1st generation Laser-Produced Plasma 100W source system for HVM EUV lithography

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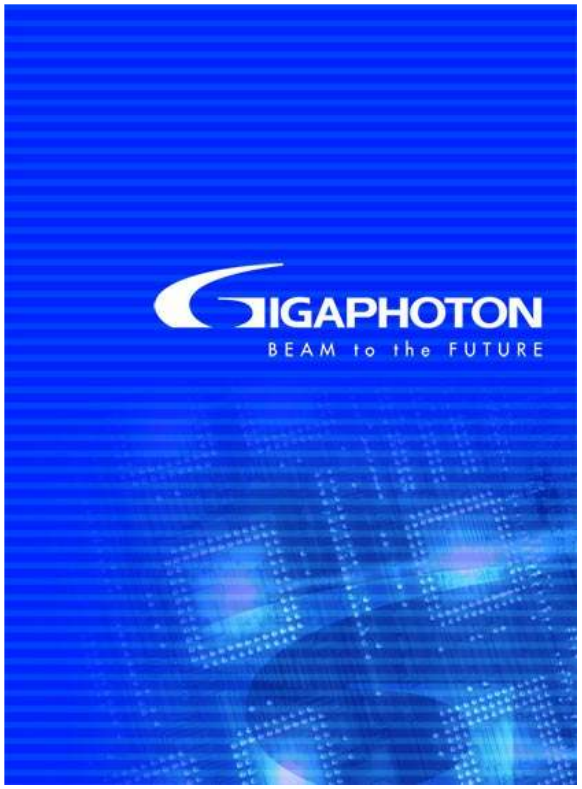

Outline

- **Introduction**
  - Concept of Gigaphoton LPP source
- **1st Generation system data**
  - Latest data
  - Critical issue and experimental data
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EUVA

EUV sources

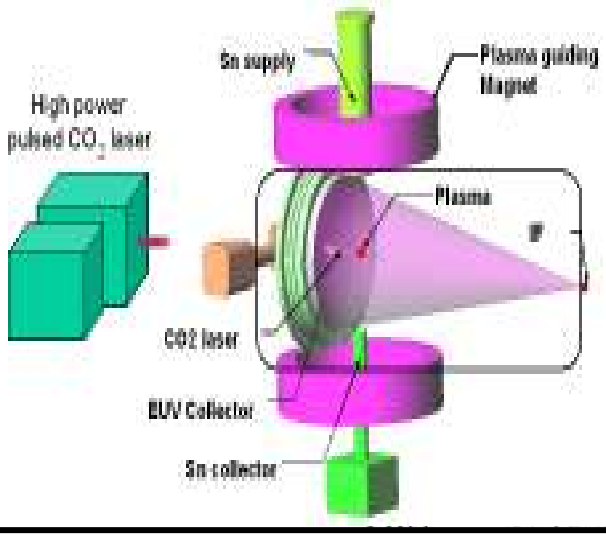
Original technologies

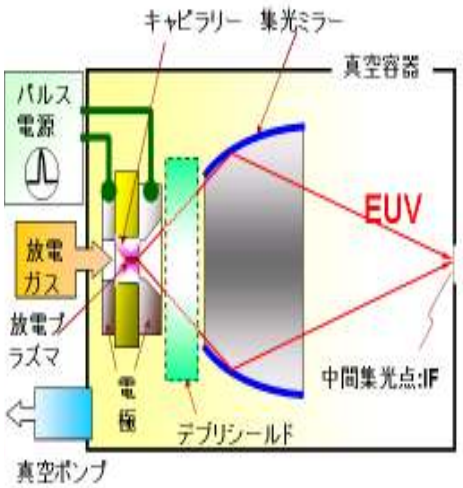
LPP : CO_2 laser and Sn source

① High power pulsed CO2 laser

② Magnetic field plasma mitigation

③ Pre-Pulse plasma technology





Type	LPP		DPP
Maker	**Gigaphoton**	Cymer	Ushio・Philips
Size	*Large*	*Very Large*	***Small***
Power (at present)	**104W/21W**	90W/20W	*34W/34W*
Plasma	**No electrode**	No electrode	Disc electrode
Mitigation	**Pre pulse + Magnet**	Gas	Gas＋mechanical shutter
Life limitation	**(several 1000 hr)**	Several 10 hr	Several 10 hr
Bottle neck	-	Mirror	Electrode/Mirror
Remark	・Theoretically no limit ・Engineering items are lot	・Trade off of power and lifetime	・Trade off of power and lifetime・ ・Trade off of power and beam quality

EUVA Project (LPP)

IRAI

	1st Mid term 2004/9	2nd Mid term 2006/3	EUVA -1 final 2008/3	EUVA-2 final ～ 2011/3	*Gigaphoton* 2011/4 ～
EUV Power (IF) Stability Laser Laser freq. CE (source) Target	5.7W [1] --- YAG:1.5kW 10kHz 0.9% Xe-Jet	10W [1] σ<±10% CO_2:2.6kW 100kHz 0.9% SnO_2 choroid liquid jet	50W [2] σ <±5% CO_2: 7.5kW 100kHz 2.5% Sn-Droplet	1st Generation (ETS) 110W [2] /140W [3] 3σ<±0.3% CO_2: 10kW 100kHz 4% Sn-Droplet	2nd Generation (proto/GL200E) 250W (clean@IF) 3σ<±0.3% CO_2: 23kW 100kHz 5% Sn-Droplet
	EUVA project-1			EUVA project-2	Commercial

Note）
Primary source to IF EUV transfer efficiency：
1) 43%
2) 28% with SPF
3) 36% without SPF
SPF: Spectral Purity Filter IF: Intermediate Focus

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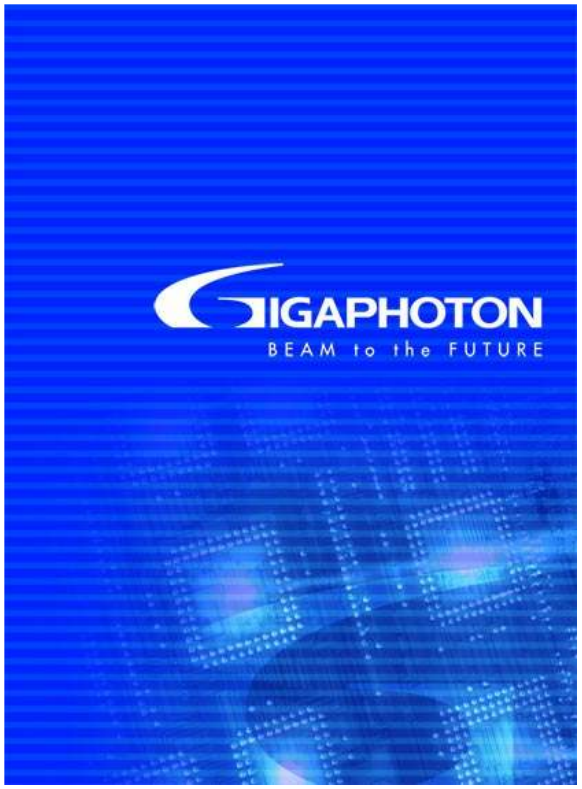

