Development of EUV light source by laser-produced plasma with Sn nano- particles

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Outline

Aim

Development of efficient and debris free laser-produce plasma light source for next generation EUV lithography

Approach

CO_2 laser produced Sn plasma for efficient EUV generation

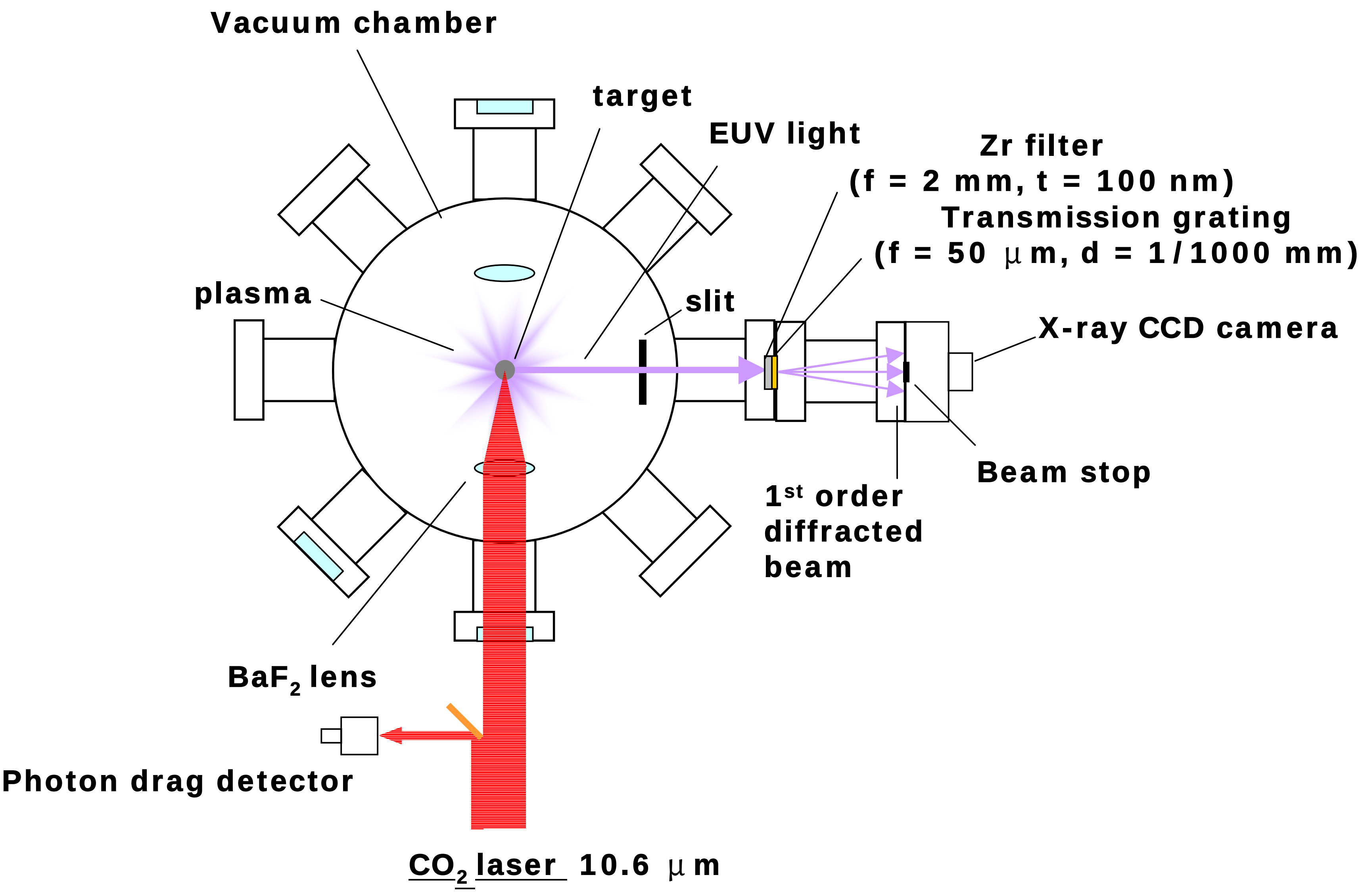
Subject to be solved

Control of debris generation

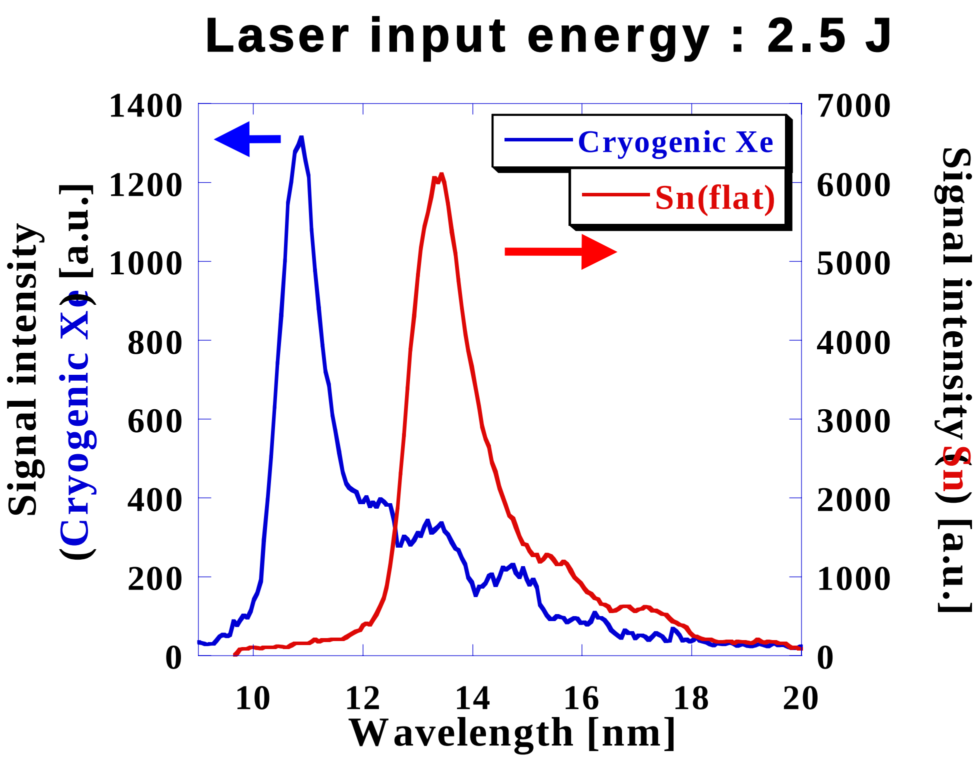
In this study

- Investigation of optimum Sn density for CO_2 LPP
- Development of nano-structured Sn target

Experimental Setup



Tin-based target



- The signal intensity of x-ray CCD camera at 13.5 nm with a flat Sn target was about 20 times higher than that of a cryogenic Xe target.
- The conversion efficiency exceeded 0.1 % with a cryogenic Xe target.

Presumptive conversion efficiency with flat Sn target is more than 2 %.

Tin-based targets are attractive for a realization of a practical EUV light source.

