Session 2

EUV emission from a laser-produced tin plasma by use of a liquid microtarget

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Joint requirements for EUV source: 13.5 nm (2%BW), 115 W, 7-10 kHz

Joint Requirements for EUV Source

SOURCE CHARACTERISTICS	REQUIREMENTS
▪Wavelength	13.5 (nm)
▪EUV Power (in-band)	115 (W) (after intermediate focus)
▪Repetition Frequency	> 7 - 10 kHz *
▪Integrated Energy Stability	± 0.3% (3σ over 50 pulses)
▪Source Cleanliness	≥ 30,000 hours (after intermediate focus)
▪Etendue of Source Output	1 – 3.3 mm^2sr (max)*
▪Maximum Solid Angle to Illuminator	0.03 – 0.2 (sr) (depending on particular optical scheme)*
▪Spectral Purity	
130 - 400 nm (DUV/VUV)	≤ TBD – 7% (design dependent)*
> 400 nm (Vis/IR)	TBD

* Not agreed among participants

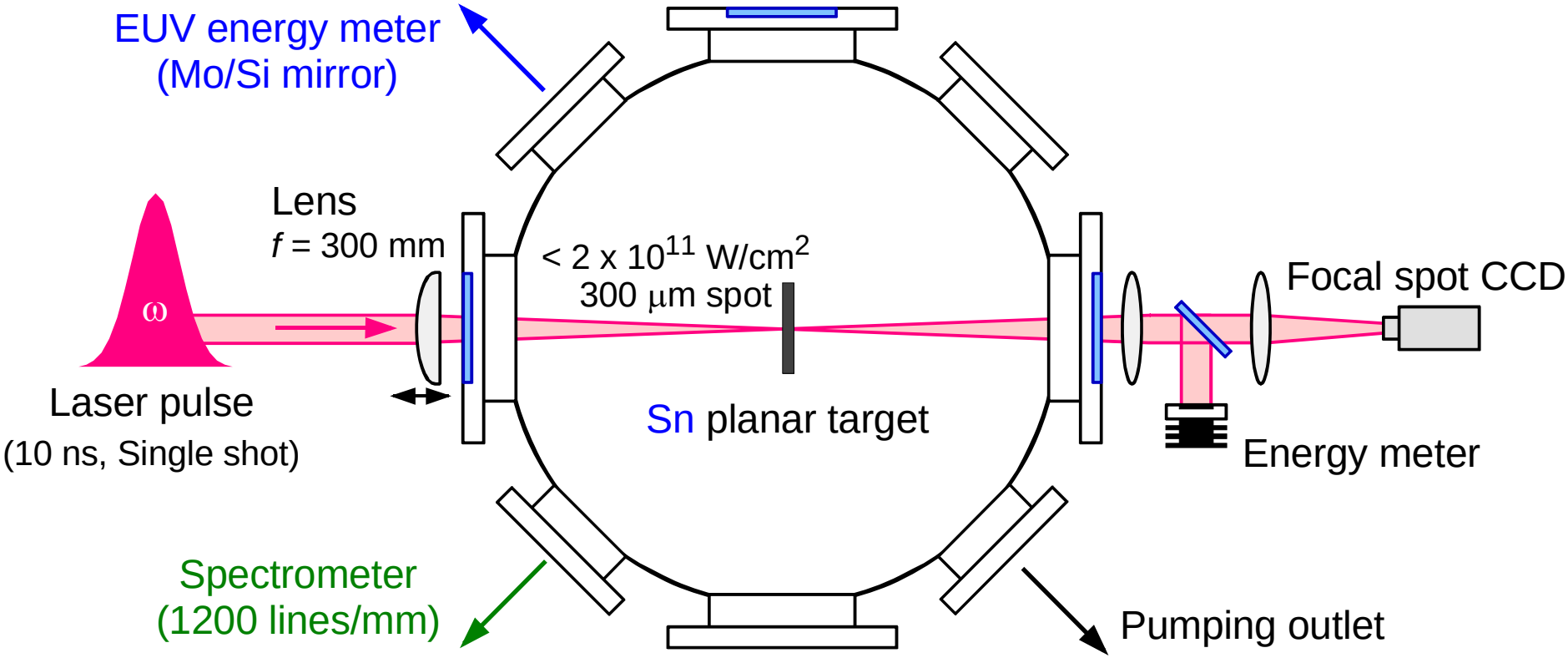
Kazuya Ota, Source Workshop, Santa Clara, CA, USA (2003).

Objective:
Enhancement of the EUV CE

- Characteristics of a laser produced tin plasma EUV source
  - EUV and debris emissions from a planar target
  - EUV emission from a filament target

