Dependence of EUV Emission Properties on Drive Laser Wavelength

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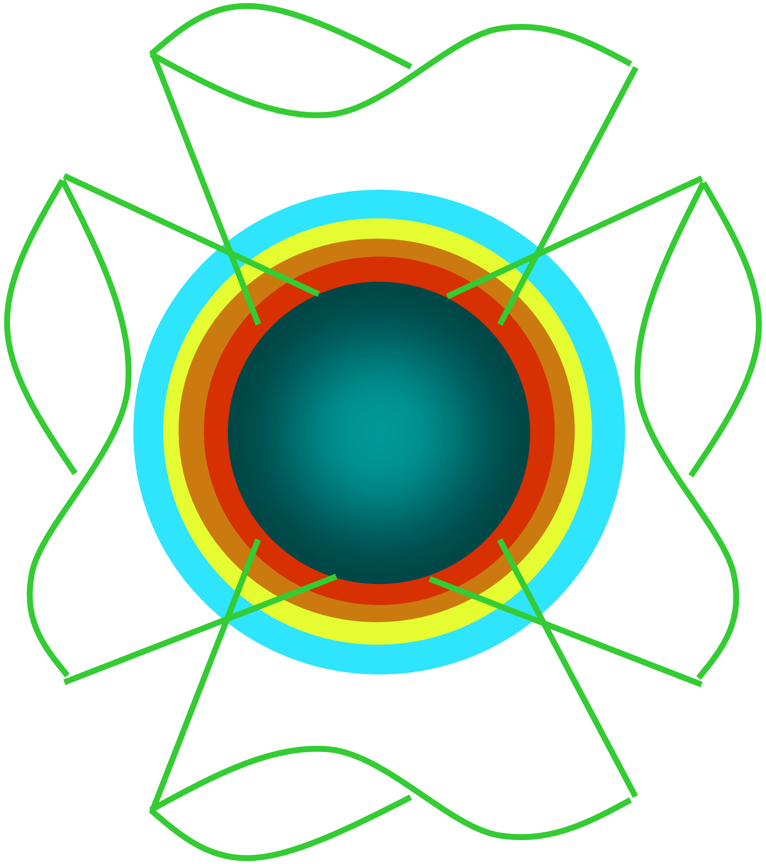
Introduction

- Key issue problem to be resolved for development of 13.5-nm EUV light source is enhancement of conversion efficiency and debris mitigation for condenser multilayer mirror.

- It is very important to optimize plasma generation conditions in order to achieve the enhancement of conversion efficiency .

The advantage of GEKKO XII laser system

One-dimensional plasma condition where there is neither lateral heat conduction nor plasma density gradient was produced by using twelve laser beams of GEKKO XII glass laser system irradiated on spherical targets.



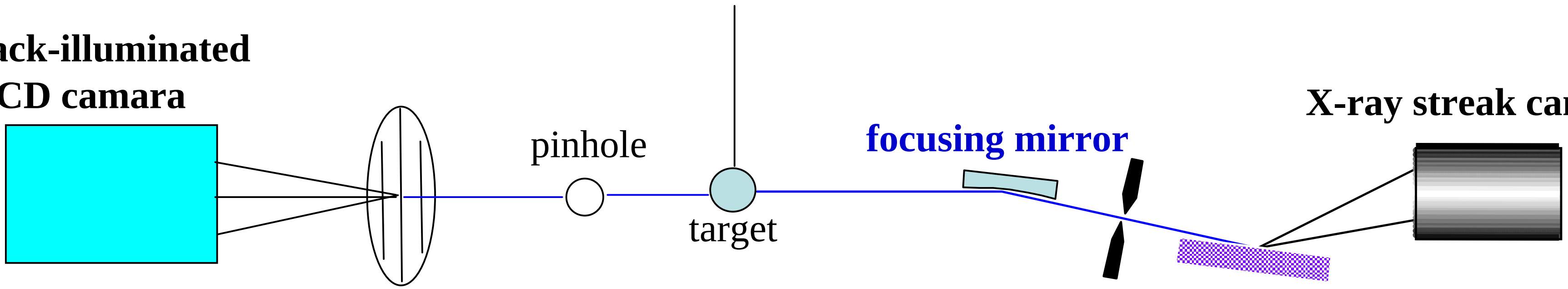
Laser conditions:

Nd:glass laser (GEKKO XII) 12 beams
wavelength: ω (1.053μm), 2ω (0.527 μm)
intensity: 5×10^{10} ~ 1×10^{12} W/cm^2
pulse width: 1.2 ns (FWHM, Gaussian)

Purpose of this study

We investigated dependence of EUV emission properties on laser wavelength in order to find out optimum conditions of laser plasma for maximum possible conversion efficiency of 13.5 nm EUV source.

