# Collinear laser spectroscopy of $Ba^+$ in $6s\,^2S_{1/2}$-$6p\,^2P_{3/2}$ transition

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The nuclear electromagnetic properties in nuclear ground states and long-life isomeric states for a wide range of nuclides have been determined using collinear laser spectroscopy (CLS).[1] We are developing a CLS apparatus for the slow RI beams that will be provided from the SLOWRI facility[2] in the near future, with the goal of realizing CLS for RIs that are difficult to obtain through the isotope separation on-line (ISOL) method. We have started off-line CLS test. As a first step, we selected stable Ba+ isotope ions since their high intensity ion beams can be produced with a compact surface ionization source.

This report describes the off-line CLS experiment for the transition from the ground state $6s\,^2S_{1/2}$ to the excited state $6p\,^2P_{3/2}$. Tajima *et al.* report on the CLS test for the transition from $4d\,^2D_{5/2}$ to $6p\,^2P_{3/2}$ in this progress report.[3] The excitation wavelength for the $6s\,^2S_{1/2} \rightarrow 6p\,^2P_{3/2}$ transition for $Ba^+$ is 455 nm. We built an external cavity diode laser (ECDL), which was assembled with an anti-reflection-coated laser diode NDBA116T (peak wavelength range: 450 to 470 nm; manufactured by Nichia Corporation) and a 2400/mm holographic grating (Thorlabs GH13-24V) in a Littrow configuration. The wavelength of the ECDL was locked to a desired wavelength using a feedback system of a high-precision wavemeter (HighFiness WS-U-10). The resulting time variation of the center frequency of the laser was narrowed to 4 MHz in full width at half maximum (Fig. 1).

The CLS test was performed using a home-built ECDL. Figure 2 shows a schematic of our CLS apparatus. Barium ions generated from the surface ionizer were accelerated by a high voltage of 10 to 20 keV. The accelerated ions were transported to an observation region after mass separation by a mass analyzing magnet.

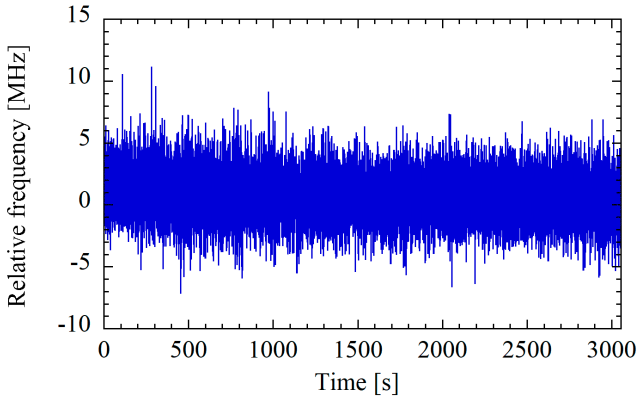


Fig. 1. Frequency locking result for our ECDL.

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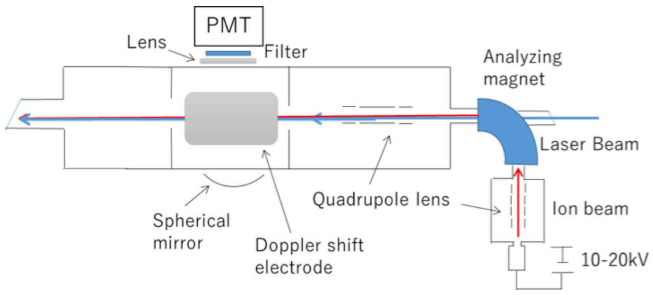


Fig. 2. Schematic diagram of our collinear laser spectroscopy apparatus.

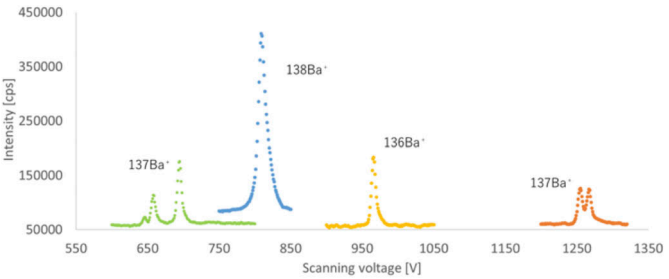


Fig. 3. Collinear laser spectroscopy spectra for $^{136-138}Ba^+$.

A series of electrodes to control the Doppler shift was placed around the observation region. Laser-induced fluorescence (LIF) from the ions was collected in a photomultiplier tube in front of the electrodes, as shown in Fig. 2. We observed resonance spectra while scanning the voltage of the electrodes to control the Doppler shift of the ions, instead of scanning the laser frequency. Figure 3 shows the observed spectra for $^{136,137,138}Ba^+$. At this time, the ions were accelerated to 10.51 keV, the laser frequency was locked to 658.372682 THz, and the laser power was 0.1 mW. The beam intensities were 200 pA, 350 pA, and 1.4 nA for $^{136}Ba^+$, $^{137}Ba^+$, and $^{138}Ba^+$, respectively. We successfully observed five resonance peaks for the transition between the hyperfine sublevels of $^{137}Ba^+$, and only the peaks for the $6s\,^2S_{1/2}$ state ($F = 1$) $\rightarrow$ $6p\,^2P_{3/2}$ state ($F = 0, 1$) transition were not resolved, because the spacing is 32 MHz at most.

We continue systematic measurements under various experimental conditions such as different laser powers, acceleration voltages, and laser light path alignments for resolution improvement. We will also improve the sensitivity using a coincidence method,[4] aiming at the spectroscopy for low-yield nuclei obtained at online experiments.

References

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