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Investigation on high conversion efficiency and Tin debris mitigation for laser produced plasma EUV light source

for International Symposium on Extreme Ultraviolet Lithography

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Oct 17, 2011

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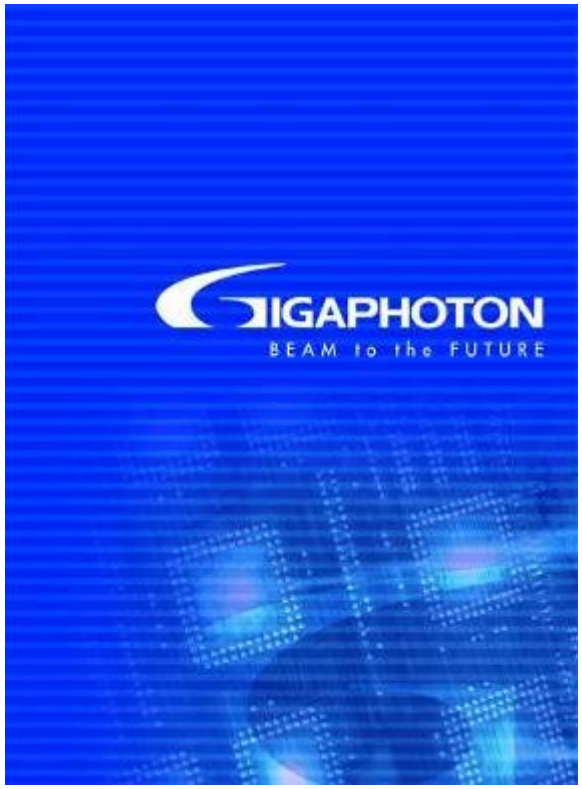
KWDR11-197



AGENDA

- **Introduction**
- **Tin debris mitigation**
  - Experimental setup
  - Experimental results
    - Fragment measurements (shadow graph)
    - Atom measurements (LIF)
    - Ion measurements (Faraday cup)
    - Mirror cleaning
- **OoB (Out of band) EUV power**
  - Experimental setup
  - OoB measurements results
- **Summary**

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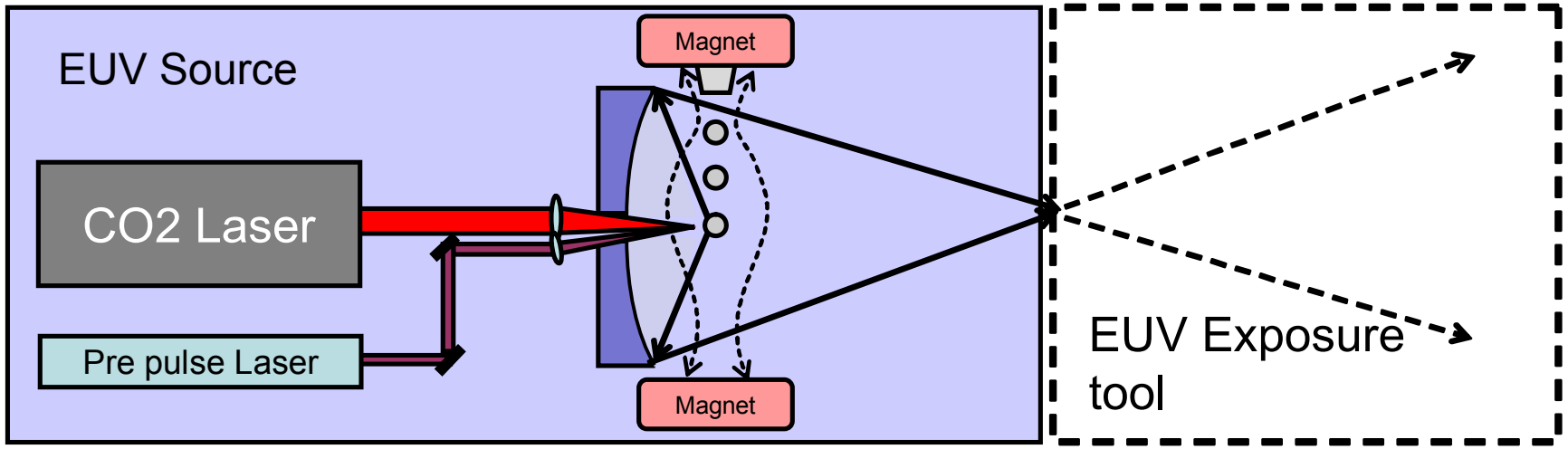
Introduction

- Requirements for HVM EUV source -

- High EUV power
  - ✓ High CE
- Low CoG, CoO
  - ✓ Long collector mirror lifetime
- Low OoB

- Our approach -

- LPP system
  - ✓ High power CO2 laser
  - ✓ Pre pulse laser
- Magnetic shield system



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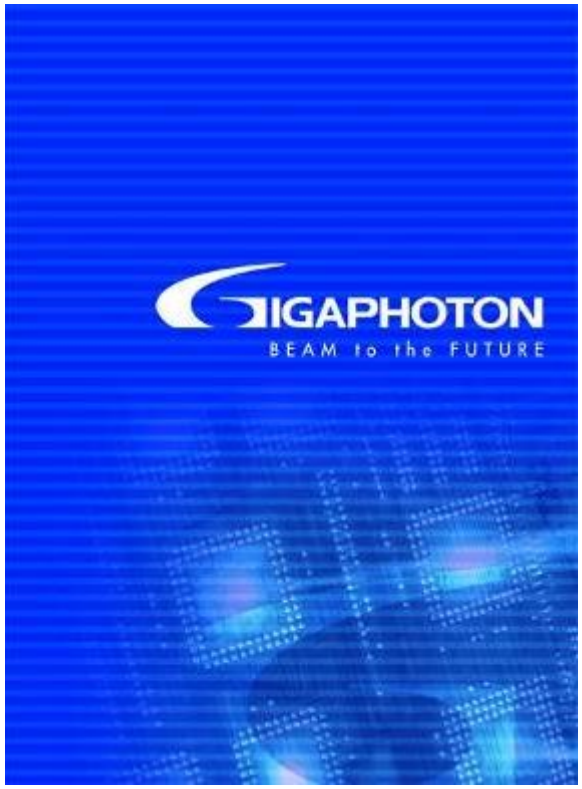

