Offline collinear laser spectroscopy of zirconium II

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The laser spectroscopy of atomic transitions is sensitive to nuclear structures in ground states. The measurement of isotope shifts and hyperfine splittings by collinear laser spectroscopy (CLS) is a powerful tool for studying radioactive isotopes (RIs) systematically along isotope chains. Charge radii, quadrupole deformation, electromagnetic moments, and spins have been extensively measured at ISOL-type facilities. We are preparing for the CLS of RIs at the gas-cell decelerator facility, SLOWRI. Our main targets include refractory elements near the $N = Z$ line in the intermediate mass region, where experimental data are not sufficient because of the experimental difficulties at ISOL-type facilities. Barium isotopes have been measured as a first offline demonstration of CLS.[1)] This report describes the next step wherein an offline measurement of zirconium ions was performed.

Zirconium ions were produced from a disk-shaped metal target by using pulsed-laser ablation. A Q-switched Nd:YAG laser (Coherent, Minilite II) was used with the time width of 5 ns at the repetition rate of 10 Hz at the maximum. Ion beams were extracted at ∼10 keV and mass separated so that a selected isotope could be transported to a photon detection region.[1)] We chose the transition $4d^2(^3F)5p\ z^4G^\circ_{5/2} \leftrightarrow 4d^2(^3F)5s\ a^4F_{3/2}$, which is at 357 nm, and the strongest transition from the atomic ground state.[2)] A continuous-wave Ti:Sapphire laser (M-square, SolsTis) pumped by a solid-state laser (Verdi, V10) was used to obtain the fundamental wavelength of 714 nm and a commercial second harmonics generator with a LBO crystal (M-square, ECD-X) was used. The fundamental wavelength was stabilized by a wavelength meter within 10 MHz (FWHM); the power was 0.5 mW at the detection region. The time-of-flight (TOF) of the ions was measured by a channeltron (Photonis, Magnum 5901) at the downstream of the beamline. We found that the TOF of the resonant ions were concentrated within 50 μs. Therefore, a time gate for the photon detection by a PMT was set to 50 μs for the timing of the pulsed laser irradiation to suppress background counts.

Figure 1 shows the observed spectra with Voigt fitting curves. Since $^{90,92,94}Zr^+$ and $^{91}Zr^+$ were measured at separate times and different wavelengths were available between them, the energy of ion beams was tuned to 13.6 keV for $^{90,92,94}Zr^+$ and 10.6 keV for $^{91}Zr^+$. The background count rates were suppressed by a factor of 1000 compared to that of the continuous measurement. In the future, we plan to suppress backgrounds further

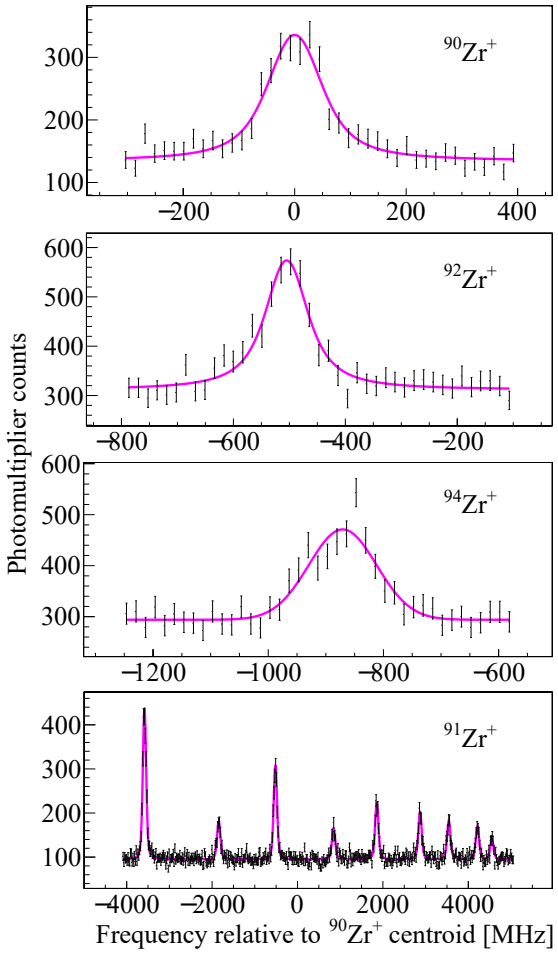

Fig. 1. Observed resonance spectra of Zr^+ at 357 nm with the time gate of 50 μs. Magenta lines represent the Voigt fitting curves.

with a shorter ion bunch by performing CLS with a multi reflection TOF mass spectrometer[3)] where the bunch length of 40 ns is possible. Although all 12 peaks were not fully resolved for $^{91}Zr^+$, hyperfine coefficients for both upper and lower levels were derived from five isolated peaks; these coefficients were consistent with those reported in previous measurements.[4,5)] In addition, this experiment is a benchmark for a new lifetime measurement of $^{93}Zr^+$,[6)] which is important to accurately evaluate the radioactivity of long lived fission products in nuclear wastes.

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