Experimental setup



⊿λ/λ = 0.3 nm

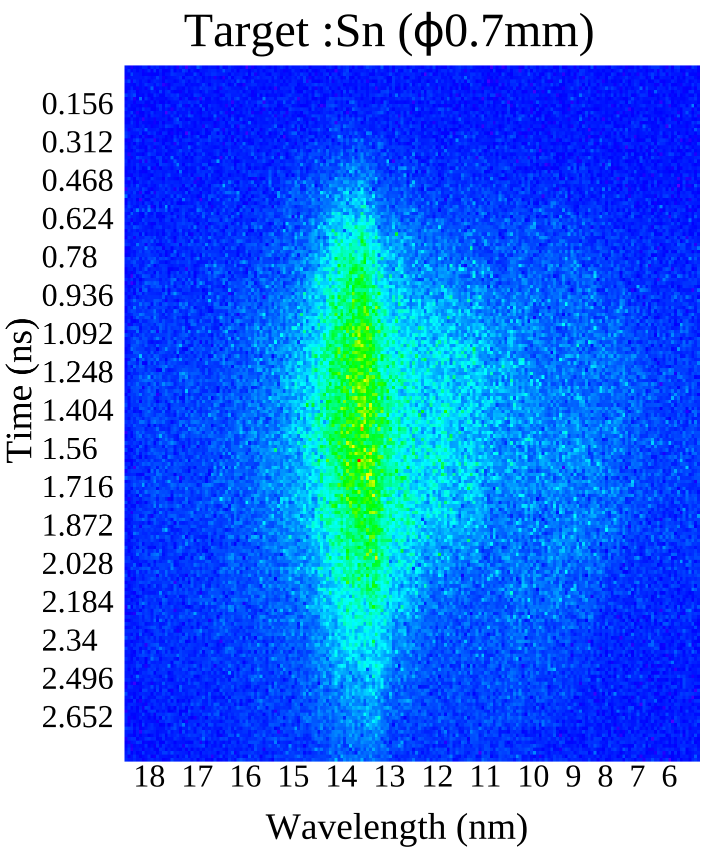
⊿λ/λ = 0.04 nm

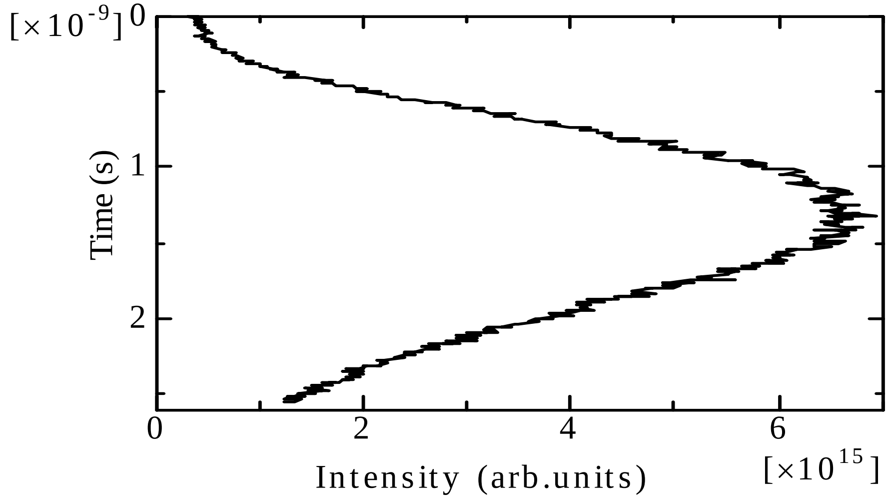
Target conditions:

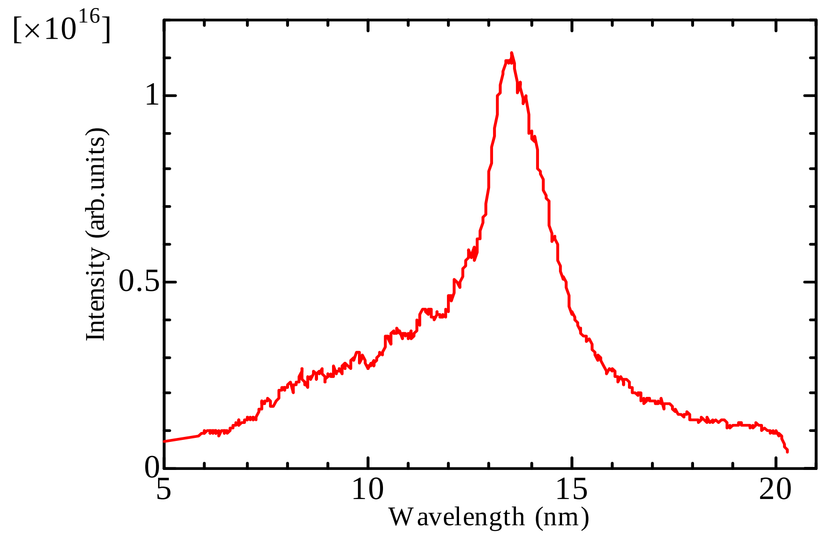
tin or tin-oxide
spherical targets
ϕ300~2000 μm

Emission spectrum and EUV emission profile of tin plasma measured by using a grazing incident spectrometer (GIS) coupled with an x-ray streak camera.

Laser wavelength =1.053μm, Pulse width = 1.2 ns,   Laser intensity = 1.34×10^{11} W/cm^2



