P-EE-02

The initial performance data of a LPP-source equipped High Power EUV Irradiation Tool (:HPEUV)

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Outline

- **Introduction**
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- **Design Concept and Configuration**
  - Design Concept
  - Parameters and Functions of “HPEUV”
- **Initial Performance Results**
  - Intensity on a wafer
  - Outgas pressure characteristics
  - Temperature Monitoring
- **Summary**

Introduction

Many researchers working for EUVL have made experiments with the sources as follows;

Current sources for experiments;

1) DPP light (Pulse-mode, Low intensity)
2) SOR light (CW-mode, Low or Middle intensity)
3) EB

But, HVM scanner irradiates objects(;resists, masks and pellicles) with a LPP source whose IF power is higher than 250W.
The average intensity on the object is estimated at 1,000mW/cm^2 or more, and the pulse intensity is much higher than that.

In this high intensity region, there is a possibility that characteristics of objects are different from ones in low intensity region.

We need a LPP-source equipped exposure tool, and need to check the above mentioned possibility.

Design Concept

The following items are possible to do.

- **To Emulate real HVM EUV scanners**
  → High intensity, Pulse-mode, Fast wafer exchange
    → LPP-source, Wafer/Mask auto-loader

- **To Monitor basic parameters**
  → Temperature(Wafer/Mask/WS), Outgas
    → IR-camera, TC, QMS

- **To Compare with conventional outgas experiments**
  → Variable intensity, EB-available, Selectable WS position
    → Attenuator, EB-gun, WS1/WS2

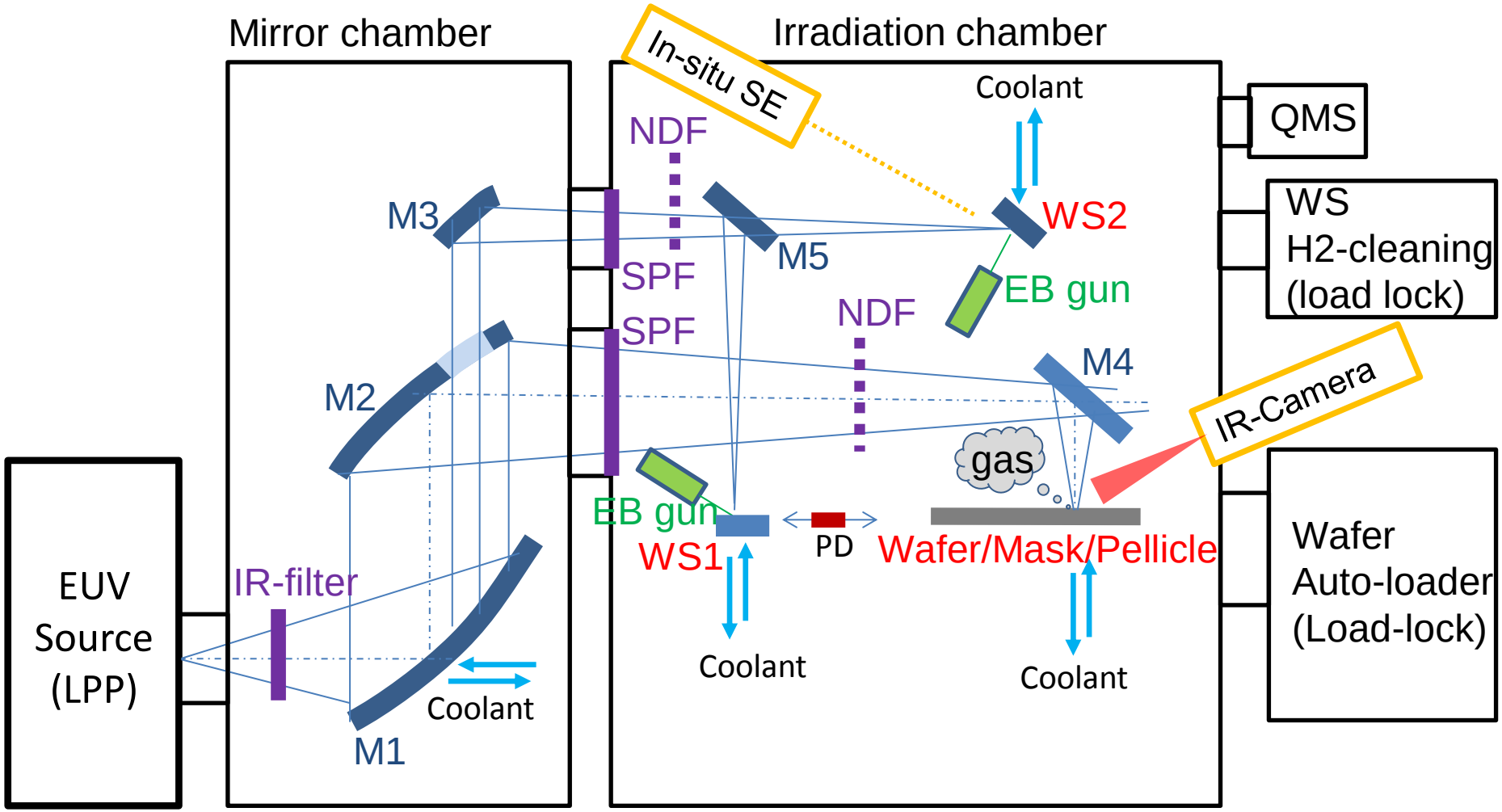
Basic Configuration(1/2)

- Source : EUV LPP source
- Optics :
  a. Two optical axis for WS and Wafer/Mask
  b. Three mirrors for each axis
     (;Collimate/Condense/Turndown)
  c. Field is 3.5mm x 3.5mm
  d. IR-filter
  e. SPF and Attenuator for each axis

- Monitor : IR-camera, TC, QMS, SE
- Wafer/Mask Loading and Stage :
  a. 25-wafers auto loading
  b. Wafer pre-alignment
  c. Wafer-shaped mask-holder
  d. R-Θ stage

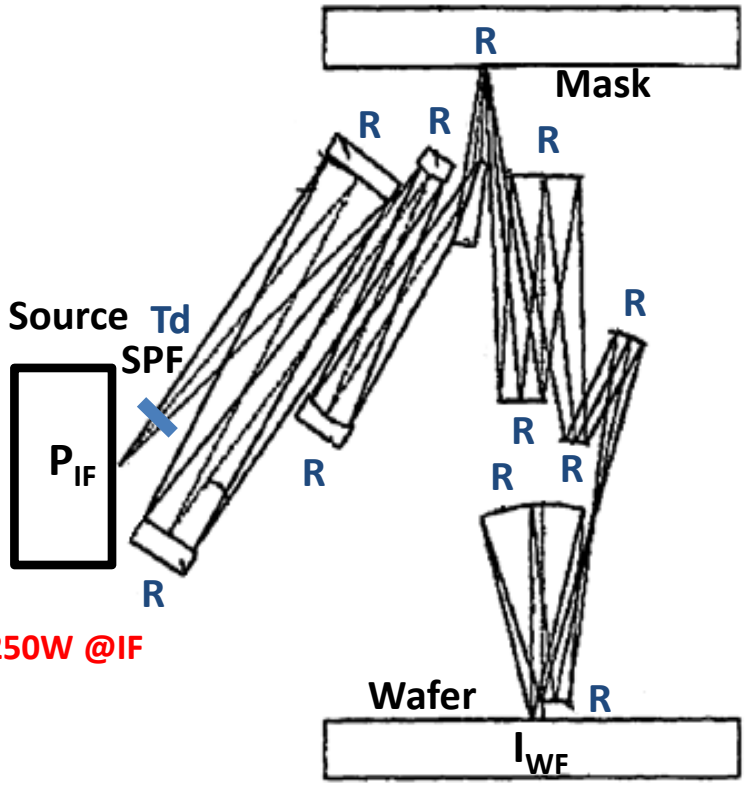
Basic Configuration(2/2)

SPF = Spectral Purity Filter
SE = Spectroscopic Ellipsometer
NDF = Neutral Density Filter
WS = Witness Sample



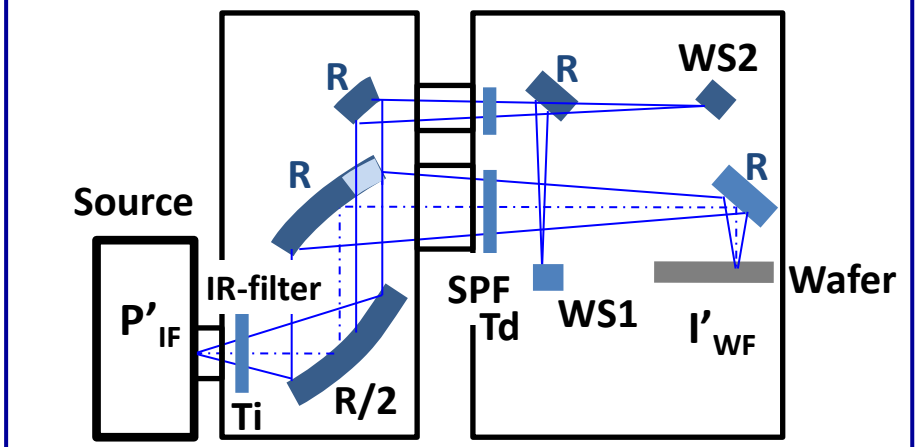
Desired Source Power for HPEUV

Scanner



$P_{IF} \times R^{11} \times Td / S = I_{WF}$

HPEUV



$P'_{IF} \times R^3 / 2 \times Ti \times Td / S' = I'_{WF}$

S,S' : Field, Ti, Td : Filter Transmittance

$I'_{WF} = I_{WF}$

$P'_{IF} \times R^3 / 2 \times Ti \times Td / S' = P_{IF} \times R^{11} \times Td / S$

