Measurements of time-resolved EUV spectra for studying the population kinetics in an electron beam ion trap plasma

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Synopsis We present time-resolved extreme ultraviolet spectra of highly charged gold ions observed with a compact electron beam ion trap. Population kinetics is studied for understanding the mechanism of the population trapping recently found in our previous studies [Kobayashi *et al.*, Phys. Rev. A 89 (2014) 010501(R) and Phys. Rev. A 92 (2015) 022510].

The ground state of promethiumlike ions is $4f^{14}5s\ ^2S_{1/2}$ and the lowest excited level is $4f^{13}5s^2\ ^2F_{7/2}$ when the atomic number Z is larger than 77. The $^2F_{7/2}$ level can decay to the ground state only via E3 transition, so that it is a long lived metastable state. Recently, we found that nearly 100 % population trapping to the metastable state can be realized in a plasma with a wide range of electron density [1, 2]. In these our previous studies, the population trapping was confirmed in the equilibrium condition. The motivation of the present work is to study the population trapping mechanism by observing the time evolution of the level population.

The present experiment was performed for gold ions ($Z = 79$) using a compact electron beam ion trap, called CoBIT [3]. The electron beam energy was kept at the value just below the ionization potential of samariumlike gold (I_p^{Sm}) to maximize the abundance of samariumlike gold (the charge state just below promethiumlike). The energy was then periodically increased to the value above I_p^{Sm} to produce promethiumlike gold for a short period (typically 0.1 s) with a cycle of several seconds. The time resolved extreme ultraviolet (EUV) spectra were observed with a grazing incidence flat field grating spectrometer [4]. The diffracted EUV photon was detected by a position sensitive detector (PSD) consisting of five micro channel plates and a resistive anode.

Figure 1 shows a typical example of the time-resolved spectra. "Sm" and "Pm" indicate the $5s-5p$ resonance transitions in the samariumlike and promethiumlike ions, respectively, whereas "Pm*" indicates transitions to the metastable level in the promethiumlike ion. The intensity of the "Sm", "Pm", and "Pm*" lines is thus considered to represent the population of the samariumlike ion, the ground-state promethiumlike ion, and the metastable promethiumlike ion, respectively. The observed evolution confirmed that the relative abundance of the promethiumlike ion to the samariumlike ion increased with time. However, both the ground-state and metastable promethiumlike ions seem to show a similar time dependence. It is thus considered that the rate for the population transfer from the ground state to the metastable state is much larger than the ionization rate from the samariumlike ion in this example.

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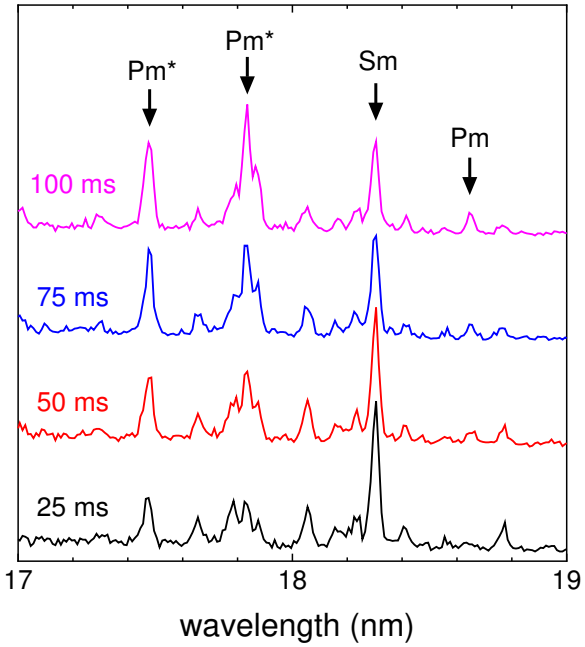

Figure 1. Time evolution of the EUV spectra of gold ions observed after the electron beam energy was changed from 420 (below I_p^{Sm}) to 500 eV (above I_p^{Sm}).

References

[1] Y. Kobayashi *et al.* 2014 *Phys. Rev. A* **89** 010501(R)

[2] Y. Kobayashi *et al.* 2015 *Phys. Rev. A* **92** 022510

[3] N. Nakamura *et al.* 2008 *Rev. Sci. Instrum.* **79** 063104

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