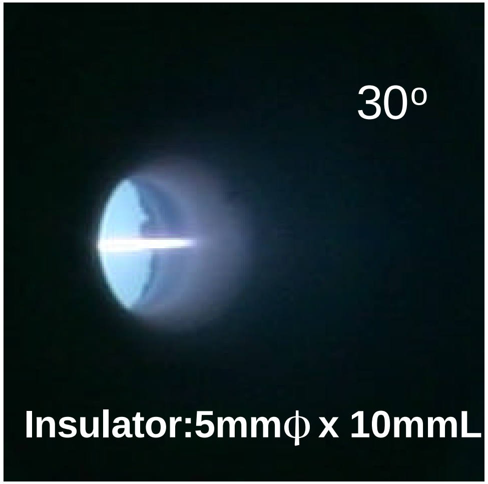
Kumamoto Univ.

Short pulse ·high current Z-Pinch Device

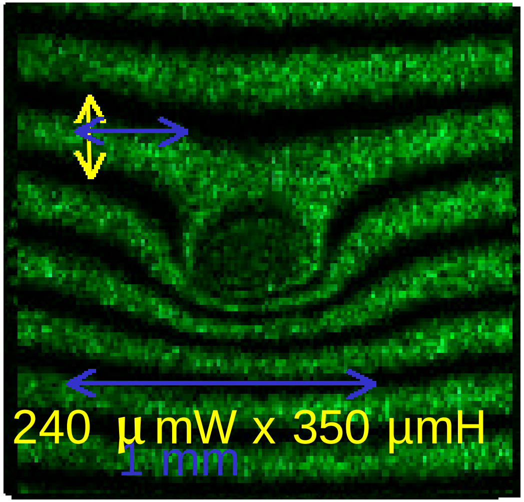


Main discharge circuit

Still photograph of pinch plasma



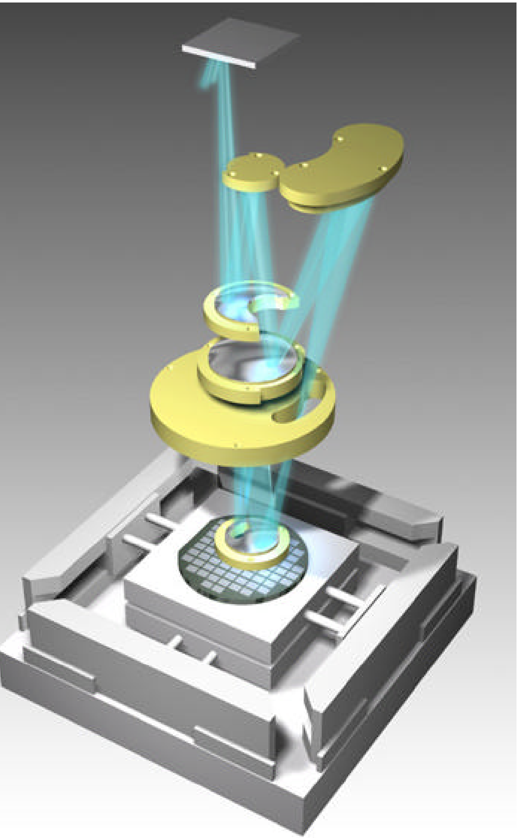
Pulse Nd-YAG laser interferometer



Peak plasma density: 10^{18}cm^{3}

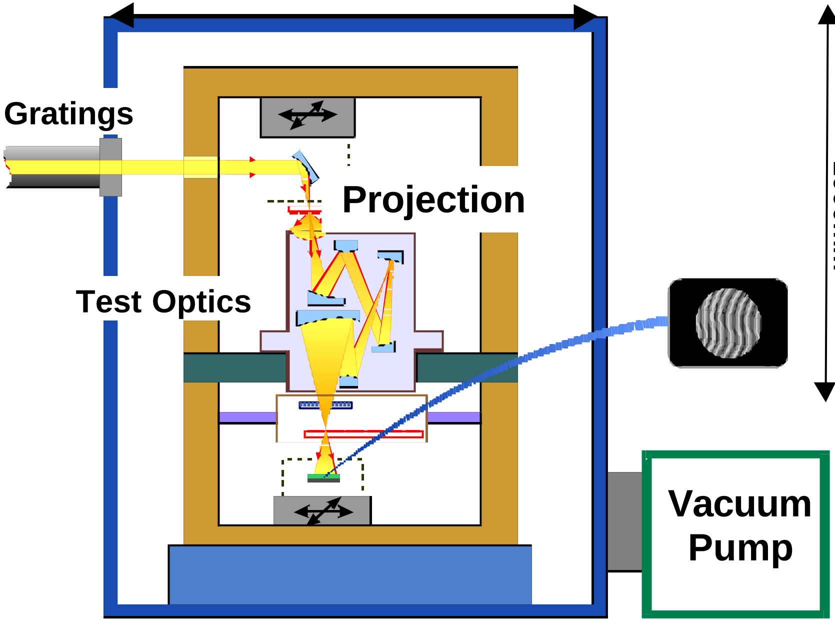
At wavelength metrology; Wave front error of optics