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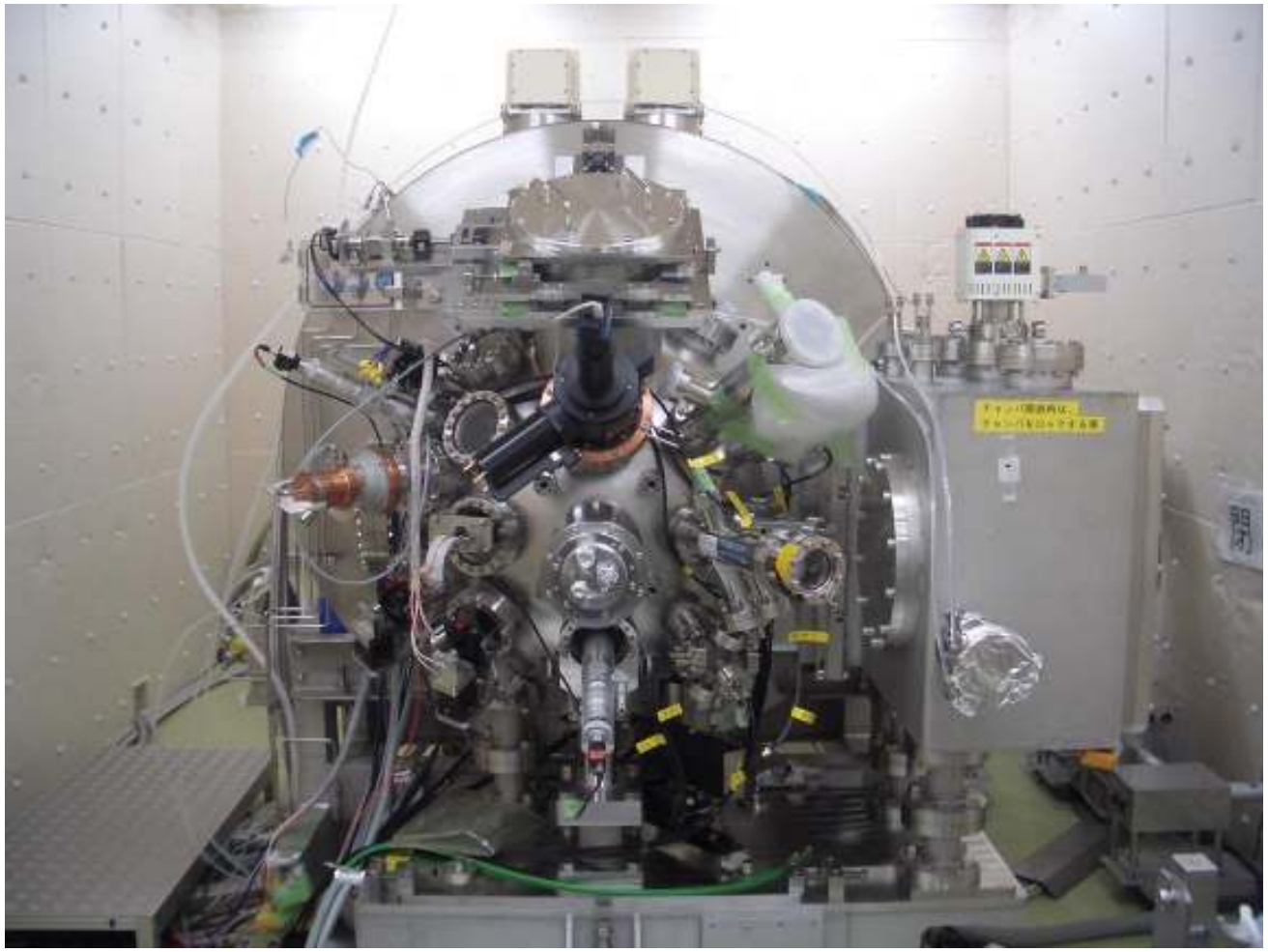
1st generation system (ETS device)



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System operation Data (1)

	Last data (SPIE 2010)	Present
Average power (@I/F)	14 W	21 W
Brightness (@I/F)	69 W	104 W
Duty cycle	20 %	20 %
Max. non stop op. time	>1 hr	<1 hr
Average CE	2.3 %	2.5 %
Dose stability (simulation)	(+/- 0.15%)	(+/- 0.15%)
Droplet diameter	60μm	60μm
CO_2 laser power	5.6 kW	7.9 kW

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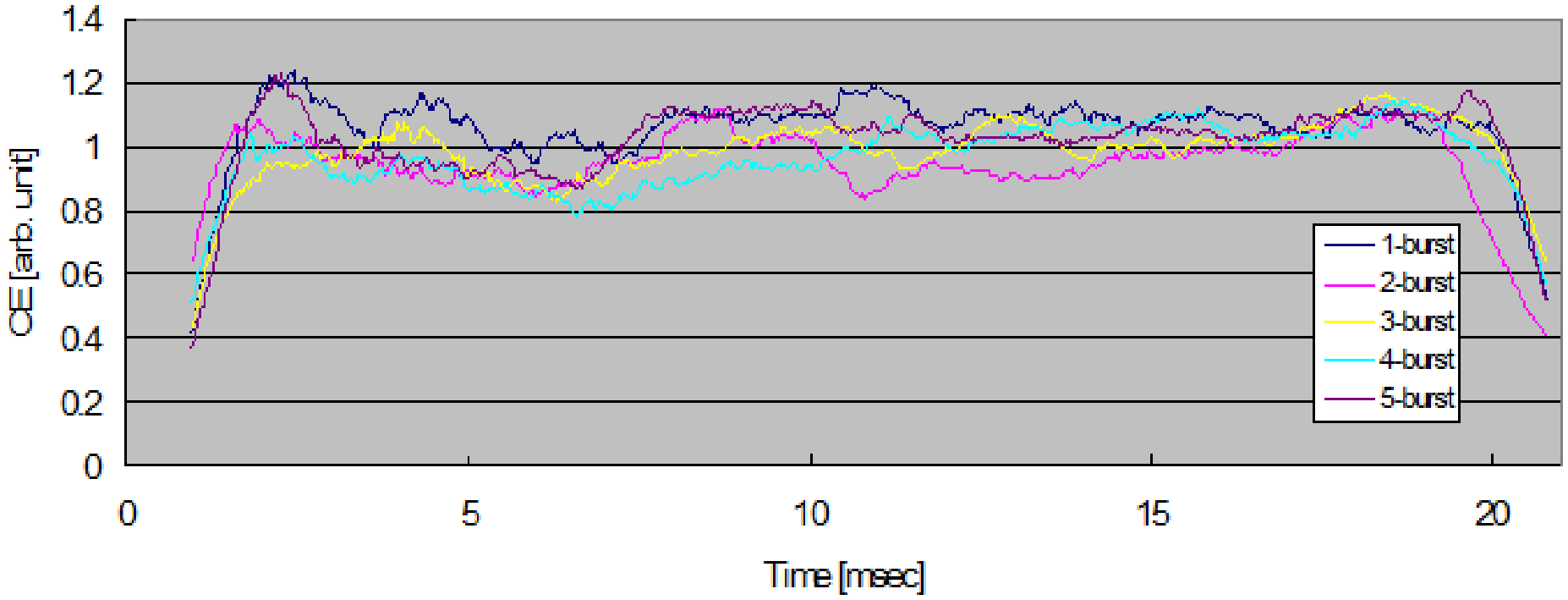
System operation Data (2)