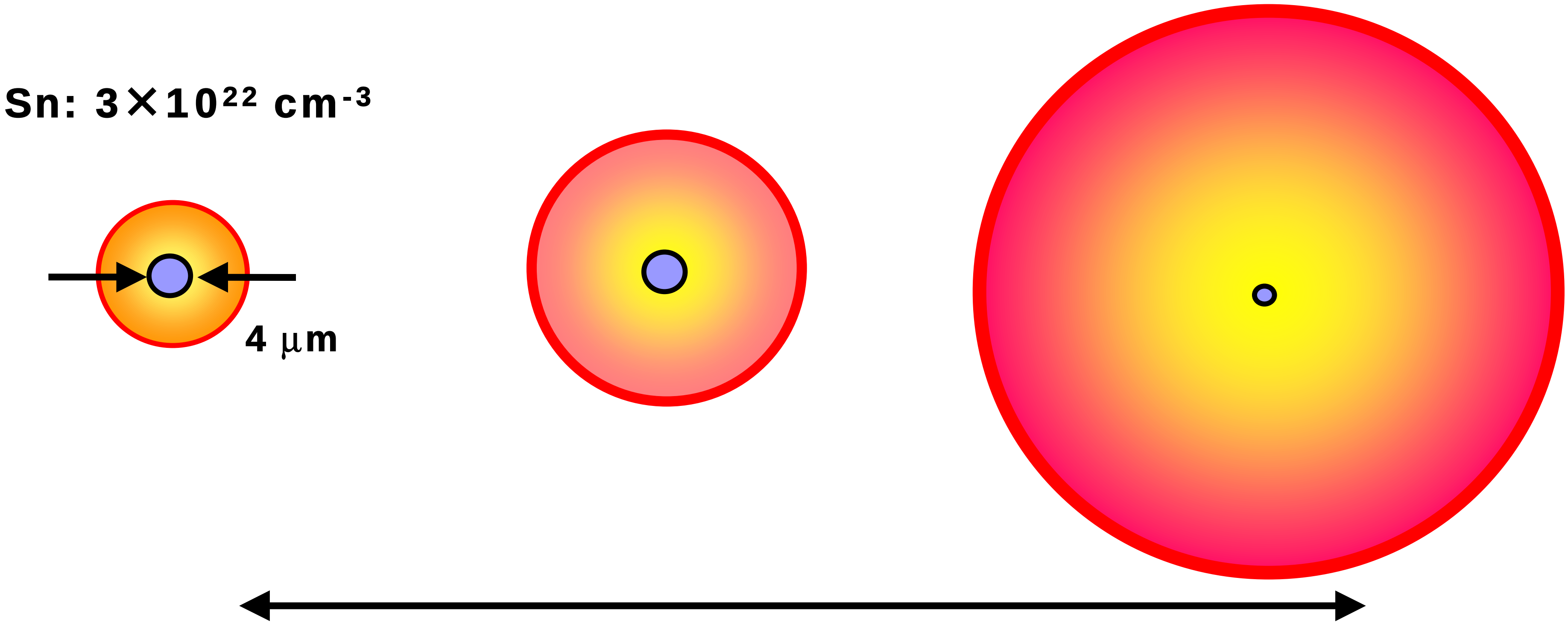
Debris generation, that limits the lifetime of the optical system, is serious.