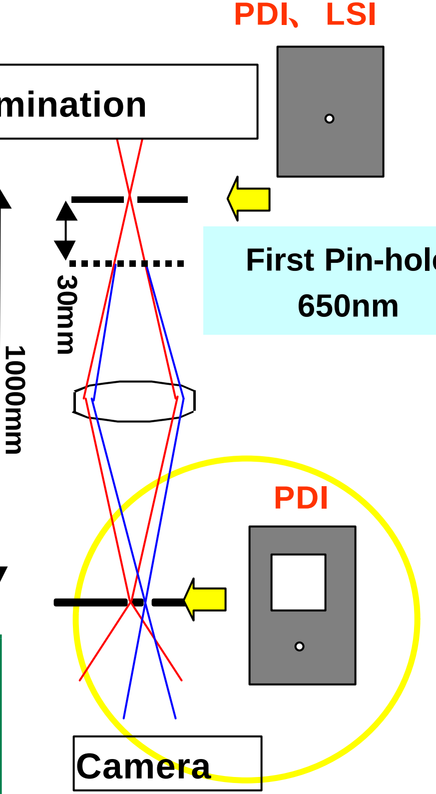
Purpose :Development of standard for WFE metrology



Schematic View of
6 Mirror System

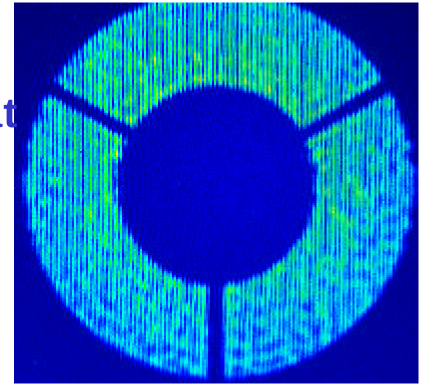
3 m in Diameter,
20 ton in Weight





Accuracy :<0.1nmRMS

The System was installed at
Hyogo Pref. Univ.



Large Window
and 2nd Pin-hole
50-80nm

Precise
Measurement
is attained by
60 nm Pin-hole.

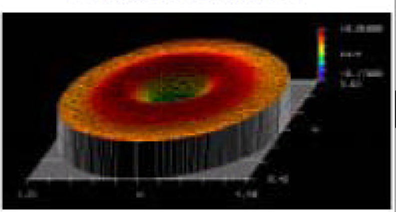
System I; Ion beam figuring systems for mirror surface