- **Burst stability data (70W open loop)**



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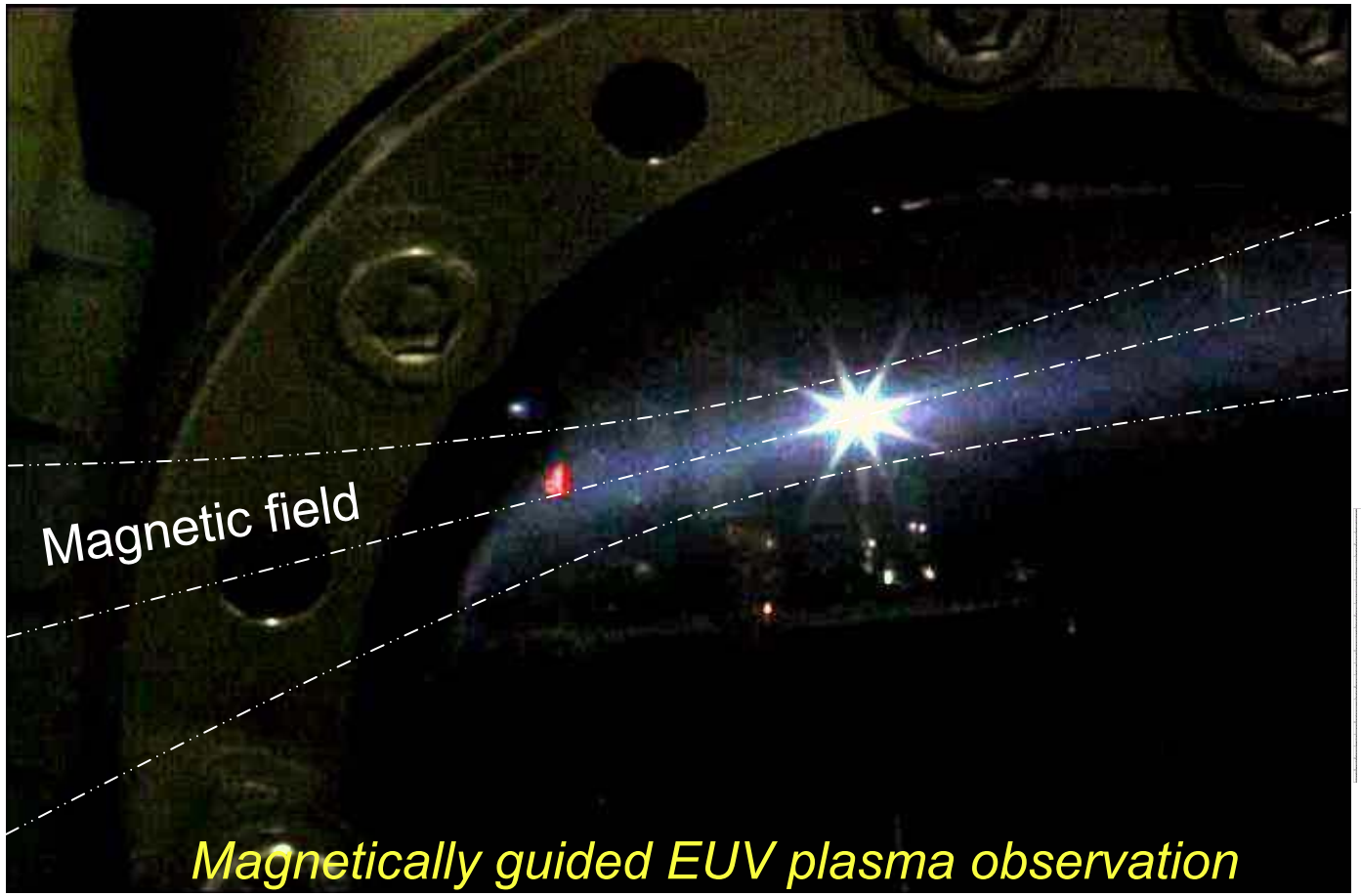
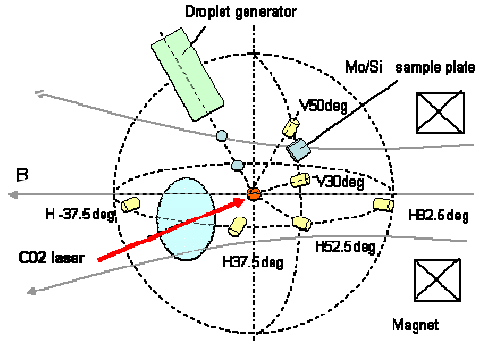
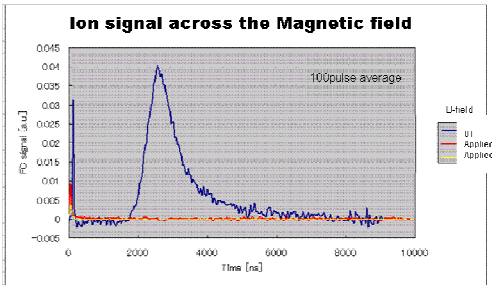
System operation data (3)

Fast Ions are perfectly shielded across magnetic field !



Ion measurement





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- ✓Laser power 5kW
- ✓Duty 20% (ON 200msec:OFF 800msec)

