EUV Emission from Tin Plasmas Generated with 1.06, 0.53, and 0.26 μm Laser Pulses

○M. Yamaura, S. Uchida, A. Sunahara, Y. Shimada, K. Hashimoto,
*H. Nishimura, *S.Fujioka, *T.Okuno, *N.Ueda, *K. Nagai,
*K. Nishihara, *T. Norimatsu, *N.Miyanaga, *Y.Izawa, and C. Yamanaka

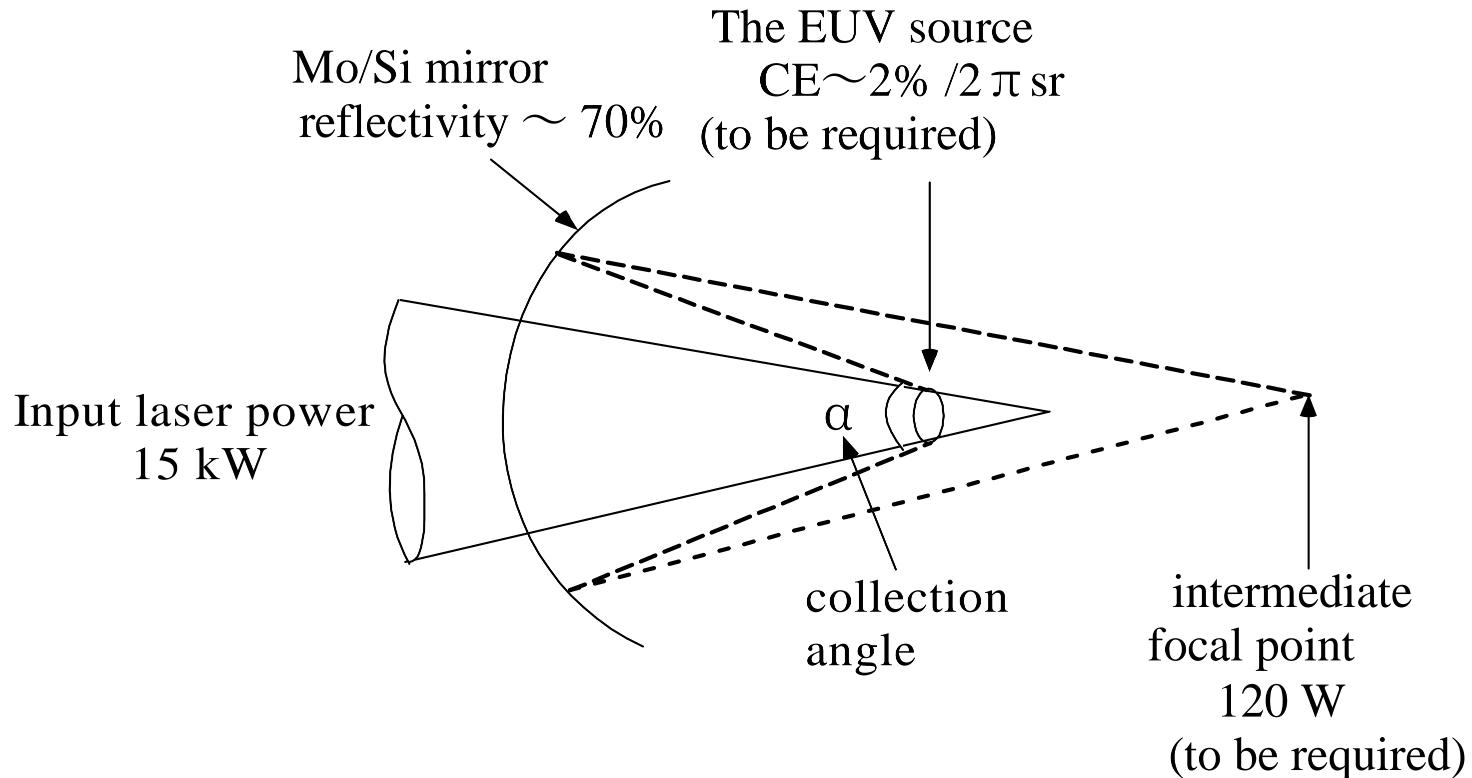
Institute for Laser Technology, Osaka, Japan
* Institute of Laser Engineering, Osaka University, Osaka, Japan

3rd EUVL Symposium Miyazaki Japan

November 1-4 2004

Introduction

It is very important to optimize plasma generation conditions in order to improve the conversion efficiency.