Goals： Less than 0.25nm rms for both HFSR and MFSR

① Aspherical Surface Creation at Period>30mm

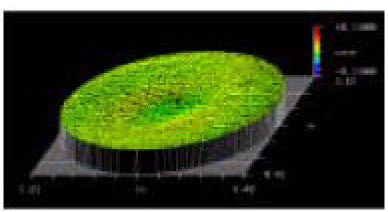
Overview of System

20.3 nmRMS



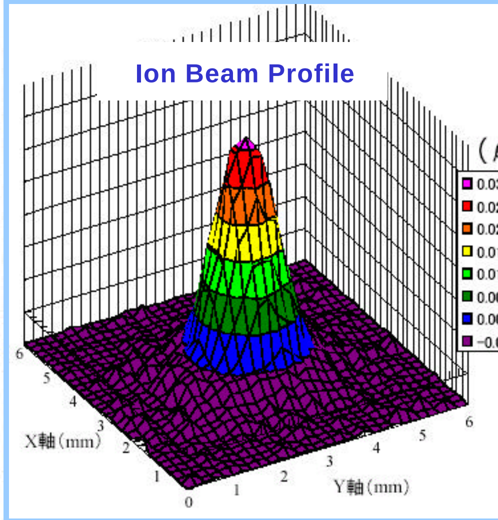
3 hours →

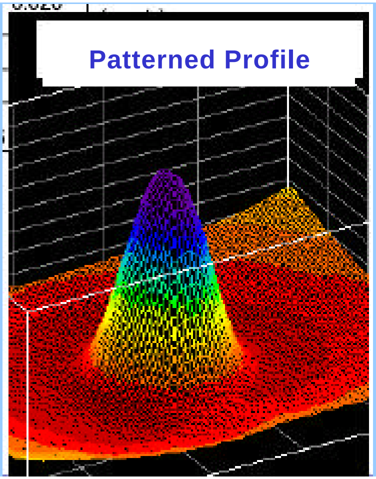
2.60 nmRMS



② Correction Polishing at Narrow Area <3mm