$P'_{IF} = P_{IF} \times R^8 \times 2 / S / Ti \times S'$

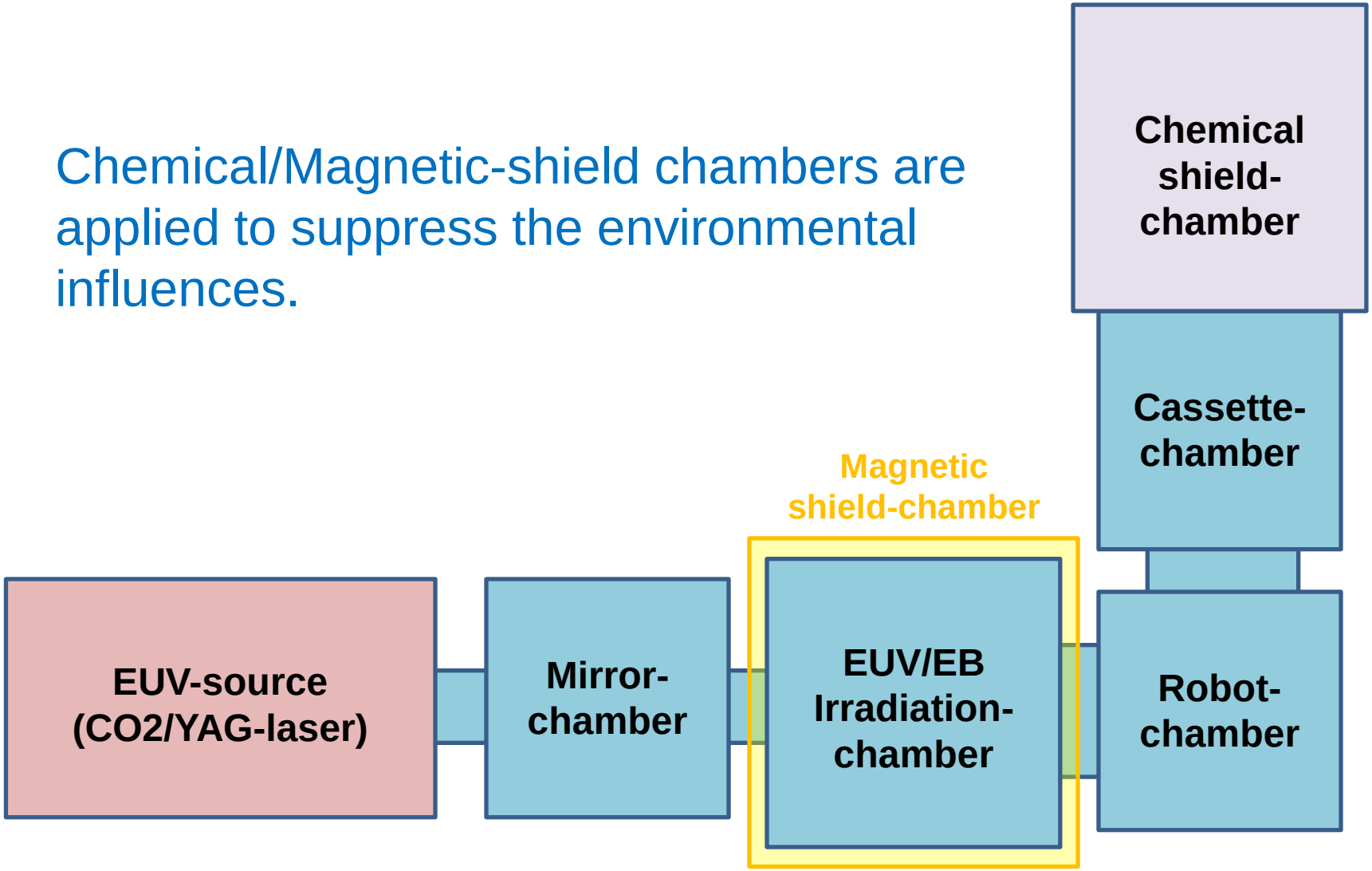
$P'_{IF} = P_{IF} \times 0.7\text{^}8 \times 2 / 52 / 0.7 \times 12$

$P'_{IF} = P_{IF} \times 0.04 = 250 \times 0.04 = 10$

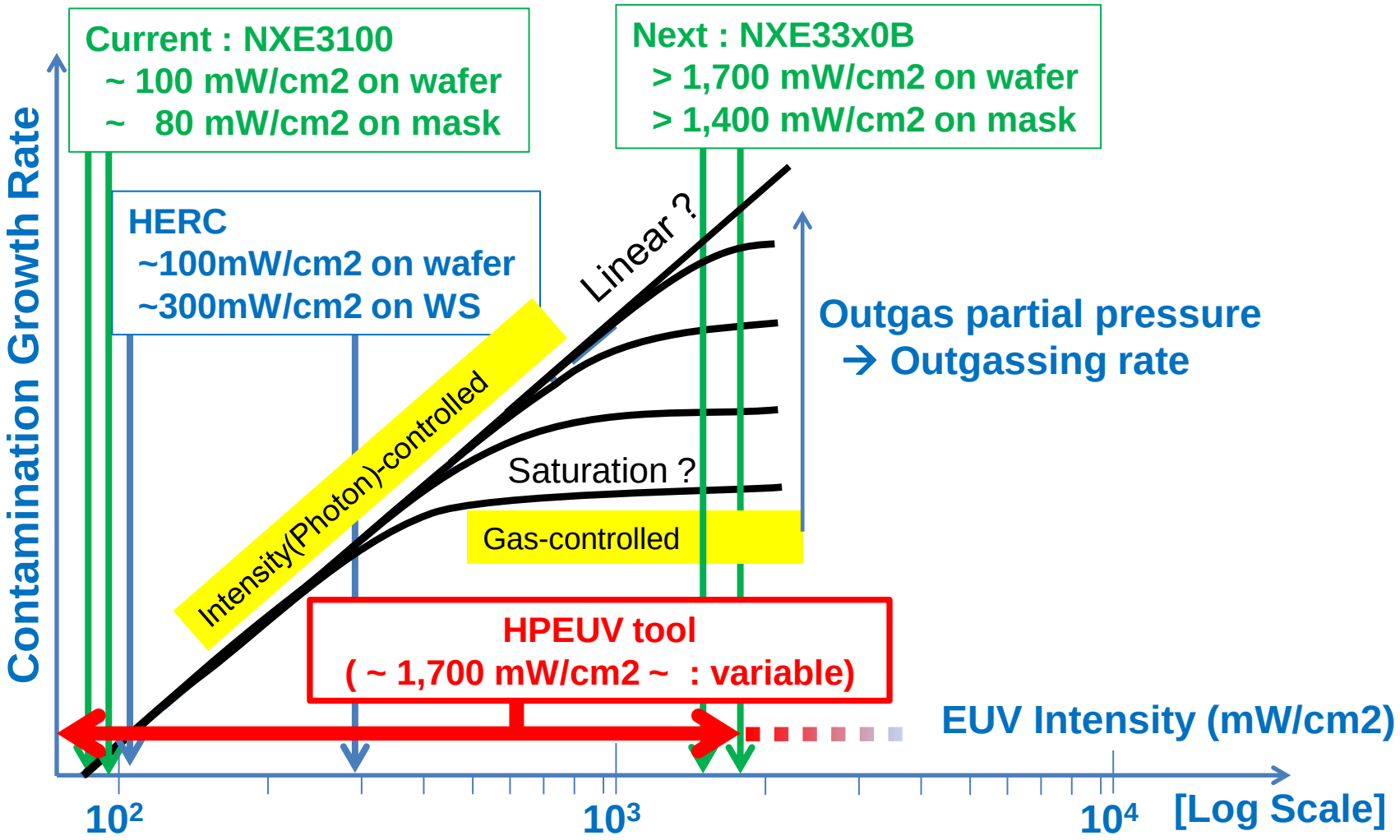
- A 10W source is sufficient for HPEUV to emulate a HVM scanner equipped with a 250W source.

Layout of HPEUV

Chemical/Magnetic-shield chambers are applied to suppress the environmental influences.



