

**030 EXTREME ULTRA-VIOLET
GENERATION PUMPED
BY CO₂ LASER-PRODUCED PLASMA**

Akihiko Takahashi¹, Hiroki Tanaka², Kiichiro Uchino³, Tatsuo Okada²

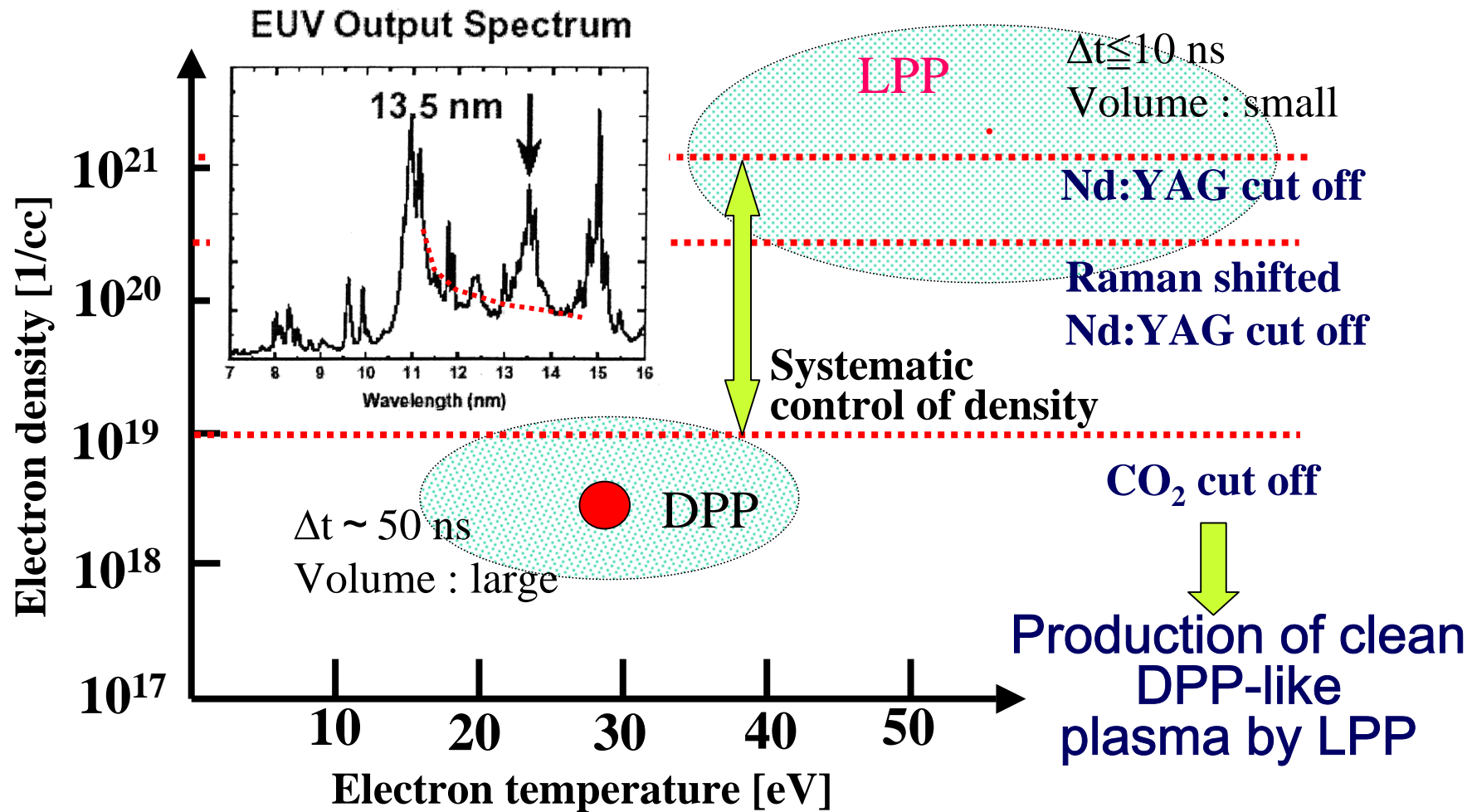
¹ School of Health Sciences, Kyushu University

² Graduate School of Information Science and Electrical Engineering,
Kyushu University