Purpose of this study

Find out optimum conditions of laser plasma for the maximum possible conversion efficiency of 13.5-nm EUV source by characterizing the laser wavelength dependence and using computer simulation code.

Experimental setup

Nd:YAG Laser

Wavelength= 1064 nm
532 nm
266 nm

pulse width = 10 ns （ω ,2ω）
6.5 ns (4ω）

CCD

Grazing incidence spectrometer

EUV calorimeter

beam splitter

debris shield

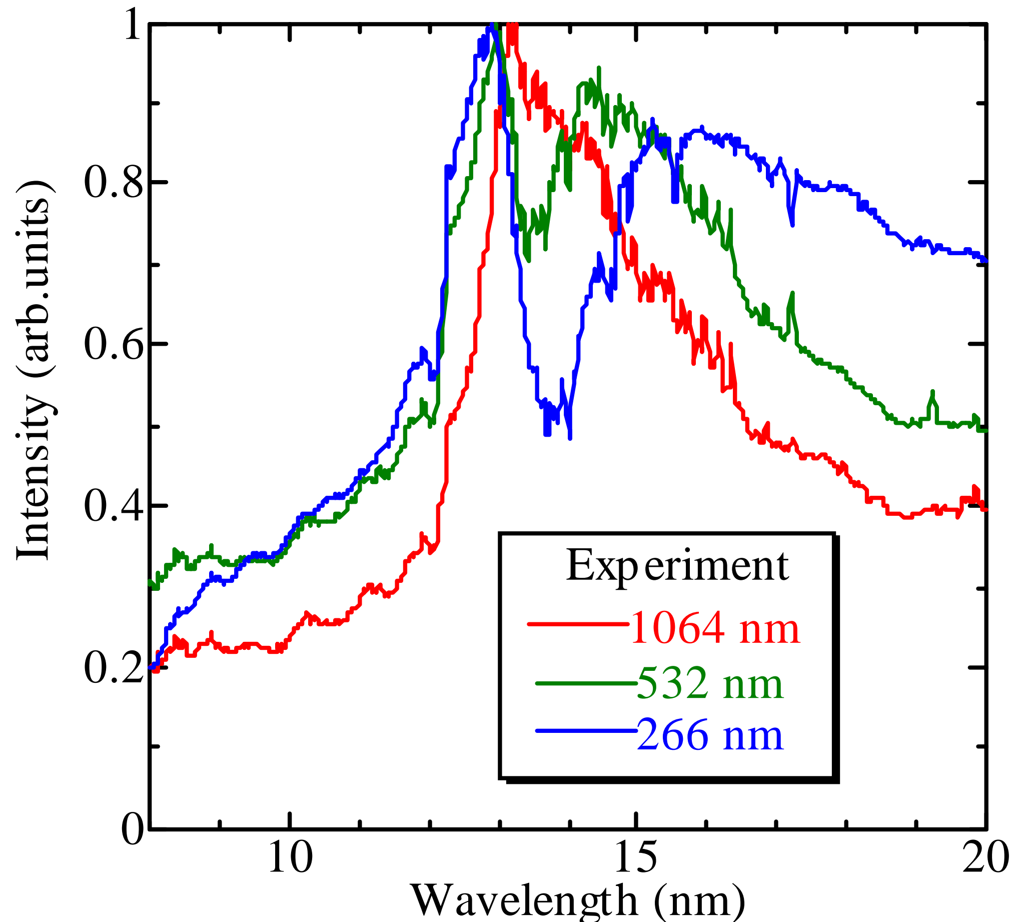
tin plate

quartz lens

quartz lens

energy monitor

Experimental comparison of emission spectra from tin plasma in the case of 1064, 532 , and 266 nm.



The EUV spectra show a dip structure particularly for 266-nm wavelength

Simulation comparison of emission spectra from tin plasma in the case of 1064, 532, and 266 nm

Simulation
1064 nm
532 nm
266 nm

Intensity (arb.units)
Wavelength (nm)

These dips are well replicated in computer simulations.