Scope of HPEUV : Intensity Viewpoint



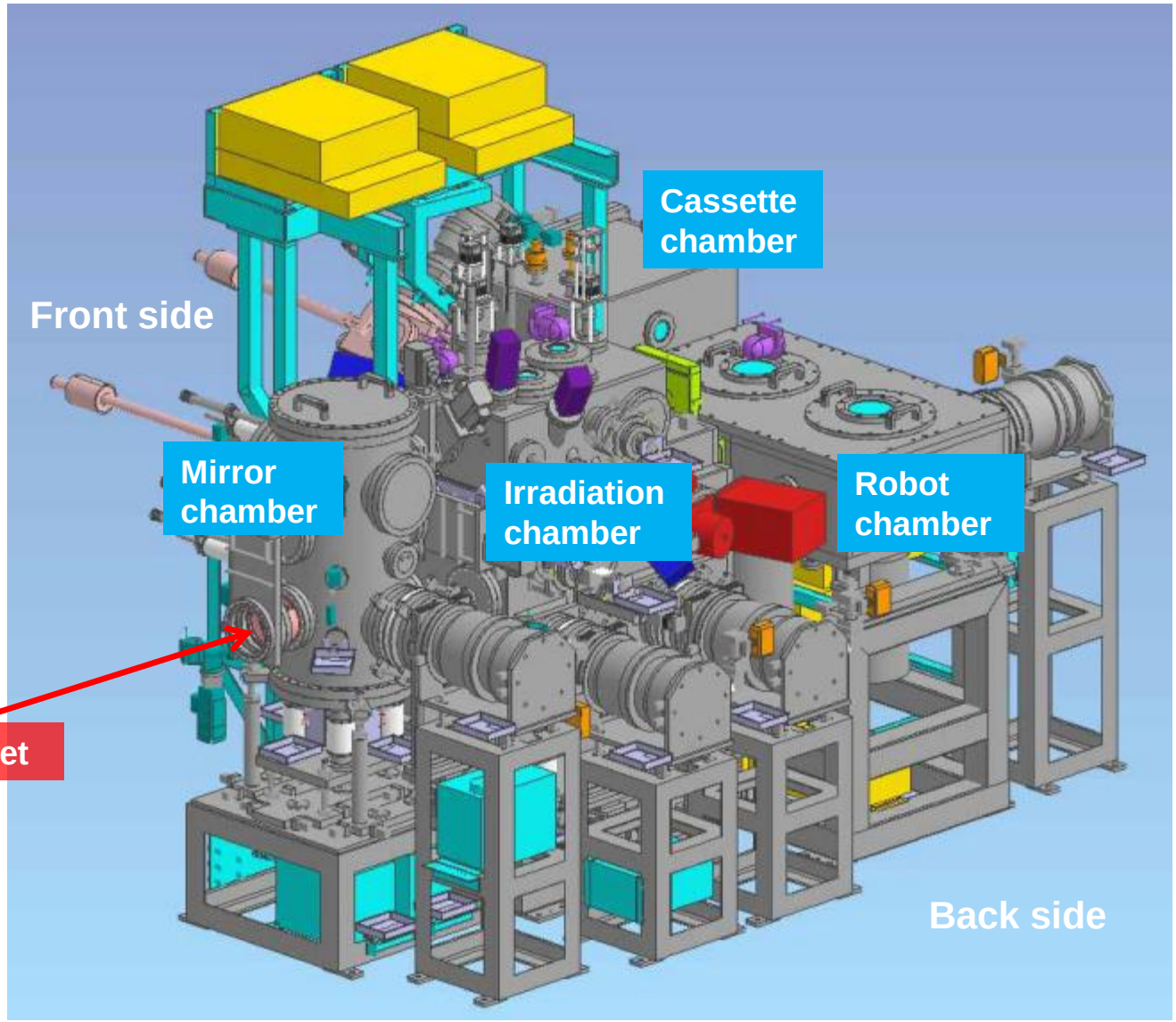
Specifications

Items	Specifications	Remarks
Wafer & WS Intensity	1,700 mW/cm2 <	Variable
IF Power	10 W (in-band) <	Dirty power
Pulse rate	20kHz~50 kHz	100 kHz is a trying target
Vacuum	2.0e-6 Pa >	Variable valve equipped
Hydrocarbon	Mw 45~100 : 1.0e-8 Pa > Mw 101~200 : 5.0e-9 Pa >	Same as EUVOM
Wafer / WS water cooling	23±1 degree C (at pedestal stage)	(Wafer/WS) / Holder / Pedestal
Field size	Wafer : 3.5mm x 3.5mm < Witness sample : 2.1 mmΦ	
Exposure Area (on wafer)	90% (target=95%) <	
CG Total Test Time	5 hours / 25 wafers >	Auto loader (load lock)
Wafer exchange time	5 min./wafer >	
D2C Repeatability	±6% >	

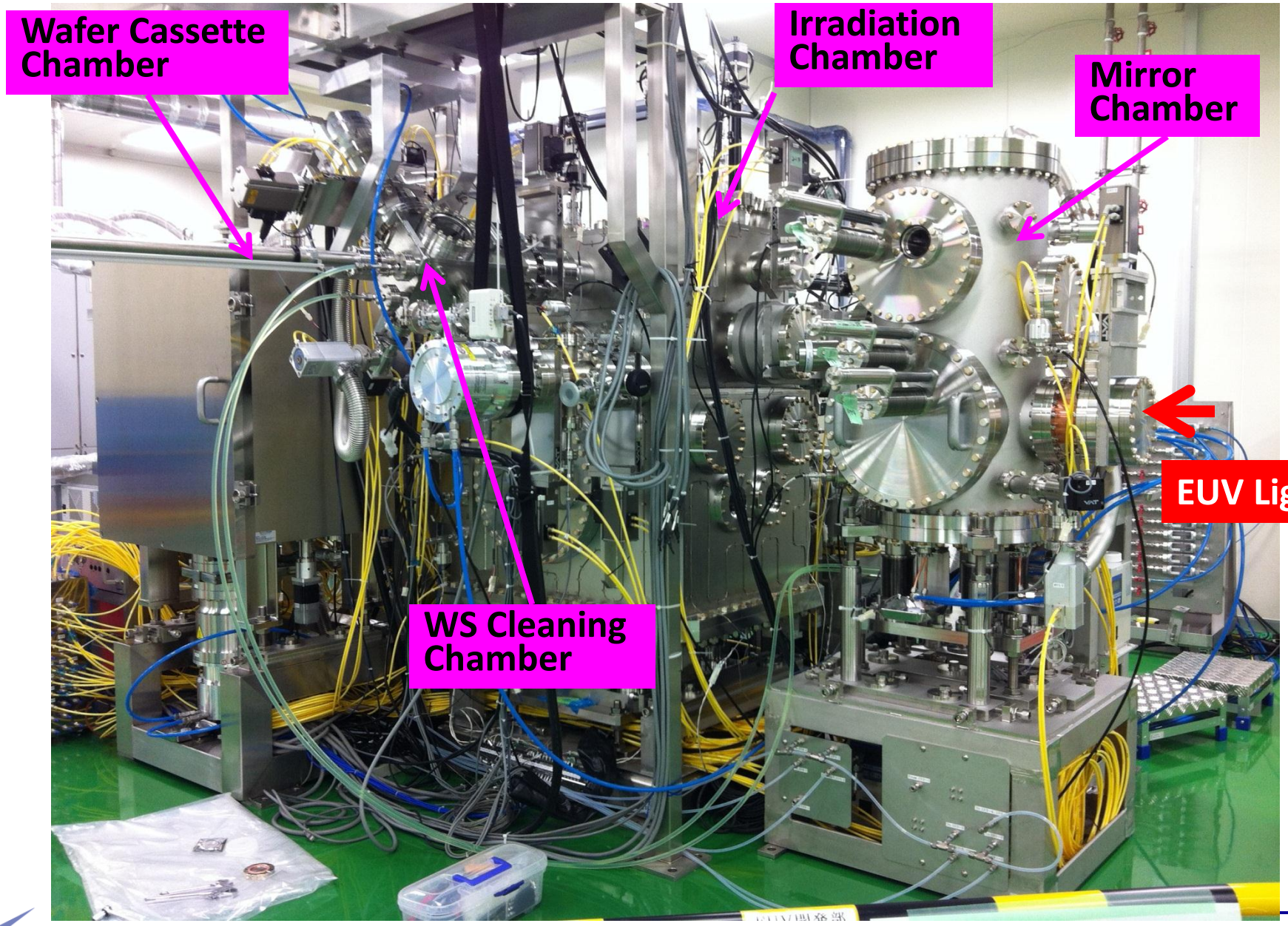
Other Characteristics of HPEUV

- **More Intensity :**
  HPEUV can move the M4 mirror along the optical axis, then it can make the focus-point near to the wafer plane.
  By increasing pulse rate (20→50kHz) and moving M4 mirror, HPEUV can enhance the intensity.
- **Optics Cleaning :**
  HPEUV has H-cleaners in front of each mirrors in the mirror chamber.
- **Spiral Exposure :**
  HPEUV can expose a wafer in spiral mode, which make it possible to expose a wafer in one minute.
  "Step and static exposure" and "Step and Rotational exposure" are, of course, available.
- **2D profiler :**
  A pin-hole sensor is located on a X/Y sensor-stage.
- **Chamber baking :**
  Heater lines are applied to the chamber walls excluding gate-valves. (~200 degree C)

