Charge-separated ion spectra in laser-produced Sn plasma

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Abstract

The 13.5-nm EUV lithography is operated in high-volume manufacturing of integrated circuits (ICs). Lithography at this wavelength is capable of reaching feature sizes below 5 nm. In order to modelling the laser-produced plasma EUV source, we should evaluate the charge-separated ion spectra in laser-produced Sn plasma¬ as an initial condition under numerical simulation for debris mitigation. In presentation, we show the detail Sn ion spectra and some dependences.

Summary

We observe the charge-separated energy spectra of suprathermal Sn ions.

- **Maximum energy higher than 10 keV with Sn^{11+} (Sn^{12+}?) ions**
- **Comparison of spectra between exp. & hydrodynamic cal.**
  - Cut-off energies were different
  - Energy distribution depends on the expanding angle

Background

One of the EUV source's issues is the debris mitigation. Debris includes neutral particle, fragments, and suprathermal ions, we focus on superthermal ions from LPP source. These particles have high kinetic energy, which damages the collector mirror. Ion kinetic energy should be 5 keV or less to extend the life of the mirror.

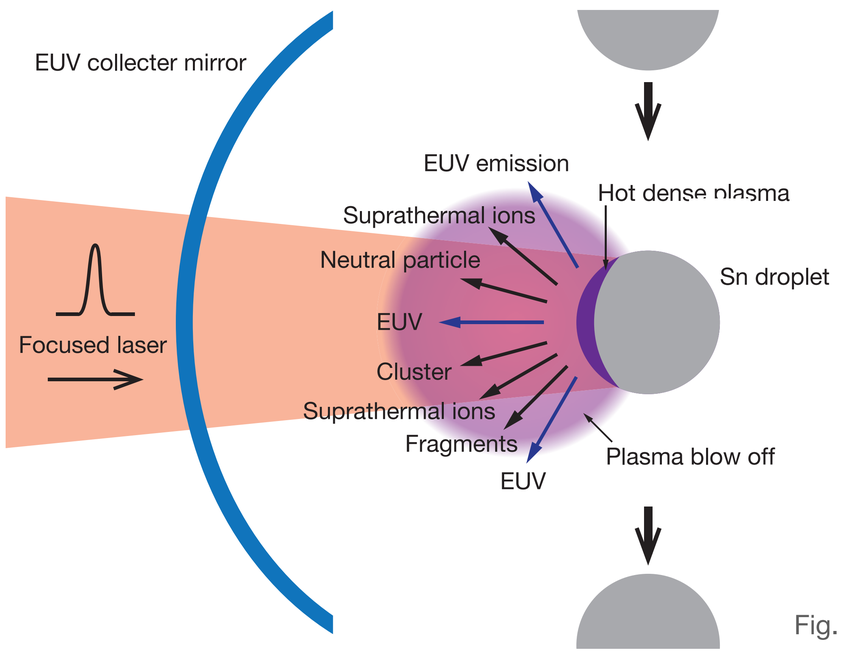


Fig. 1: Debris from LPP source.

Objective

We observe the charge-separated energy spectra of suprathermal Sn ions in a 1 -μm laser-produced plasma.