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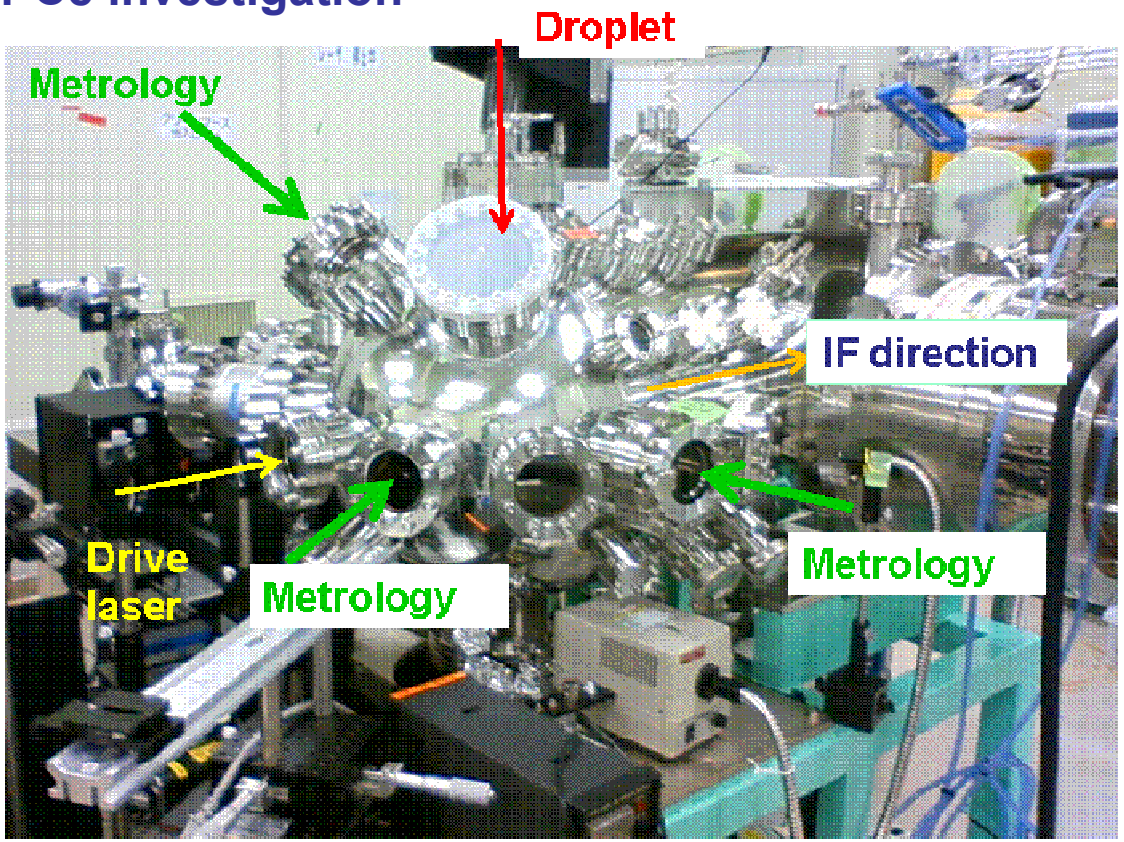
Critical issue investigation

(Experiment with research device 10Hz experiment)

- Double pulse optimization
- Debris mitigation mechanism
- Higher Ce investigation



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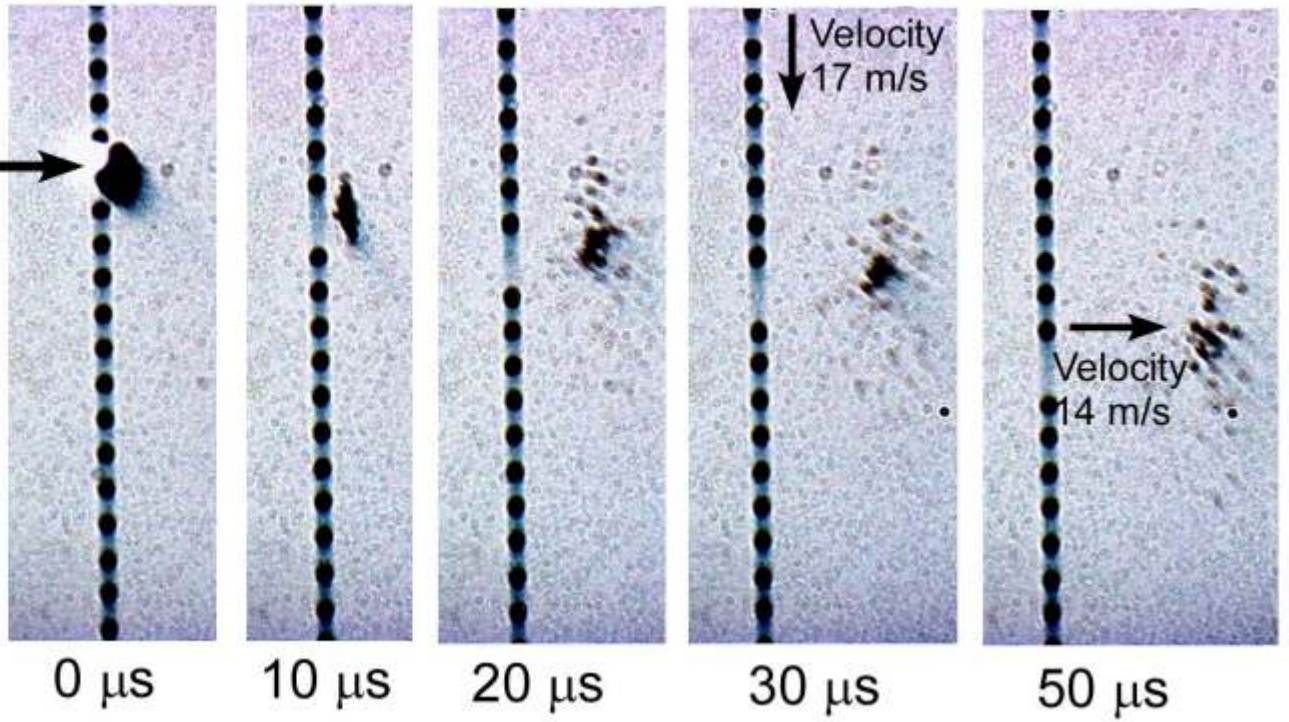
Liquid droplet experiment

Nd:YAG Laser

Wavelength : 1064 nm
Pulse length : 5 ns (FWHM)
Spot size : ~ Φ100 μm
Laser intensity
: ~ 1.6×10^9 W/cm^2