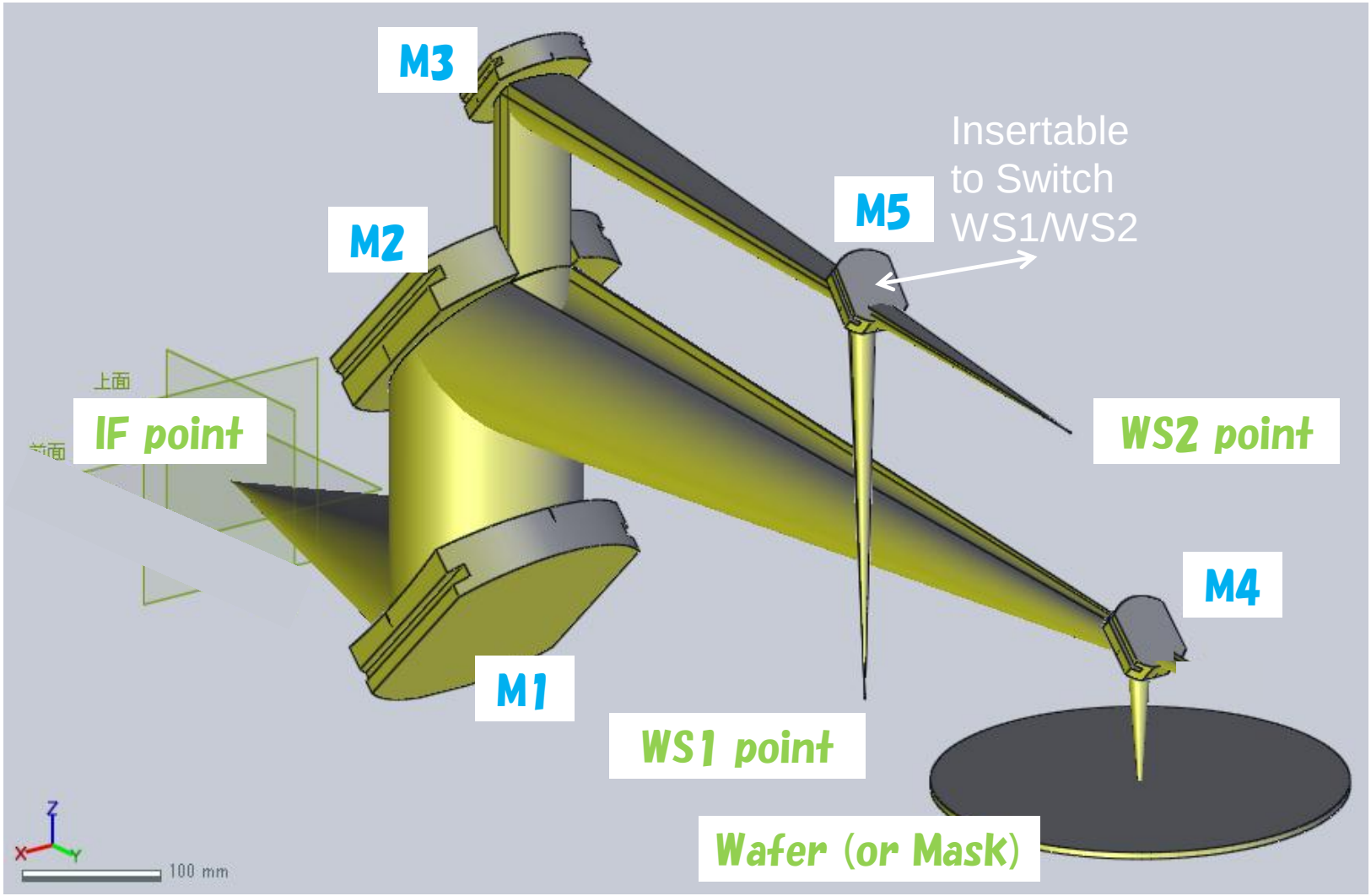
Bird's Eye CAD picture



Front View of HPEUV

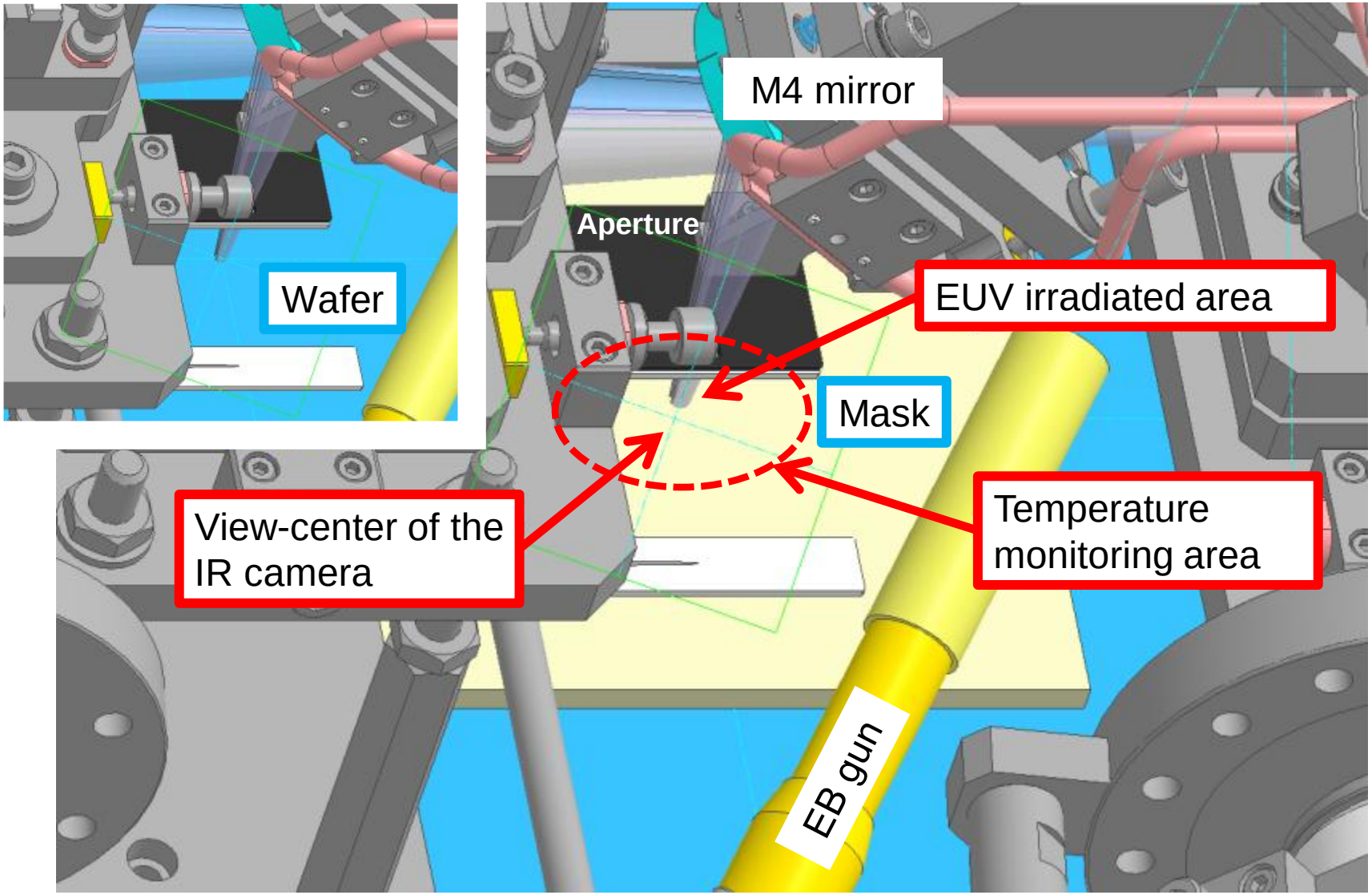


Optics

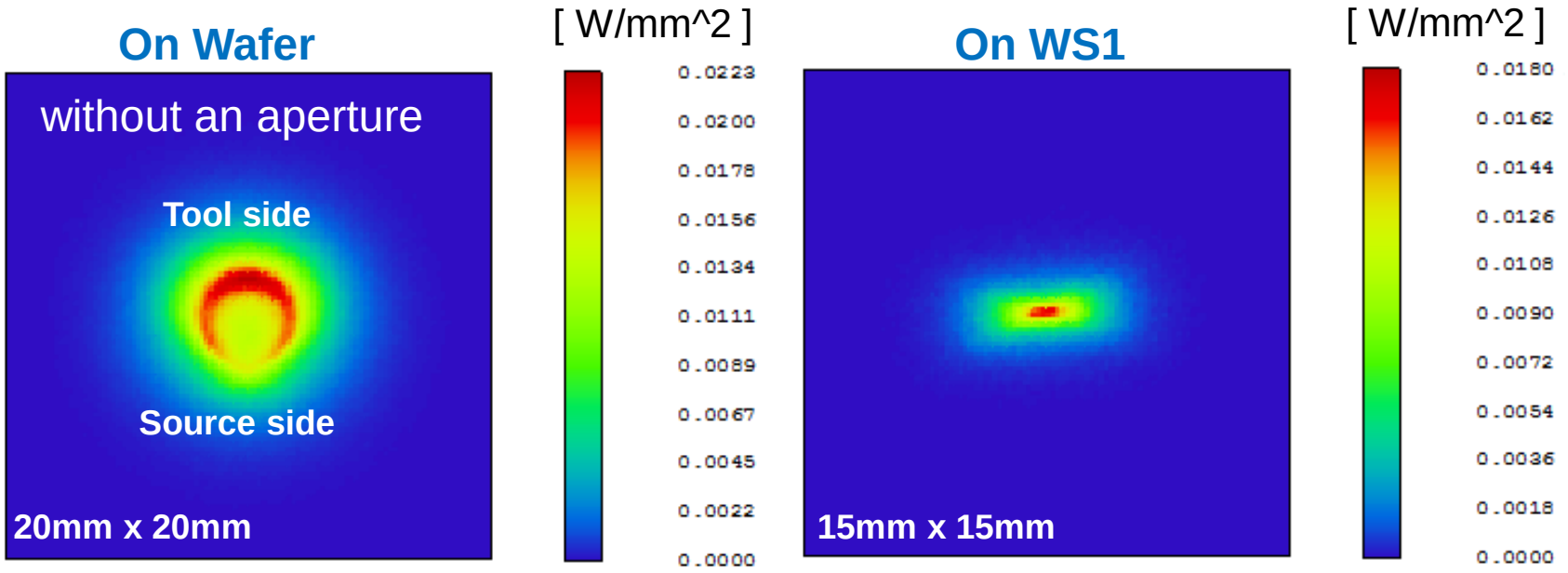

M3
M2
M5
Insertable
to Switch
WS1/WS2
IF point
WS2 point
M4
M1
WS1 point
Wafer (or Mask)
100 mm