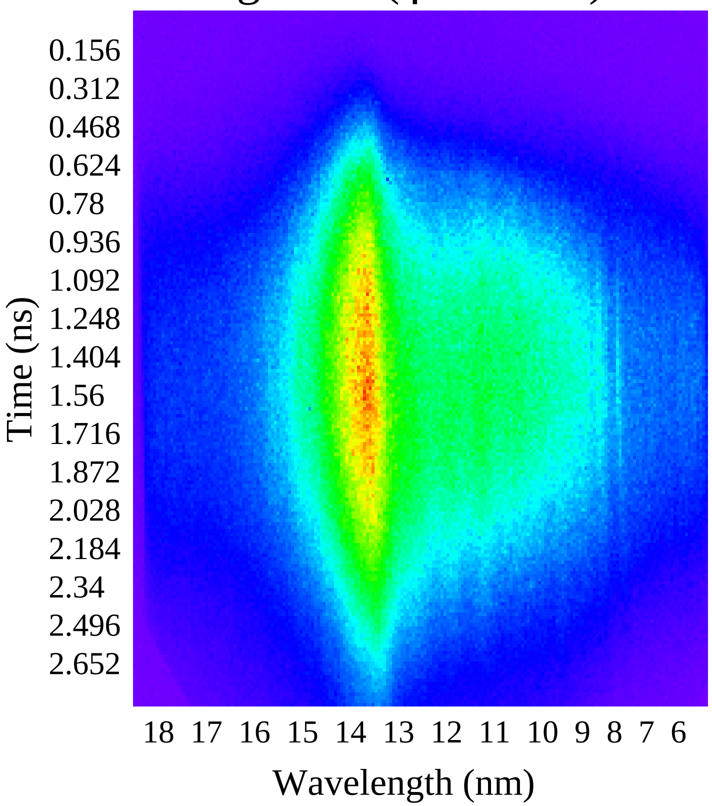


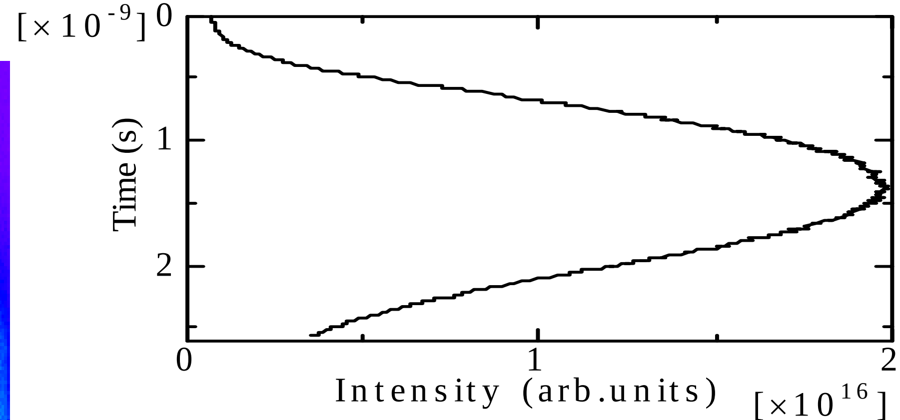


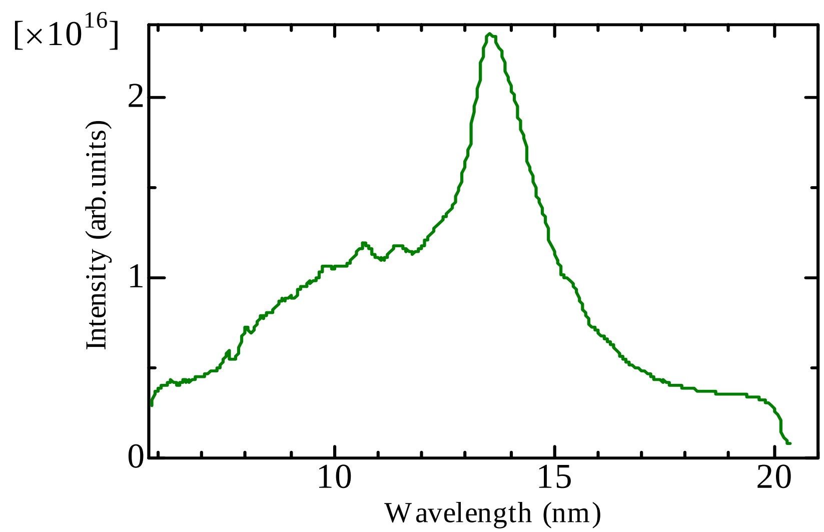
Emission spectrum and EUV emission profile of tin plasma measured by using a grazing incident spectrometer (GIS) coupled with an x-ray streak camera.

Laser wavelength =0.527μm, Pulse width = 1.2 ns, Laser intensity = 1.57×10[11] W/cm[2]

Target :Sn (ϕ2.15mm)