Angular distribution in the case of 1064 nm, 532 nm, and 266 nm laser wavelength

EUV intensity (arb.units)

1
0.8
0.6
0.4
0.2
0

0 20 40 60 80

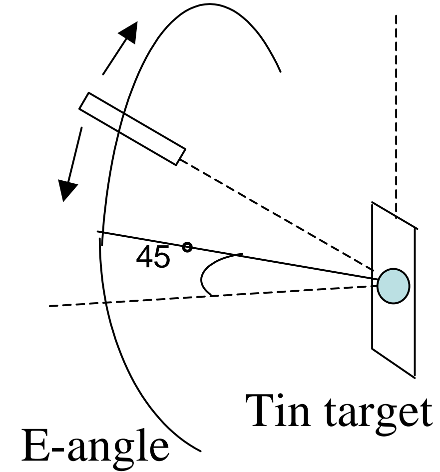
Angle (degree)

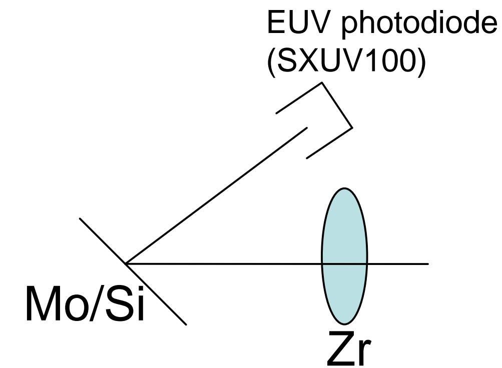
$\cos^{0.5}\theta$