EUV emission by use of a planar tin target

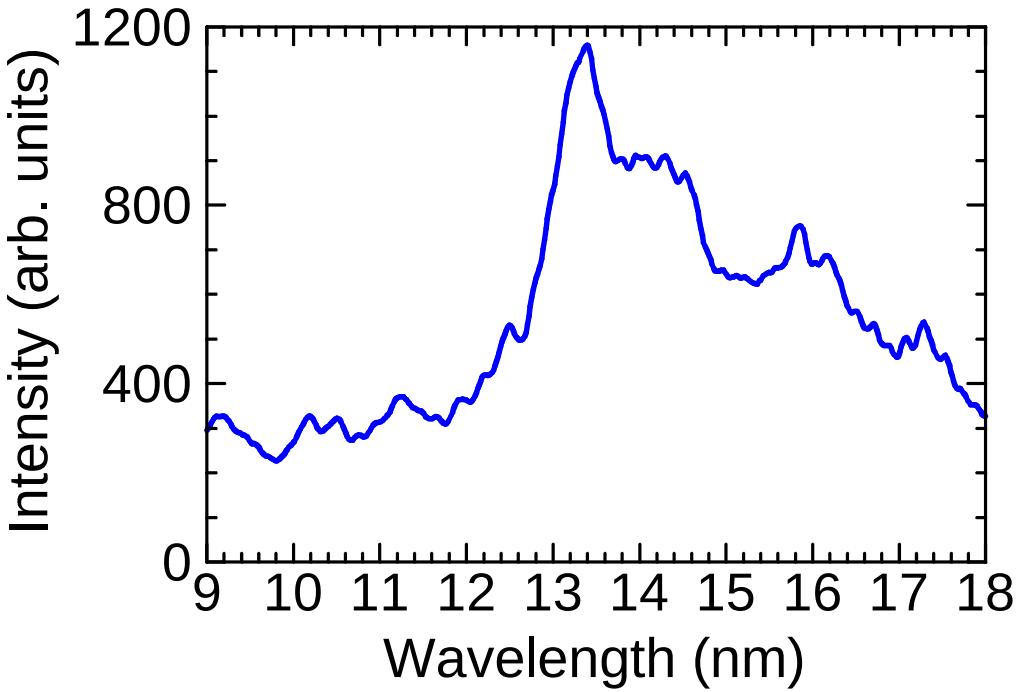
Schematic diagram of experimental setup



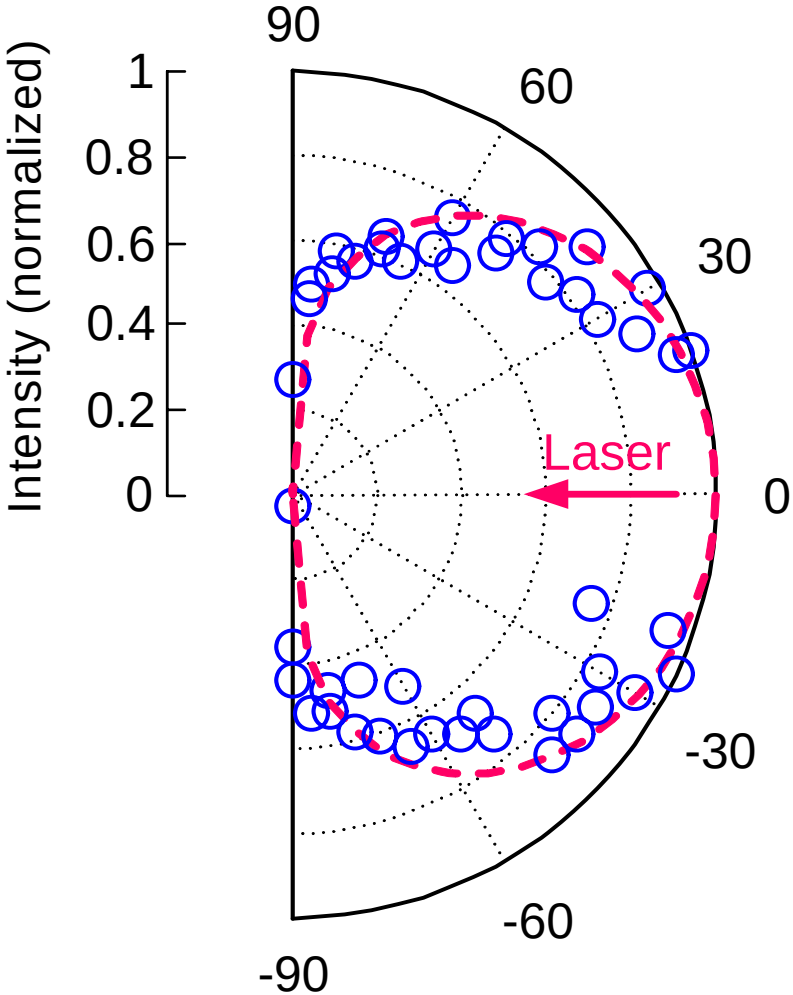
EUV emission by use of a planar tin target

EUV spectrum and angular distribution

Laser intensity: 7 x 10^{10} W/cm^2
Spot size: 300 μmϕ
EUV CE: 1.2%
Laser energy: 500 mJ
Laser pulse width: 10 ns