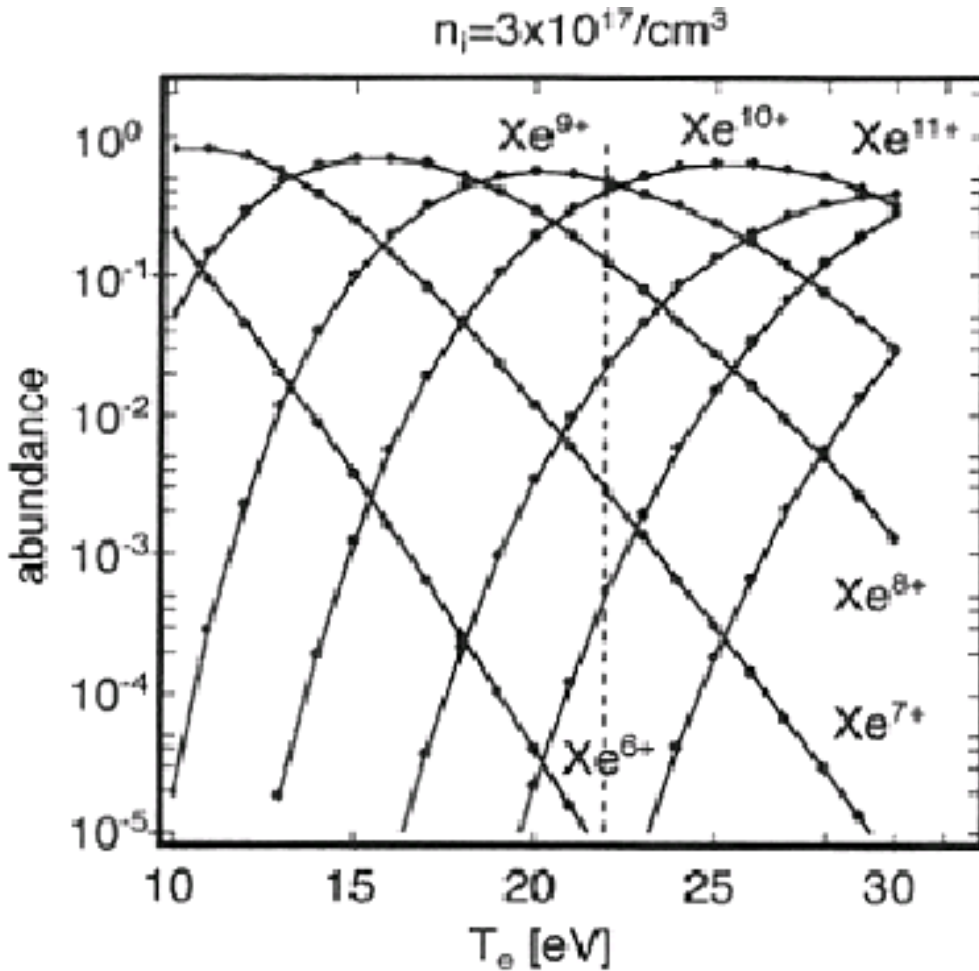
³ Interdisciplinary Graduate School of Engineering Sciences, Kyushu
University

EUV Light Generation from CO₂-LPP

--comparison between DPP and LPP--



The optimum plasma temperature is 20-30 eV



Dr. Sasaki et al.

Threshold intensity for production of LPP (multi-photon/cascade model)

$$I_{th} \propto \frac{1}{\lambda^2 n_g \Delta t}$$

λ : Laser wavelength

n_g : Gas density

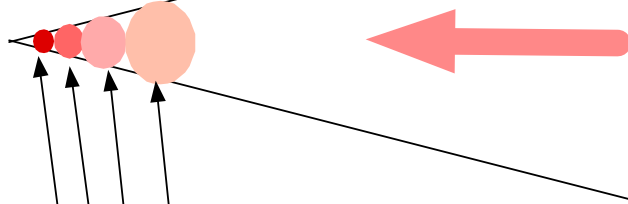
Δt : Laser pulse width

$$I_{th}(\text{YAG}) \gg I_{th}(\text{CO}_2)$$

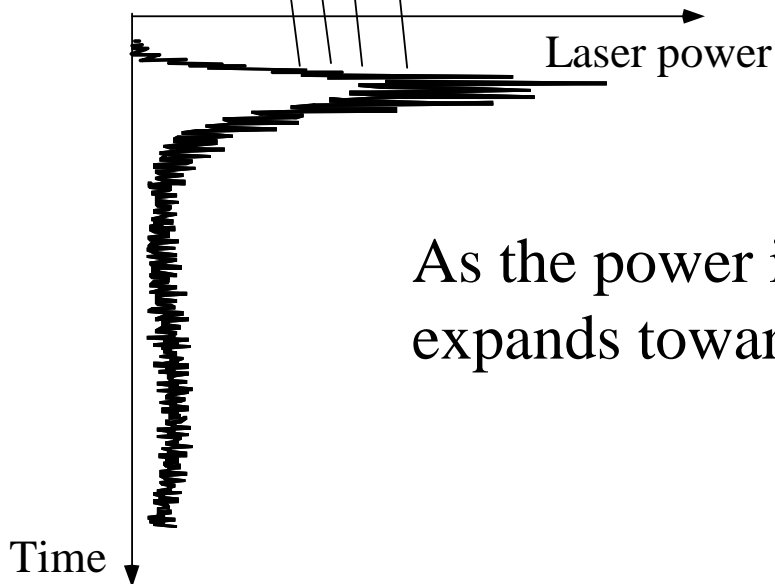
The temperature of LPP with YAG laser is too high due to a higher threshold intensity, I_{th} .

CO₂-LPP may be DPP-like plasma with large volume and low temperature.