Target
Liquid droplet : Φ60 μm

Shadowgraphs of the liquid droplet target



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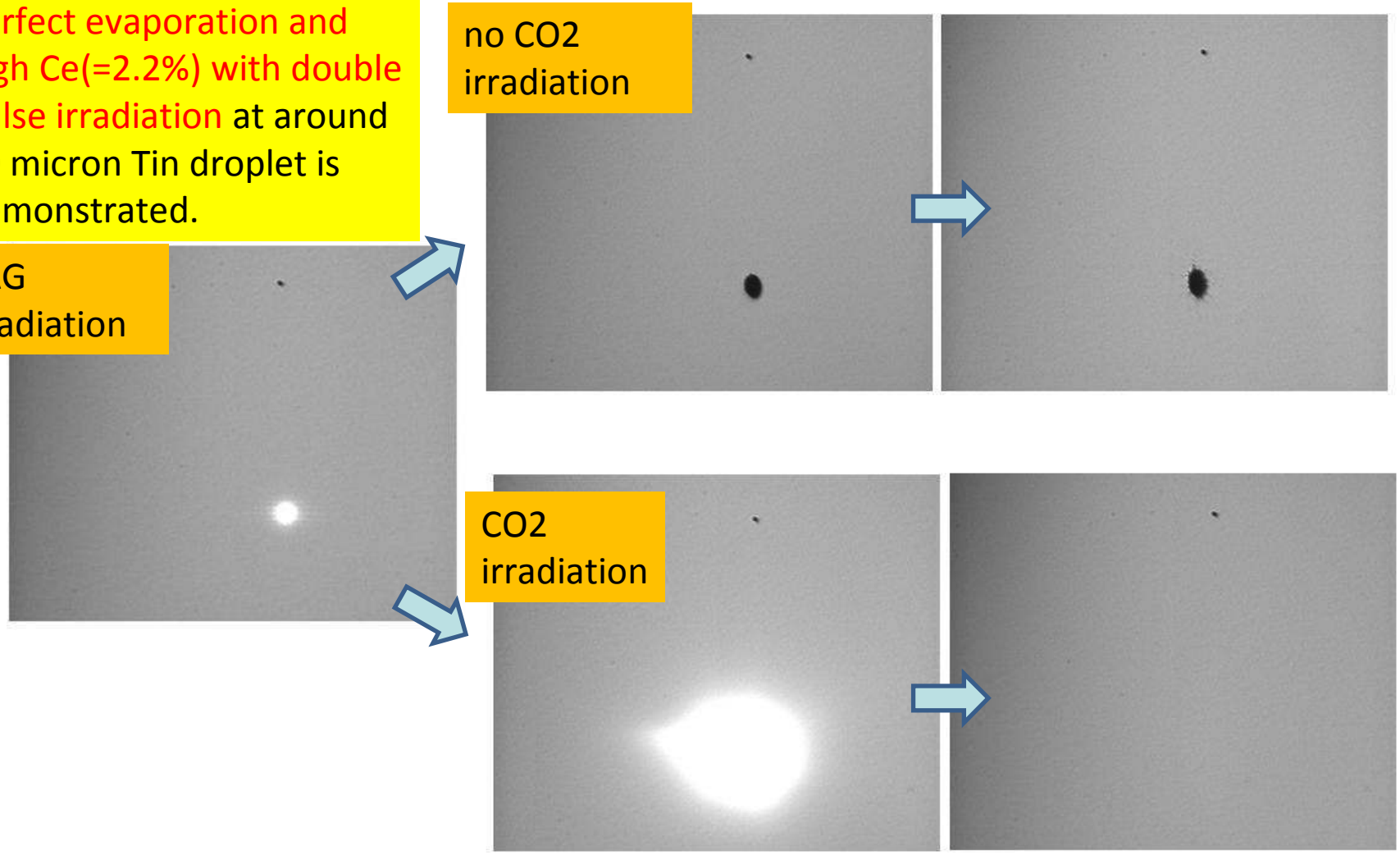
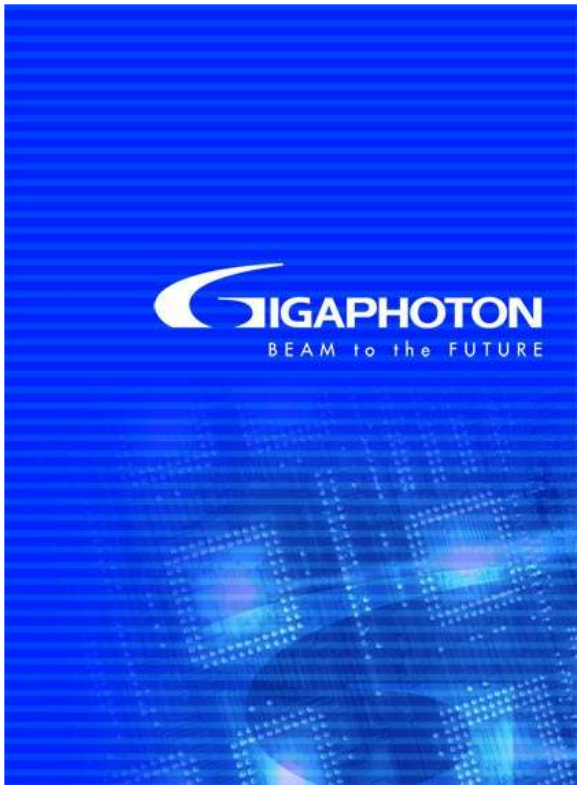
Liquid droplet experiment with double-pulse

Perfect evaporation and high Ce(=2.2%) with double pulse irradiation at around 20 micron Tin droplet is demonstrated.



SO-04 T. Hori "Investigation on high conversion efficiency and tin debris mitigation for LPP EUV light source.

SO-P15 A. Sunahara "Radiation Hydrodynamic Simulation of laser produced Tin plasma."



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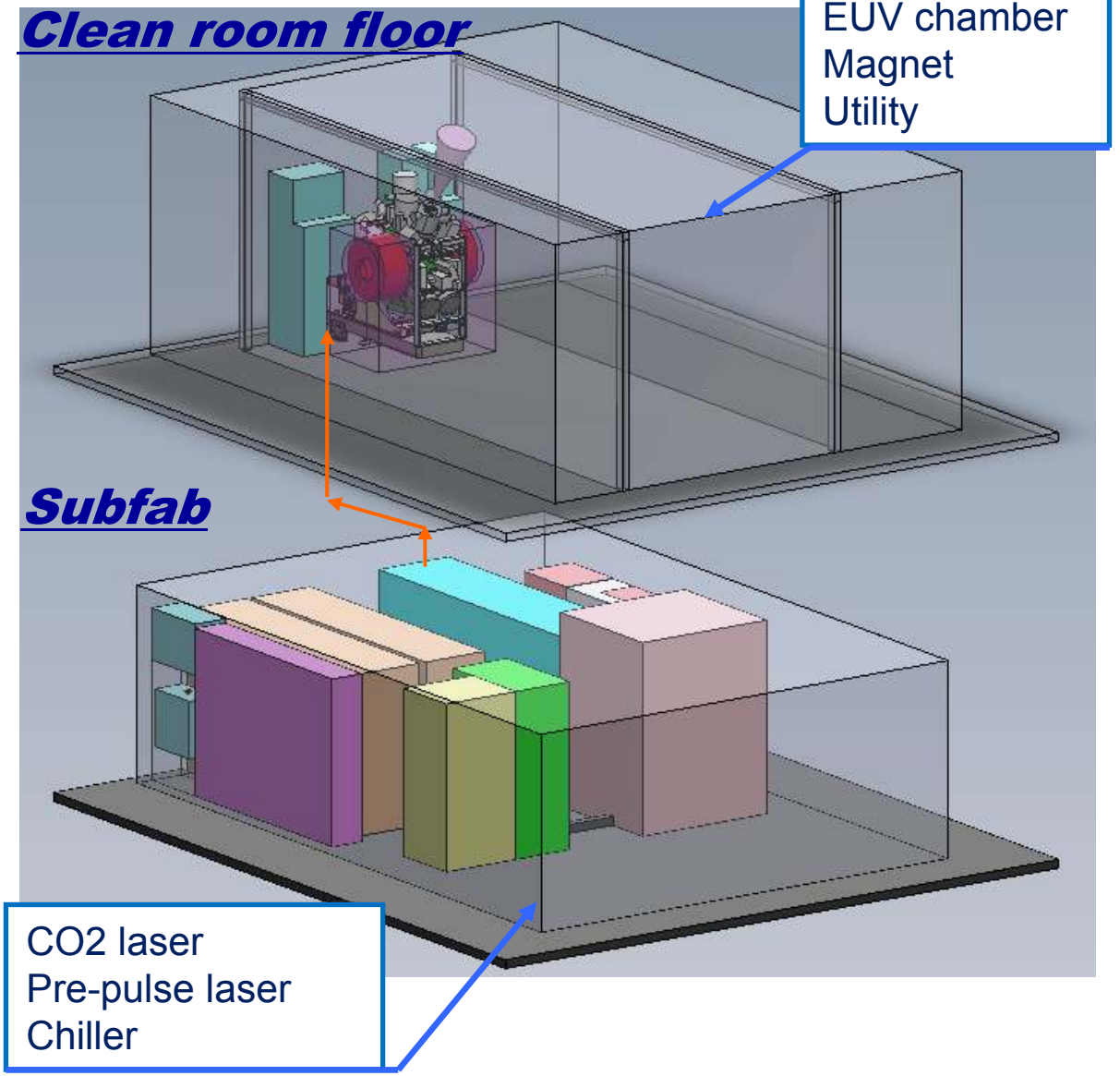
EUV Light Source Major Specifications

2nd generation GL-200E-proto is under development !