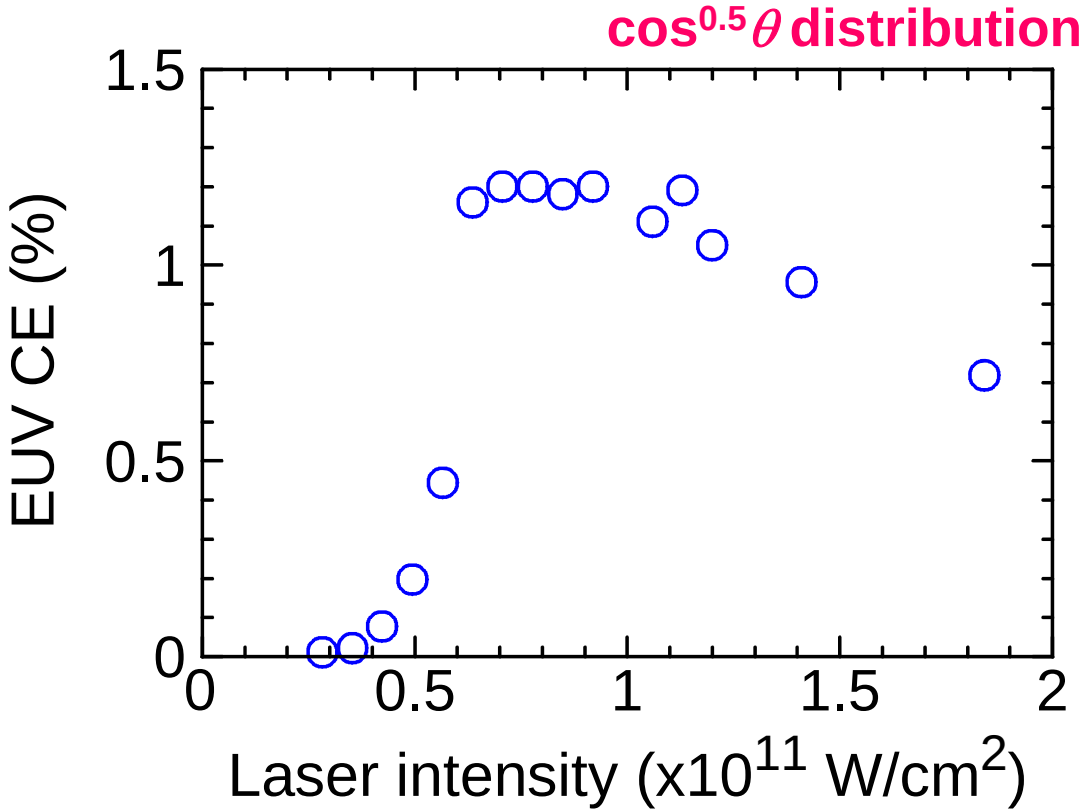


$\cos^{0.5}\theta$ distribution



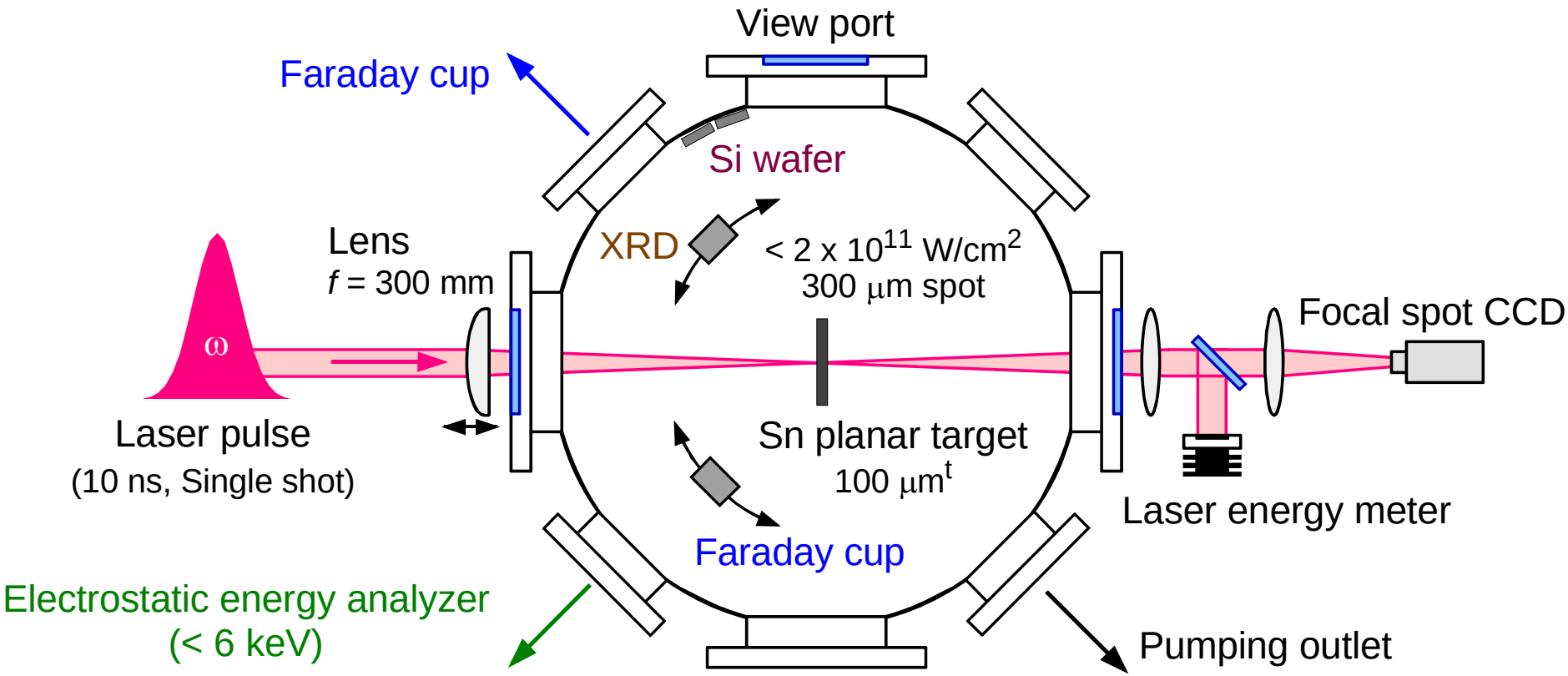
EUV emission by use of a planar tin target