Direction of plasma production

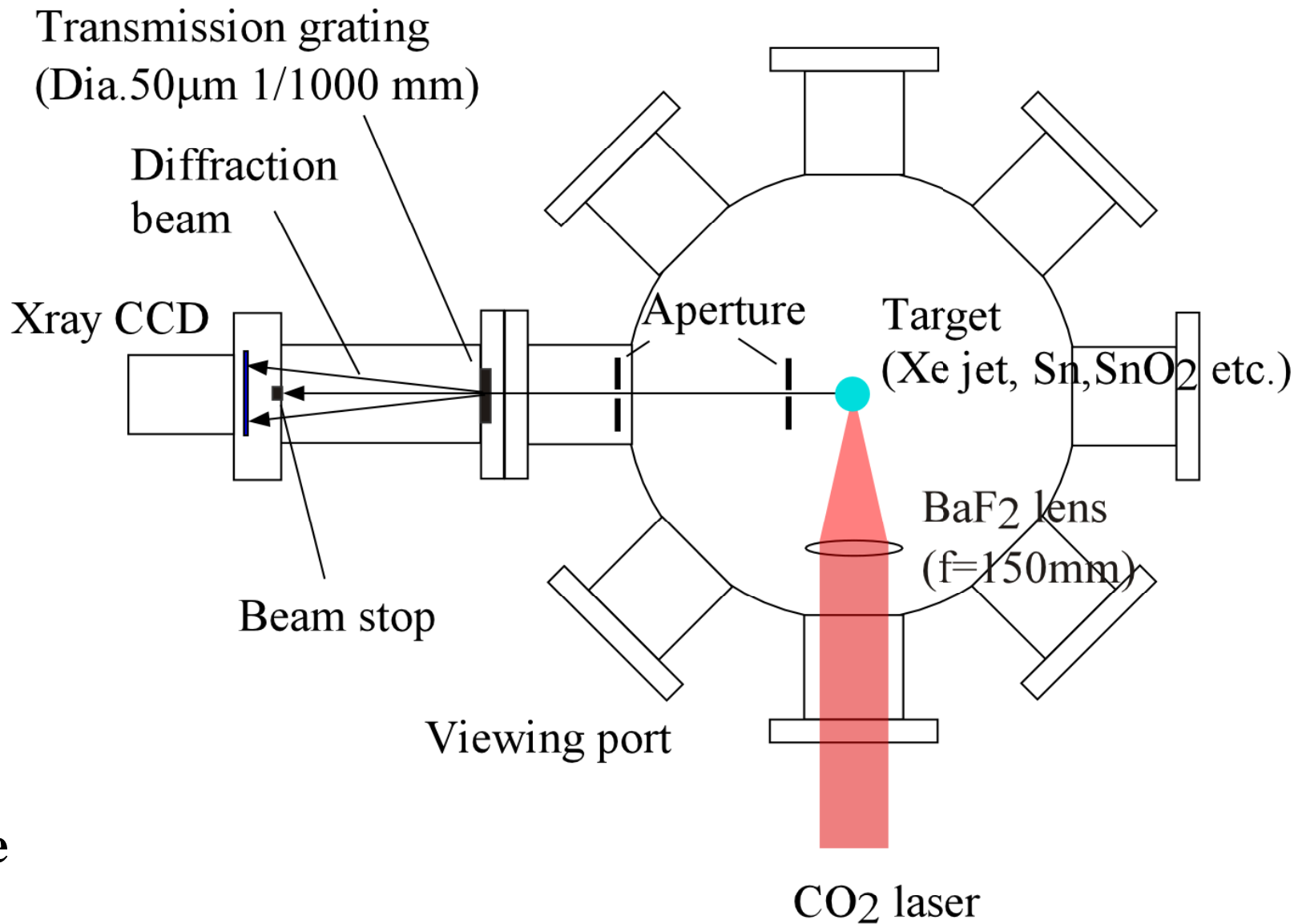


CO₂ laser beam

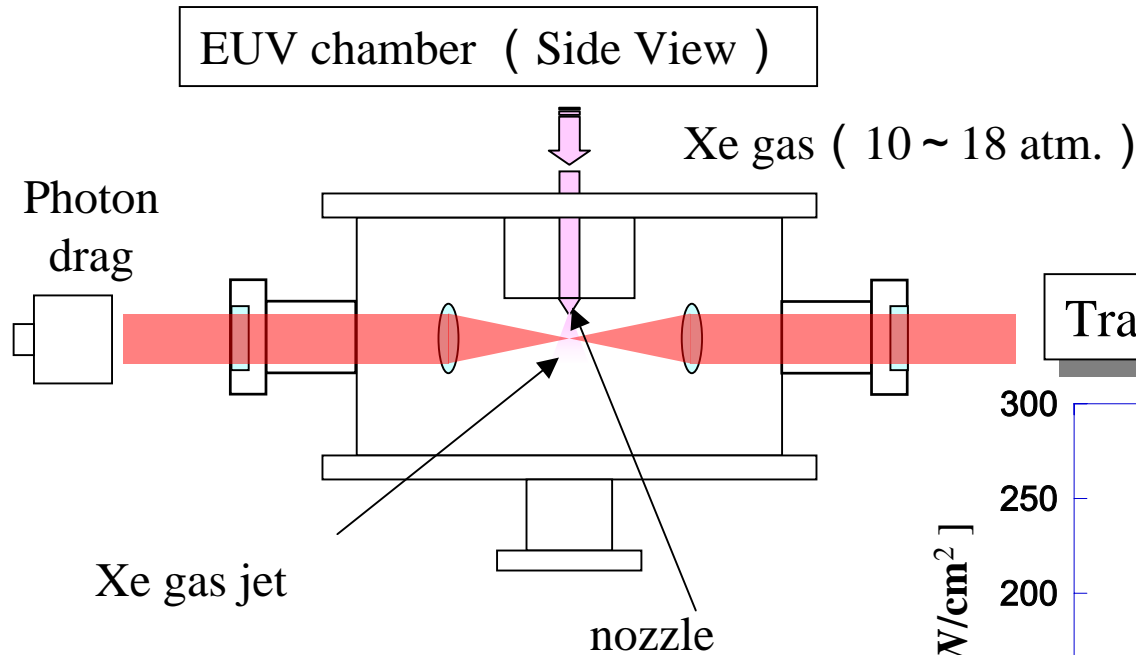


As the power increases, the plasma expands towards the off-focal region.