$\cos^{0.8}\theta$

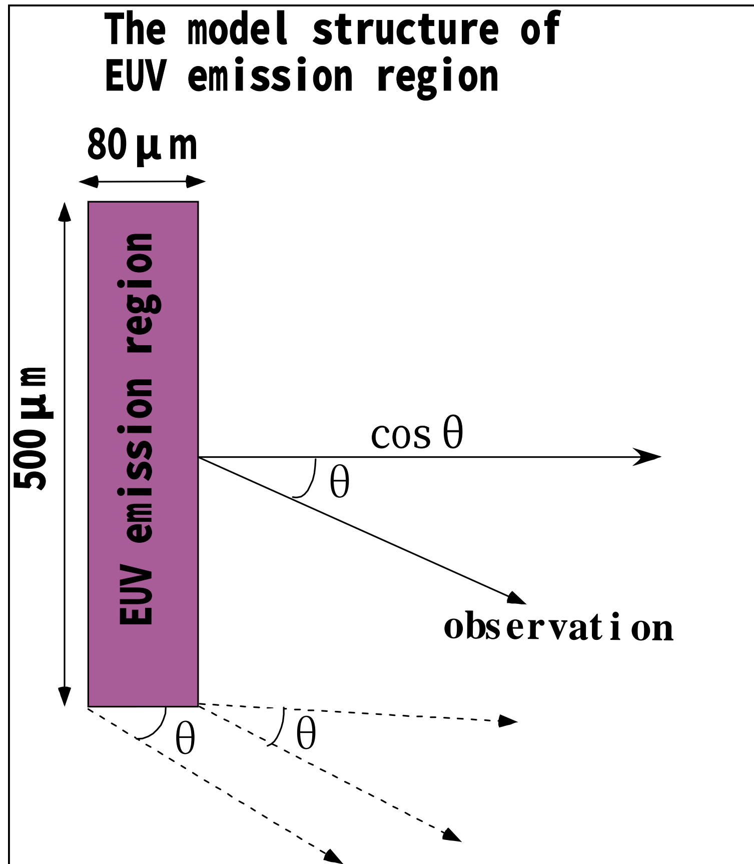
$\cos^{1.3}\theta$

1064 nm
532 nm
266 nm



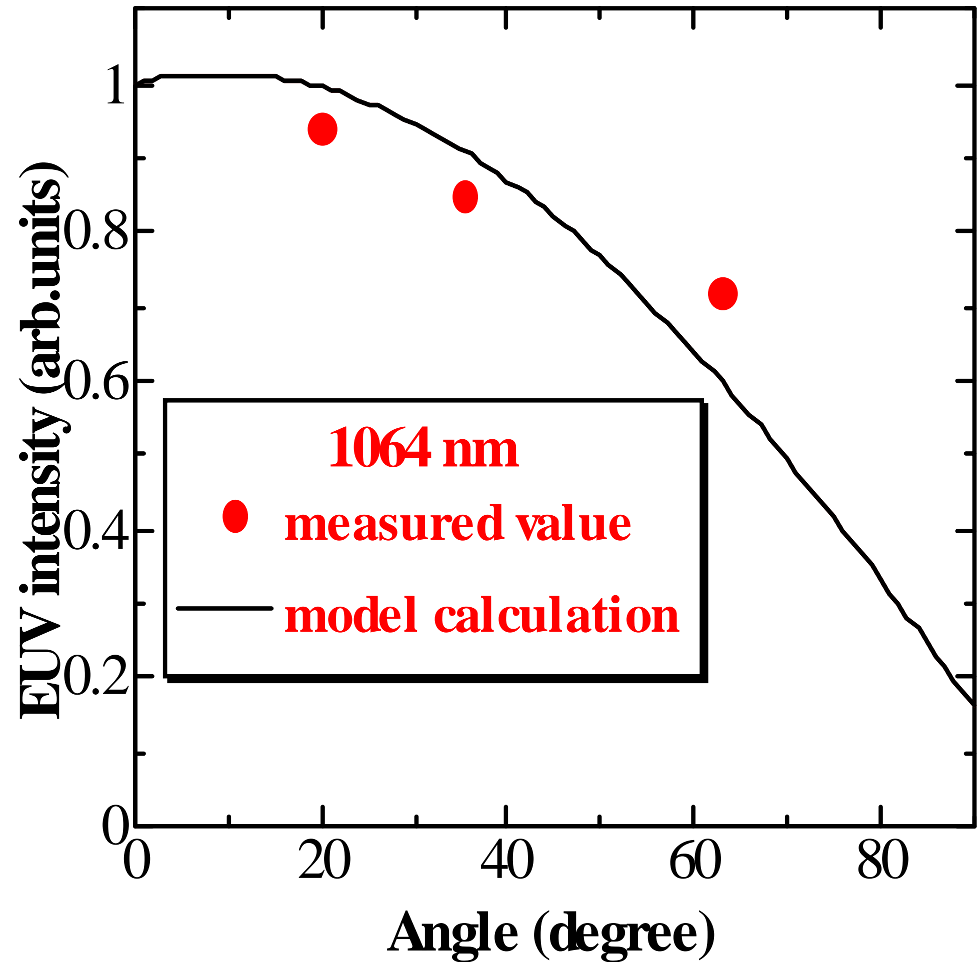


Comparison of 1064 nm angular distribution and model calculation in account of absorption region.