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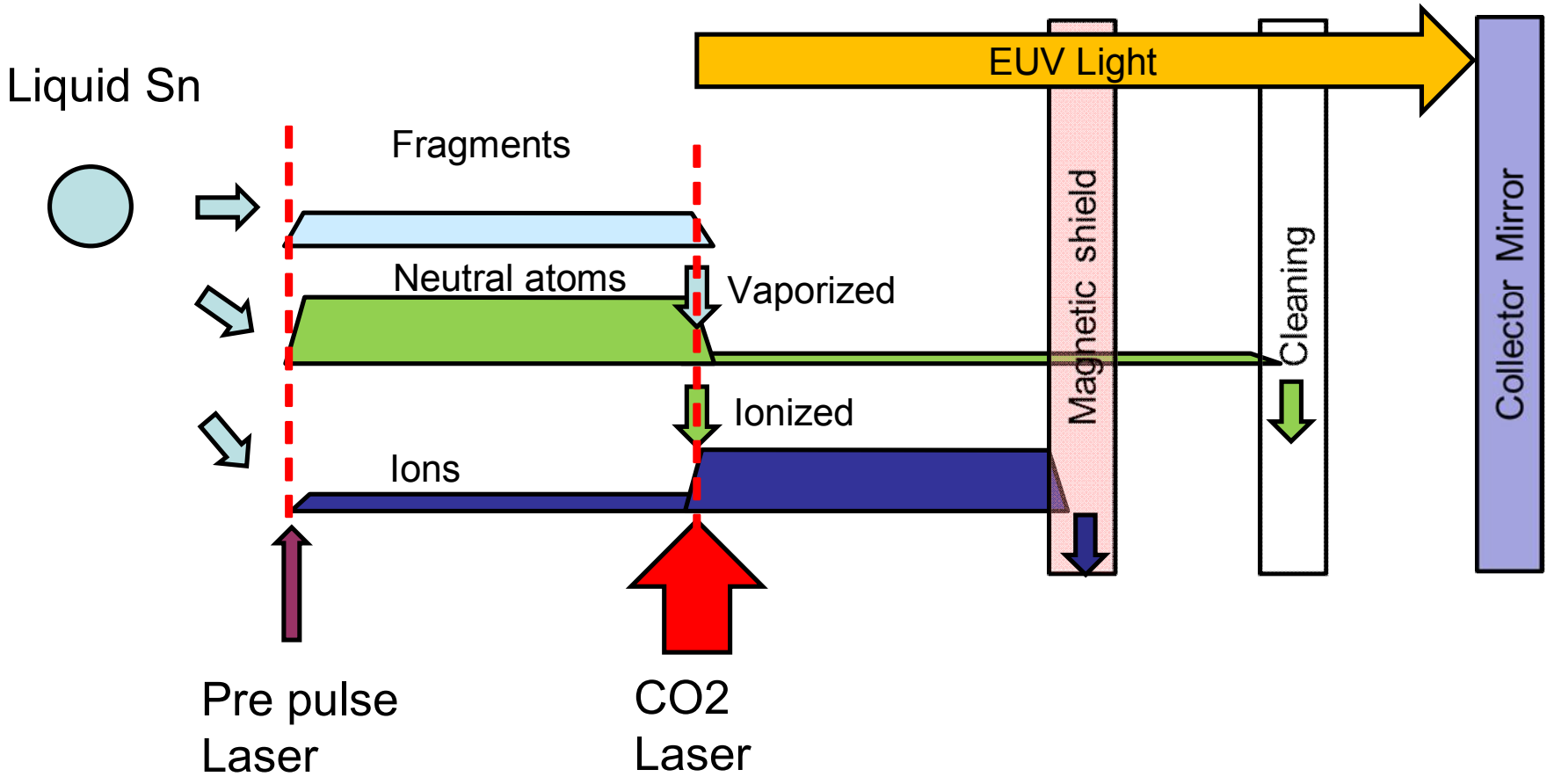
Tin debris mitigation

- Collector mirror protection concept



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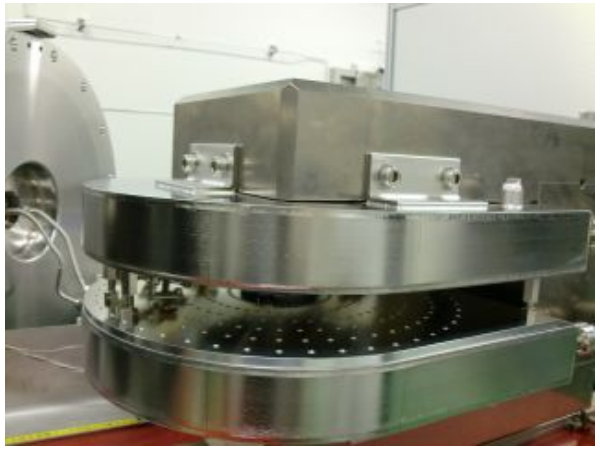
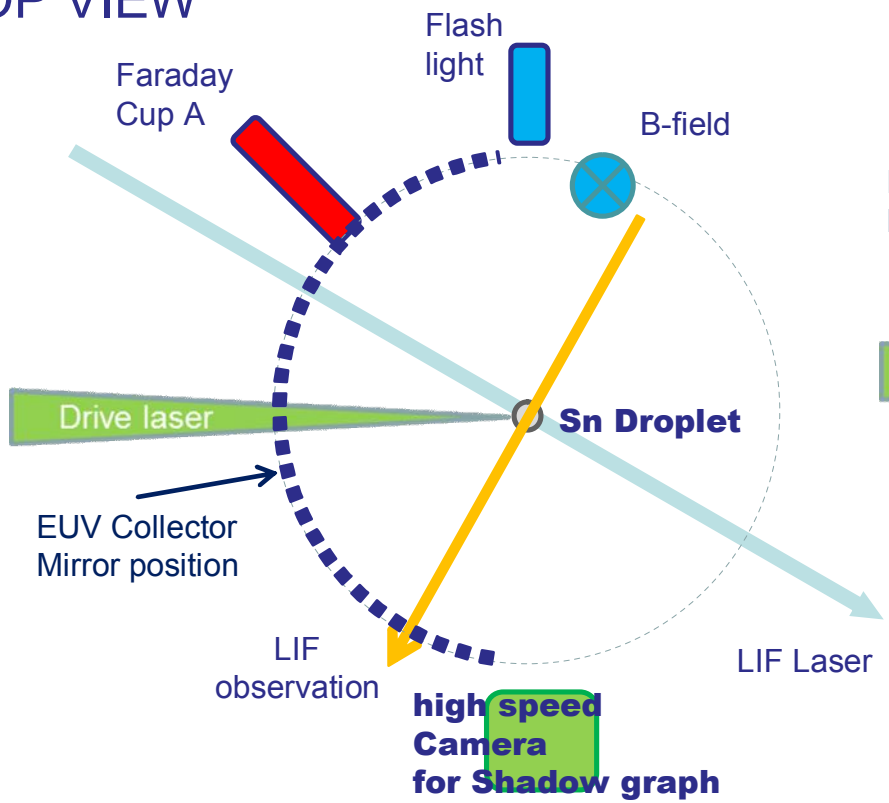
Experimental setup 1/4