Experimental Setup

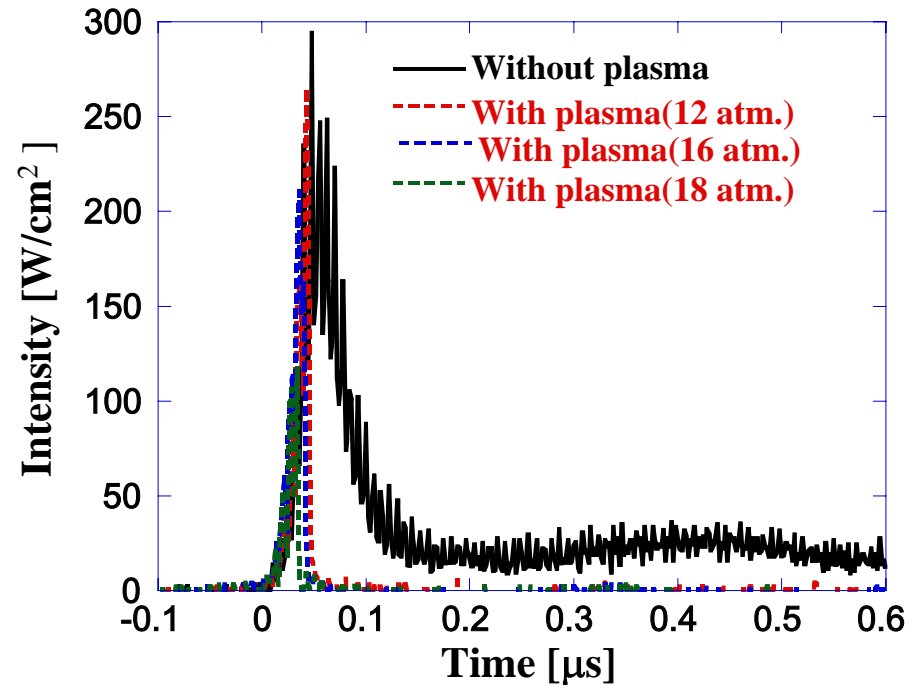


Production of CO₂ Laser-Produced Xe Plasma



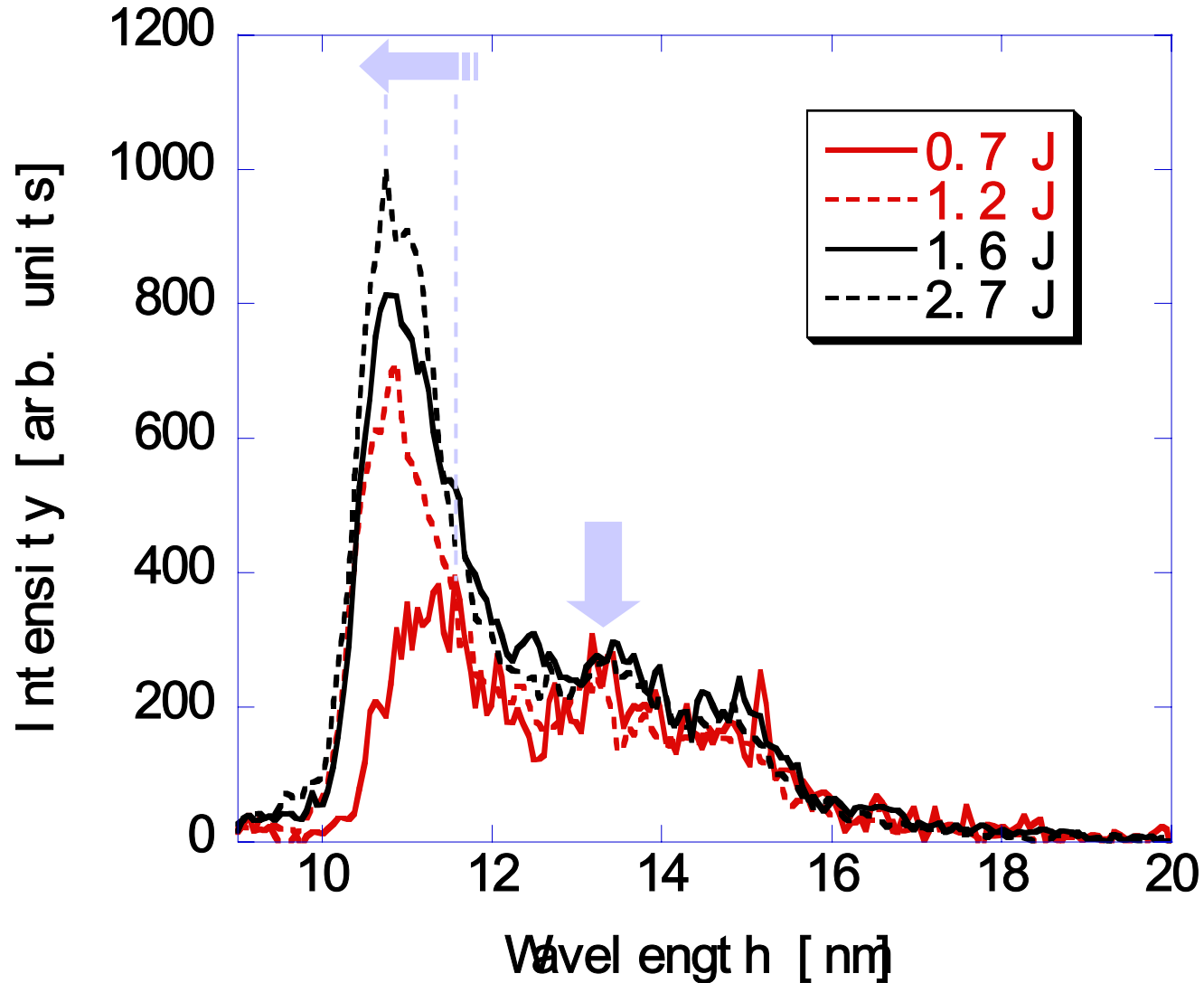
Plasma was produced only when the backing pressure of Xe exceeded 10 atm..

