Optimized highly charged ion production for strong soft x-ray sources with UTA spectra

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1. Abstract

We studied source optimization from strong emission with an unresolved transition array (UTA) spectrum. The peak UTA wavelengths follow a quasi-Moseley's law as $\lambda = 33.82 \times R_\infty^{-1} (Z - 20.86)^{-1.61}$ nm for a critical density of 1×10^{21} cm^{-3} and $\lambda = 165.8 \times R_\infty^{-1} (Z - 12.44)^{-1.94}$ nm for a critical density of 4×10^{21} cm^{-3}, respectively. The photon flux decreased with increasing atomic number. We also mapped the optimum electron temperatures and corresponding charge states required to produce strong UTA emission. The present quasi-Moseley's law is sufficient for identifying the optimum element for numerous applications, such as material ablation and ionization, nano-lithography, and *in vivo* biological imaging.

2. Background

Interest in the use of high power and/or high brightness soft x-ray pulses has been motivated in various fundamental and/or engineering fields, such as material ablation and ionization, nano-lithography, and *in vivo* biological imaging. Strong soft x-ray sources is produced by the unresolved transition array (UTA). The atomic number dependent peak wavelength of UTA has been investigated [1]. The peak wavelength becomes shorter with increasing atomic number. This law is quasi-Moseley's law. However, the photon flux has not been studied in detail and remains unclear. The optimum electron temperatures and corresponding charge states has not been evaluated.

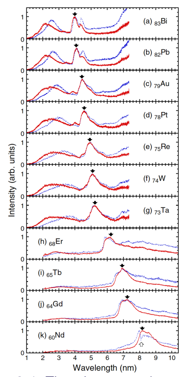

Fig. 2-1: Time-integrated spectra.

[1] H. Ohashi *et al*., APL **104**, 234107 (2014).

3. Objective

Our objective is observe spectra of soft x-ray sources and evaluate the electron temperatures and corresponding charge states. We observe the spectra of soft x-ray sources at different color laser wavelengths of 1064 and 532 nm. Laser pulse energy is 130 mJ.We evaluate the optimum charge states by comparing the calculation results of flexible atomic code (FAC) and experimental results. We evaluated the optimum electron temperatures from optimum charge states and collisional-radiative (CR) model.

4. Time-integrated spectra

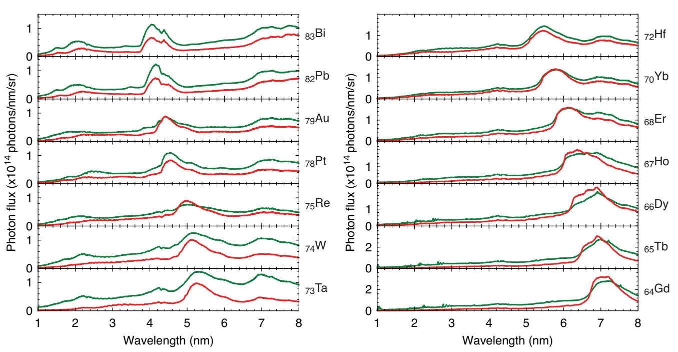

Fig. 4-1: Time-integrated spectra of soft x-ray sources (red : 1064 nm, green : 532 nm).

5. Peak wavelength and photon flux

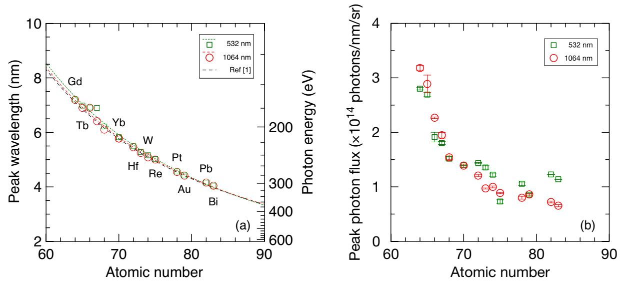

Fig. 5-1: Atomic number dependences of the wavelength (a) and the photon flux (b).

6. The electron temperatures and charge states

$_{83}$Bi

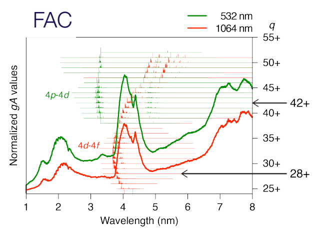

Fig. 6-1: Time-integrated bismuth spectra and charge states separated *gA* values by the FAC.

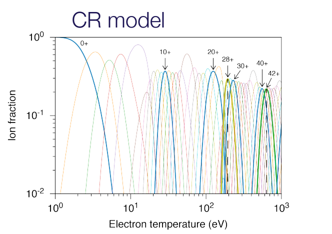

Fig. 6-2: Electron temperature dependence of ion fraction by the CR model.

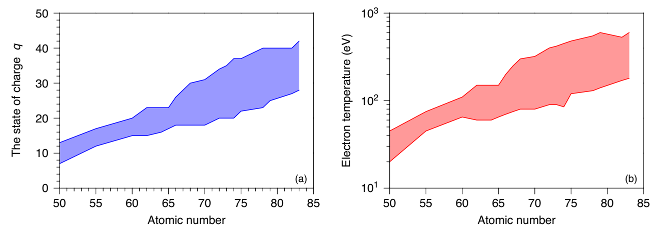

Fig. 6-3: Atomic number dependences of the charge states (a) and the electron temperatures (b).

7. Summary

We have observed the spectra of soft x-ray sources at different color laser wavelengths of 1064 and 532 nm. We have also mapped the optimum electron temperatures and corresponding charge states required for strong UTA emission from heavy element plasmas.

(1) Quasi-Moseley's law

λ = 1064 nm	λ = 532 nm	Ref [1]
$\lambda(z) = \frac{33.82}{R_\infty}(z - 20.86)^{-1.61}$	$\lambda(z) = \frac{165.8}{R_\infty}(z - 12.44)^{-1.94}$	$\lambda(z) = \frac{(21.86 \pm 12.09)}{R_\infty}(z - (23.23 \pm 2.87))^{-(1.52 \pm 0.12)}$

(2) We evaluated the optimum charge states by comparing the calculation results of FAC and experimental results .

(3) We evaluated the optimum electron temperatures from the optimum charge states by the collisional-radiative (CR) model.