Relation between wavelength and plasma size

Mass limited target → **reduction of debris**

suppose 3.3×10^{11} excited atoms @ 1 %

XeCl laser	Nd:YAG laser	CO_2 laser
308 nm	1064 nm	10640 nm



desirable short pulse

desirable long pulse
effectively pre-pulse

Estimation of required quantity of tin-nano-particles

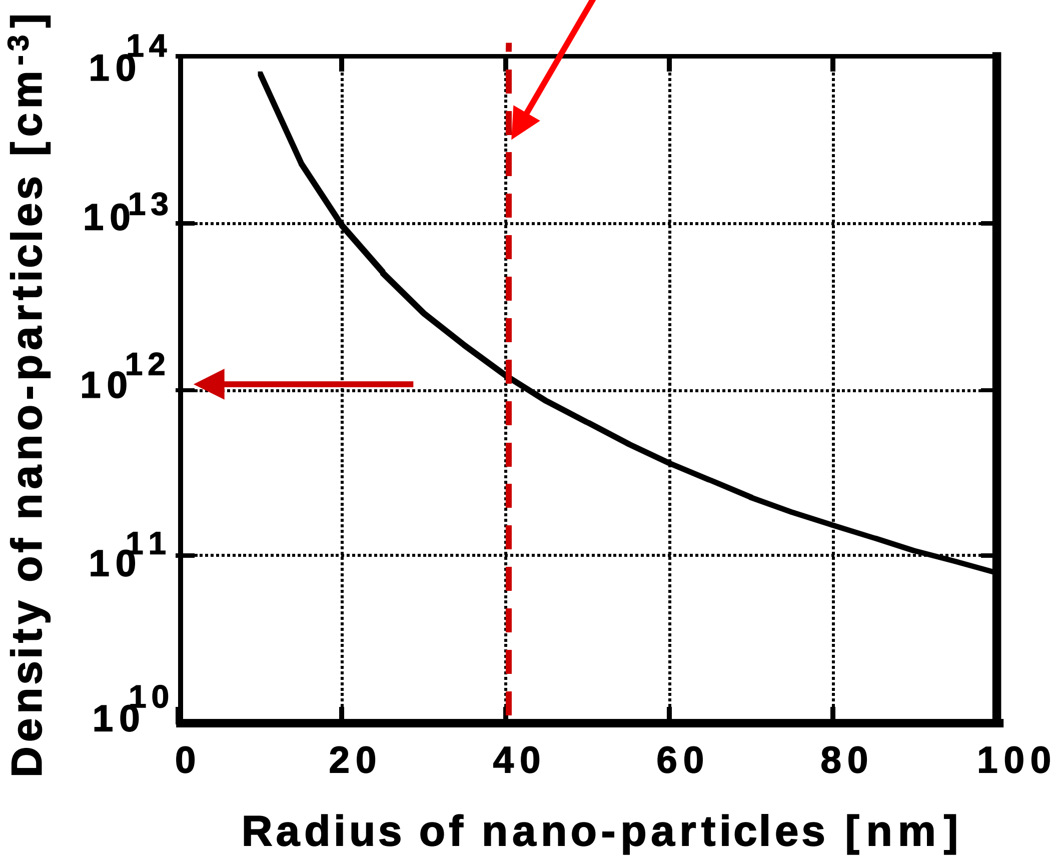
Assuming the fully ionization,

$$N_{nano}\, r^3 = \frac{3\, n_e\, M}{4\pi\, \rho\, ZF}$$

- N_{nano} : Density of nano-particles
- r : Radius of nano-particles
- M : Atomic mass of tin
- r : Density of solid tin
- Z : Valence
- F : Ratio of Sn^{+Z}

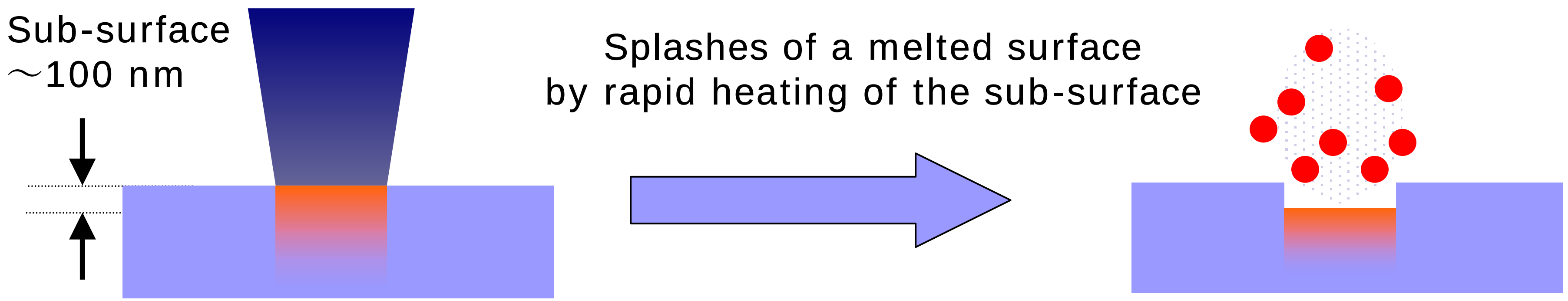
CO_2-LPP : $n_e \sim 10^{19}$ cm^{-3}

Max radius without sub-surface (supposition)