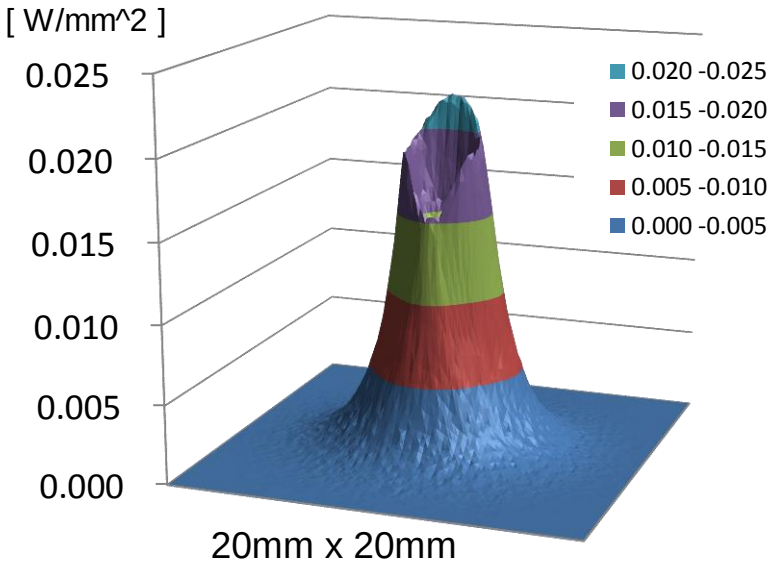
View from the IR-Camera

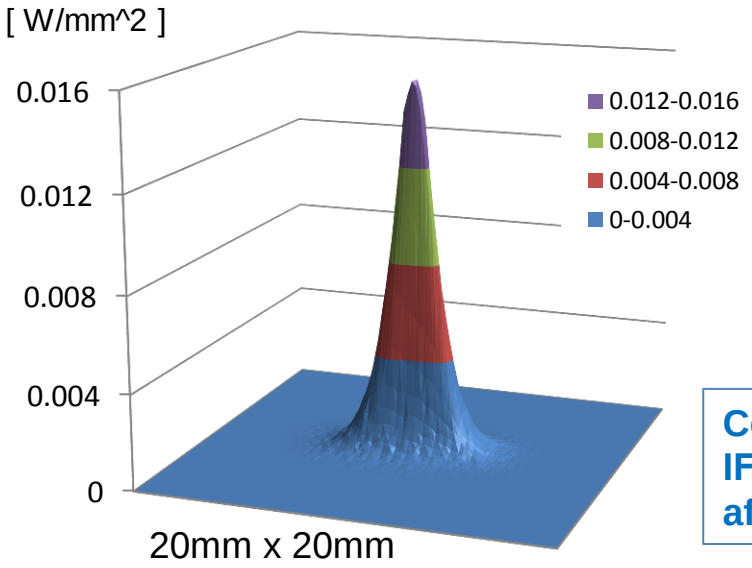
Mirror Chamber side ← Intra Irradiation Chamber → Robot Chamber side



Intensity profiles (Simulation)







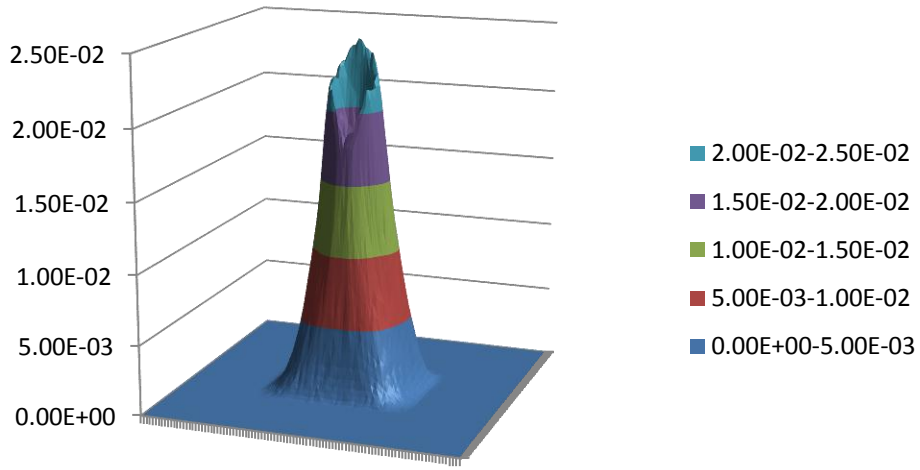
Condition :
IF = 4W/2πsr
after filtering