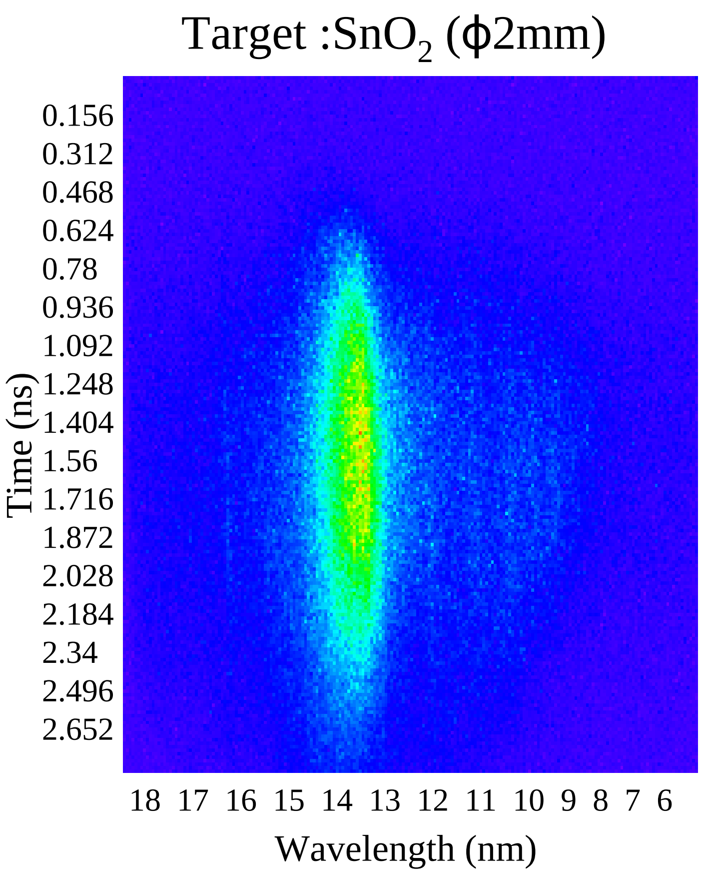


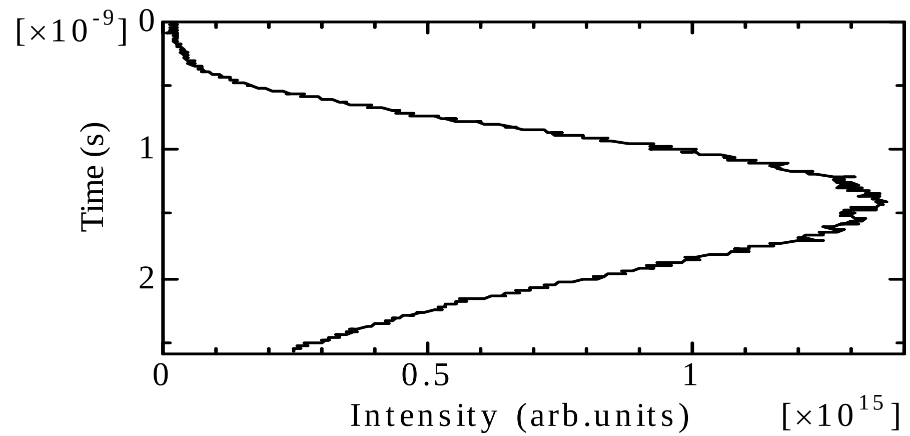


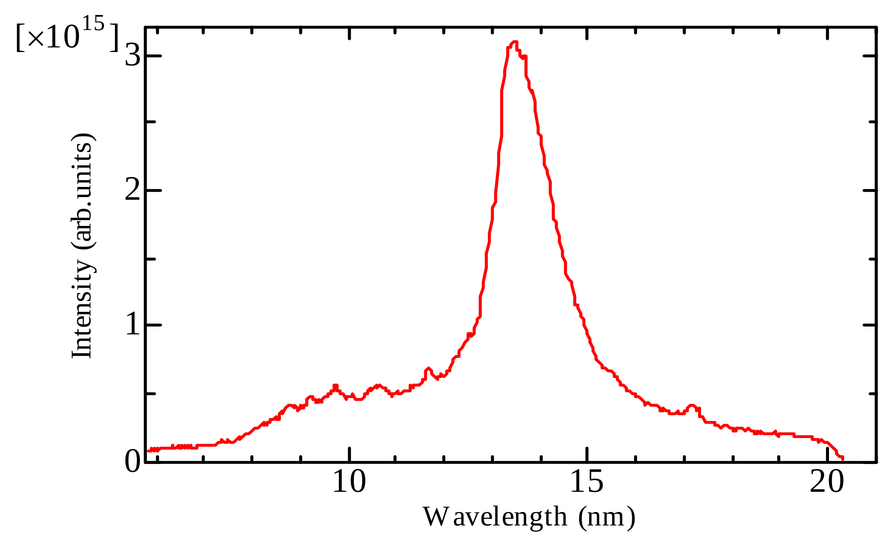


Emission spectrum and EUV emission profile of tin-oxide plasma measured by using a grazing incident spectrometer (GIS) coupled with an x-ray streak camera.

Laser wavelength =1.053μm, Pulse width = 1.2 ns, Laser intensity = 5.0×10^{10} W/cm^2



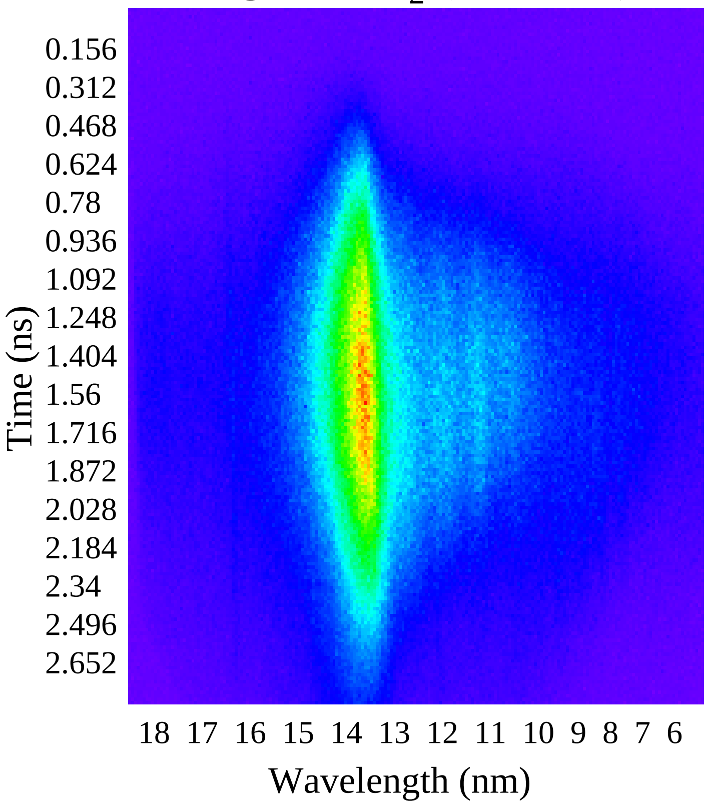


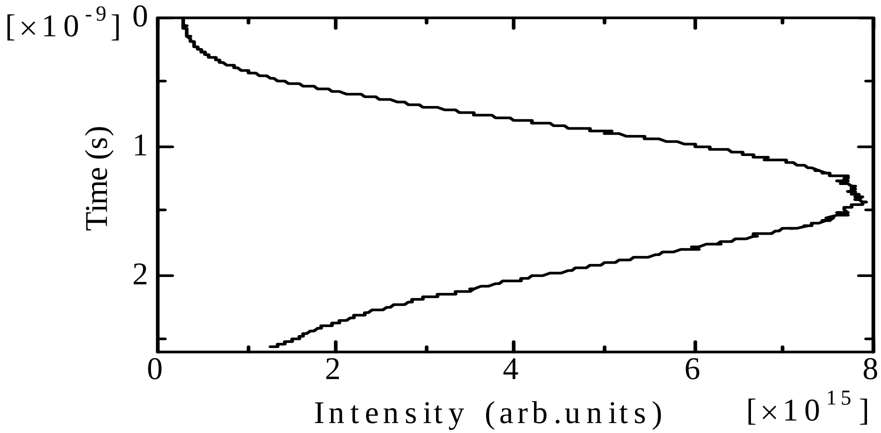


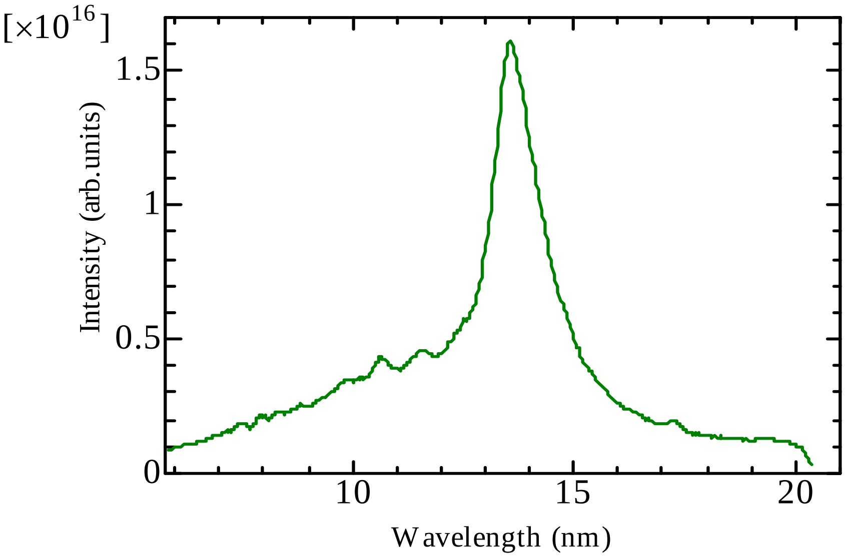
Emission spectrum and EUV emission profile of tin plasma measured by using a grazing incident spectrometer (GIS) coupled with an x-ray streak camera.