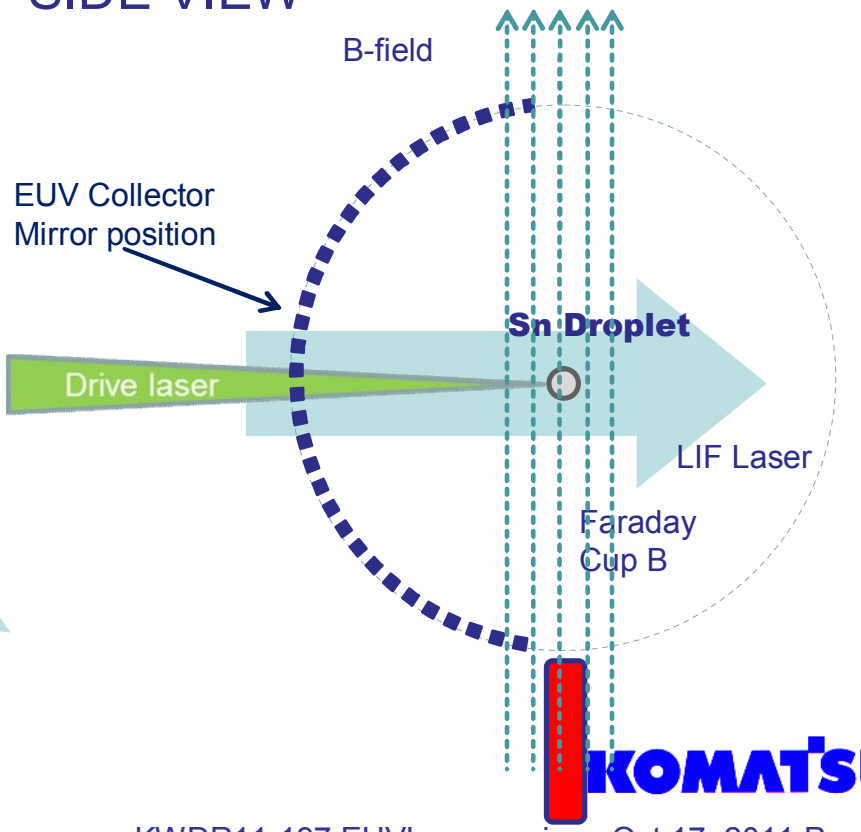
items	Tools to measure
Fragments	Shadow graph
Neutral atoms	LIF (Laser Induced Fluorescence)
Ions	Faraday cup A : Perpendicular to B-field Faraday cup B : Parallel to B-field



TOP VIEW



SIDE VIEW



Experimental setup 2/4

- 10Hz source test rig study

- **Goal of 10Hz source test rig**
  - ✓ **Prove design concept, physical analysis, etc**

- **Having extra metrology system**
  - ✓ **LIF (Laser Induced Fluorescence)**
    - ✓ **Detection system for Sn atom density measurement**

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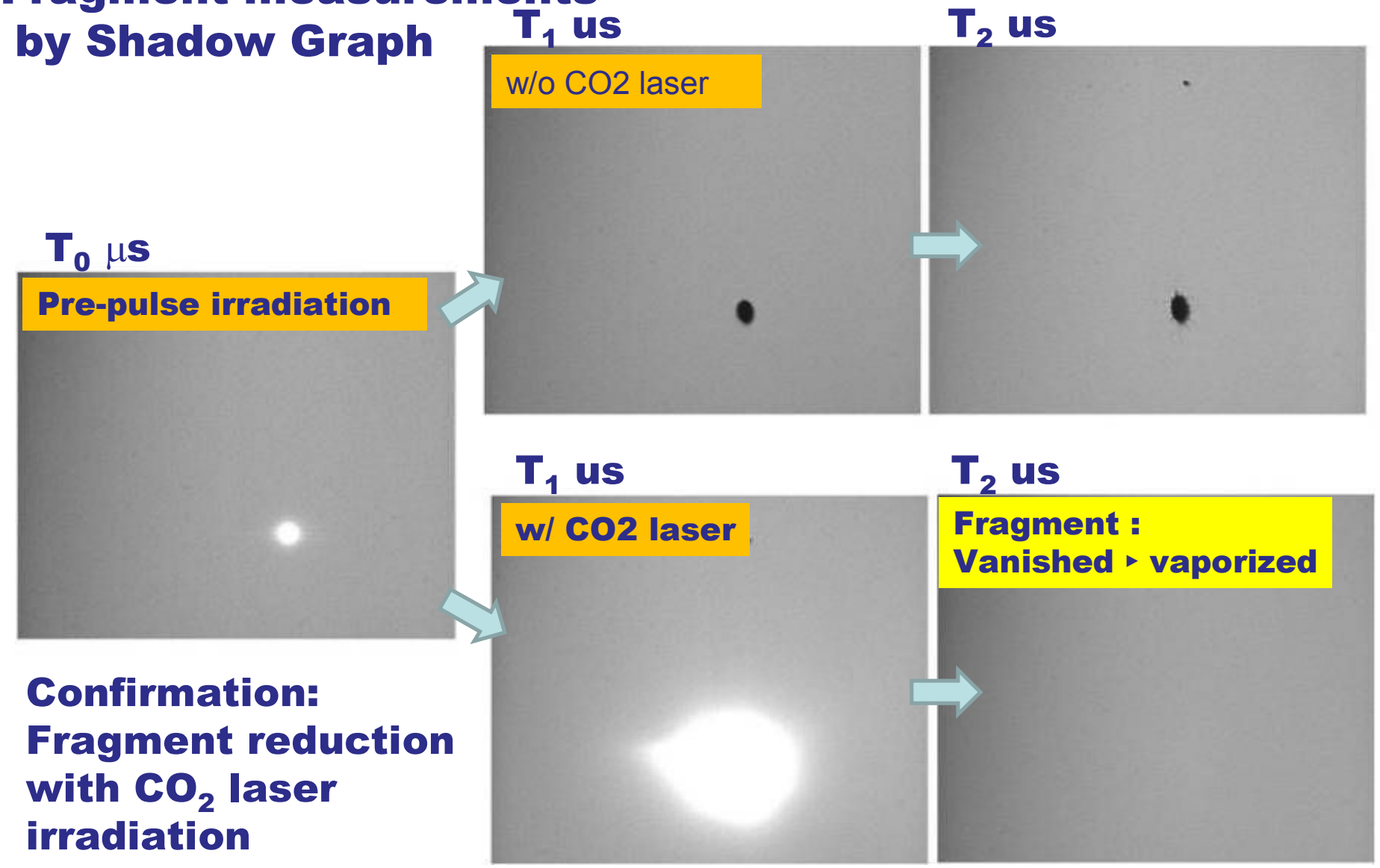
Fragment measurements by Shadow Graph