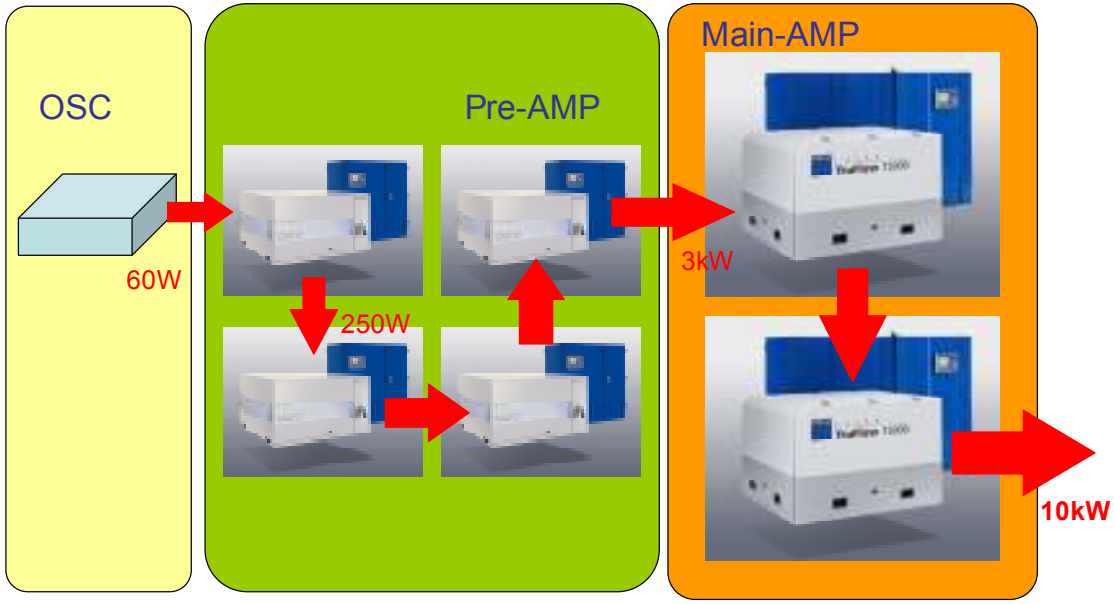
		1st generation	*2nd generation*	
EUV model		**ETS**	**GL200E proto**	**GL200E**
Power	**W**	**100**	**>100**	**>250**
Pulse energy	**mJ**	**1**	**>1**	**>2.5**
Max rep rate	**kHz**	**100**	**100**	**100**
Max Duty Cycle	**%**	**75**	**>75**	**>75**
Sub systems				
Target Material and Shape		**Sn droplet**	**Sn droplet**	**Sn droplet**
Droplet Diameter	**micro meter**	**60**	**10**	**10**
Debris Mitigation		**Magnet and cleaning**	**Magnet and cleaning**	**Magnet and cleaning**
Collector Mirror Lifetime	**Bpls**	**11**	**>200**	**>1250**
Tool Interface		**No**	**Yes**	**Yes**

GL200E-proto System Overview



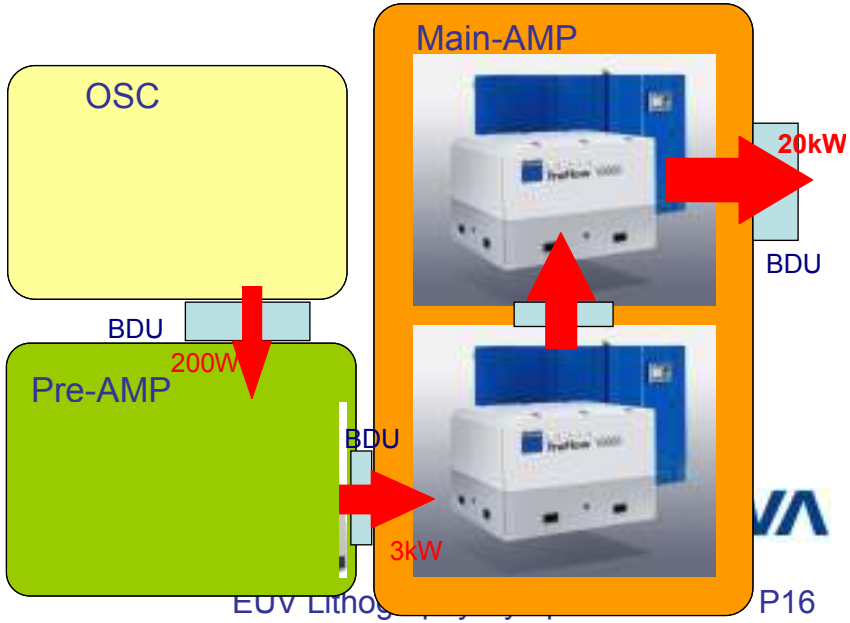
2nd gen. high power pulsed CO2 laser system

- 1st gen. laser system



- 2nd gen. laser system

  - *Compact: footprint -> <50%*
  - *Efficient: Plug in eff. x2*
  - *Higher power: 10kW-> 20kW*



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2nd Gen. CO_2 laser system is under construction