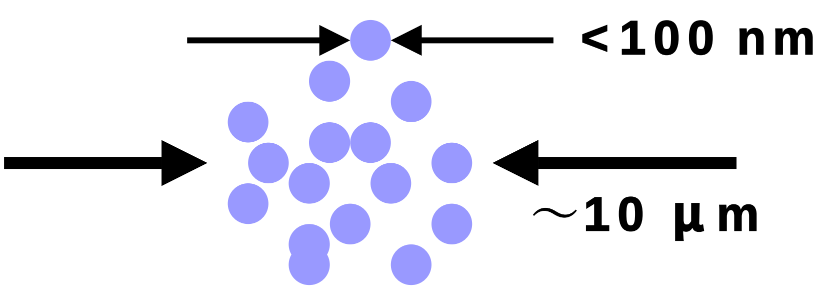
Consideration on Debris Generation
- Nano-structured Sn targets -

Mechanism of debris generation



Without sub-surface

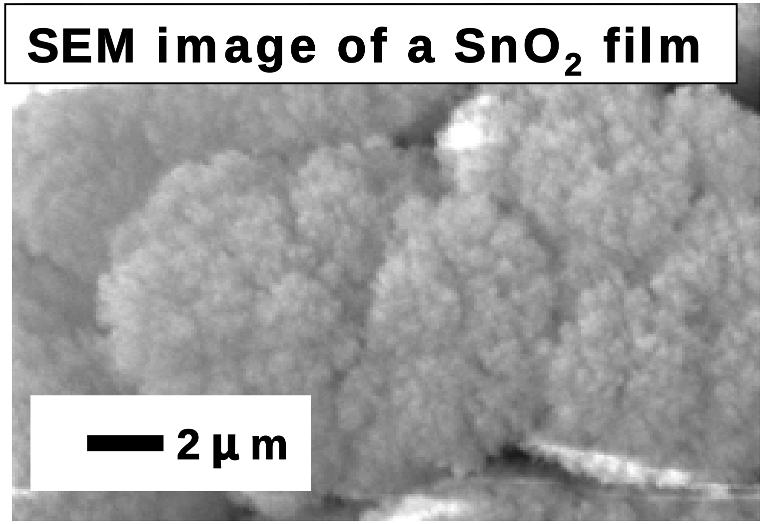
Nano-particle

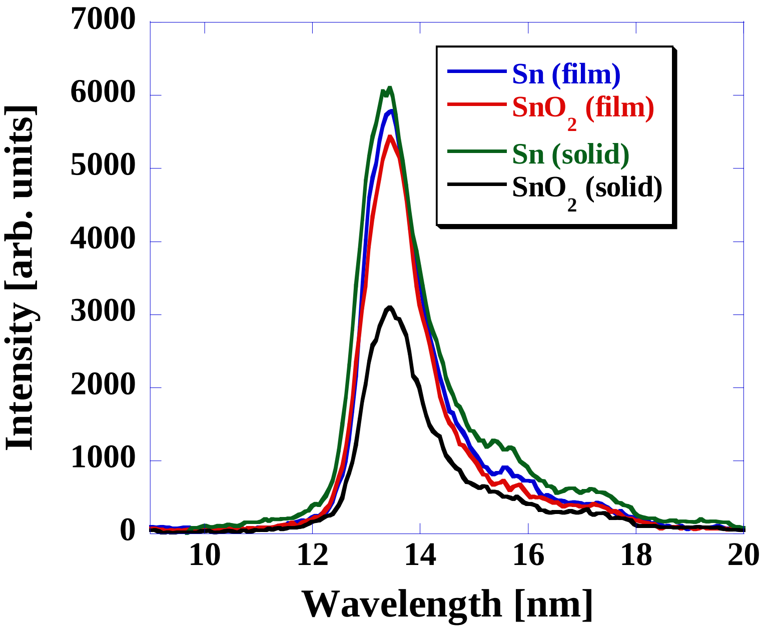


The EUV intensity is proportional to the number density ions contained in the plasma