Laser intensity dependence of EUV CE



Debris emission by use of a planar tin target

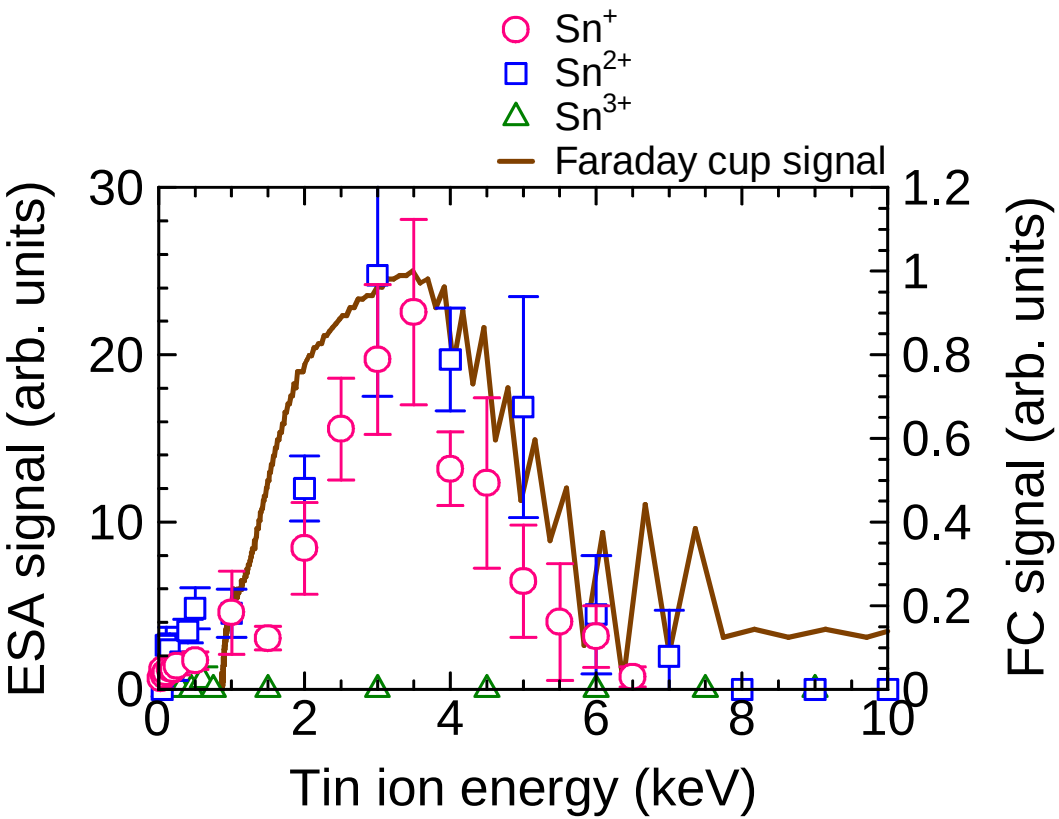
Schematic diagram of experimental setup

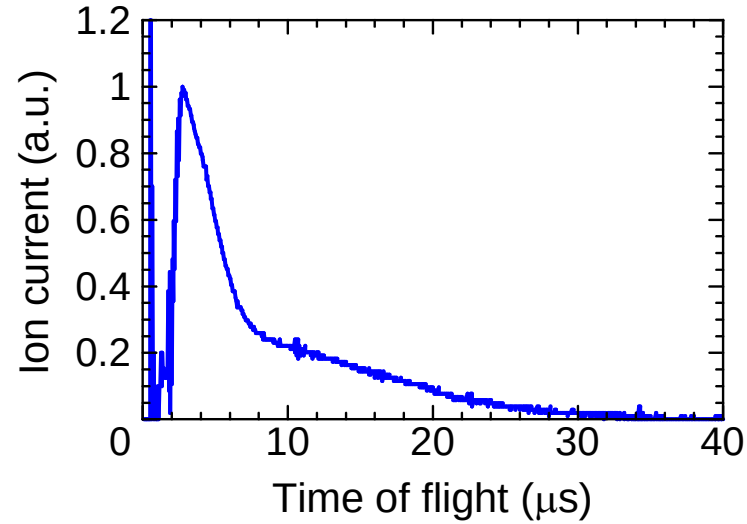


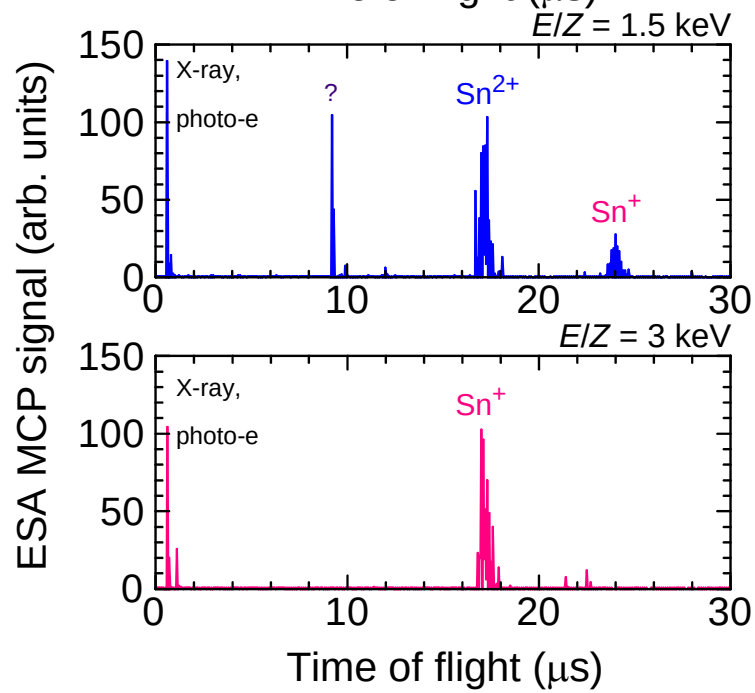
Debris emission by use of a planar tin target

Energy spectrum & charge state of fast ions

Laser intensity: 7 x 10^{10} W/cm^2
Spot size: 300 μmϕ
EUV CE: 1.2-1.5%
Laser energy: 500 mJ
Laser pulse width: 10 ns



