# Evaluation of suprathermal ions in a laser-produced plasma beyond-EUV source

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## Abstract

According to the latest international semiconductor roadmap, Gd plasma has been proposed for the next-generation [beyond-EUV (B-EUV)] light source at a wavelength of 6.*x* nm. This study is very important for debris mitigation to extend the life of $C_1$ mirror toward B-EUV lithography.

## Objective

**We evaluate the charge-separated energy spectra of suprathermal ions emitted from laser-produced Gd plasma for debris mitigation.**

- We observe the maximum kinetic energy of fast Gd ions.
- We compare the effect of laser pulse duration on the kinetic energy of Gd ions.

## Background

Opt. Express **21**, 31837 (2013).

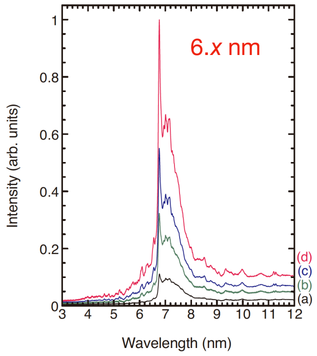


Fig. 1. Characteristics of EUV emission from a Gd plasma at wavelength is 6.*x* nm.

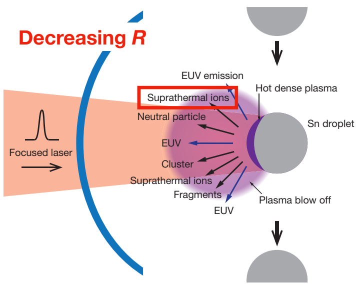


Fig. 2. Debris from EUV source

**Previous study**

- Wavelength from Gd plasma: 6.*x* nm (Fig. 1).
- Highly reflective collecting mirror for 6.*x* nm (La/$B_4C$).

**The characteristics of EUV emission from a Gd plasma are clear.**

**Sprathermal ion debris emitted from plasma is unclear (Fig. 2).**

**Issues**

(a) Ion debris damage the $C_1$ mirror.
(b) How high energy ions are there?

**We focus on suprathermal ions from B-EUV source.**

## Experimental apparatus

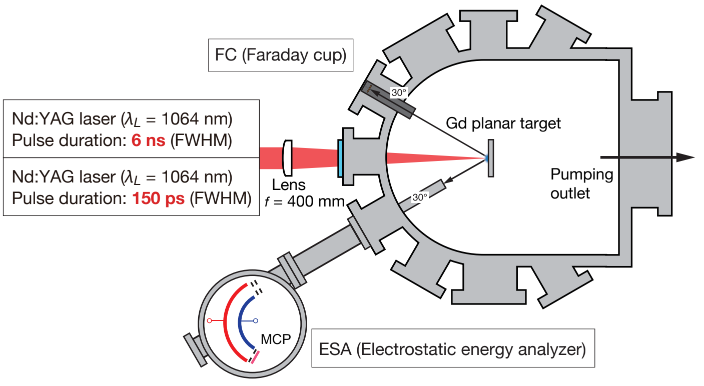


Fig. 3. Schematic diagram of the experimental apparatus.

## Conclusion & highlight

**We evaluated the charge-separated energy spectra of fast Gd ions.**

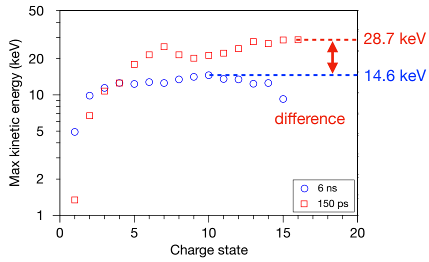


Fig. 4. Compare max kinetic ion energy at the laser intensity of 2 × $10^{12}$ W/cm$^2$.

- Max ion energy
  【6 ns】 14.6 keV ($Gd^{10+}$)
  【150 ps】 28.7 keV ($Gd^{16+}$)
- The result (Fig. 4) showed that the max kinetic energy of Gd ions depends on the pulse duration.

## Experimental detail & discussion

### Experimental detail

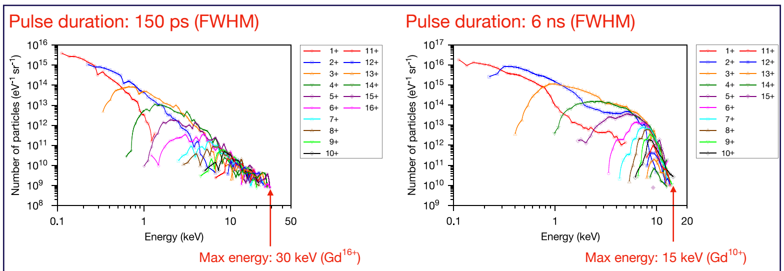


Fig. 5. Charge-separated spectra with two different pulse durations at the laser intensity of 2 x $10^{12}$ W/cm$^2$.

### Discussion

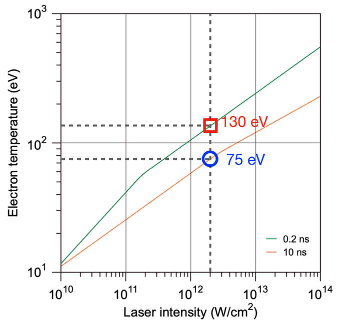


Fig. 6. Laser intensity dependences of electron temperature at the laser wavelength of 1064nm.

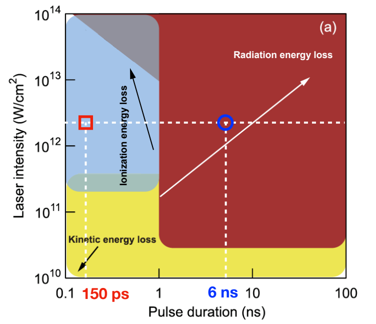


Fig. 7. Laser pulse duration and laser intensity dependences of energy flow losses at the laser wavelength of 1064nm.

Ref. H. Kawasaki *et al.*, AIP Advances **10**, 065306 (2020).

### Conversion from TOF signal to energy spectrum

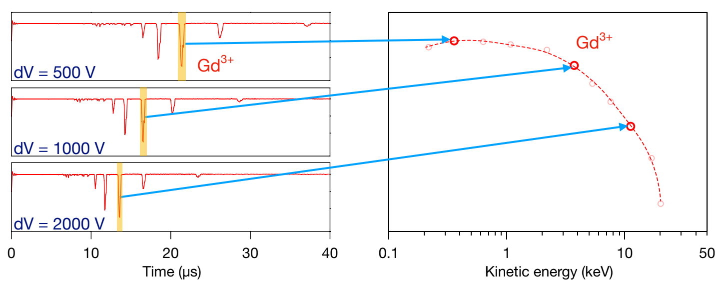


Fig. 8. Schematic diagram of conversion from TOF signal to energy spectrum.