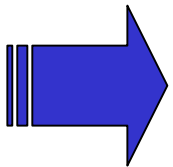
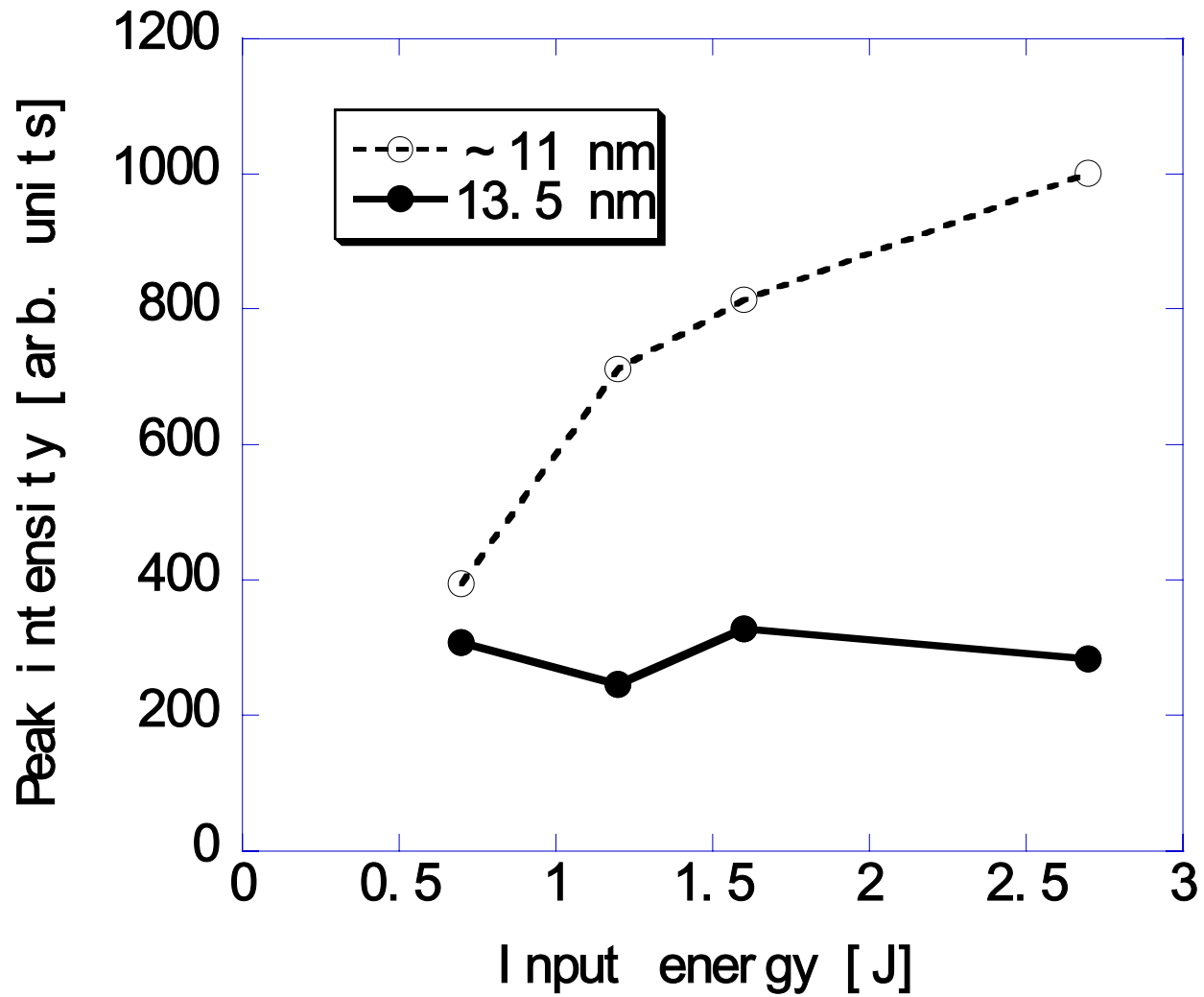
Transmitted CO₂ pulse shapes



