Plasma-assisted laser spectroscopy of highly charged ions: Application of the study on collisional processes in a laboratory plasma

N Kimura[1 *], Priti[2], S Kuma[1], T Azuma[1] and N Nakamura[3]

[1]Atomic, Molecular and Optical Physics Laboratory, RIKEN, Saitama 351-0198, Japan
[2]National Institute for Fusion Science, National Institutes of Natural Sciences, Gifu 509-5292, Japan
[3]Institute for Laser Science, The University of Electro-Communications, Tokyo 182-8585, Japan

Synopsis We present recent demonstrations regarding the plasma-assisted laser spectroscopy of highly charged ions. The time-resolved plasma-assisted laser spectroscopy has revealed the hyperfine-structures and the electric-quadrupole transition rate in highly charged heavy ions with many electrons, which were difficult to measure using conventional methods.

Laser spectroscopy of highly charged ions (HCIs) is one of the remarkable topics in recent atomic physics research. Visible and near-visible transitions in HCIs are attractive spectroscopic targets for studying relativistic and quantum electrodynamics theories. In addition, recent proposals for new types of atomic clocks using a highly charged heavy ion with many electrons have spurred the development of laser spectroscopy of HCIs.

Laser spectroscopy of HCIs requires sophisticated experimental approaches different from standard techniques for neutral atoms and singly charged ions. Historically, the laser-ion beam merging technique pioneered this research field [1,2] and measured the transition wavelengths of many electric-dipole (E1) and magnetic-dipole (M1) transitions in several HCIs with a few electrons, such as H-like, He-like, and Li-like ions. In recent two decades, electron beam ion traps (EBITs) have contributed demonstrations of laser spectroscopy of trapped HCIs free from systematic Doppler shifts [3,4]. Recently, quantum logic laser spectroscopy and clock operation were achieved by employing sympathetically laser-cooled B-like Ar^{13+} transported from an EBIT to a radio-frequency quadrupole ion trap [5,6].

Here we present recent demonstrations of plasma-assisted laser spectroscopy of Pd-like $^{127}I^{7+}$ trapped in an EBIT [7,8]. Figure 1 briefly shows the experimental scheme with the energy diagram of I^{7+}. We observed extreme ultraviolet laser-induced fluorescence with the aid of collisional excitation processes in the EBIT plasma. This scheme enabled us to precisely measure the M1 transition between the high-energy metastable fine-structure levels and reveal their hyperfine-structures [7]. Additionally, we also succeed in measuring the electric-quadrupole (E2) transition rate $(4d_{3/2}^{-1}5s)_{J=2} \rightarrow (4d^{10})_{J=0}$ using the present time-resolved plasma-assisted laser spectroscopy [8].

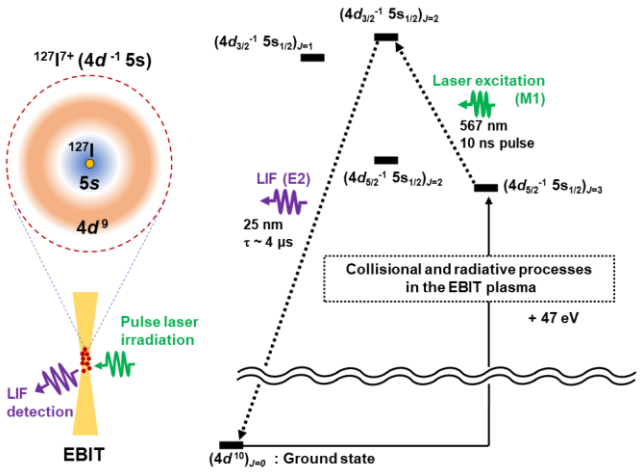

Figure 1. Experimental scheme with the energy diagram of I^{7+}.

References

[1] Myers E G 1981 *Phys. Rev. Lett.* 47 87
[2] Klaft I *et al.* 1994 *Phys. Rev. Lett.* 73 2425
[3] Hosaka K *et al.* 1994 *Phys. Rev. A* 69 011802(R)
[4] Mäckel V *et al.* 2010 *Phys. Rev. Lett.* 107 143002
[5] Micke P *et al.* 2020 *Nature(London)* 578 60
[6] King S A *et al.* 2022 *Nature(London)* 611 43
[7] Kimura N *et al.* 2023 *Comm. Phys.* 6 8
[8] Kimura N *et al.* 2023 *Phys. Rev. A* 107 022805

* E-mail: naoki.kimura@riken.jp