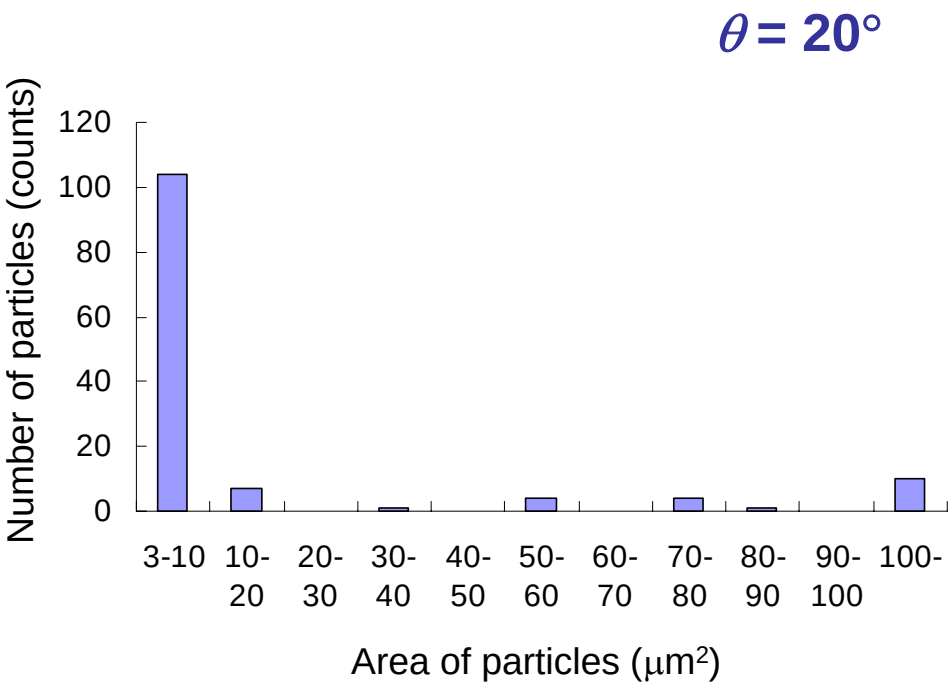


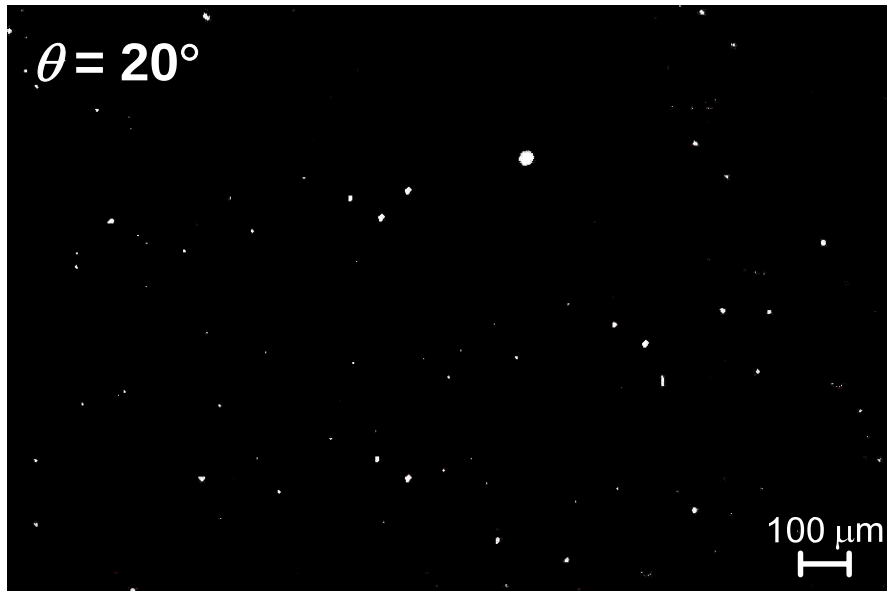


Debris emission by use of a planar tin target

Observation of neutral fragments

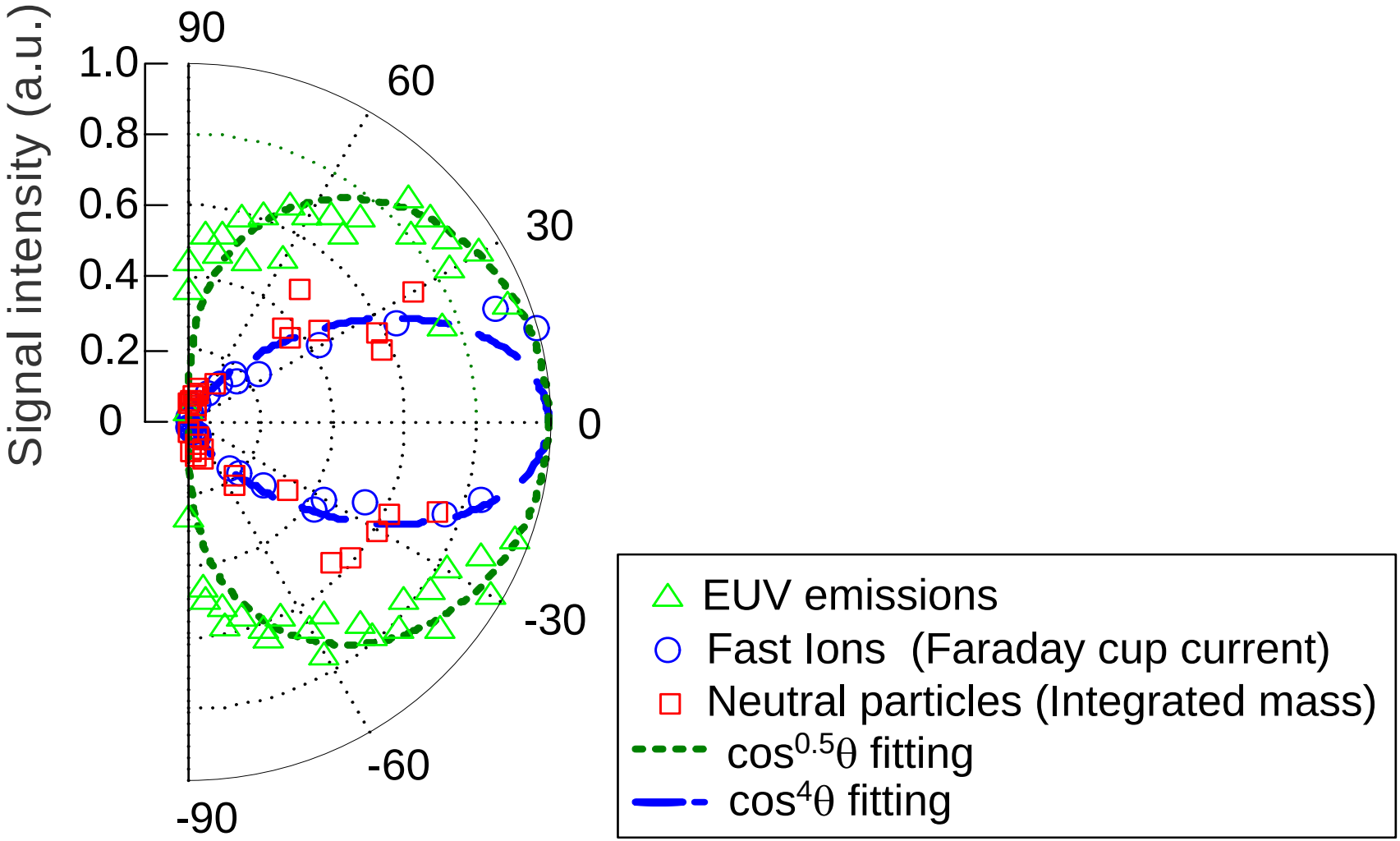
Laser intensity: 7 x 10^{10} W/cm^2
Spot size: 300 μmϕ
Laser energy: 500 mJ
Pulse width: 10 ns
1000 shot