One of an ideal target for an efficient and debris-free EUV source

Film type target (previous study)



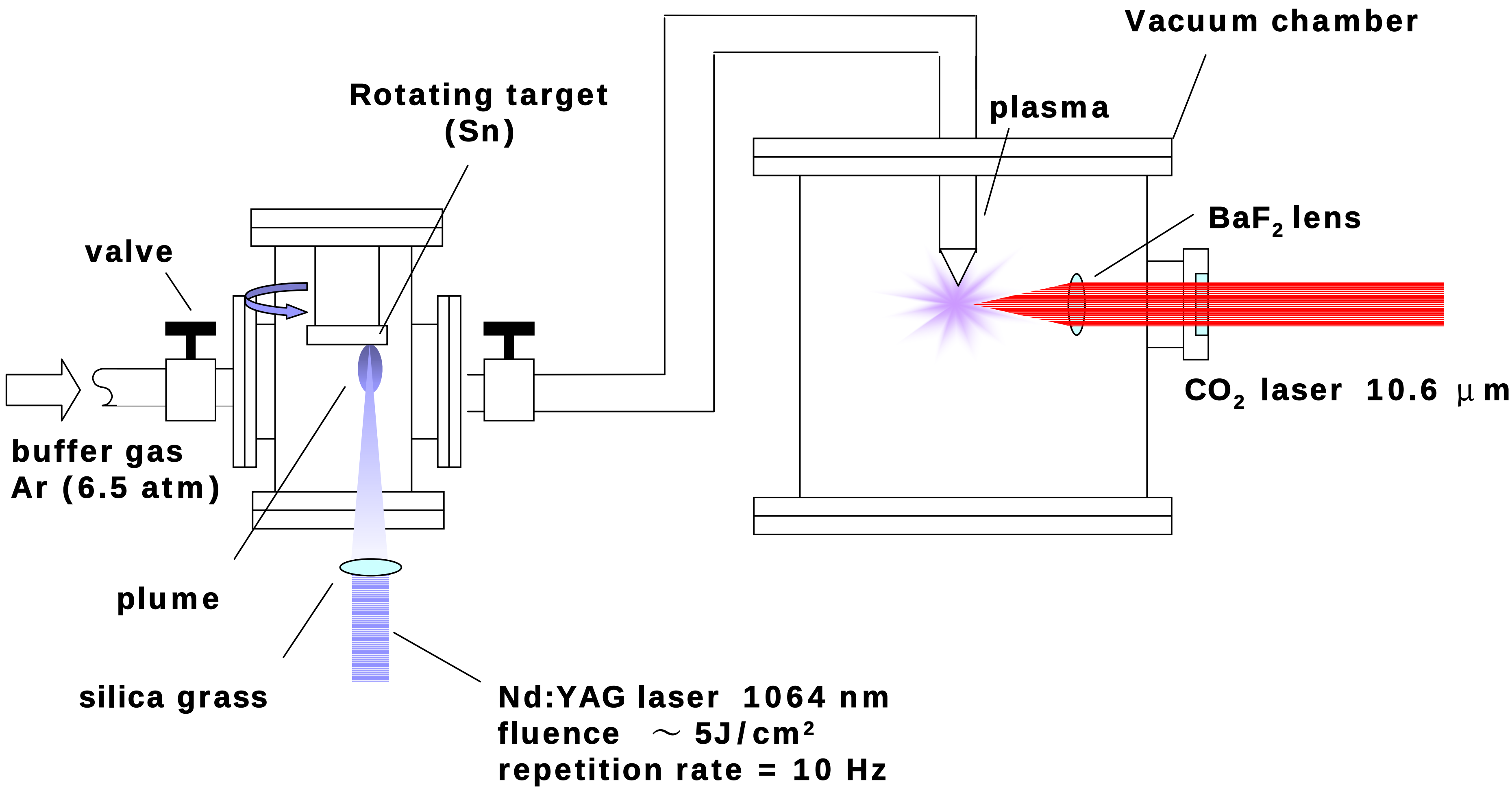


- Nano-structured tin-based film type targets were fabricated by the pulsed laser deposition (PLD) method.
- The SnO_2 film has cauliflower-like structure that consisted of aggregation of nano-particles of less than 100 nm, and its thickness reaches to more than 20 μm.