Confirmation: Fragment reduction with CO_2 laser irradiation

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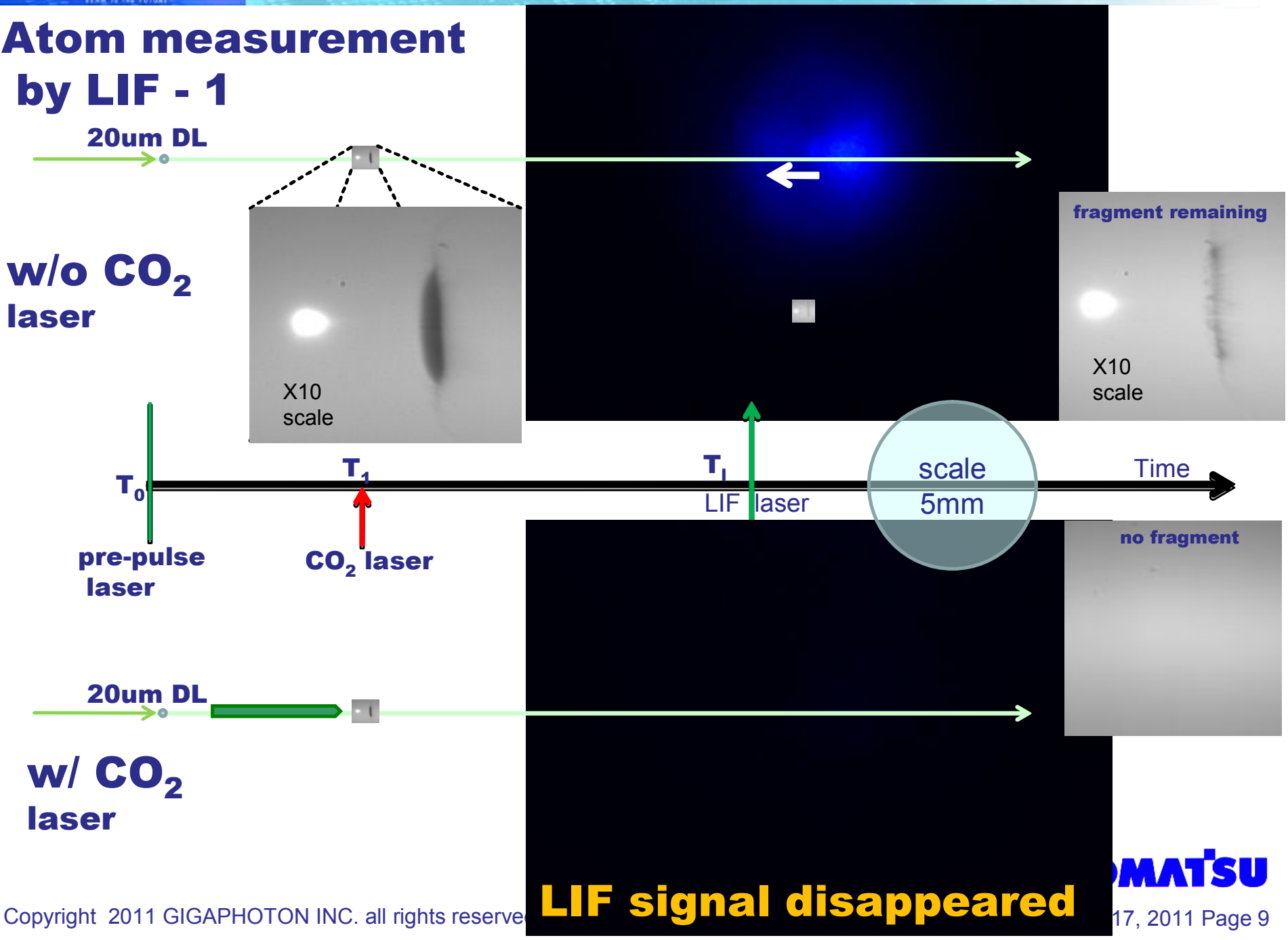
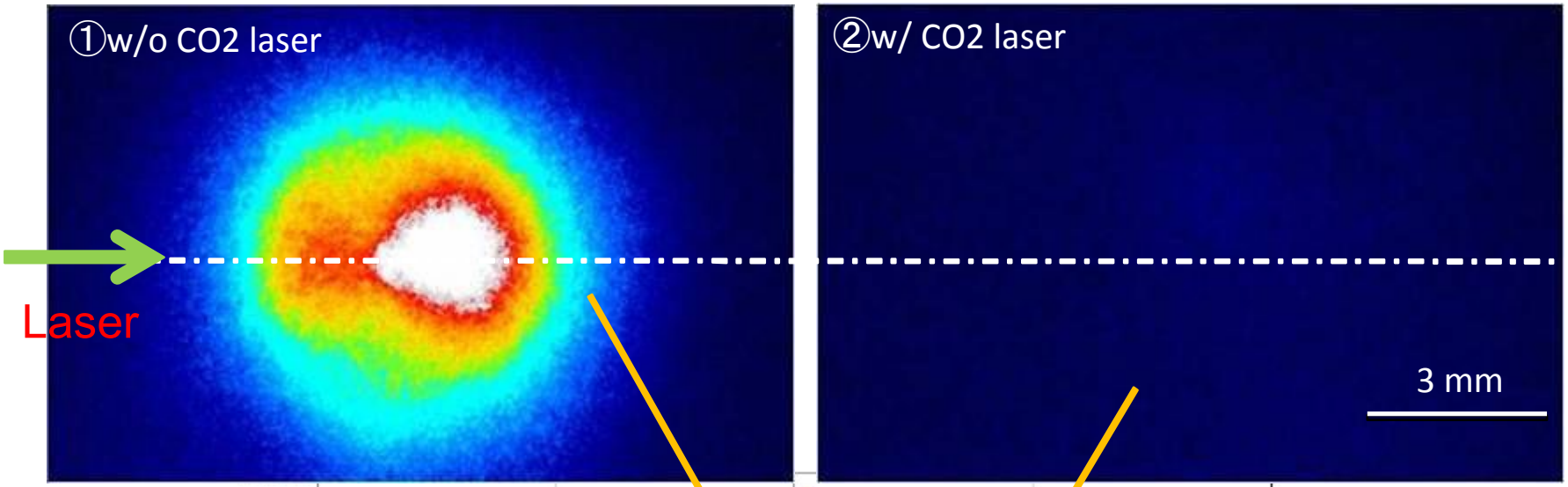
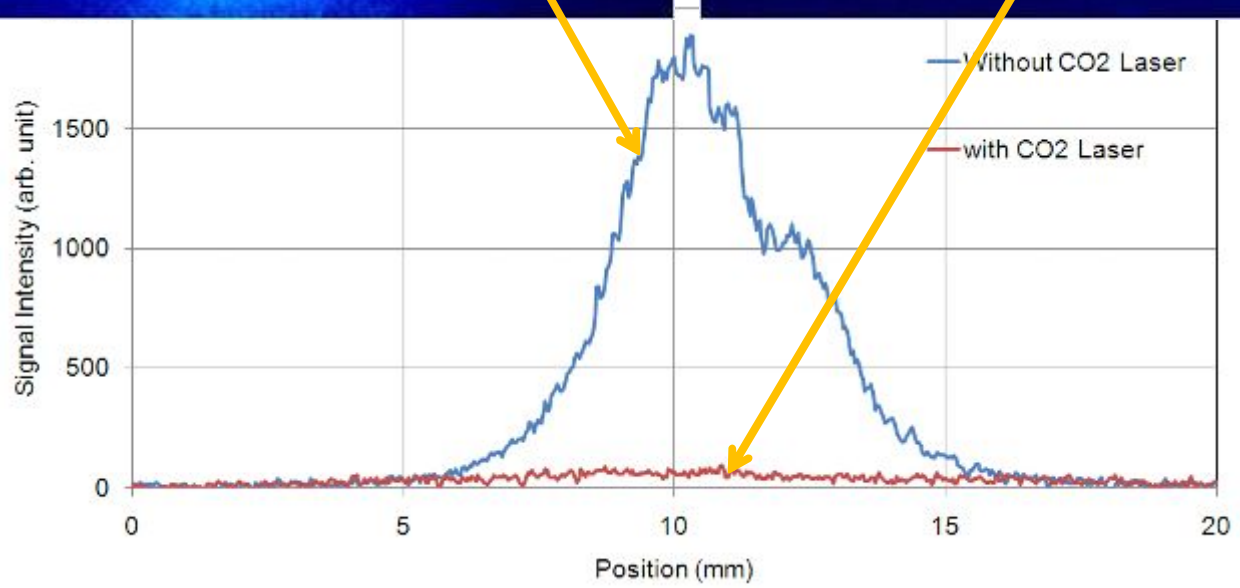
Atom measurement by LIF - 1