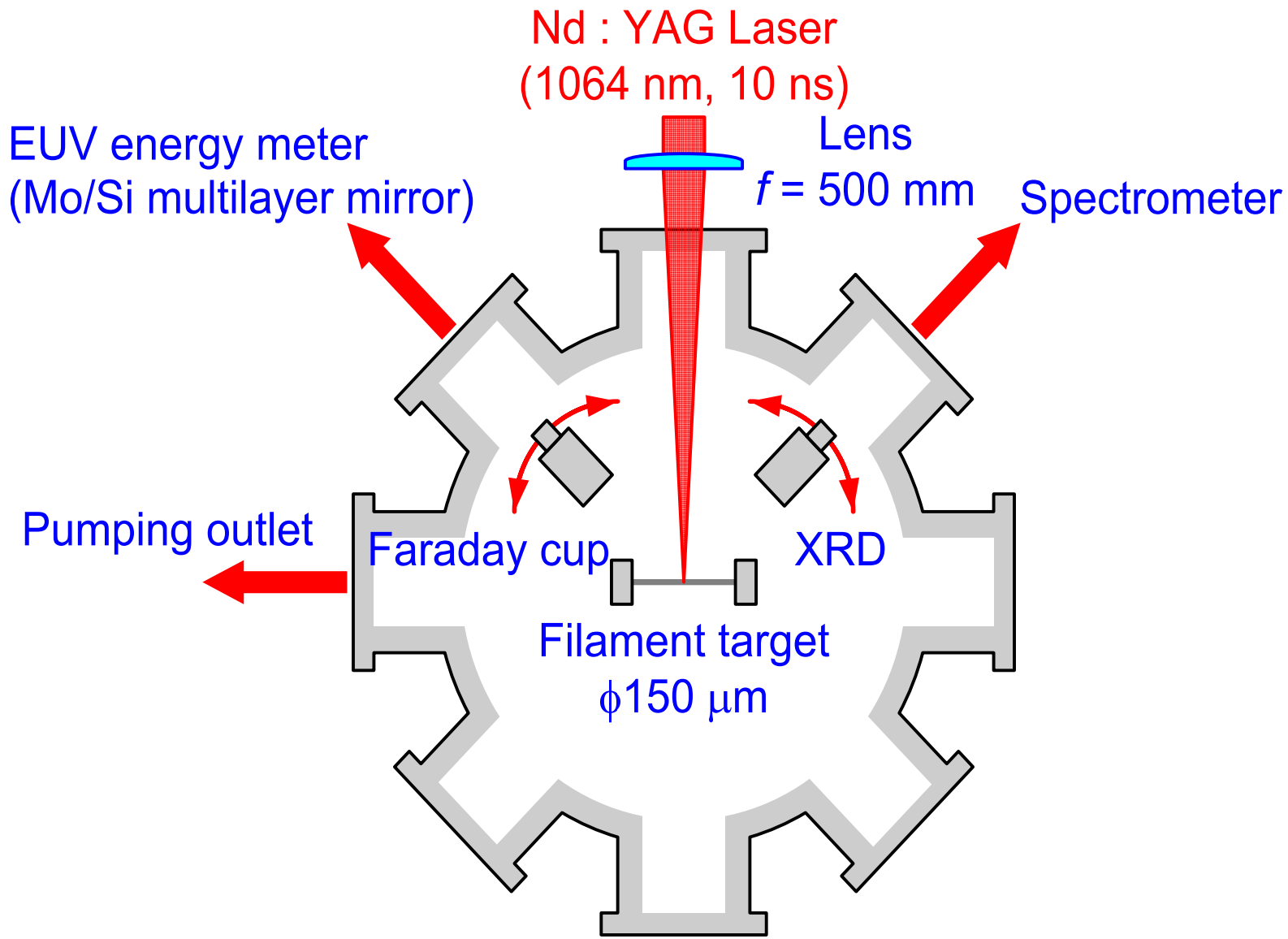
EUV and debris emissions

Comparison of angular distributions



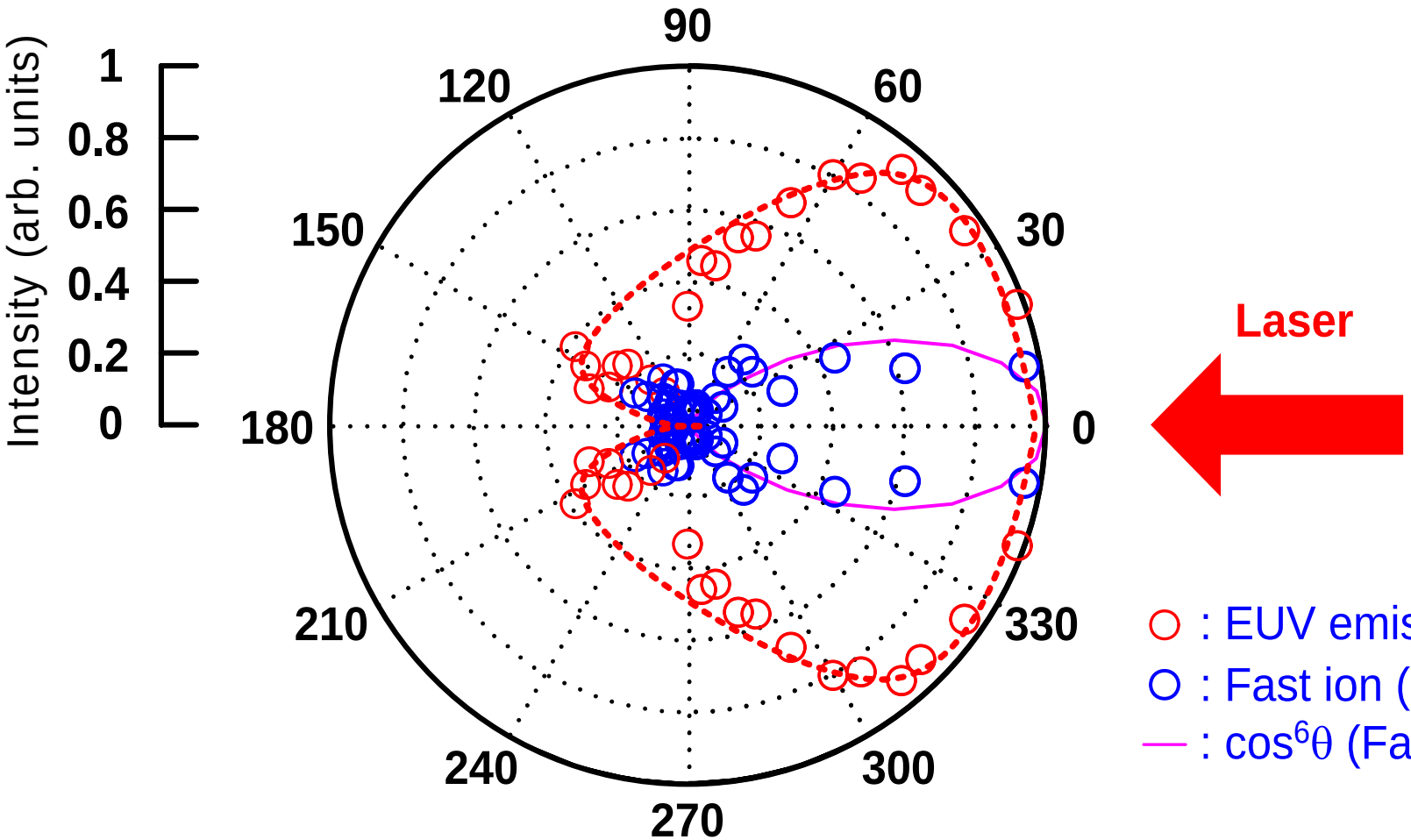
Use of a filament target

Schematic diagram of experimental setup



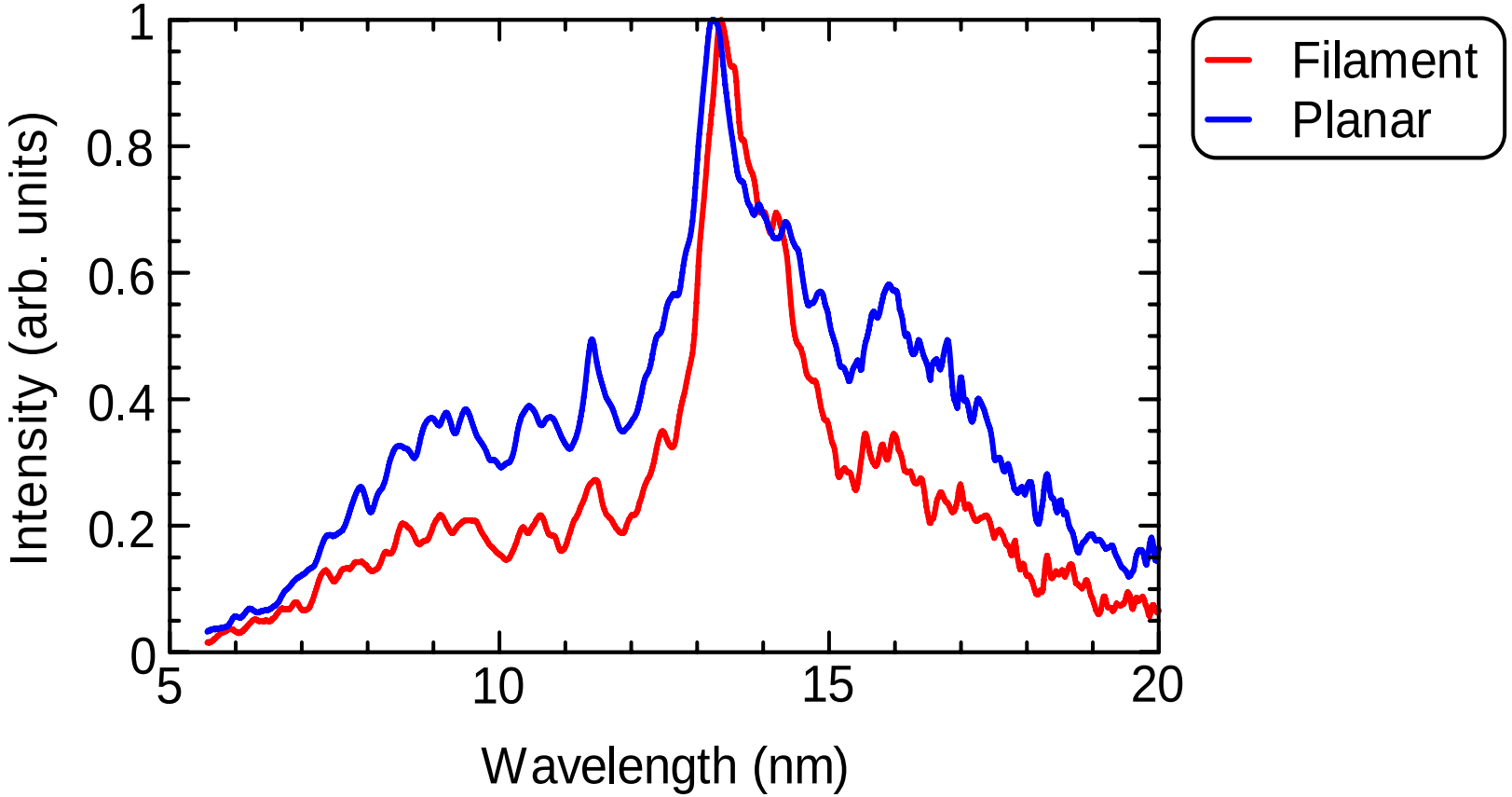
Use of a filament target

Comparison of angular distributions



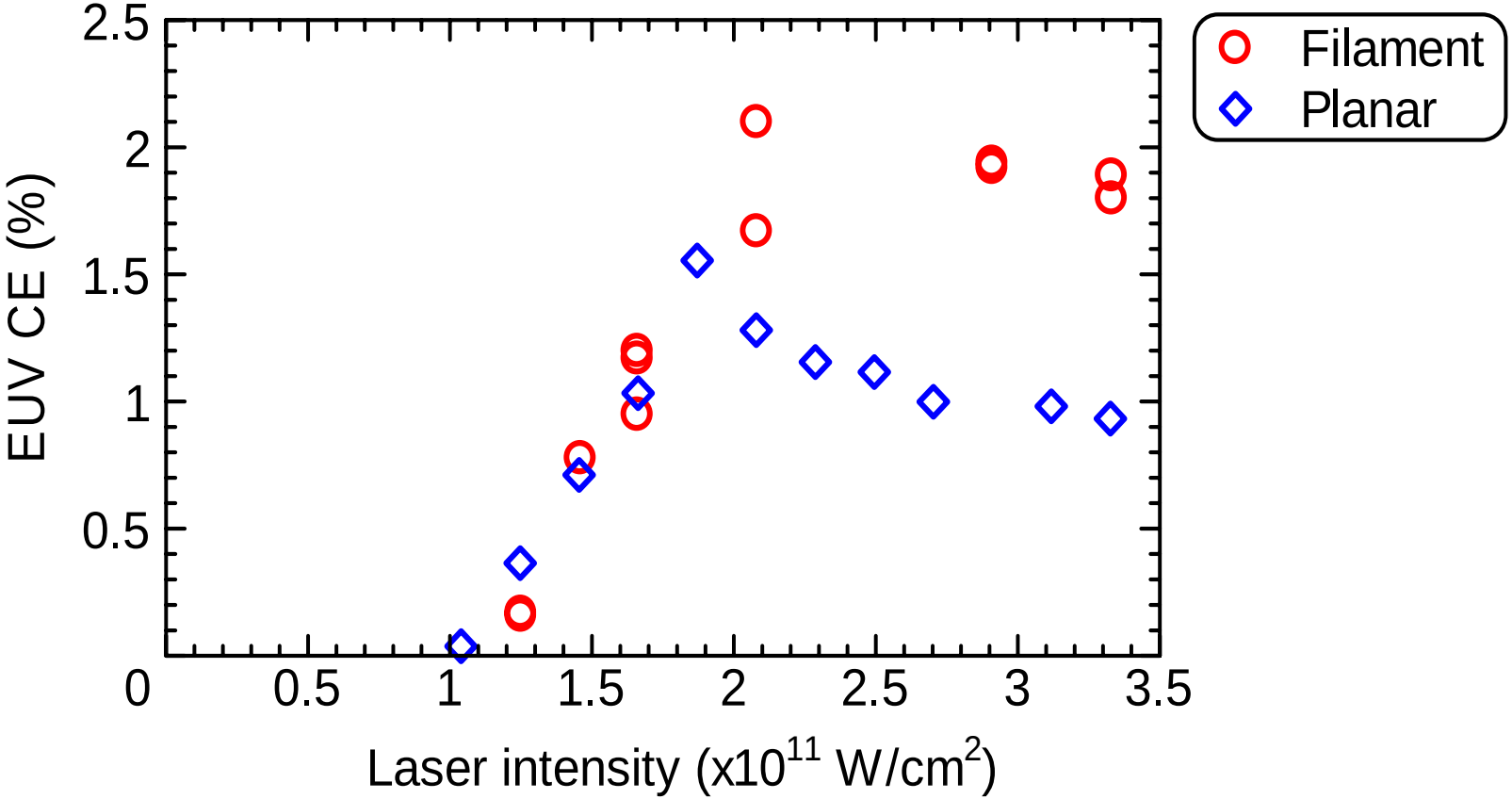
Use of a filament target

Comparison of EUV spectra



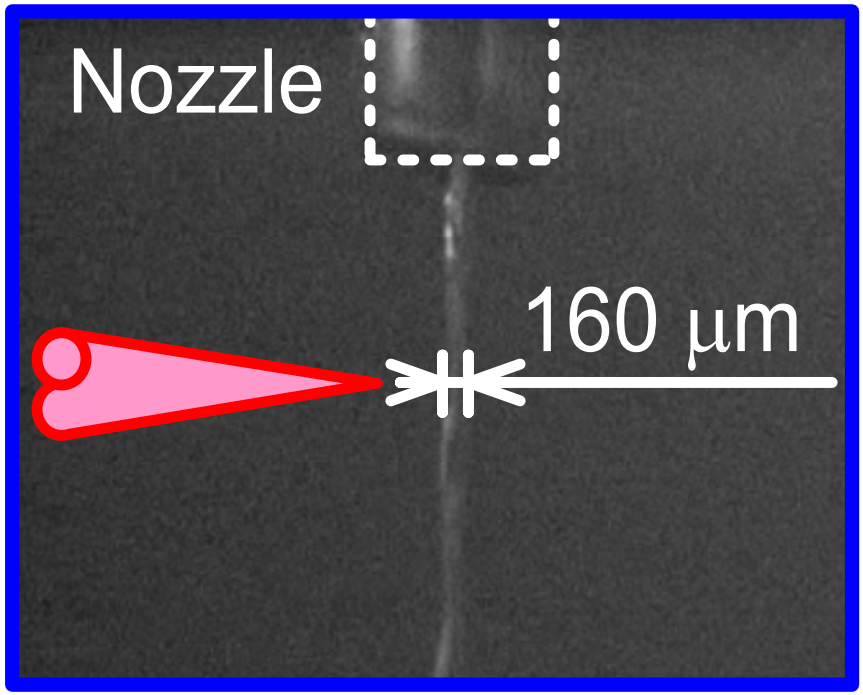
Use of a filament target

Laser intensity dependence of EUV CE



Use of a filament target

Development of a liquid tin microjet target



Summary

Characteristics of a laser-produced tin plasma EUV source

- EUV and debris emissions from a planar tin target.
  - EUV conversion efficiency: ~ 1.2% with $\cos^{0.5}\theta$-angular distribution
  - Optimum laser intensity: ~ 7 x 10^{10} W/cm^2 with a spot size of 300 μm (FWHM)
  - Suprathermal ion emission around 3 keV at a peak current with Sn^+ and Sn^{2+} ions
  - A maximum ion energy: ~ 7 keV
  - Comparison of angular distributions
    - * EUV emissions: $\cos^{0.5}\theta$
    - * Suprathermal ions and neutral fragments: $\cos^4\theta$
    - * Angular distribution of debris was narrower than that of the EUV emission

- EUV emissions from a filament target as a model of a liquid microjet target.
  - EUV conversion efficiency: ~ 2% with narrowed spectrum
  - Isotropic EUV emission between ±60°
  - Development of a liquid tin microjet target with a diameter from 50 to 150 μm