Experimental apparatus

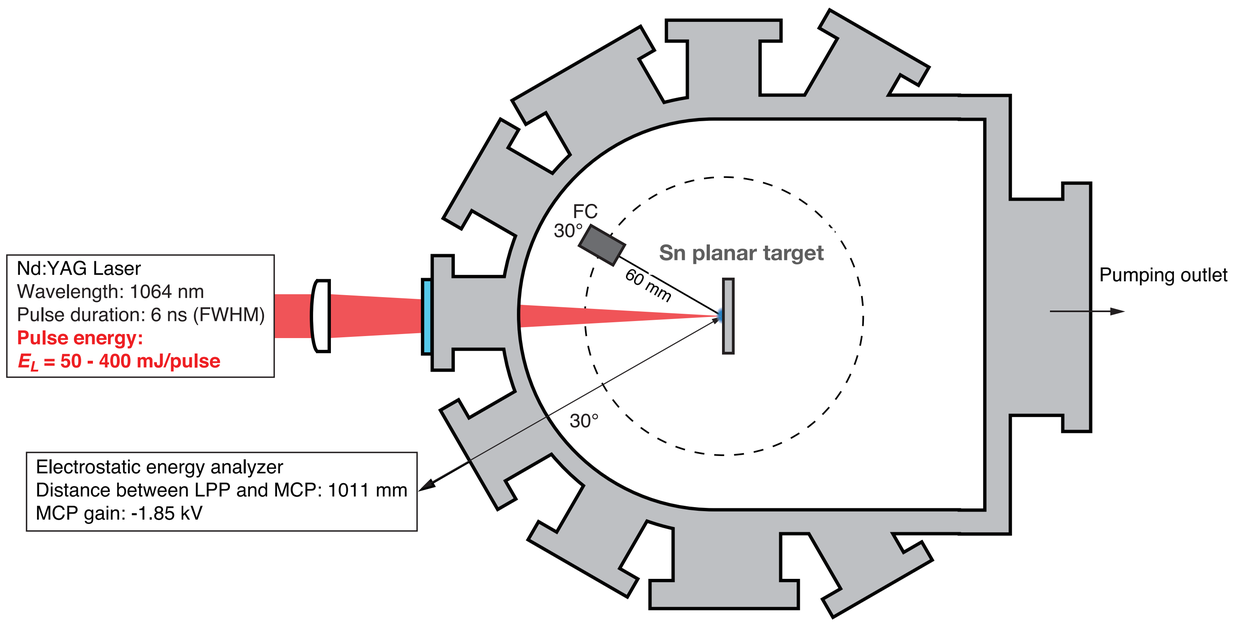


Fig. 2: Schematic diagram of experimental apparatus.

Experimental results & discussion

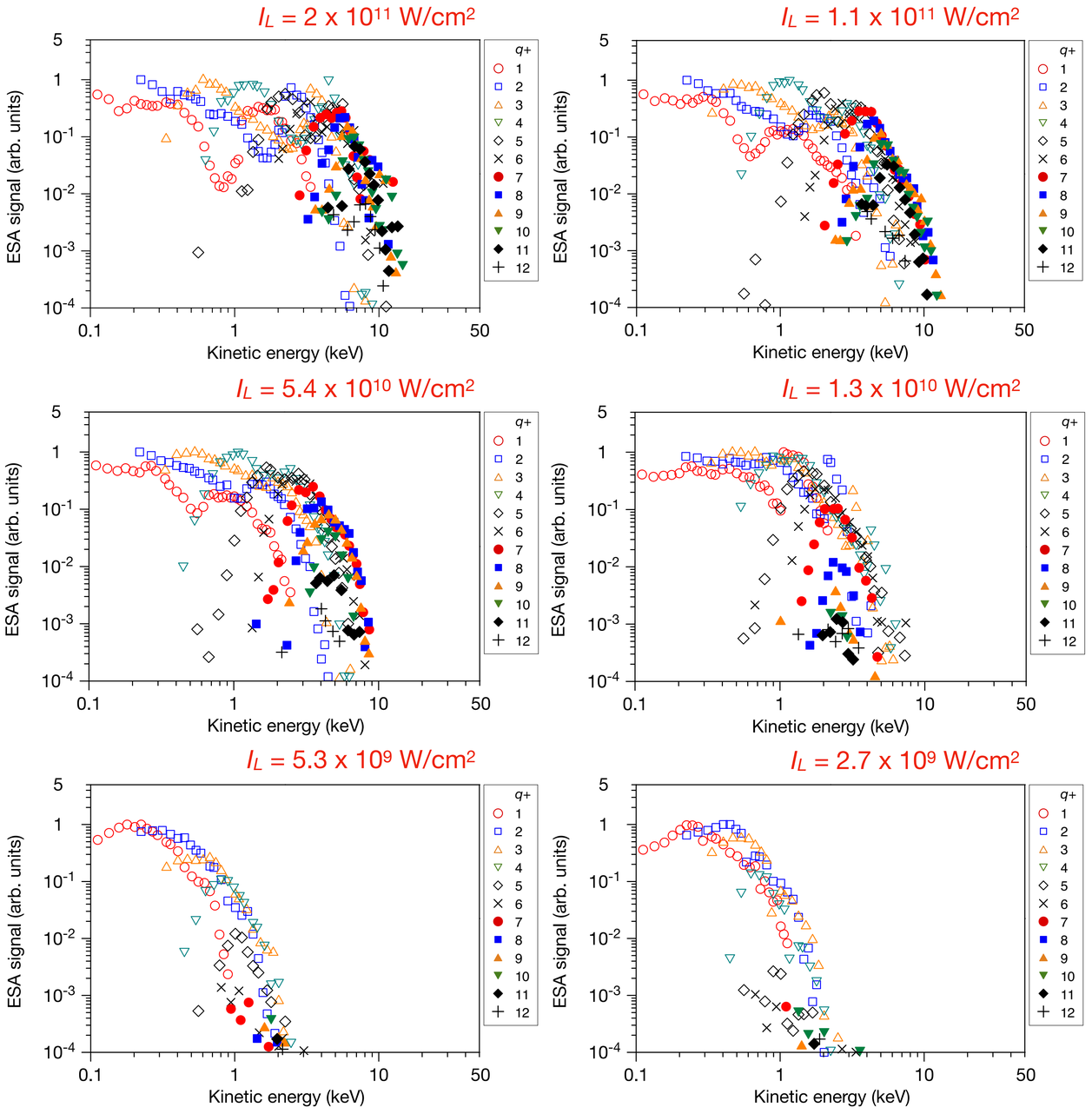
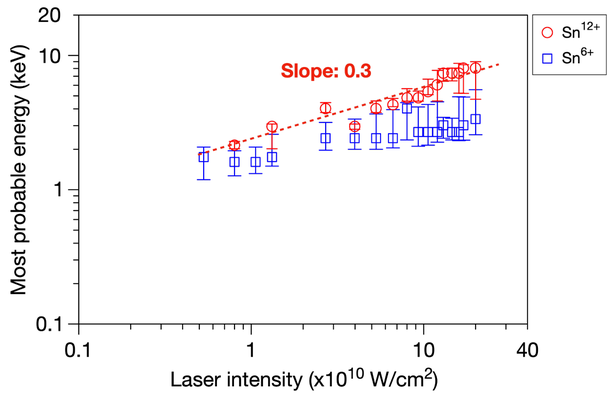