Laser wavelength =0.527μm, Pulse width = 1.2 ns, Laser intensity = 4.61×10^{10} W/cm^2

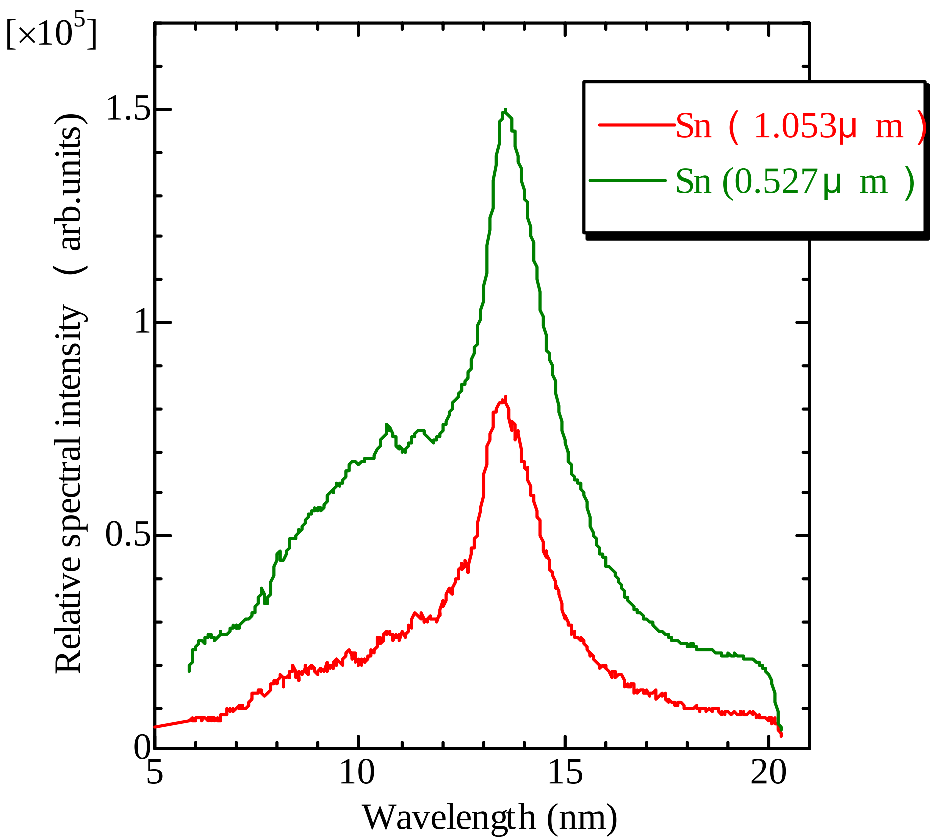
Target :SnO_2 (ϕ2.1mm)