EUV Spectra as a Function of Input Energy

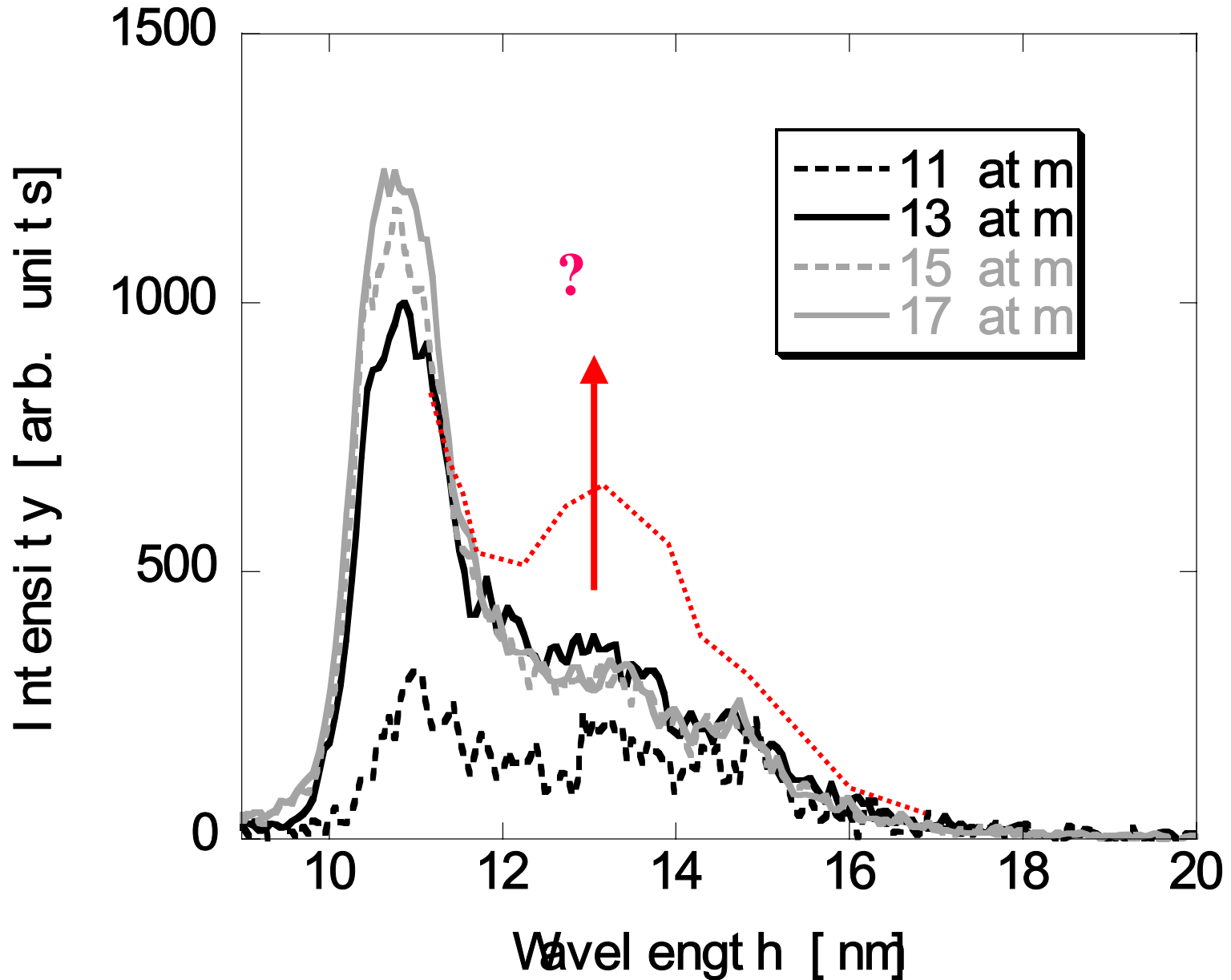
Target: Xe gas-jet (backing pressure 17 atm)