Fig. 3: Charge-separated energy spectra at six different laser intensities.



Electron temperature: $T_e \propto I_L^{\alpha}$

$\alpha = 0.3 - 0.4$

Expanding velocity: $v_s \propto T_e^{1/2}$

Kinetic energy: $K = \frac{1}{2} m v_s^2 \propto v_s^2 \propto I_L^{\alpha}$

Fig. 4: Laser intensity dependence of most probable energy of Sn^{12+} and Sn^{6+} ions.
Ref. H. Kawasaki *et al.*, AIP Advances **10**, 065306 (2020).

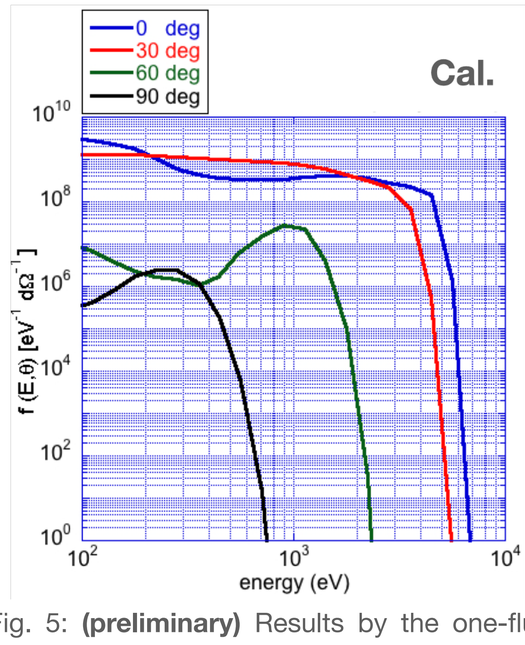


Fig. 5: **(preliminary)** Results by the one-fluid, two-temperature hydrodynamic simulation, star-2D. The cut-off energy was 5.5 keV at 30 deg., corresponing the present experiment. We found the mismatching between exp. and cal.