M4 shift effect on Intensity(1/2): Simulation

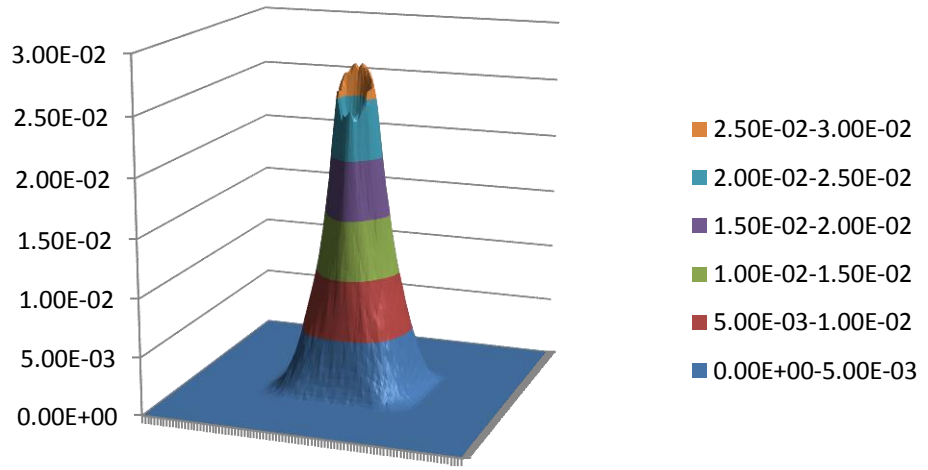
With A3 aperture

Units = W/mm^2

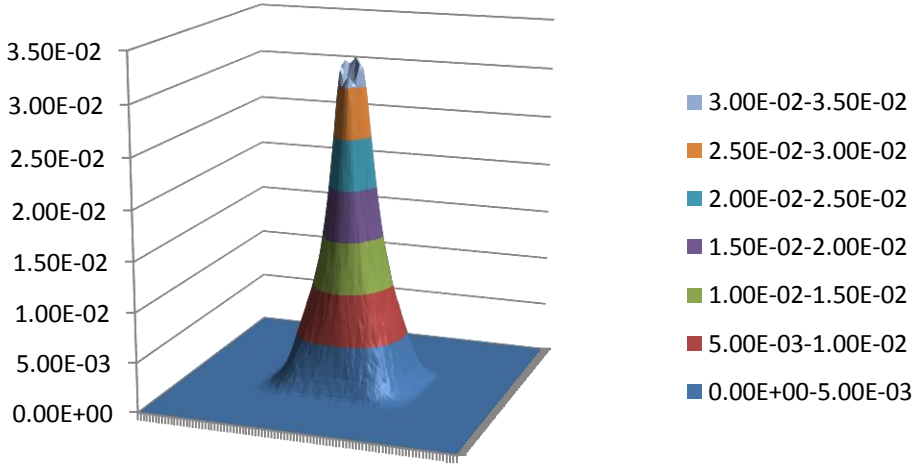
M4: +5mm



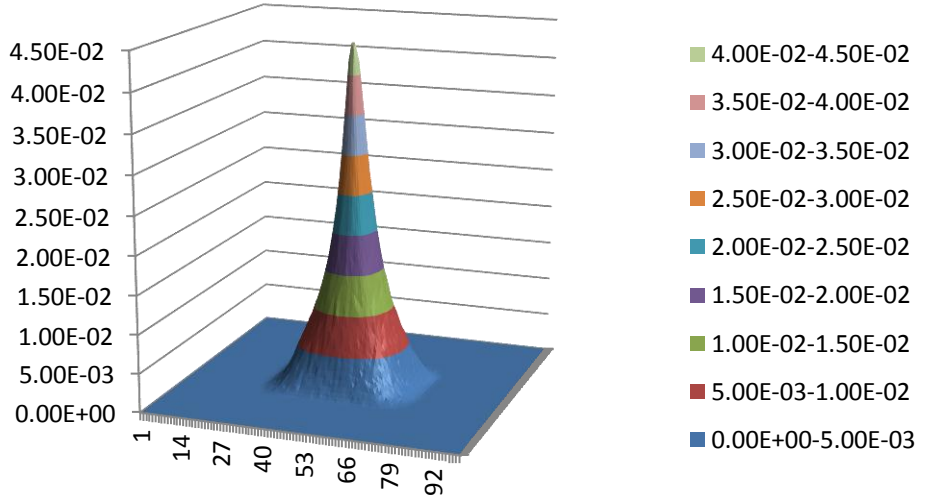
M4: +10mm



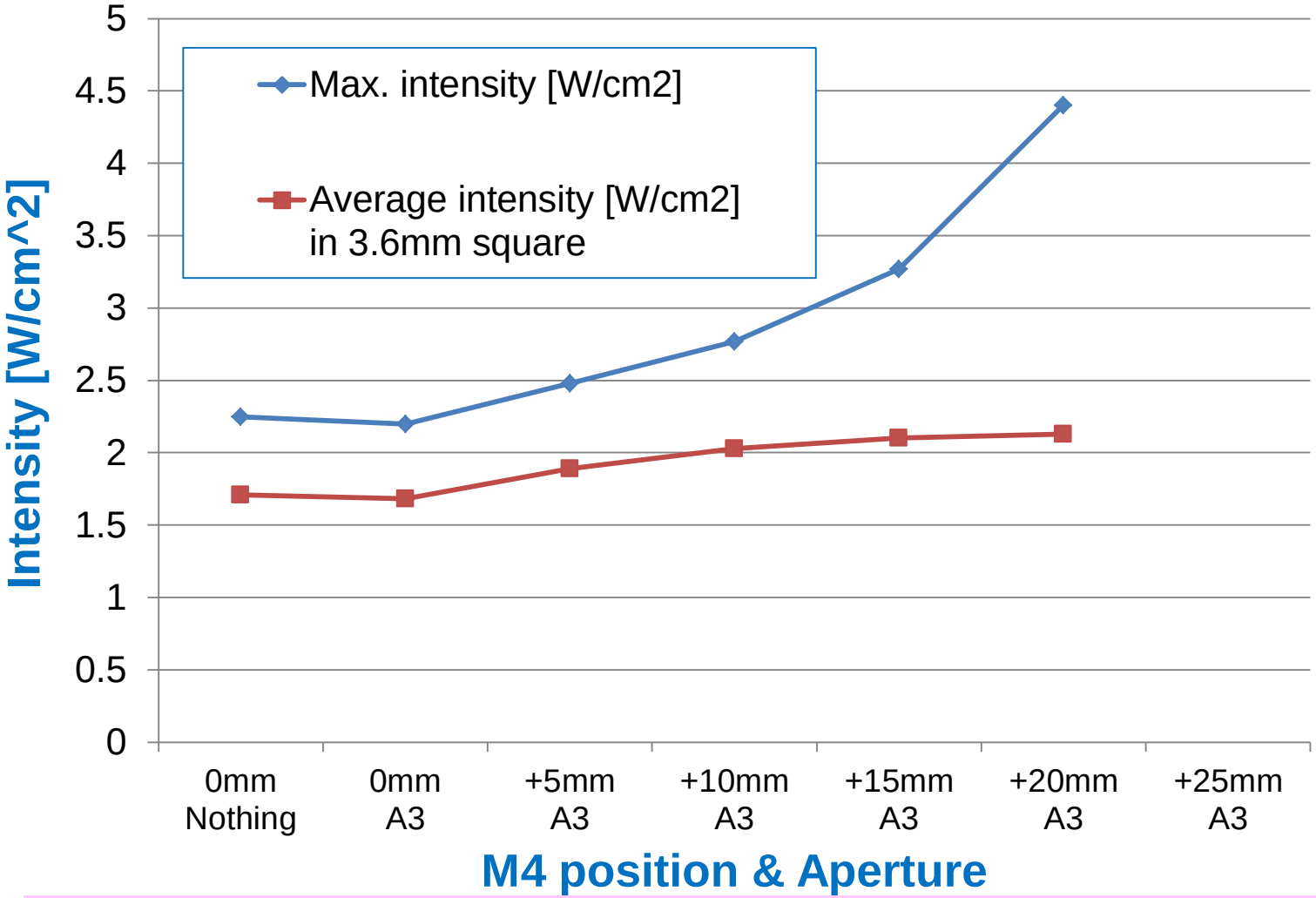
M4: +15mm



M4: +20mm



M4 shift effect on Intensity(2/2): Simulation



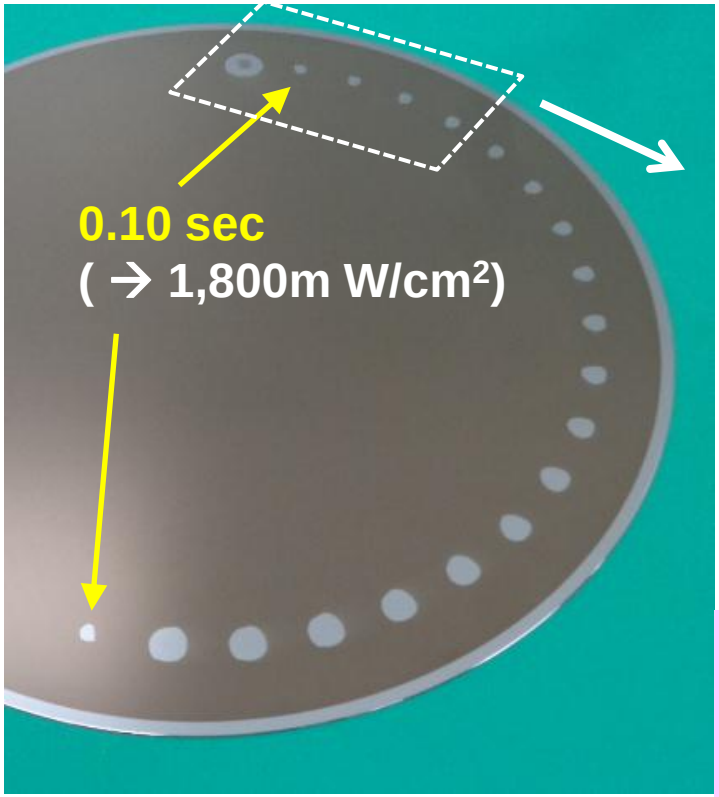
- By changing the M4 position, the peak intensity was increased by a factor of two.

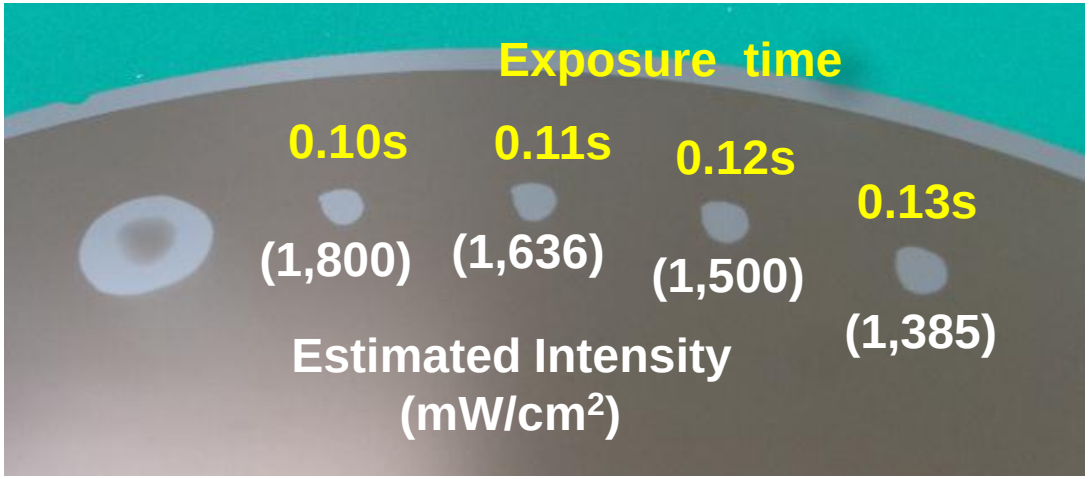
Intensity (Measurement)

Wafer intensity was confirmed with using the resist of which sensitivity is 4.5mJ/cm^2.

EUV pulse rate = 50kHz
NDF = 2.5%

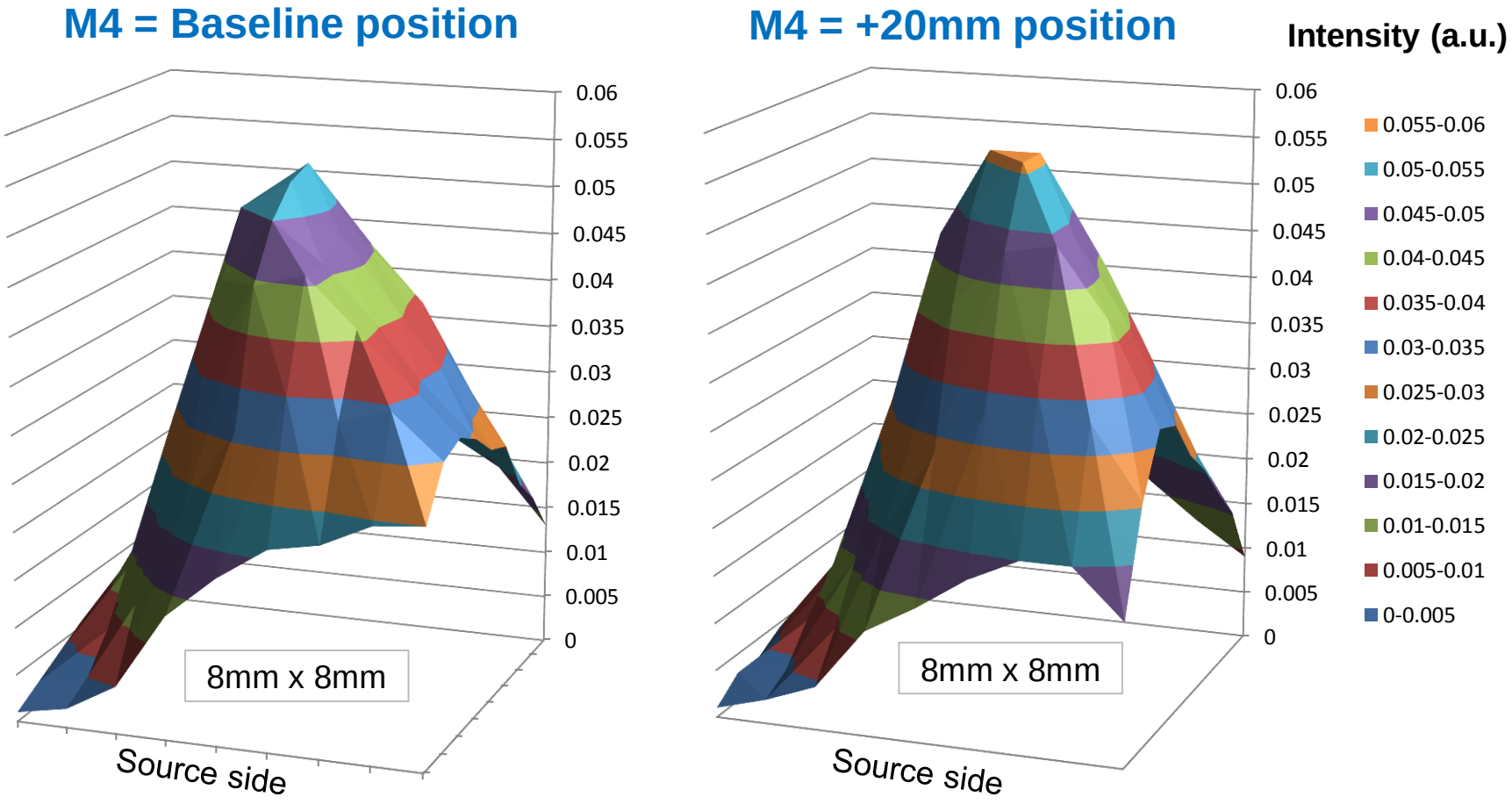
Wafer picture after development





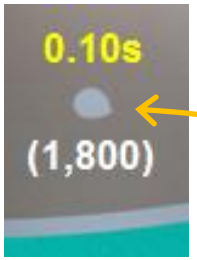
- Wafer intensity is calculated from the open shot's exposure time, which showed more than 1,800mW/cm2.