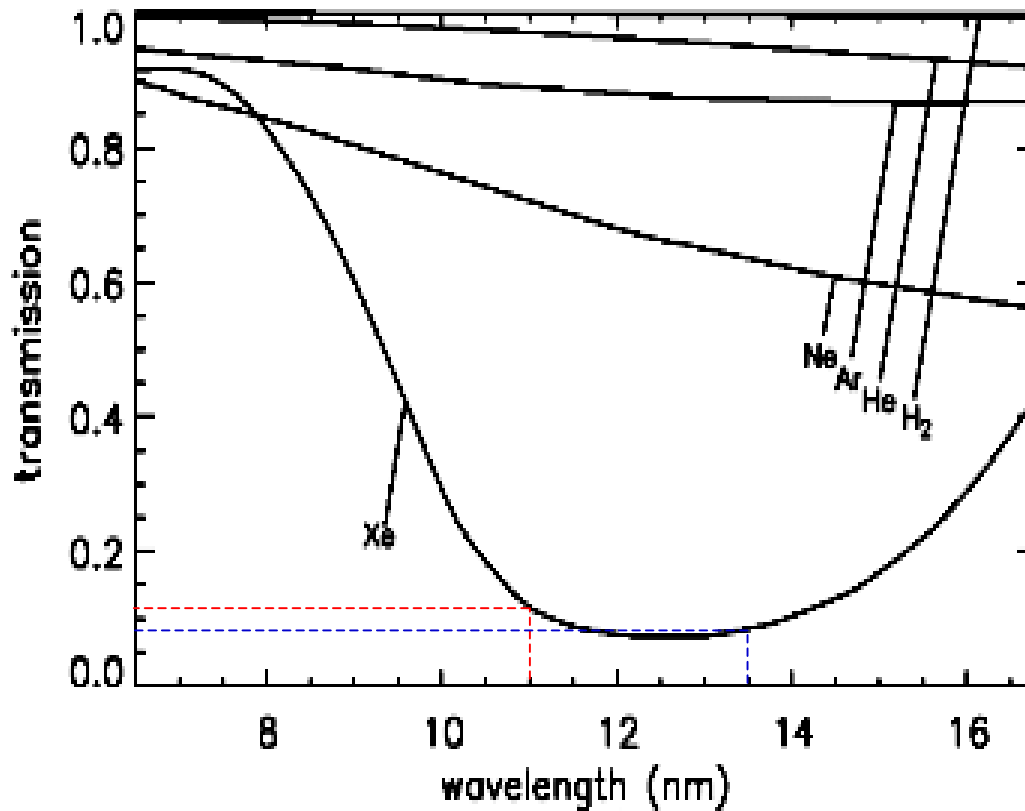




Intensity at 11 nm increases with increase in the input energy

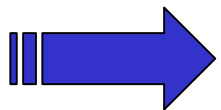
Dependence of EUV Spectra on Gas Density





Transmission curves of Xe, H₂, He, Ar, and Ne

:Bruijn et al. J. Quantitative Spectroscopy & Radiative Transfer



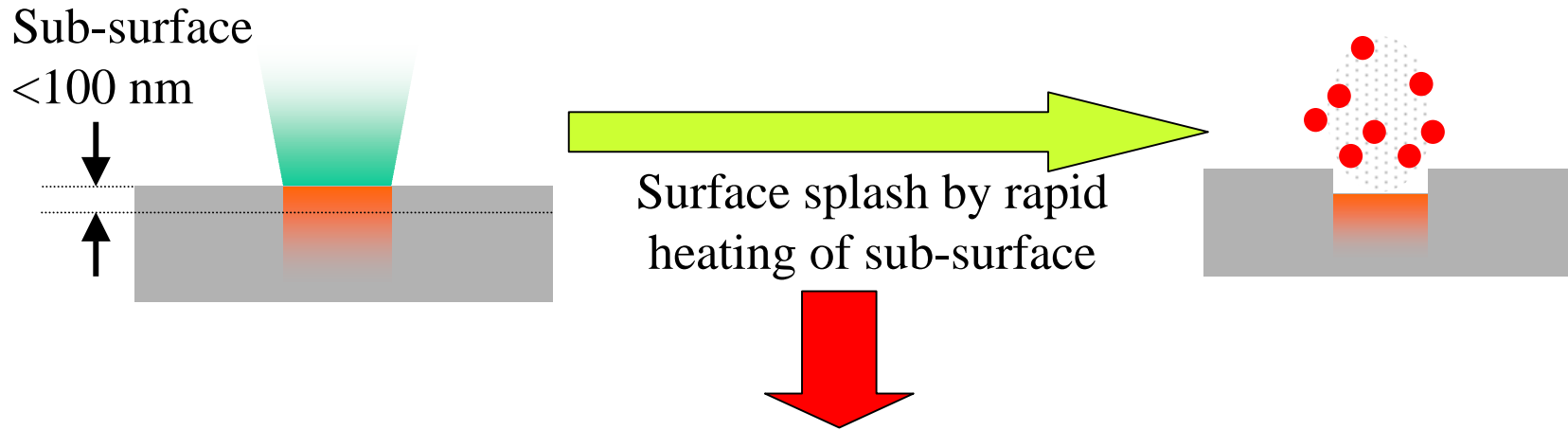
Intensity at 13.5 nm did not increase for higher gas density



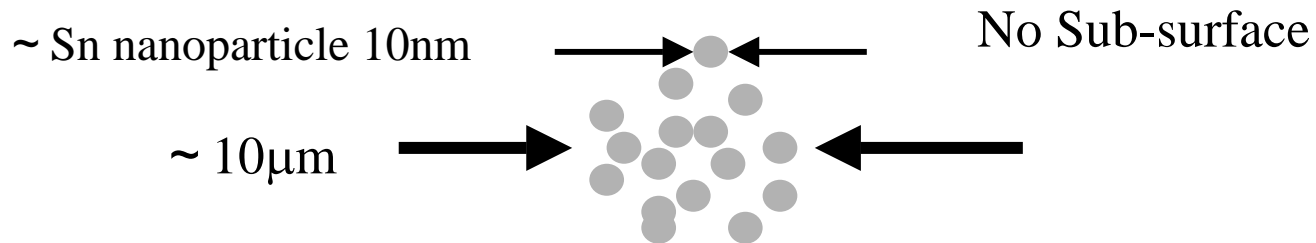
Absorption by neutral Xe atoms ?

Target Strategy

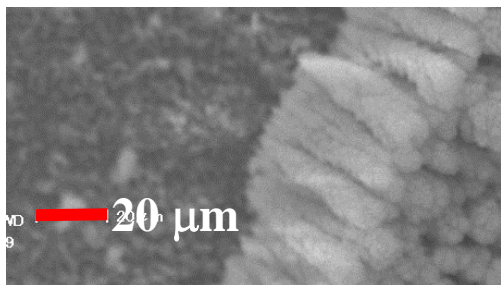
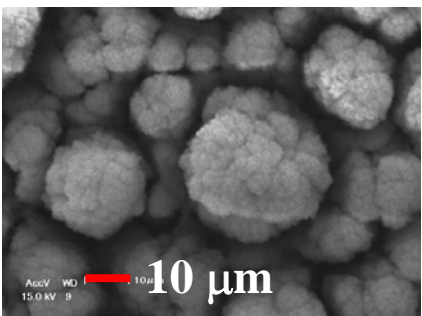
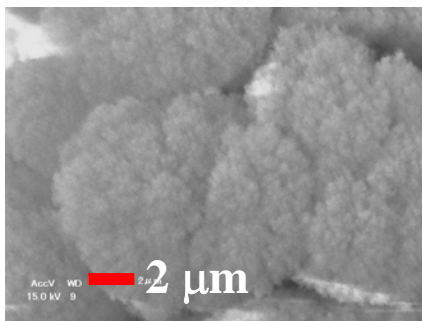
Evaluation of conversion efficiency and debris generation with nano-structured target.