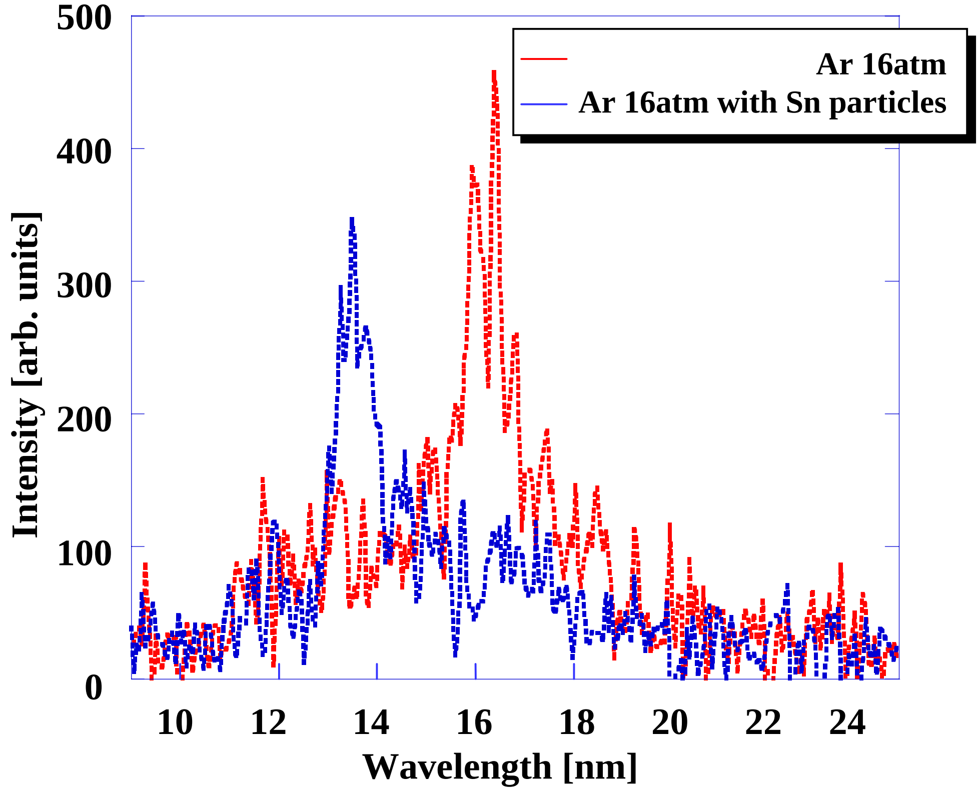
Nano-structured film type targets are as efficient as a flat Sn target.

Some droplet-like debris was observed even from nano-structured targets due to the blow-off the porous flake next to the laser-heated area.

Setup for production of Sn nano-particles targets



Sn particles targets



- Sn particles targets were fabricated by the pulsed laser ablation.
- The size of Sn particles were ~5 μm.
- The perk of spectrum at 13.5 nm increased and near 16nm decreased

Sn particles targets is able to produce the 13.5 nm EUV light.
The perk at around 16 nm that is produced by Ar is vanished.

Summary

Film type target

Nano-structured film type targets are found as efficient as a flat Sn target. But some droplet-like debris was observed even from nano-structured targets due to the blow-of the porous flake next to the laser-heated area.

Particle targets

Particle type targets are able to produce the EUV light , and it's emission is not much strong as bulk or film type target. We think that density of Sn particles is not enough.

It is necessary to optimize Sn particle's size, density and buffer gas's pressure.