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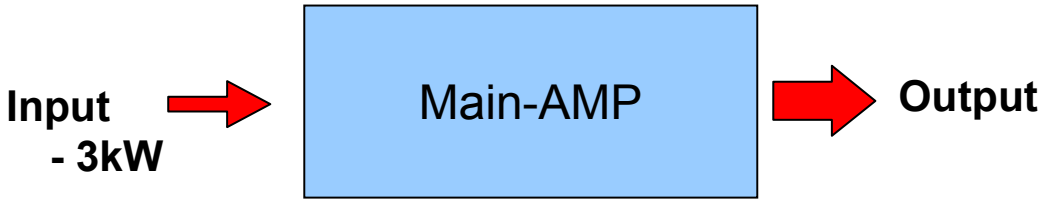
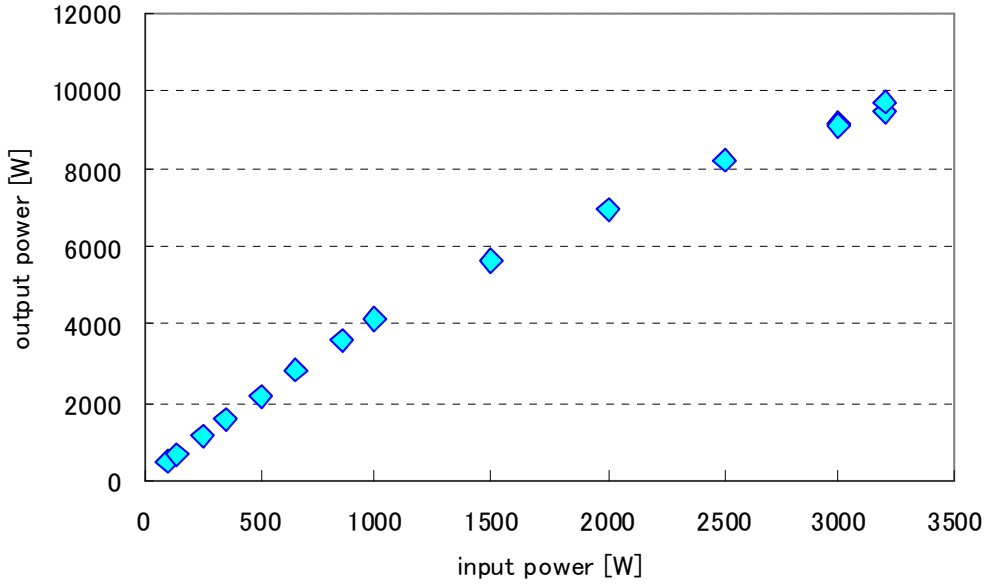
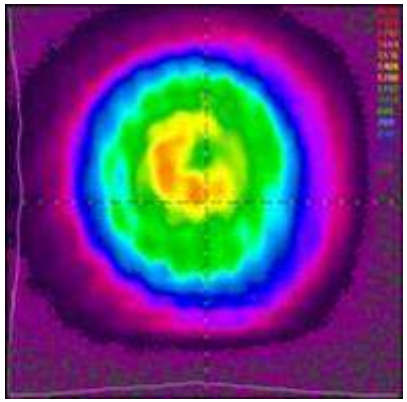
Main Amplifier performance

- **Main amplifier characteristics : experimental results**
  - ✓ **~10kW output achieved at 3kW input power**
  - ✓ **Good beam quality: M^2<2.0**





Output beam profile



2nd Gen. Magnet system is under construction

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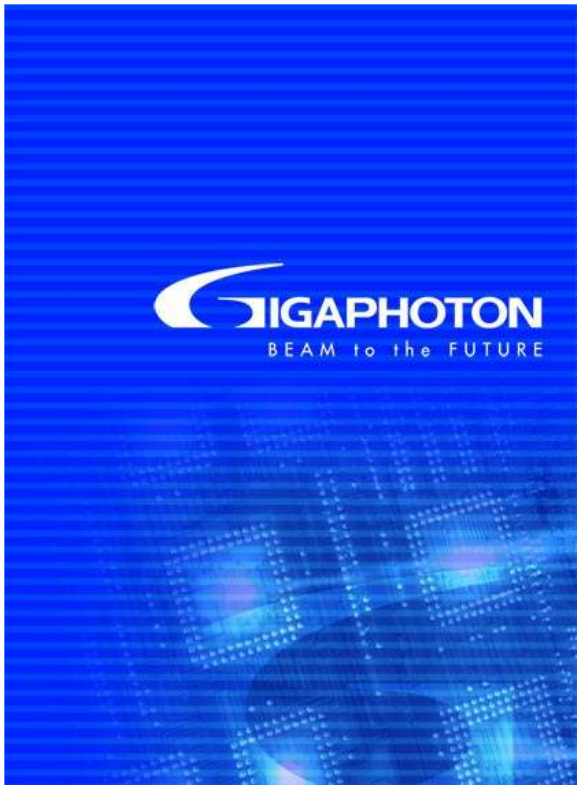

