

# Present Status of Laser-Produced Plasma EUV Light Source

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## Abstract

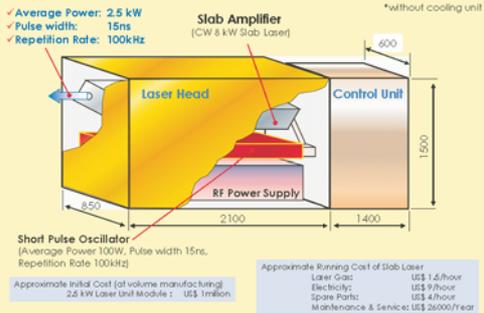
The development status of the key technologies for a HVM Laser Produced Plasma EUV light source is presented. This includes the high-power RF-excited CO<sub>2</sub> laser, the Sn droplet target and the collector mirror lifetime enhancement (debris, ion mitigation). Basic experiments that support the development, e.g. a conversion efficiency of 2.5-4.5% has been obtained with a 15 ns TEA CO<sub>2</sub> laser and a Sn wire, as well as a general outline of the system development, i.e. system scaling towards 50/115 W is presented.

## High Power Pulsed CO<sub>2</sub> Laser

### Laser System



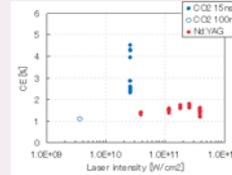
### Laser Module for HVM (High Volume Manufacturing) EUVL



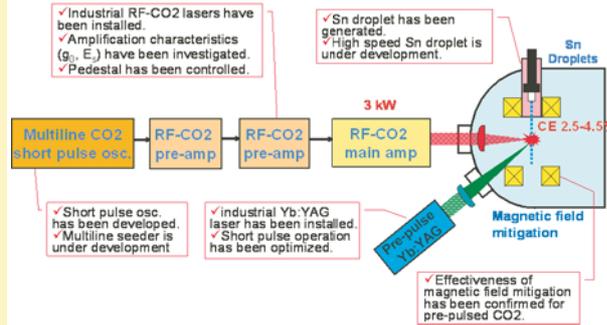
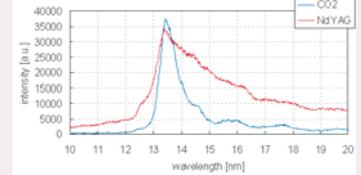
## EUV from CO<sub>2</sub> laser produced Sn plasma

Conversion efficiency dependence on the laser intensity

CE: 2.5% - 4.5% with CO<sub>2</sub> laser  
 Laser intensity :  $3 \times 10^{10}$  W/cm<sup>2</sup>  
 \*energy: 30 mJ  
 \*Pulse width: 11 ns  
 \*Spot size: d=100 μm

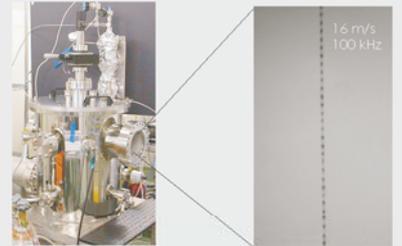


EUV spectra from Sn plasma



## Sn droplet target

Item	Demonstrated	Goal
Droplet speed	16 m/s	100 m/s
Diameter	75 μm	20 μm (tentative)
Repetition rate	100 kHz	100 kHz

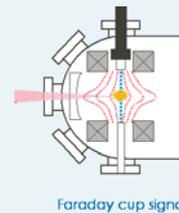
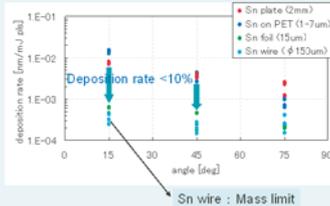


## Characterization of Sn debris

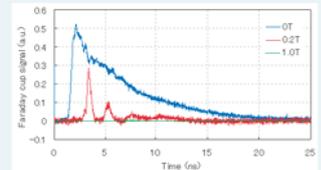
### Sn debris evaluation by QCM measurement

- Laser: Nd:YAG, 35 mJ, spot size 100μm
- EUV pulse energy: 0.4-0.45mJ
- Target: Sn Plate (t = 2mm), Sn on PET (Cu), (t = 1.7-μm/40μm) Sn foil (t = 15μm, free-standing), Sn wire (d = 150μm)

### Angular dependence of debris deposition for various Sn target



EUV energy: 0.4mJ  
 Chamber pressure: 4E-4Pa  
 Target: Sn (d=6mm Rod)  
 Faraday cup location: 15deg



Fast ion signal decreased < 0.1% with 1 T magnetic flux density

## EUV power scaling

### Calculated IF Power

Laser Power	CE	Xe					Sn				
		0.5%	2.5%	3.0%	3.5%	4.0%	0.5%	2.5%	3.0%	3.5%	4.0%
2.5kW	3.5W	17.5W	21.0W	24.5W	28.0W						
5.0kW	7.0W	35.0W	42.0W	49.0W	56.0W						
7.5kW	10.5W	52.5W	63.0W	73.5W	84.0W						
10.0kW	14.0W	70.0W	84.0W	98.0W	112.0W						

Primary source to IF EUV transfer efficiency: 26%

EUVA goal

HVM source

## Conclusion

### CO<sub>2</sub> LPP light source (Achievement):

- CE: 2.5% - 4.5% with Sn
- EUV source power: 100 W (2 πsr, 2% BW, Calculated)
- CO<sub>2</sub> laser power: 3 kW
- Sn droplet target: 16 m/s, d = 75 μm, 100 kHz
- Fast ion mitigation: < 0.1% with 1 T magnetic flux density
- Sn debris: < 10% by using mass limited target

### Next step:

- Higher droplet speed (100 m/s)
- Smaller droplet size
- Increase laser power (5 kW)

### CO<sub>2</sub> drive laser system:

- HVM laser system will be based on slab amplifier modules.

## Acknowledgments:

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