Laser cooling and spectroscopy of trapped isotope ions injected through Mass Spectrometer

Shuichi Hasegawa*‡ [1], Kyunhung Jung†, Yoshihiro Iwata*, Kazuhiro Yamamoto‡, Yuta Yamamoto‡, Masabumi Miyabe†, Ikuo Wakaida†

* Nuclear Professional School, The University of Tokyo, Tokai, Ibaraki, 319-1188, Japan

†CLADS, Japan Atomic Energy Agency, Tokai, Ibaraki, 319-1195, Japan

‡ Department of Nuclear Engineering and Management, The University of Tokyo, Tokyo 113-8656, Japan

Synopsis We have developed a novel apparatus combining Mass Spectrometer and Ion Trap-Laser Cooling Spectroscopy. Mass selected ions through a quadrupole mass spectrometer were trapped with a linear Paul trap. Isotope ions were laser cooled and laser induced fluorescence from cooled ions were observed and isotope shifts of trapped ions were measured.

Trapped ions are one of the ideal targets for laser spectroscopy, which are widely used for variety of fields such as frequency standards, quantum information and so on. Using laser cooling and heating techniques enhances controllability of trapped ions [1] and enables one to perform sympathetic cooling of atomic and molecular ions. Other advantages of laser cooling of trapped ions are not only to reduce Doppler broadening but also crystalize trapped ions, which makes it possible to observe individual isotope ions with a sensitive CCD.

We have developed an apparatus of Ion Trap Laser Cooling Spectrometer (ILECS) with various ion sources such as an Inductively Coupled Plasma Mass Spectrometer (ICPMS) shown in Fig. 1 [2]. With this apparatus, liquid samples are atomized and ionized by the interaction with Ar plasma. The ions are mass selected through a quadrupole mass spectrometer. Following trap of calcium ions [1,2], we extended elements to be trapped to strontium. Cooling scheme of

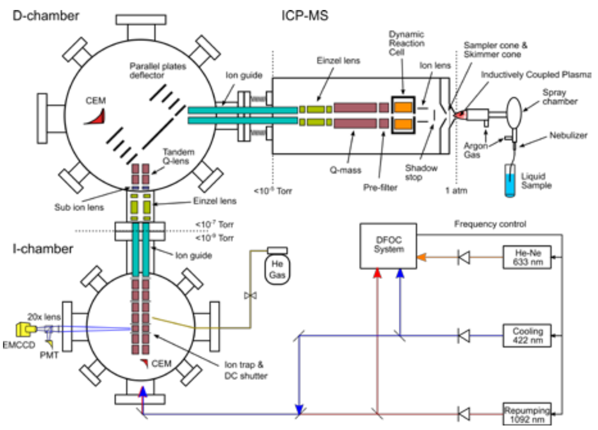

Figure 1. Schematics of experimental apparatus of Inductively Coupled Plasma Mass Spectrometer-Ion Trap Laser Cooling Spectrometry (ICPMS-ILECS) for strontium ions.

strontium ions requires lasers of 422 nm for cooling (5s $^2S_{1/2} \rightarrow$ 5p $^2P_{1/2}$) and 1092 nm for repumping (4d $^2D_{3/2} \rightarrow$ 5p $^2P_{1/2}$), which were constructed in our lab. The frequencies were controlled with Digital Fringe Offset Control (DFOC) system [3].

Less than ten trapped isotope ions were prepared to reduce rf heating and laser induced fluorescence from the ions was observed as a function of the cooling and repumping laser frequencies. Isotope shifts obtained from the spectra are in good agreement with the previous report [4].

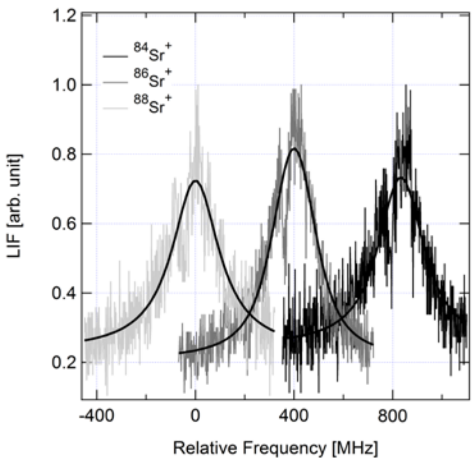

Figure 2. Laser induced fluorescence of Sr^+ isotope ions as a function of repumping laser frequencies.

References

[1] M. Kitaoka and S. Hasegawa 2012 *J. Phys. B* **45**, 165008

[2] M. Kitaoka, T. Yoshida, Y. Yamamoto, K. Jung, S. Hasegawa, 2013 *J. Anal. At. Spectrom.* **28**, 1292

[3] K. Jung, Y. Yamamoto, S. Hasegawa, 2015, *Hyperfine Interact.* 236, 39

[4] B. Dubost, R. Dubessy, B. Szymanski, S. Guibal, J.-P. Likforman, L. Guidoni, 2014 *Phys. Rev. A.* **89**, 032504

‡ [1] E-mail: hasegawa [at] tokai.t.u-tokyo.ac.jp