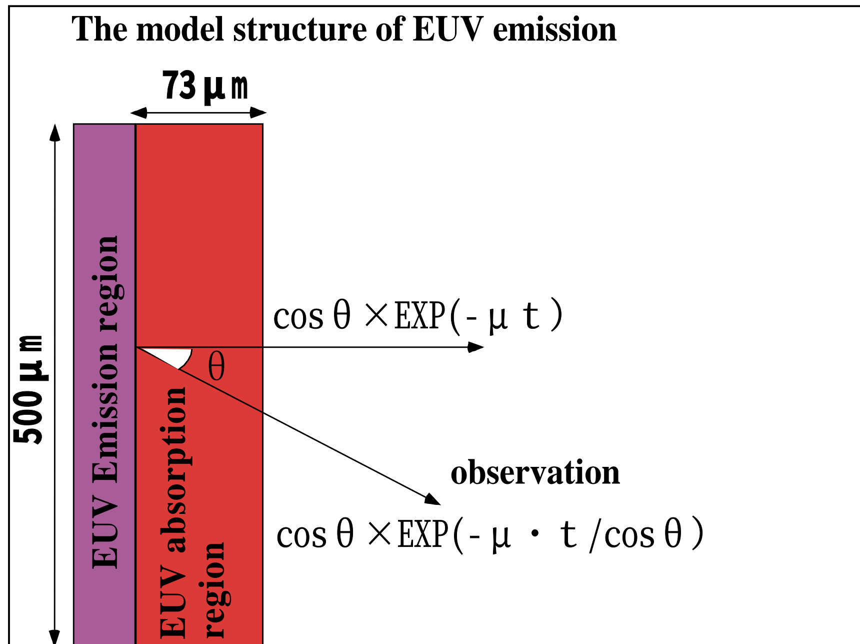


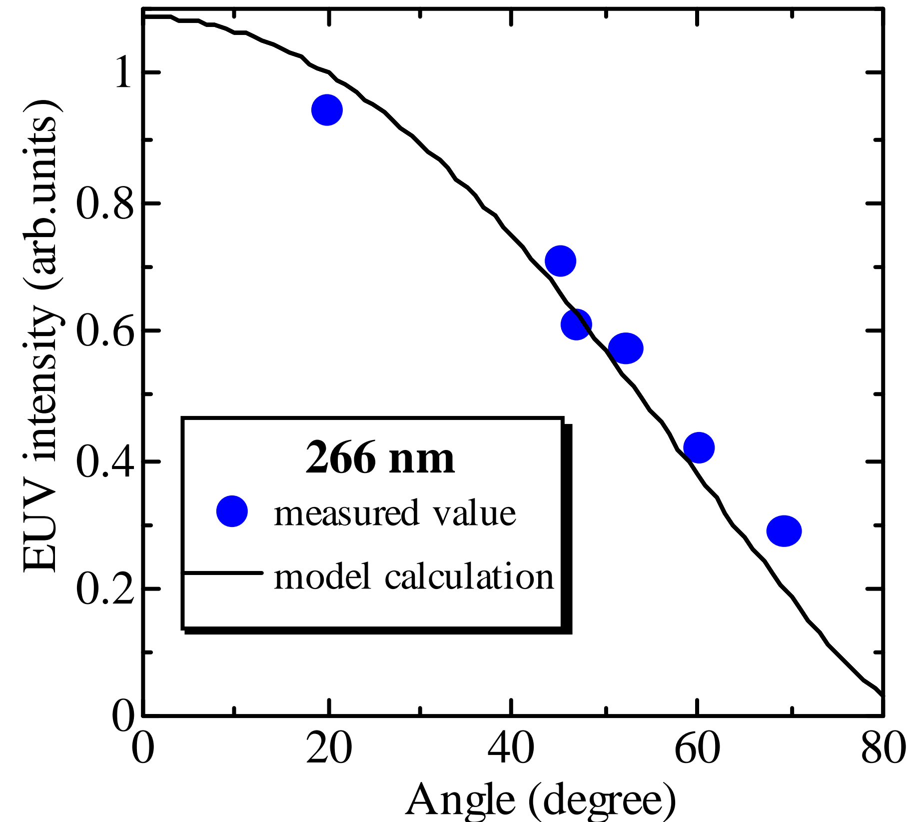
The amount of EUV emission

$= 500 \times \cos\theta + 80 \times \sin\theta$



Comparison of 266 nm angular distribution and model calculation in account of absorption region.





μ (absorption coefficient)****=50 cm**$^{-1}$

(Sn^{10+},30 eV, 10^{19} cm^{-3})

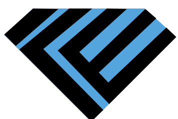
t = thickness of absorption region

**** T.Nishikawa, et al,Laser and Particle Beams Vol. 11, 1993, pp.81-87.**

It is considered that opaque plasmas are surrounding the EUV emission region in the case of 266 nm.

Conclusions

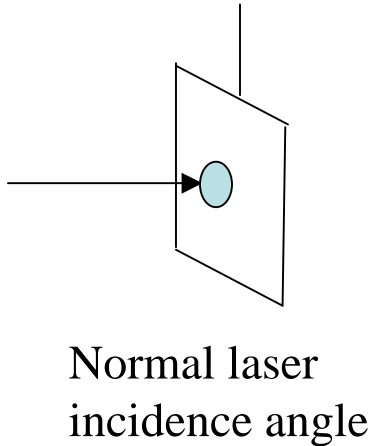
- The EUV spectra show a dip structure particularly for 266-nm wavelength and these dips are well replicated in computer simulations.
- The angular distribution of EUV emission from 266-nm plasma shows very sharp $\cos^{1.3}\theta$ distribution.
- These results can be atributed to the existence of opaque plasmas surrounding the EUV emission region.
- Above inference suggests that higher conversion efficiency is possible by controlling density scale length in the case of 266-nm plasmas.



Acknowledgment

A part of this work was performed under the auspices of MEXT (Ministry of Education, Culture, Science and Technology, Japan) under contract subject “Leading Project for EUV lithography source development ”.

Conversion efficiency as a function of laser intensity in the case of 1064 and 532 nm laser wavelength



1064 nm
532 nm

CE (%)(2% BW at 13.5 nm, 2π sr)

0
1
2
3
4
5

10^{10}
10^{11}
10^{12}

Laser intensity (W/cm^2)