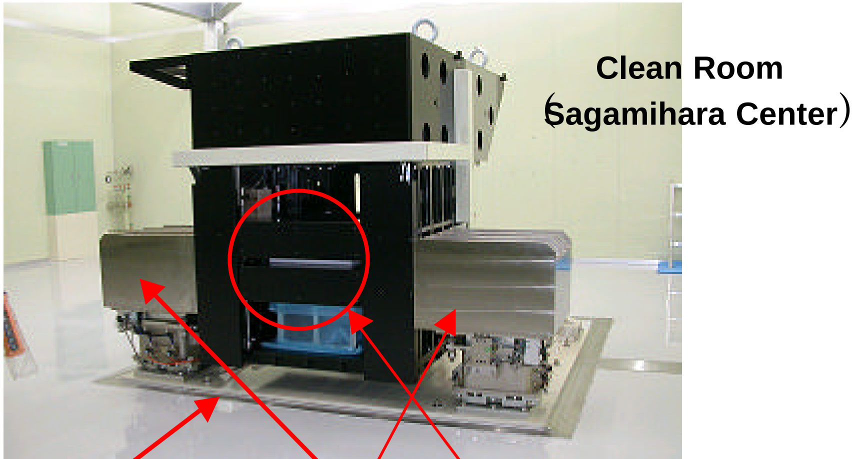
Bottom of Chamber
（IB Gun for 5KV）

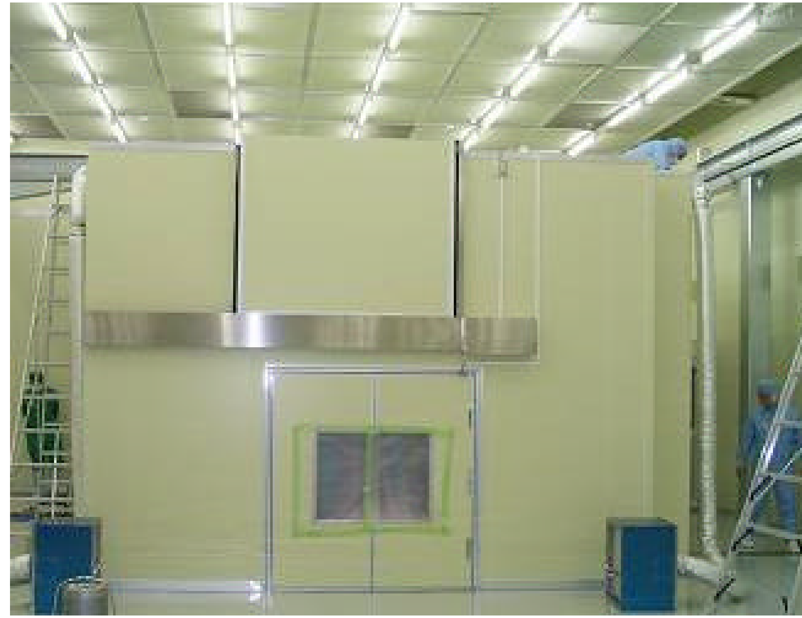




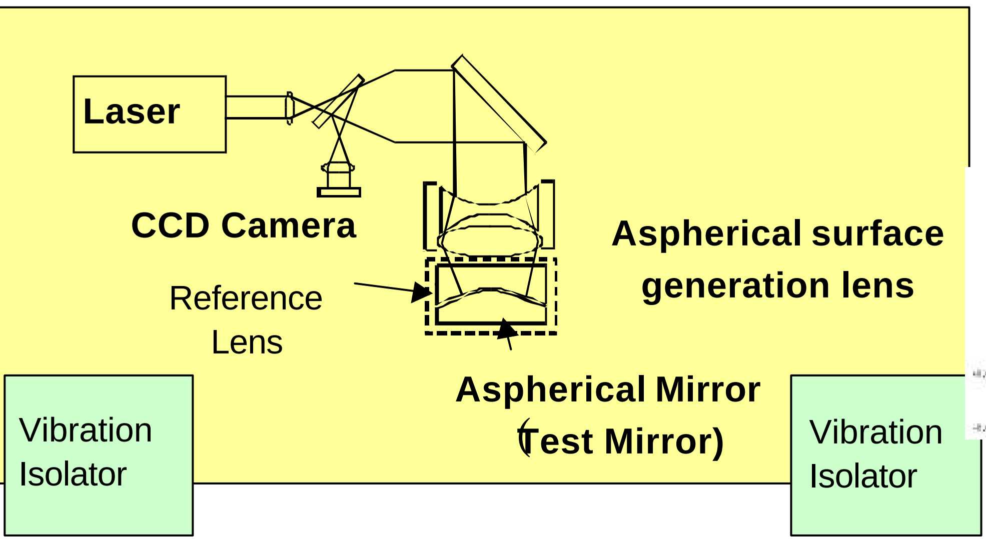
Beam Profile is coincident with Patterned Profiles

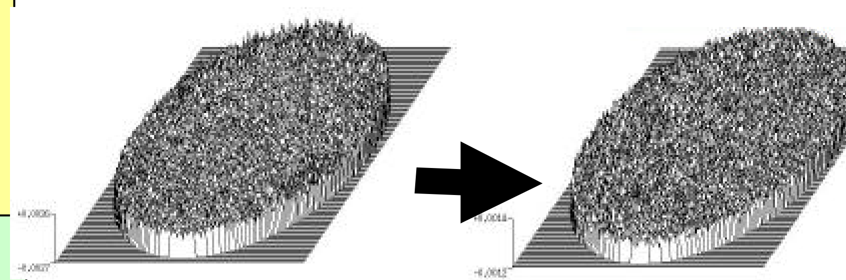
System II; Interferometer for mirror production