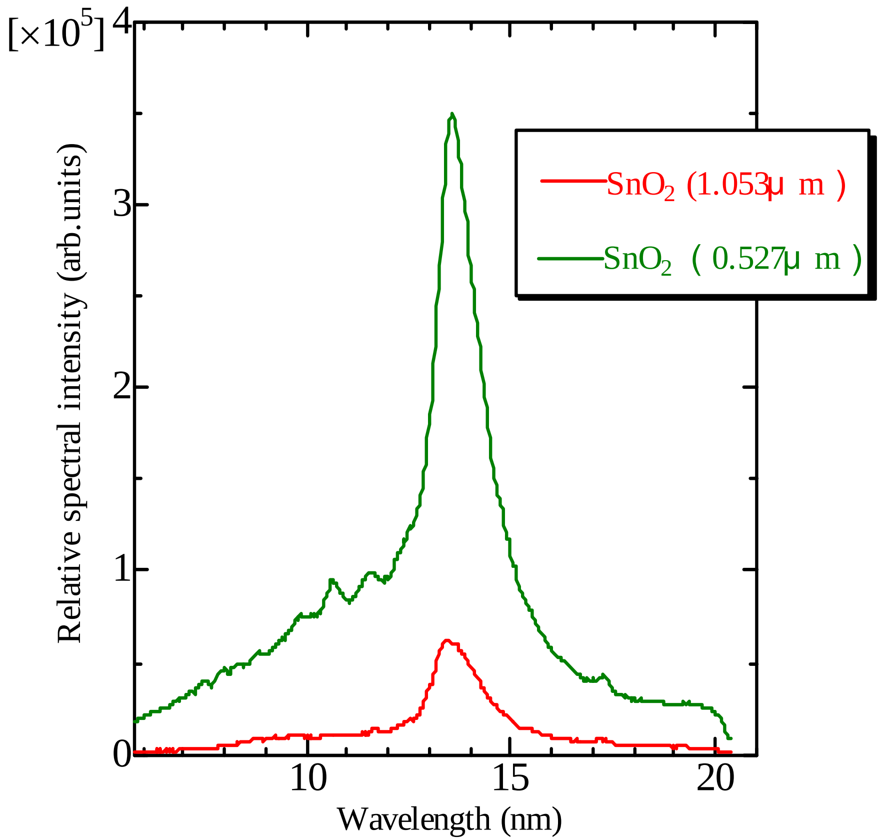




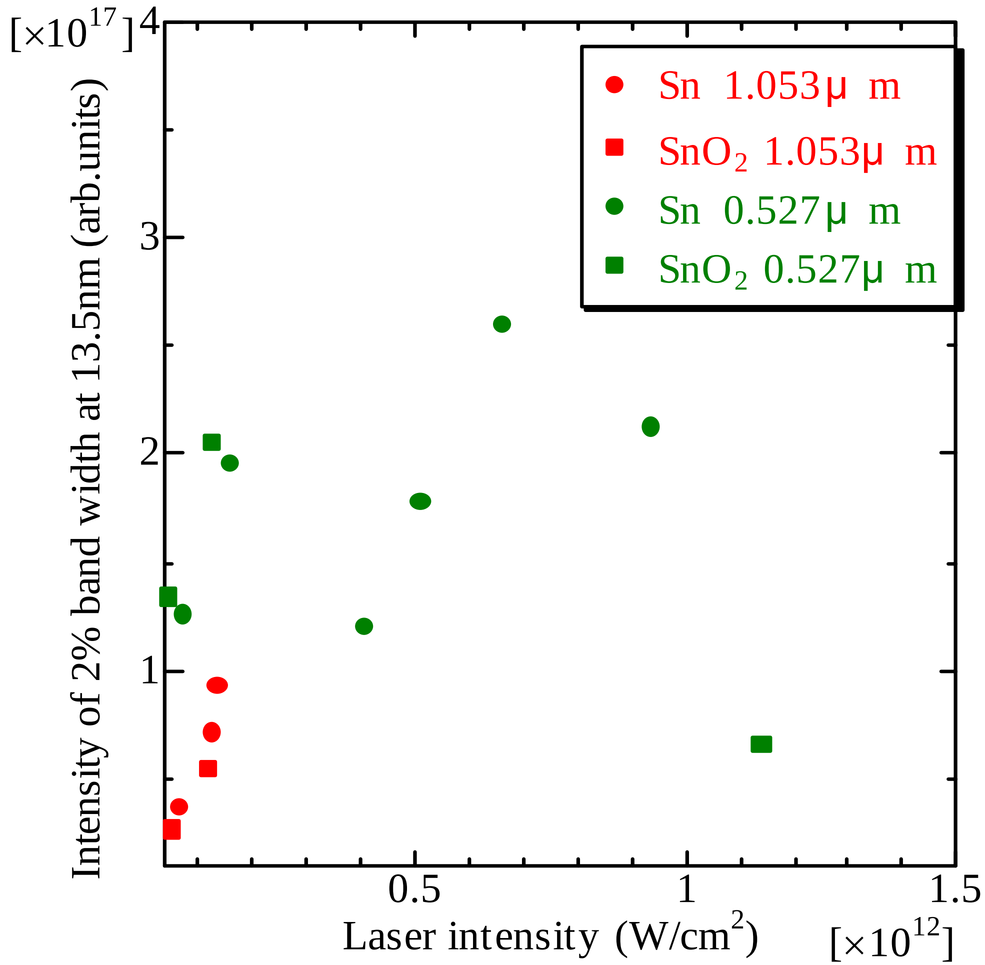


Dependence of relative spectral intensity of the tin or tin-oxide plasma on laser wavelength



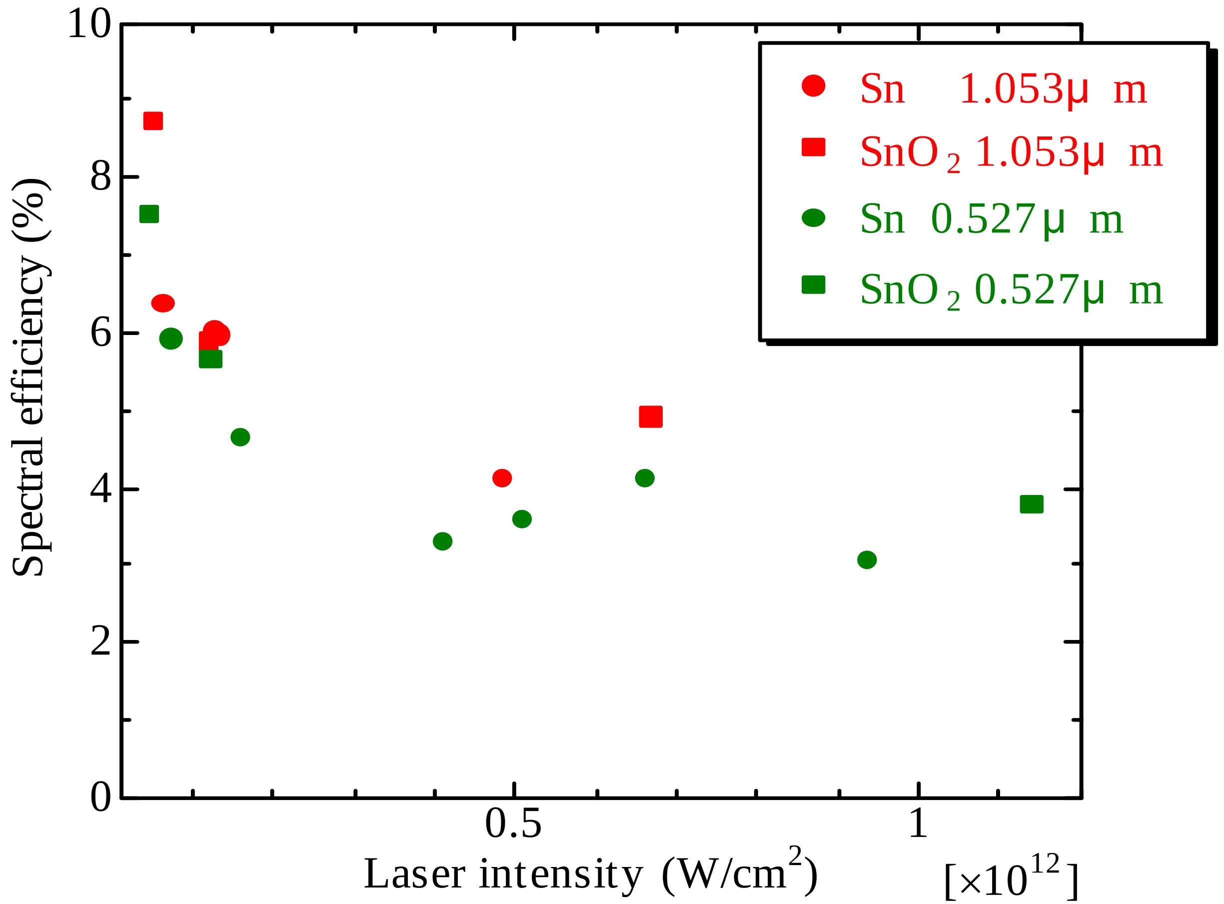


Dependence of intensity of 2% band width at 13.5 nm of the tin and tin-oxide plasma on laser wavelength