Atom measurement by LIF - 2

Remaining atoms was estimated by subtracting w/ CO2 vs w/o CO2 measurement





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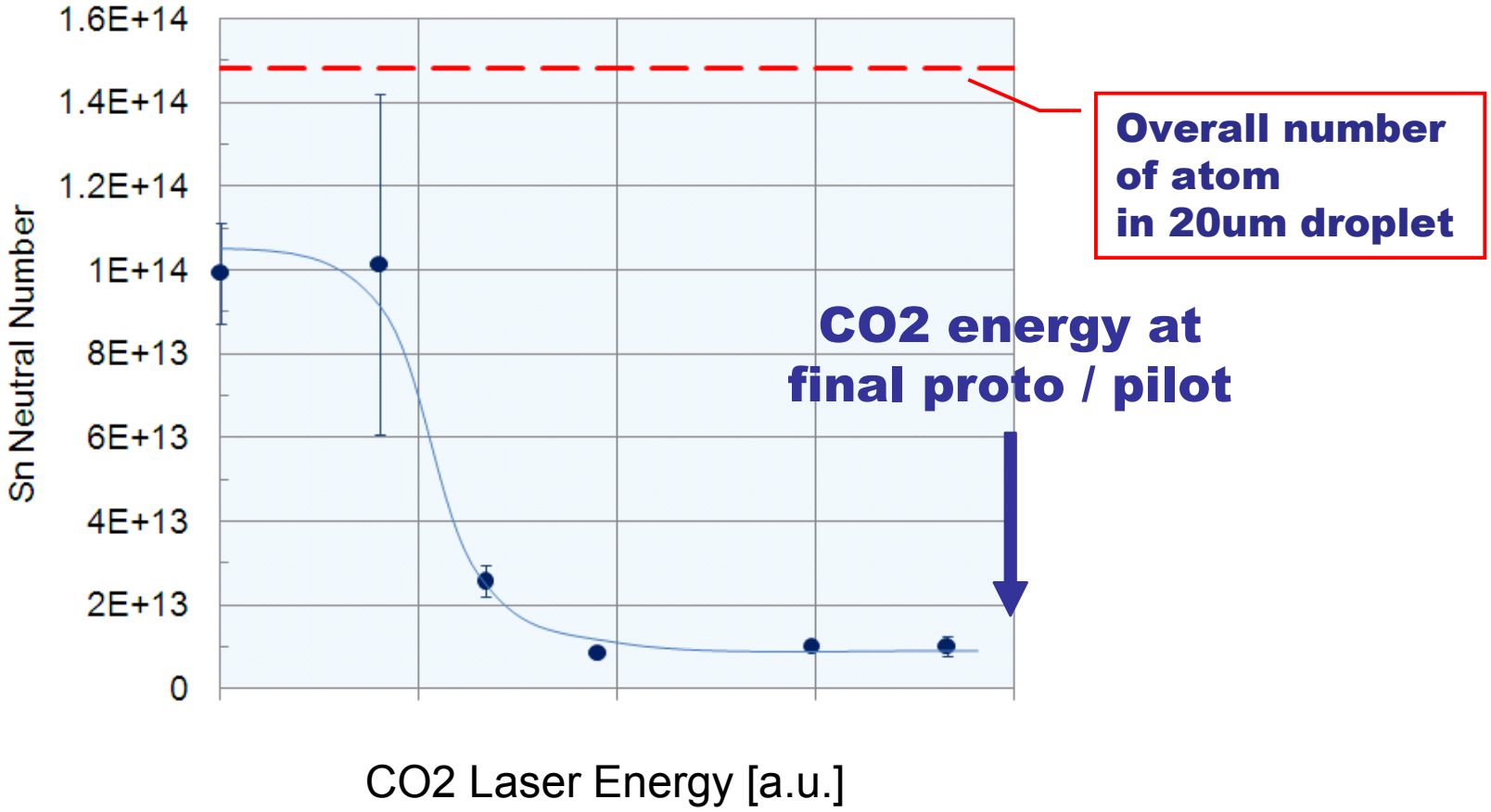
Atom measurement by LIF - 3

- **Remaining atoms : decreasing with increasing CO_2 laser energy**
- **7% atoms remaining for 20um droplet**



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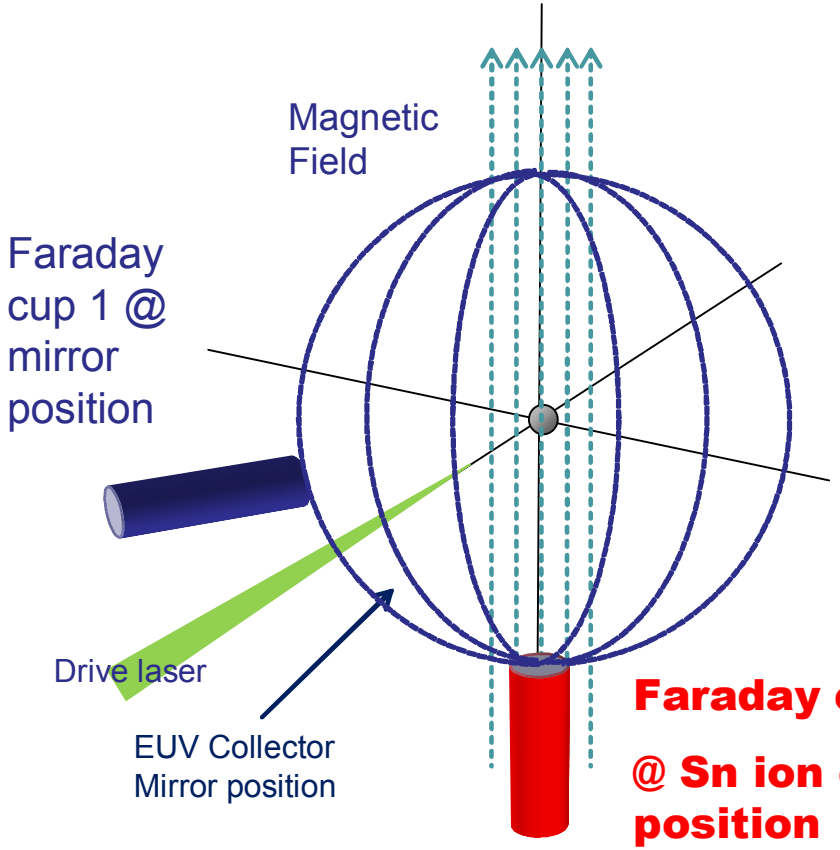
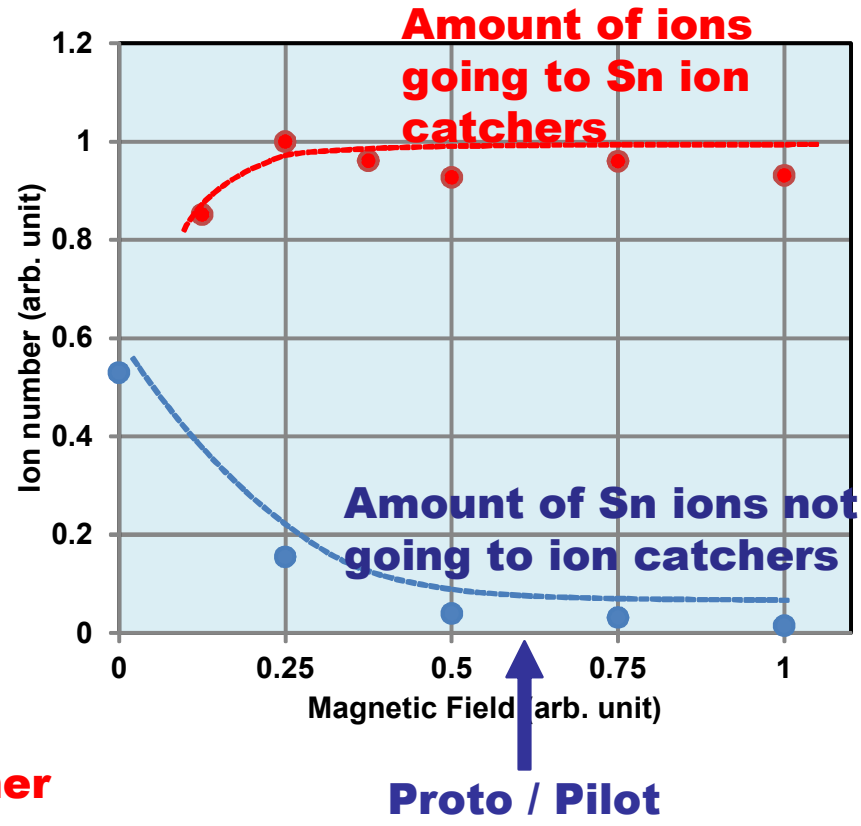
Ion Measurements by Faraday cups