Thermal Chamber



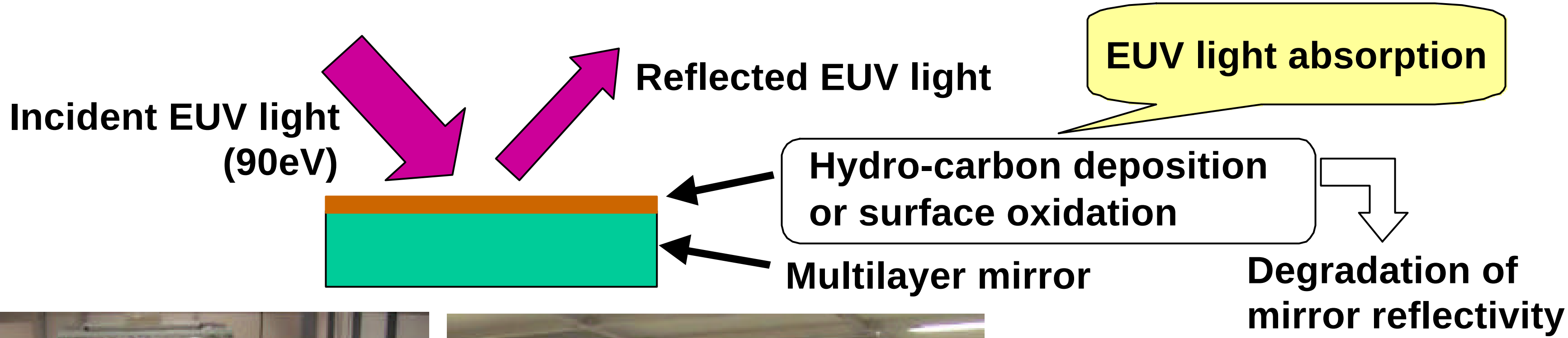


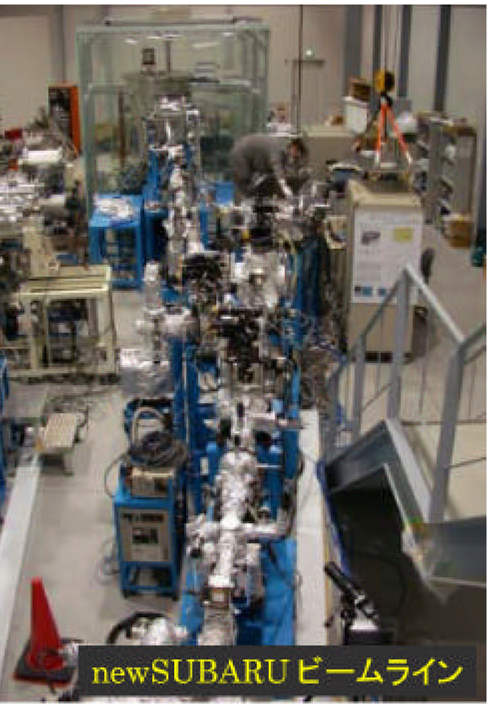
0.18nm rms → 0.13nm rms

Improved reproducibility

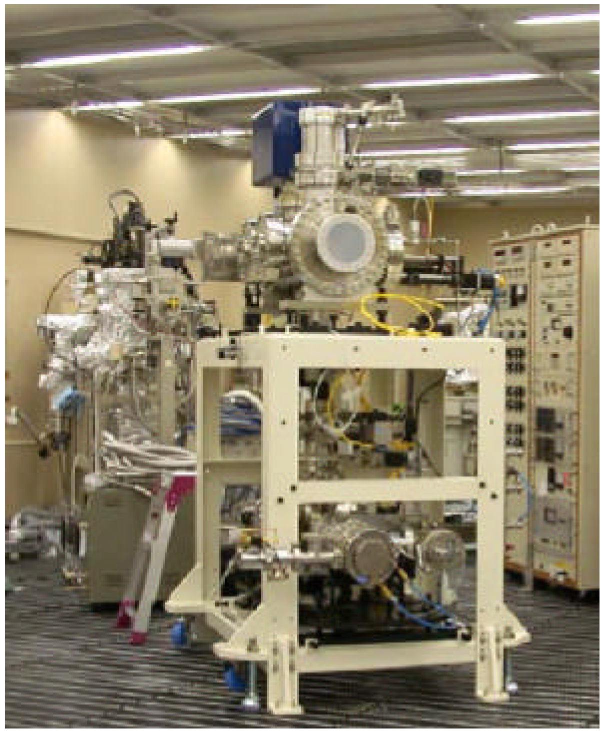
This system is fitted for upward reflection surface. The system for downward reflection surface is also needed.