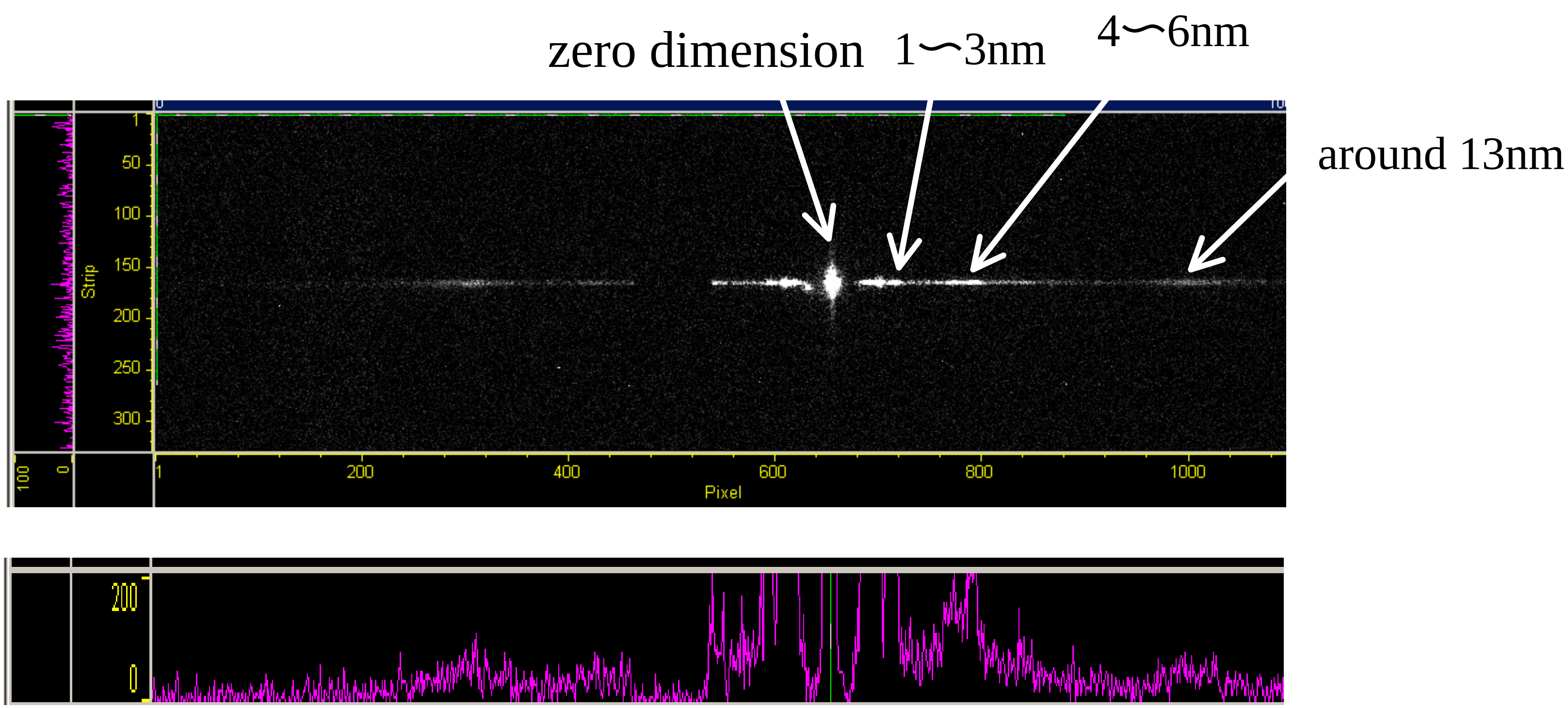


Dependence of spectral efficiency of the tin and tin-oxide plasma on laser wavelength