Intensity Profiles (Measurement)



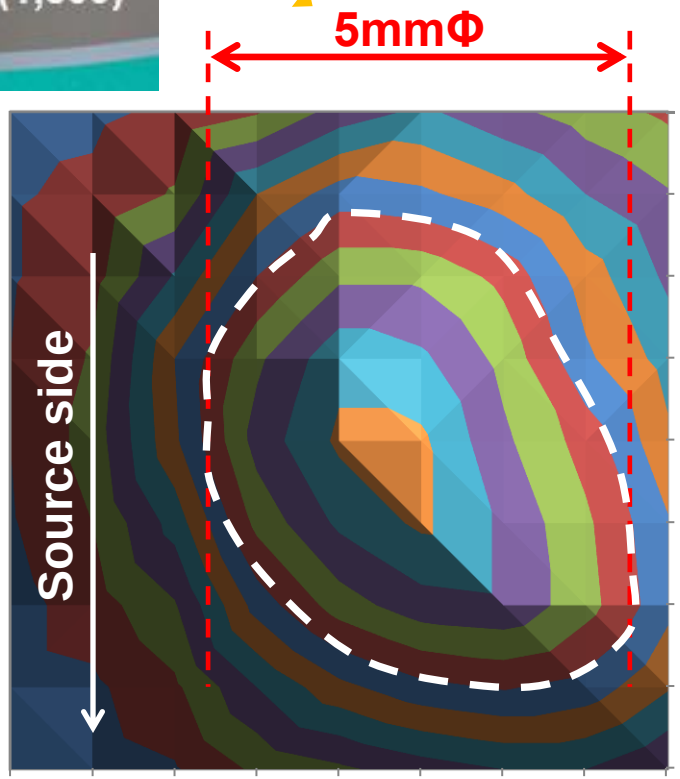
- The pin-hole sensor could measure the EUV intensity profile.
- Intensity/Profile could be changed by shifting M4 position.
- Relative position should be more precisely readjusted.

Maximum Intensity : Estimation



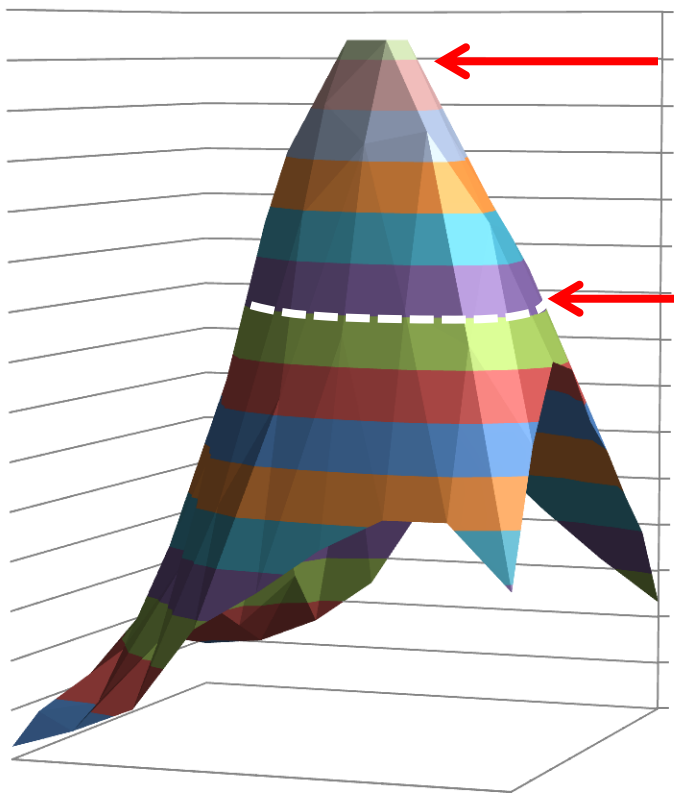
Circle edge intensity = 1,800mW/cm^2
Circle size = 5mmΦ

a.u.: 0.035 = Intensity :1,800mW/cm^2



Intensity [a.u.]

- 0.055-0.06
- 0.05-0.055
- 0.045-0.05
- 0.04-0.045
- 0.035-0.04
- 0.03-0.035
- 0.025-0.03
- 0.02-0.025
- 0.015-0.02
- 0.01-0.015
- 0.005-0.01
- 0-0.005



Intensity [W/cm^2]

3.0 2.8 2.6 2.4 2.2 2.0 1.8 1.6 1.4 1.2 1.0 0.8 0.6 0.4 0.2 0.0

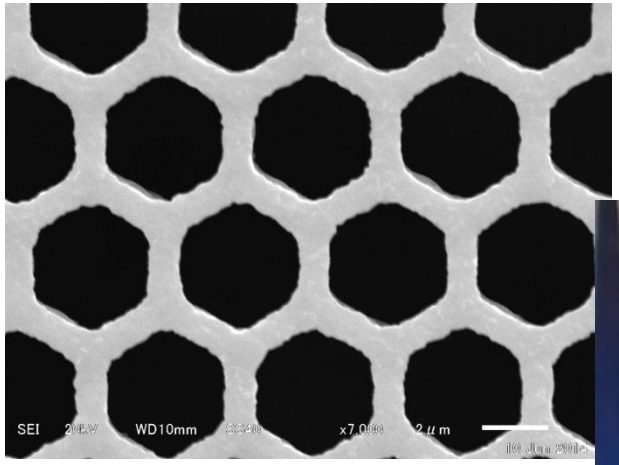
- 2.8-3.0
- 2.6-2.8
- 2.4-2.6
- 2.2-2.4
- 2.0-2.2
- 1.8-2.0
- 1.6-1.8
- 1.4-1.6
- 1.2-1.4
- 1.0-1.2
- 0.8-1.0
- 0.6-0.8
- 0.4-0.6
- 0.2-0.4
- 0.0-0.2

- By comparing 2D-intensity map with the resist cleared size mentioned before, the peak intensity is estimated to exceed 2,800mW/cm^2 in 1mmΦ area.

IR-Filter

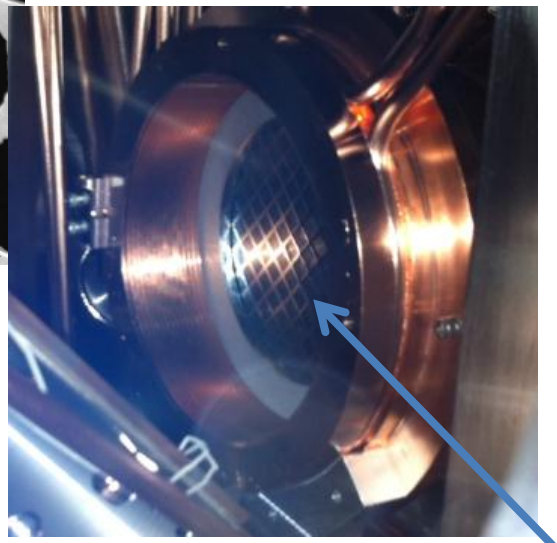
Mesh-type filter was made with the use of SOI wafer and MEMS process.

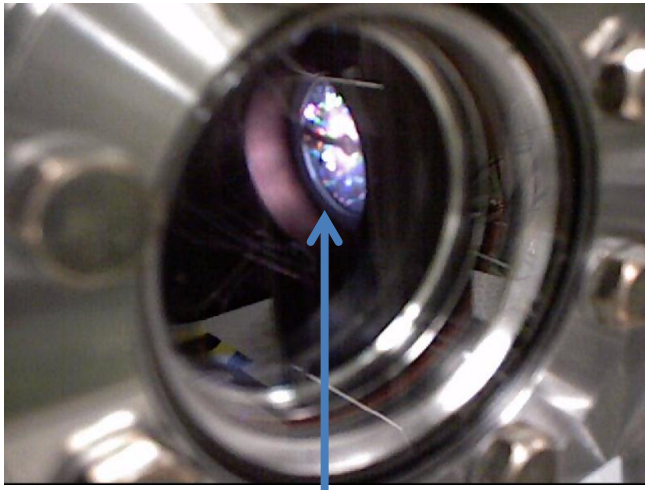
SEM picture of the Honeycomb structure



CO2 laser transmittance
=< 0.25% (Simulation)
=0.3~0.5% (Measured)

