Contribution ID: **68** Type: **Poster**

Progress towards realization of an optical frequency standard using trapped Ba+ ions

We aim at realization of an optical frequency standard with barium ion (Ba^+). The $^2S_{1/2}$ $(F = 2, m_F = 0)$ - $^2D_{3/2}$ $(F = 0, m_F = 0)$ clock transition in odd isotopes $^{135}Ba^+$ or $^{137}Ba^+$ is insensitive to quadrupole electric field[1]. Therefore, it is possible to improve the frequency stability by increase of the number of ions without degradation of uncertainty.

As a first step, we are developing an optical clock referenced to the $^2S_{1/2}$ - $^2D_{5/2}$ transition at 1.76 μm in $^{138}Ba^+$ ions[2-5]. So far, we conducted single-ion spectroscopy of the clock transition using a linenarrowed external-cavity laser diode (ECLD) and resolved motional sidebands [6]. To accelerate the detection of the spectra of the clock transition, we employed deexcitation of the $^2D_{3/2}$ state owing to its long lifetime of 31 s. We first drove the $^2D_{5/2}$ - $^2P_{3/2}$ transition at 614 nm by irradiating with radiation from an orange LED. The deexcitation rate was measured to be 10 s. Then, we irradiated with radiation around 614 nm from an optical frequency comb (OCF) based on a Yb:KYW laser[6] to further accelerate the deexcitation. We estimated the deexcitation time to be 200 ms, where the optical power in 30-nm bandwidth was 40 μW. This is a similar approach to use of an amplified spontaneous-emission in a Yb-doped fiber amplifier for deexcitation of the $^2D_{5/2}$ state in Sr^+ ions[8].

We also succeeded in laser cooling of single $^{137}Ba^+$ ions loaded through odd-isotope-selective photoionization[9]. We employ two-step photoionization of Ba atoms using the $^1S_0$ - $^1P_1$ transition at 553 nm as the first excitation. Ba atoms in the $^1P_1$ state is further excited using the second radiation above the ionization potential. Radiation at 553 nm is generated using a frequency-doubled ECLD and the second radiation is generated from a laser diode (LD) at 396 nm. Radiation for the first excitation is blue-detuned by 500 MHz from the absorption line of $^{138}Ba^+$ ions. We laser cooled $^{137}Ba^+$ ions by driving the $^2S_{1/2}$ - $^2P_{1/2}$ transition using two frequency-doubled ECLDs at 493 nm to avoid optical pumping in the hyperfine structures. We simultaneously drove the $^2D_{3/2}$ - $^2P_{1/2}$ transition using three ECLDs at 650 nm. We detected the fluorescence of a photon counting rate of 700 s^{-1} for a $^{137}Ba^+$ ion.

[1] J. Sherman *et al.*, 2005 Digest of the LEOS Summer Topical Meetings, p.99
[2] W. Nagourney *et al.*, Opt. Commun., **79**, 176 (1990)
[3] B. Appasamy *et al.*, Appl. Phys. B, **60**, 473 (1995)
[4] N. Kurz *et al.*, Phys. Rev. A, **82**, 030501(R) (2010)
[5] L. Slodička *et al.*, Phys. Rev. A, **85**, 043401 (2012)
[6] H. Fujisaki *et al.*, 6th international conference on Trapped Charged Particles and Fundamental Physics (TCP2014), Japan, p.92
[7] M. Mitaki *et al.*, Appl. Opt., **57**, 5150 (2018)
[8] T. Fordell *et al.*, Opt. Lett., **40** No.8, 1822 (2015)
[9] M. R. Dietrich *et al.*, Phys. Rev. A, **81**, 052328 (2010)

Authors: Mr FUJISAKI, Hiroto (Kyoto University); Mr IMAI, Yasutaka; Dr SUGIYAMA, Kazuhiko (Kyoto University)

Presenter: Mr FUJISAKI, Hiroto (Kyoto University)

Session Classification: Poster Session

Track Classification: Atomic Clocks