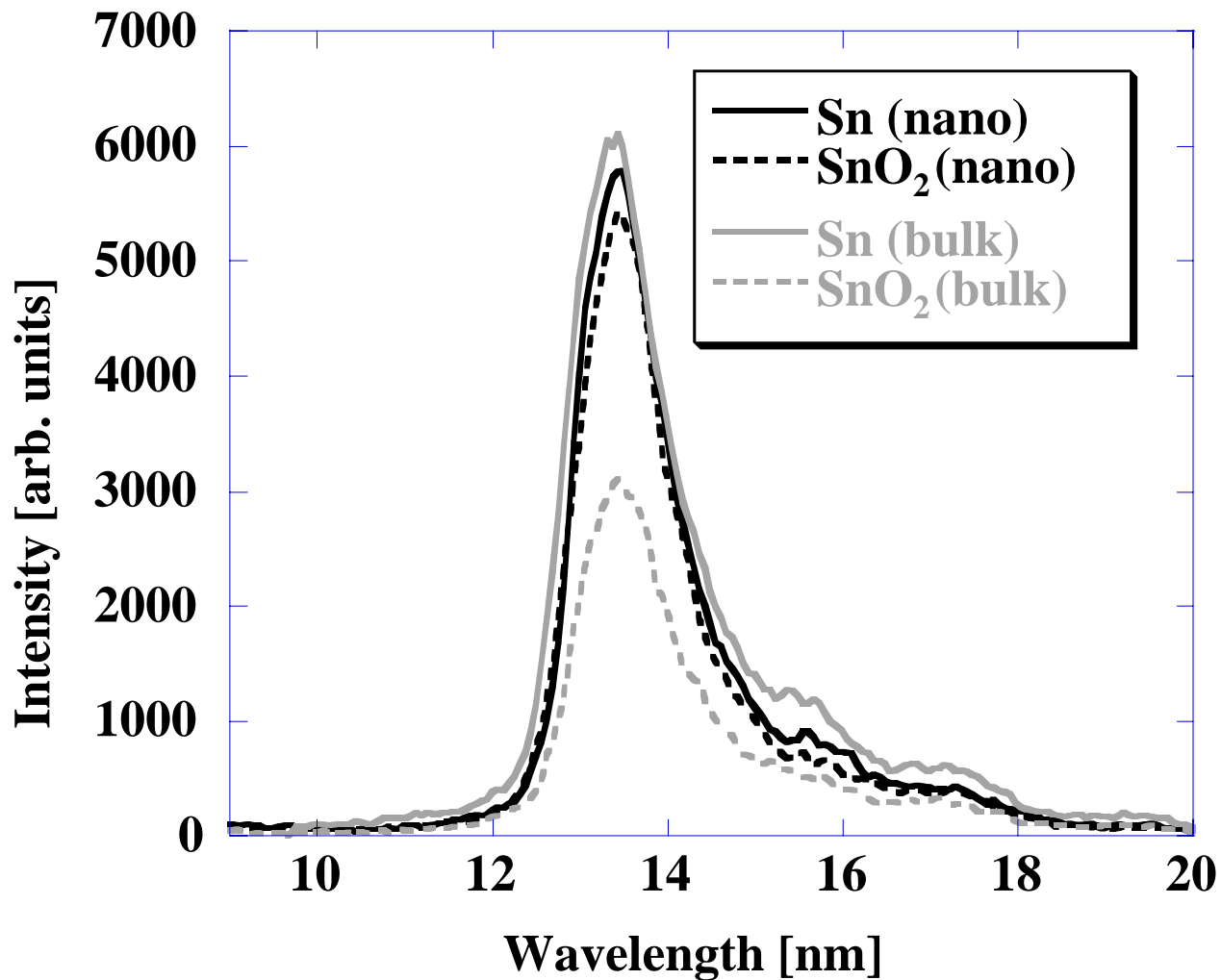
Sn nano-particle dispersed Xe target



Experimental results for Sn/SnO₂ targets



SEM Images of nano-particle target made by PLD method



PLD: Pulsed Laser Deposition



Summary

EUV radiation with CO₂ laser-LPP was obtained.

In the case of Xe gas-jet target, the characteristics of EUV radiation are qualitatively similar to those of DPP. The absorption by neutral Xe atoms was recognized.

In the cases of Sn/SnO₂ targets, bulk target as well as nano-particle target (produced by PLD) were used. With this approach, measured EUV spectrum was similar to that of YAG-laser LPP. The EUV radiation from the nano-particle target was almost similar to that from the bulk target.



Future plan

For Xe target

1. Experiments for Xe cryostat target to avoid the absorption by neutral Xe atoms.
2. Measurements of the electron density and electron temperature by a laser Thomson scattering method.

For Sn/SnO₂ target

1. Measurements of the behavior of Sn atoms or other particles in the LPP by a laser-induced fluorescence method.
2. Visualization of debris by a Rayleigh-Mie scattering method.