Pitch= 4.4um
Width ~ 0.4um
Height = 5um
Mo-coat = 100nm
Filter size = 83mmΦ

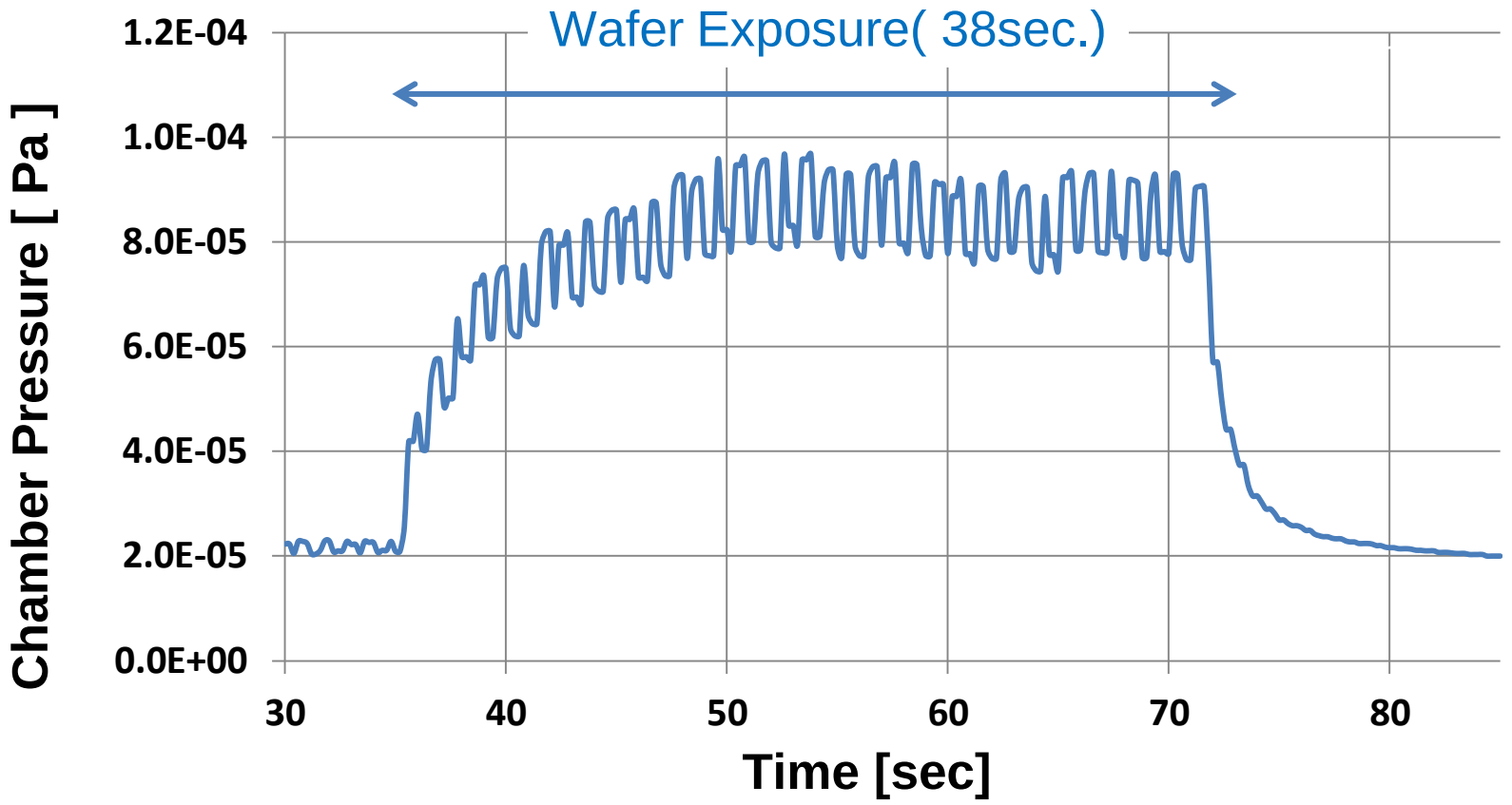




The look of the IR-filter installed and irradiated.

- Mesh-type IR filter was fabricated and functions well.

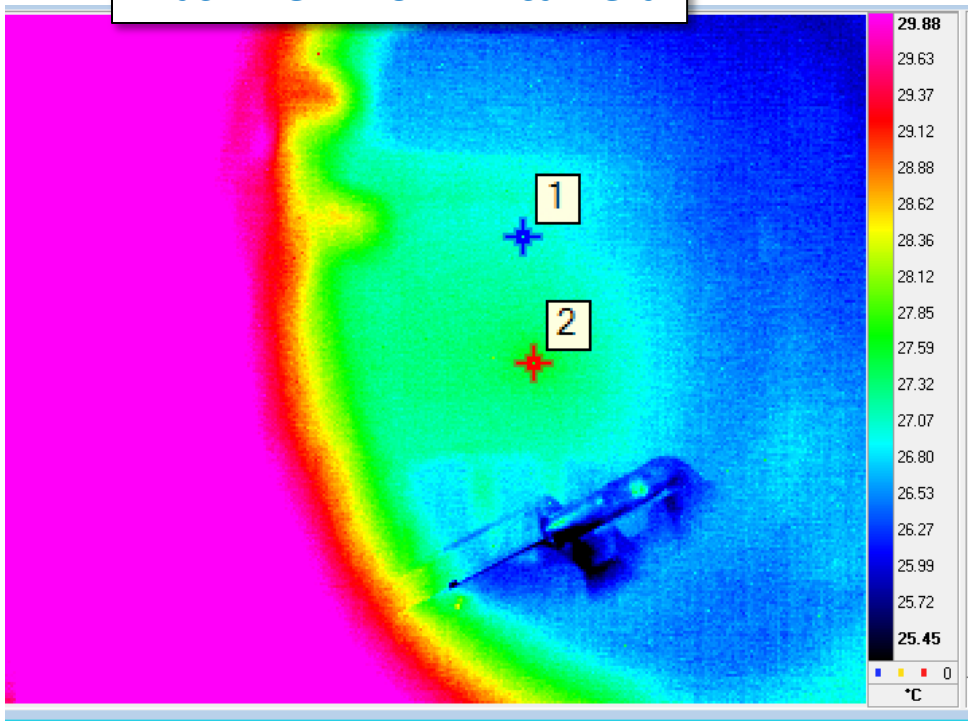
Pressure Rising by Resist Outgassing



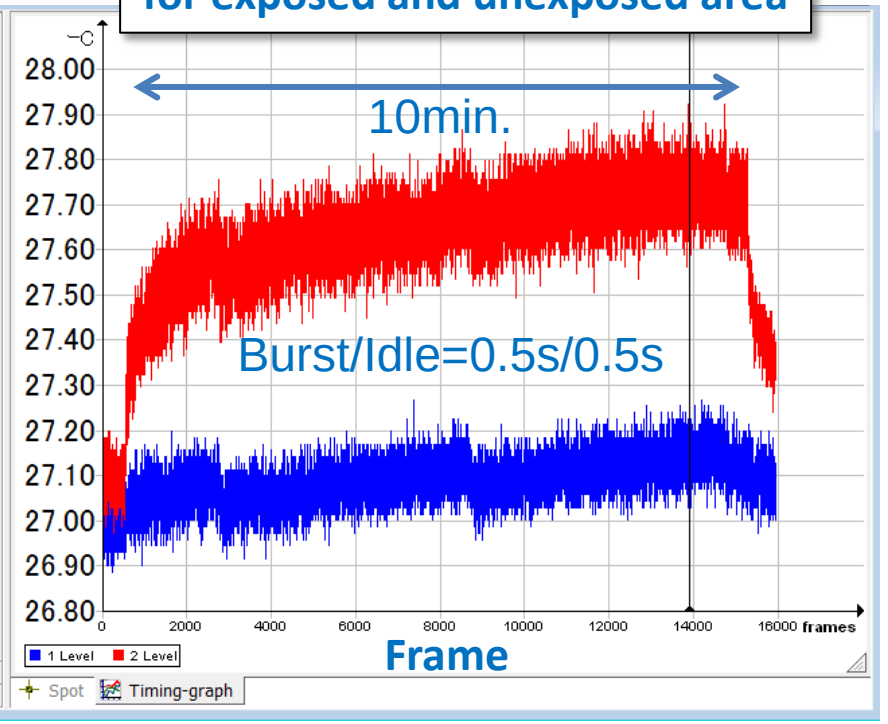
- The frequency of the pressure undulation matches that of the EUV burst emission.
- HPEUV tool worked properly. Further precise tool qualification will be necessary as the next step.

Mask Temperature Measurement during Expo. by IR Camera

Mask view from IR-camera



Transition of Temperature for exposed and unexposed area



- IR-camera could measure the temperature rise of a mask.

Temperature Rise at

- ✓ **Exposed Area:** **~0.5 degree**
- ✓ **Unexposed Area:** **~0.1 degree**

Discussion about the Potential Intensity

- The intensity 2,800mW/cm2 was obtained on the condition of 50kHz and M4=20mm, and the IF power at that time is estimated to be more than 40W (;dirty power).
- The measured intensity profile differs from the simulation results. It means that the optics maybe has some alignment errors. And, we need to check and readjust the optics.
- Further fine adjustment of optics will make it possible for HPEUV to exceed 5,000mW/cm2.

Summary

- A High Power EUV irradiation tool (HPEUV) equipped with an actual LPP source and relay mirror optics has been designed and constructed.
- The EUV intensity on wafer was confirmed to be more than 2,800mW/cm^2, which is extremely higher than conventional test tools.
- Pressure rise due to resist outgassing in the irradiation chamber and temperature rise of EUV mask blanks have been demonstrated as initial results of the HPEUV tool.
- HPEUV has the potential to exceed 5,000mW/cm2.
- The impact of higher power and pulsed irradiation on outgassing and damage of blank/pellicle will be taken place as the next step.

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