- **Amount of ion is measured by Faraday cup**

- ***>99% Sn go to Sn ion catcher !!***





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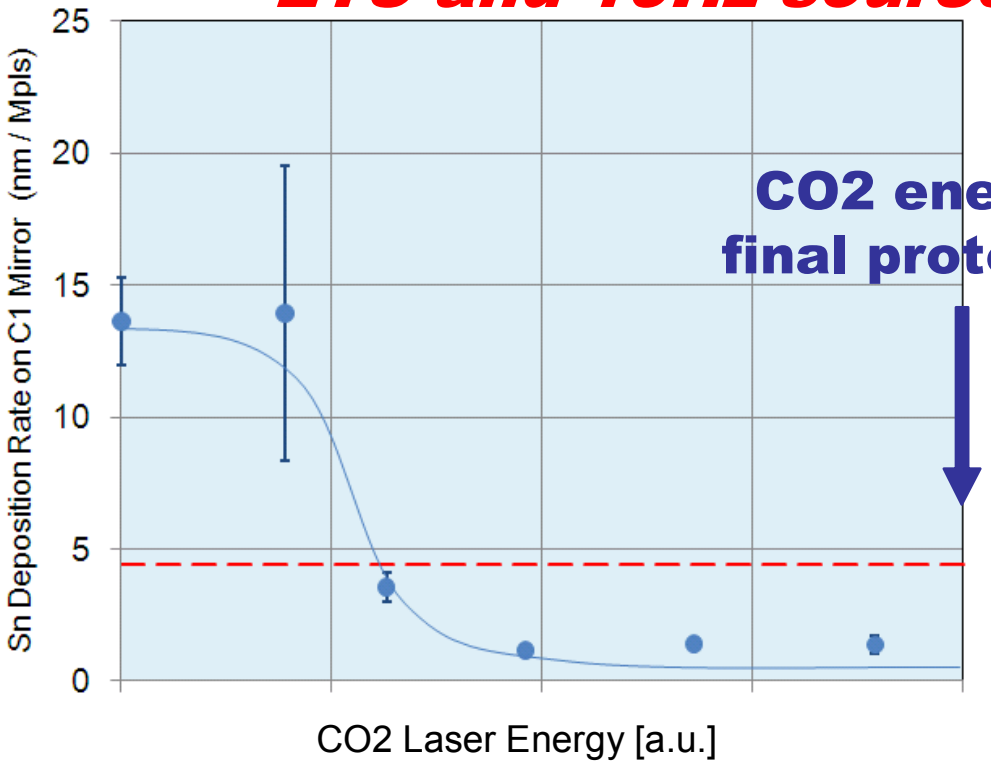
Clean operation feasibility proven

- **Estimated deposition and cleaning rates**
  - ✓ **Deposition rate: 1.2 nm / Mpls***
  - ✓ **Cleaning rate: 4.4 nm / Mpls****

Clean operation is proven by test data with ETS and 10Hz source



Estimation of Sn atom dispersion : isotropic

*** Estimation based on experimental ata under pilot conditions**

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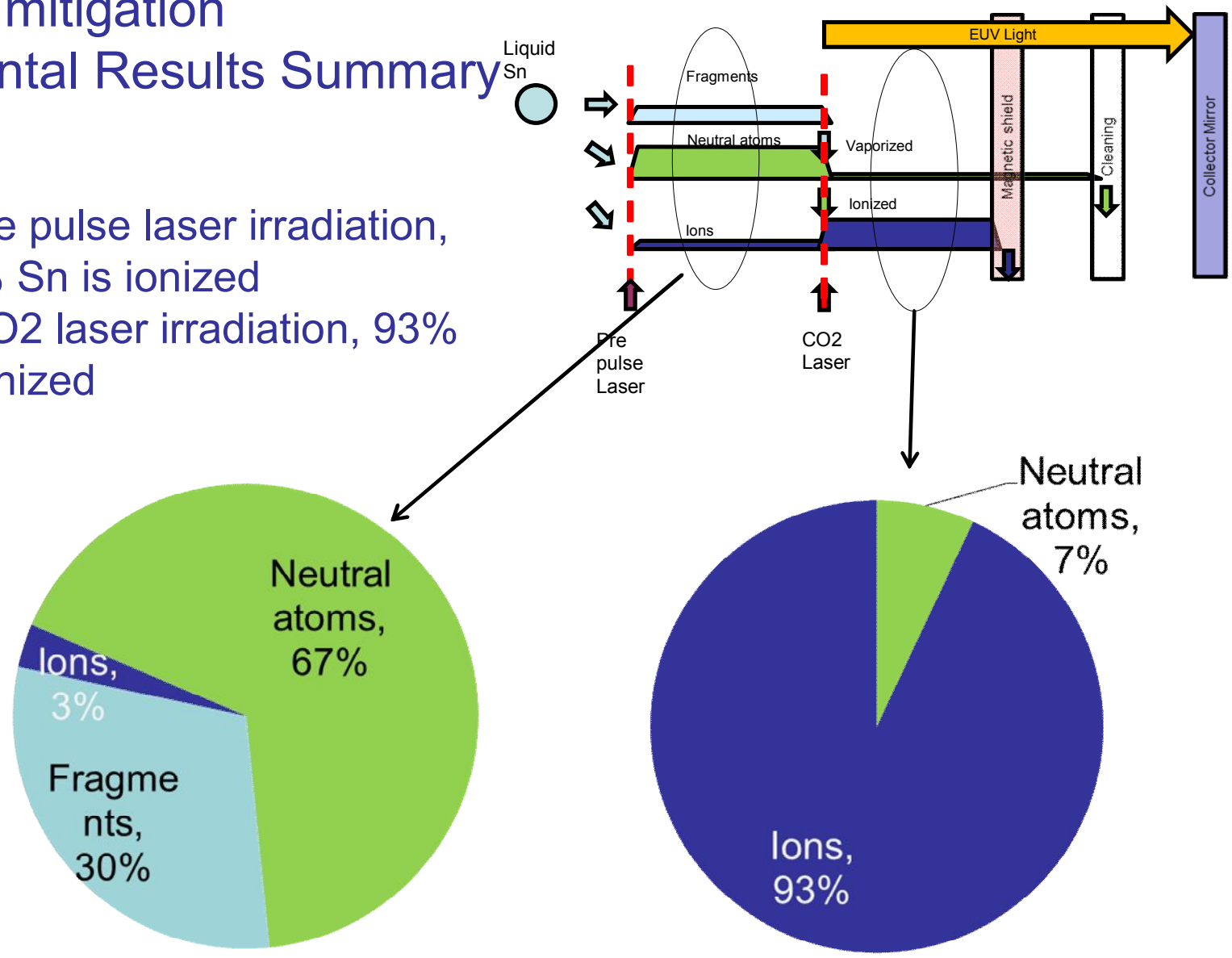
Tin debris mitigation
Experimental Results Summary