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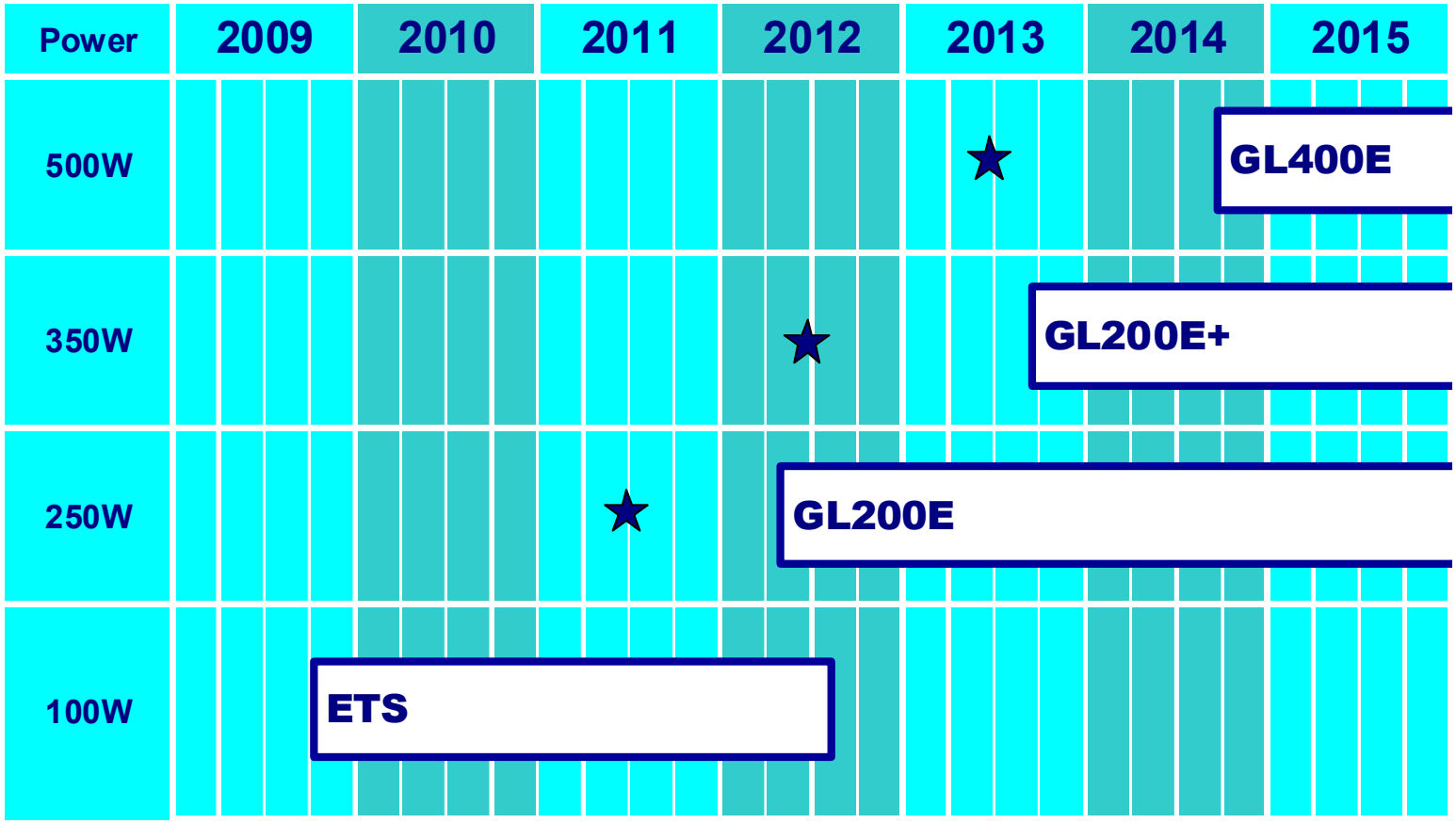
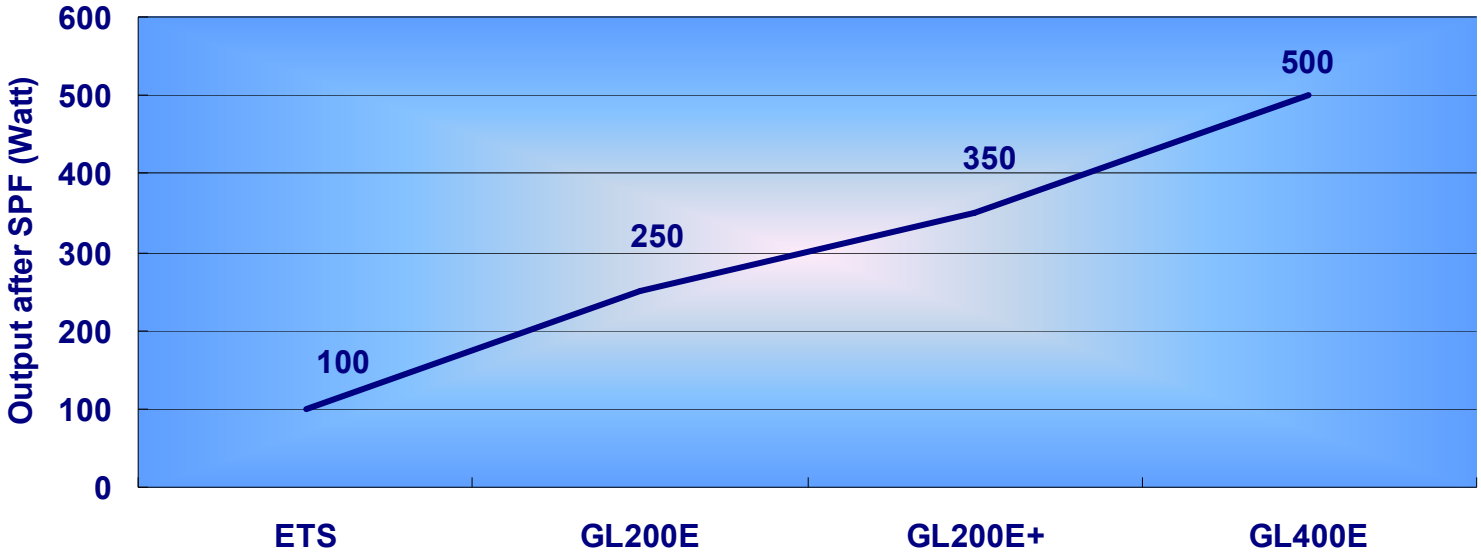
Gigaphoton EUV roadmap



★ 1st source delivery

Power roadmap (Clean EUV Power)

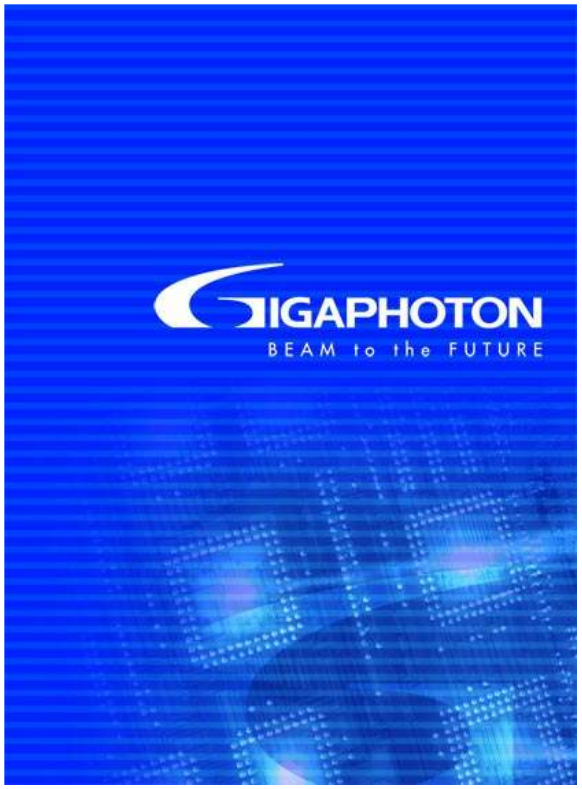


EUV model		ETS	GL200E	GL200E+	GL400E
Drive laser power	kW	10	23	33	40
Conversion efficiency	%	3.0	5.0	5.0	6.0
C1 mirror collector angle	sr	5.5	5.5	5.5	5.5
efficiency*	%	74	74	74	74
C1 mirror reflectivity	%	(50)	57	57	57
Optical transmission	%	95	95	95	95
SPF (IR, DUV)	%	N/A**	62	62	62
Total EUV power (after SF	W	100	250	350	500

LPP-EUV Development Facility (1)

- ✓ Shinomiya, Hiratsuka (60km south-west from Tokyo)
- ✓ In industry park of Hiratsuka beside the Sagami river
- ✓ Production capacity is up to 4 units/year (at present)
- ✓ Building is extendable to surrounded open space

LPP-EUV Development Facility (2)



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- **ETS-2 (1st generation integrated setup LPP source)**
  - Latest operation data is reported
    - 104W at duty cycle of 20% (i.e. average power = 21W)
    - Stability under burst operation <+/- 0.23% (dose simulation)
    - Long term (> 1 hour operation)
  - Investigation of critical issue is in advance at research device.
    - Under 20 micron Tin droplet can evaporate perfectly with double pulse method.

- **2nd generation LPP source**
  - Construction of 1st proto machine is on going.
    - CO_2 laser operate with good beam quality around 10kW 30% duty.
    - Super conductive magnet is installed.

- **Product roadmap and new facility**
  - Target specification and schedule of Gigaphoton LPP source product is updated.
  - New EUV facility is introduced.

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Acknowledgments

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- ***Thanks to co-workers***
  - Tamotsu Abe, Yukio Watanabe, Takanobu Ishihara, Takeshi Ohta, Tsukasa Hori, Akihiko Kurosu, Hiroshi Komori, Kouji Kakizaki, Akira Sumitani

  EUVA/Komatsu (Japan): 1200 Manda, Hiratsuka, Kanagawa, 254-8567, Japan

  - Osamu Wakabayashi, Hiroaki Nakarai, Junichi Fujimoto

  Gigaphoton (Japan): 400 Yokokura shinden, Oyama, Tochigi,323-8558 Japan


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