spectral efficiency = intensity within 2% BW@13.5nm / whole intensity

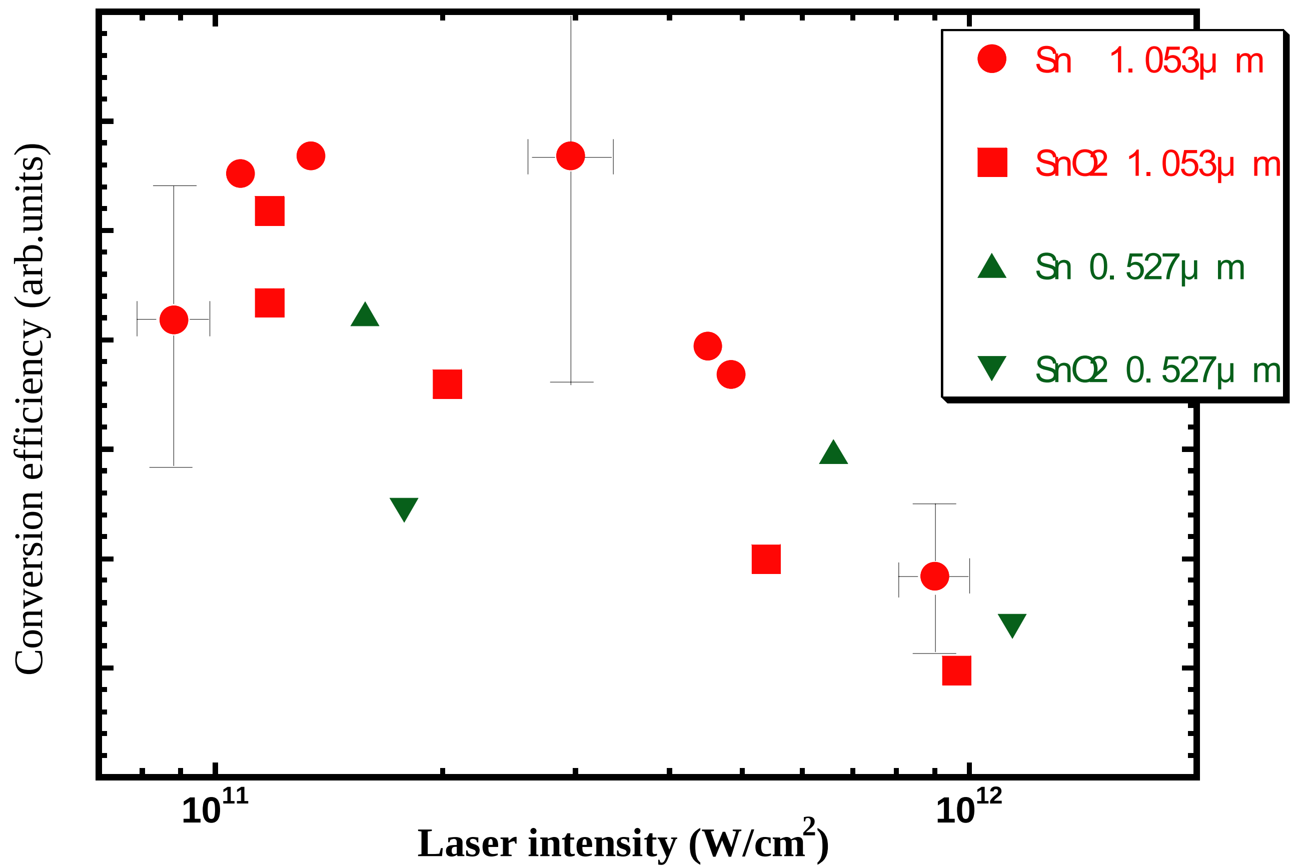


Transmission grating spectrometer (TGS) image for tin plasma recorded on a back-illuminated CCD camera.

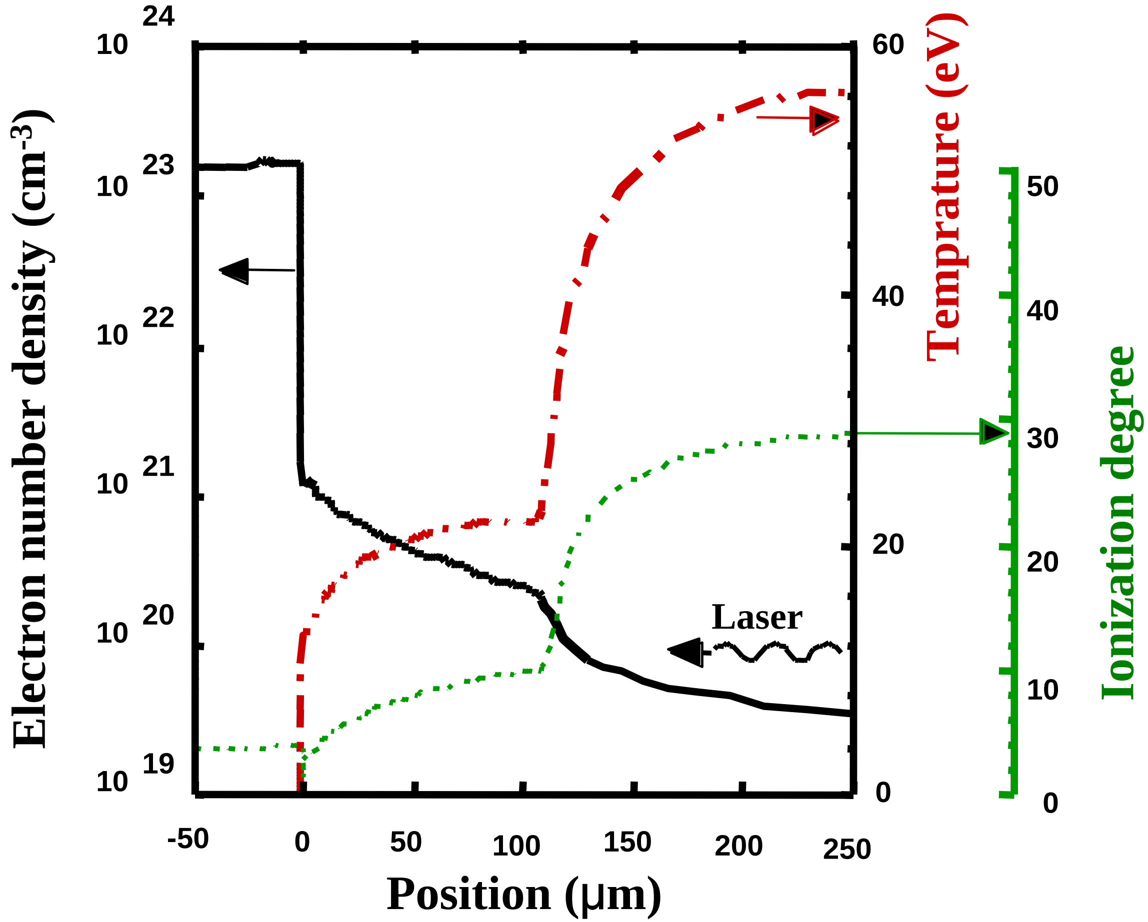


Dependence of conversion efficiency of the tin and tin-oxide plasma on laser wavelength

Conversion efficiency was measured by using a transmission grating spectrometer (TGS) coupled with a back-illuminated CCD camera.



Electron density, electron temperature and ionization state of tin-plasma irradiated with a 1.053 μm, 10 ns laser pulse at 10^{11} W/cm^2 calculated by a 1D radiation hydrodynamic code.



Conclusions

- It was hardly appeared that dependence of intensity of 2% band width at 13.5 nm of the tin and tin-oxide plasma on laser wavelength.

- It is considered that the 13.5-nm EUV emission is occurred by the condition under plasma density of 10^{20} cm^{-3}.

Acknowledgment

A part of this work was performed under the auspices of Leading Project promoted by MEXT.