System III; Study on photo induced contamination

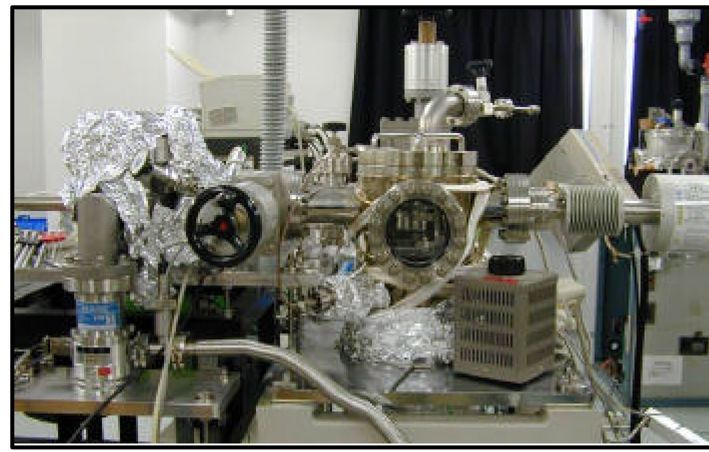




Hyogo Prefect. Univ.; Accelerated test for EUV irradiation

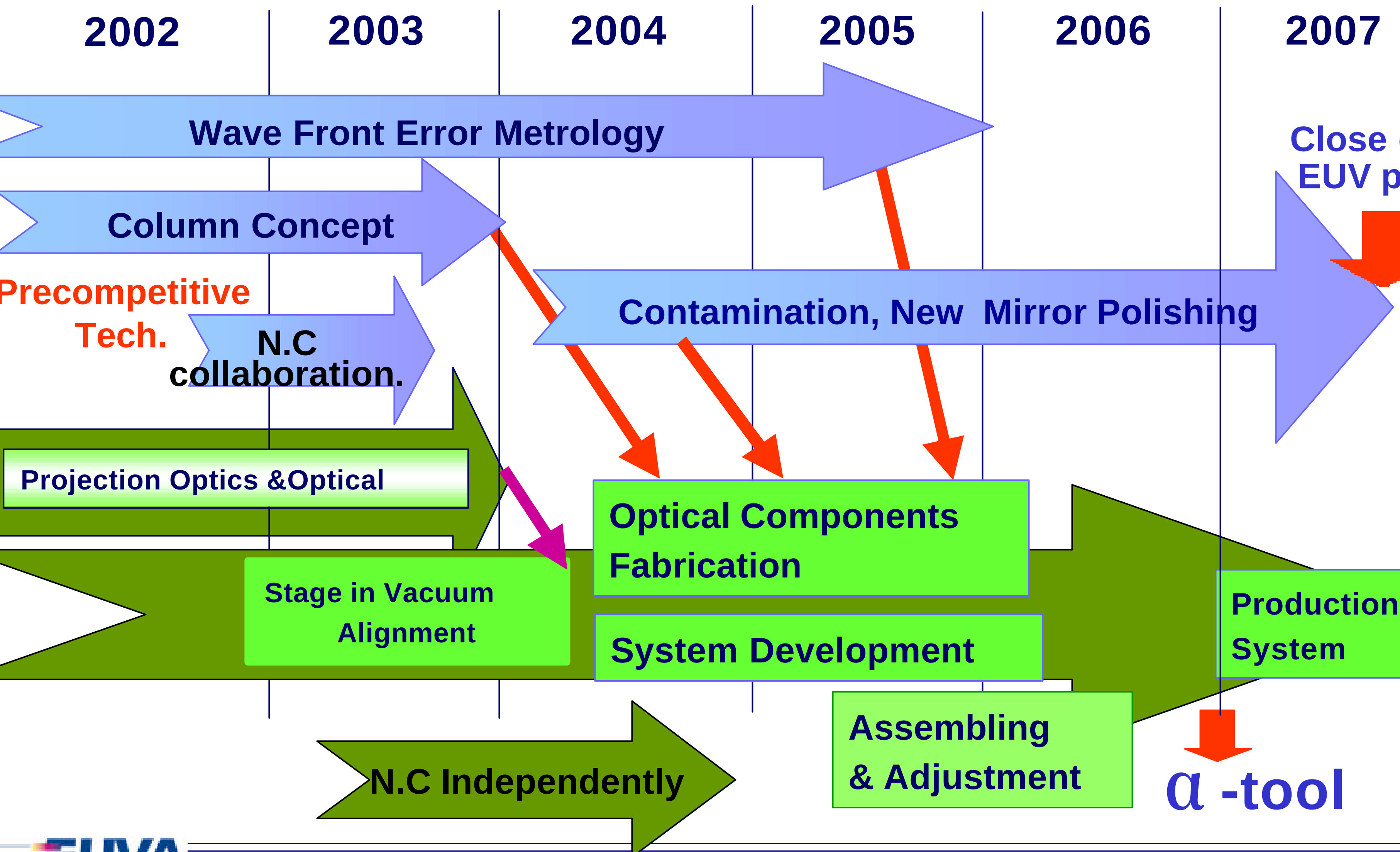


NTT Atsugi BL; Analysis of deposited materials



NTT Atsugi BL; Surface cleaning

Nikon & Canon EUV Exposure Tool Development



EUVA

Conclusion

- Our a tool with more than 10W source will be introduced to the new facility of semiconductor R&D center in Tsukuba at the end of 2006.
- To advance semiconductor technologies less than 45 nm node, we are now constructing infrastructures of process, materials and metrology besides the tool.
- Our light source project is still 1-1.5 years behind, but we will achieve practical 115W light source by 2009 under close collaboration of EUVA and LP.
- We have to develop the EUVL system by focusing on lower cost.