- After pre pulse laser irradiation, only 3% Sn is ionized
- After CO2 laser irradiation, 93% Sn is ionized



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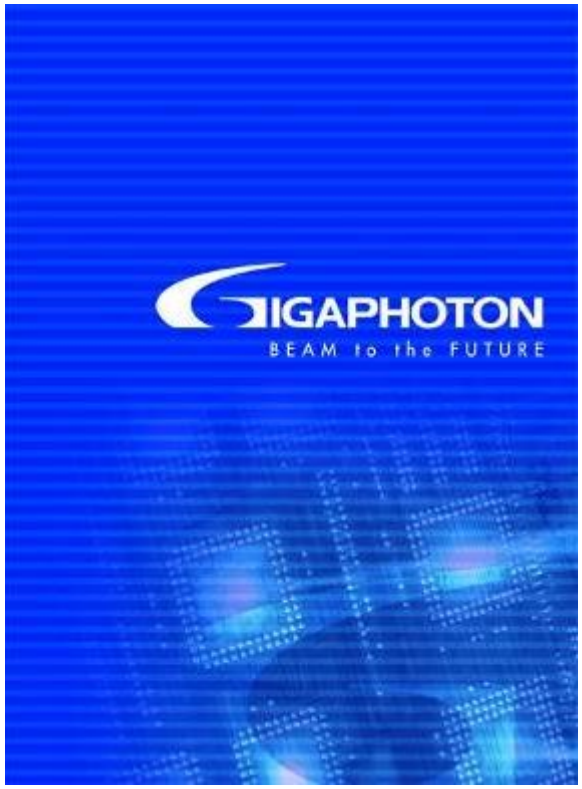

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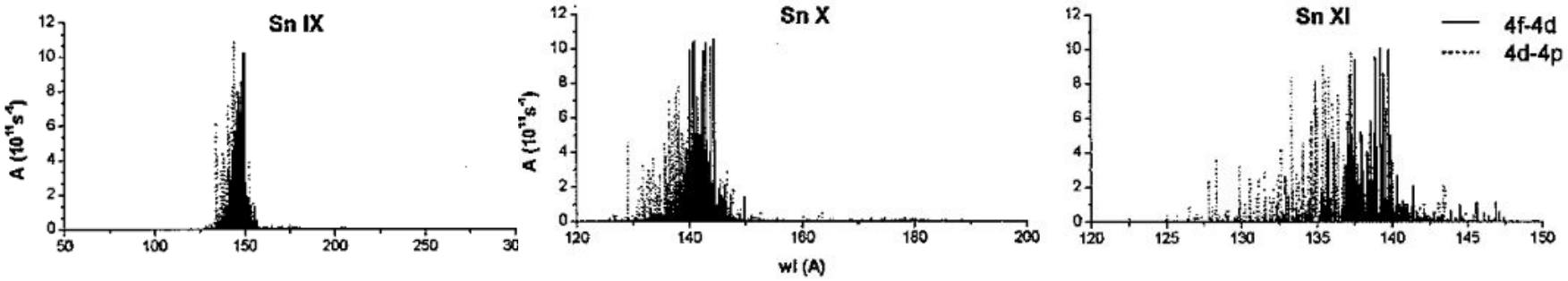
OoB (Out of Band) EUV power

Cause of OoB

	Black body irradiation	Sn emission lines	CO2
DPP	Large(10^5K)		-
LPP	Small(10^4K)		Large
Side effects to Litho imaging	Flare	Flare	Defocus

reduced by filter.

Emission lines are different for charge states of Sn
-> OoB depend on Sn charge condition
Check EUV spectrum profile and OoB power at different CE conditions.



Ref: EUV Sources for lithography, 2005 SPIE press

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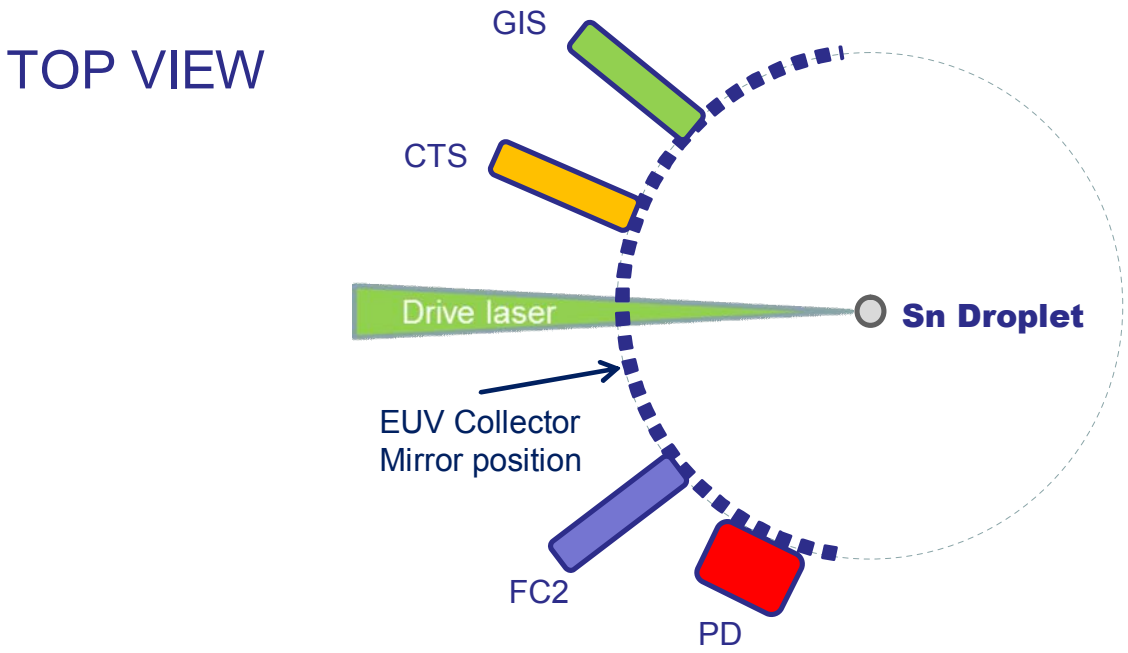
Experimental setup

items	Tools to measure
EUV Power	FC2 (Flying circus 2)
OoB Power	PD (Photo diode + band-pass filters)
EUV spectrum	GIS (grazing incidence spectrometer)
DUV-Vis spectrum	CTS (Czerny-Turner spectrometer)



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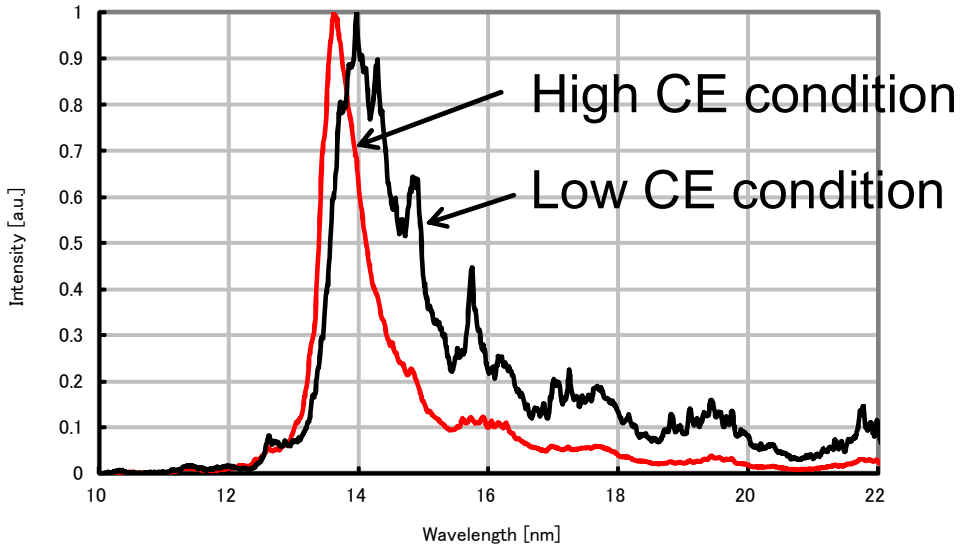
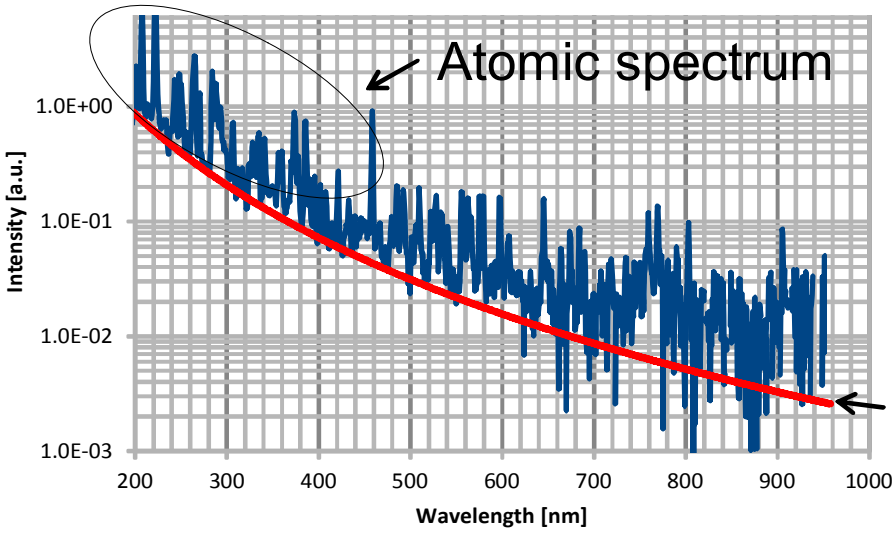
OoB measurement results 1/2



Spectrum differences are estimated that it was caused by the deviation of Sn ion charge condition.



OoB at DUV wavelength consists of black body irradiation and atomic spectrum.

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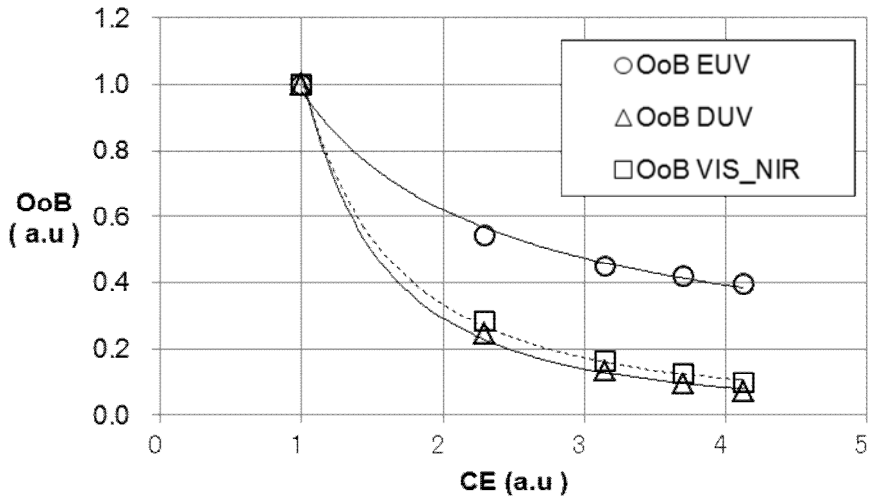
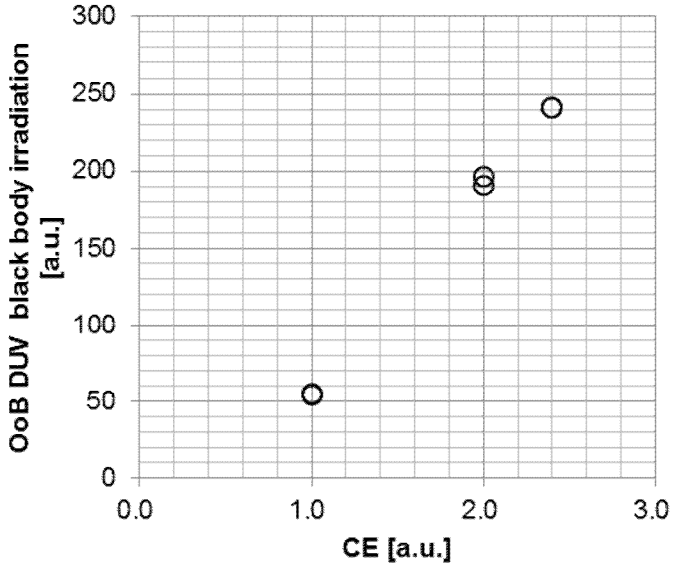
OoB measurement results 2/2



OoB EUV: 5-150nm w/o in-band
OoB DUV: 150-400nm
OoB VIS-NIR: 400-1000nm

OoB becomes smaller for high CE conditions. If CE is increased to get high EUV power, OoB will be reduced.



OoB at DUV induced by black body irradiation increases as high CE. Contribution of black body irradiation to OoB DUV is small. Atomic spectrum is dominant for OoB DUV at LPP system.

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Summary

- Sn debris mitigation, collector mirror protection concept is confirmed.
- The amounts of ions and neutral atoms are measured for both condition after Pre pulse laser and CO2 laser irradiation.
- Sn ionization rate is obtained 93% after CO2 irradiation.
- >99% Sn^{n+} is trapped by Magnetic field.
- The amounts of remained neutral atoms are smaller than cleaning capacity.
- OoB strongly depend on the CE. OoB becomes smaller at high CE condition.

Acknowledgement

A part of this work was supported by the New Energy and Industrial Technology Development Organization (NEDO), Japan.

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