Offline ion source for laser spectroscopy of RI at SLOWRI†

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The collinear laser spectroscopy of radioactive isotope (RI) beams is a powerful technique used to directly measure the nuclear properties of ground or isomeric states. Isotope shift measurement is planned using RI ion beams supplied from the universal slow RI-beam facility (SLOWRI) at RIBF. The main targets are medium-mass nuclei of refractory elements, for which experimental studies are insufficient. To achieve high precision, it is essential to determine a reference frequency with well-studied isotopes for the planned spectroscopy apparatus to minimize systematic uncertainties. In this work, an ion source combining the laser ablation of solid targets in helium gas and a radio frequency (RF) ion guide system with an RF carpet[1)] was constructed for the reference measurement of isotope shifts.

Figure 1(a) shows a sketch of the ion source. It consists of cylindrical DC electrodes, an RF carpet, a quadrupole ion beam guide, and an RF quadrupole (RFQ). A solid target for laser ablation was fixed on the surface of the cylindrical DC electrodes. Helium gas was continuously introduced into the first chamber via a piezo valve while the second and the third chambers were evacuated. The pressure of the first chamber was measured using a capacitance manometer and stabilized by controlling the piezo valve with proportional-integral-derivative (PID) feedback. A Q-switched Nd:YAG laser (532 nm, ∼5 ns width) was installed outside the chamber. The laser light was focused using a lens, and the light passed through a view port normal to the ablation target surface. The laser power was 25 mJ per pulse at maximum, and it could be varied using a manual attenuator. The spot size was ≤1 mm, which corresponds to a maximum fluence of 3.2 J/cm^2. The lens was moved using XY linear stages remotely controlled via a LabVIEW program on a step-by-step basis such that the laser spot moved randomly on the surface of the target. This ion source system was connected to a test beamline through an insulation flange. The ion source could be biased to 10 kV to extract ion beams to the downstream beamline, which was grounded. A dipole magnet with movable slits was placed in front of and behind the magnet to observe mass spectra.

Figures 1(b) and (c) show the observed mass spectra when solid targets of the refractory elements Zr and W were used for laser ablation, respectively. The ratio of intensity among the isotopes was consistent with natural abundance. The performance of the ion guide

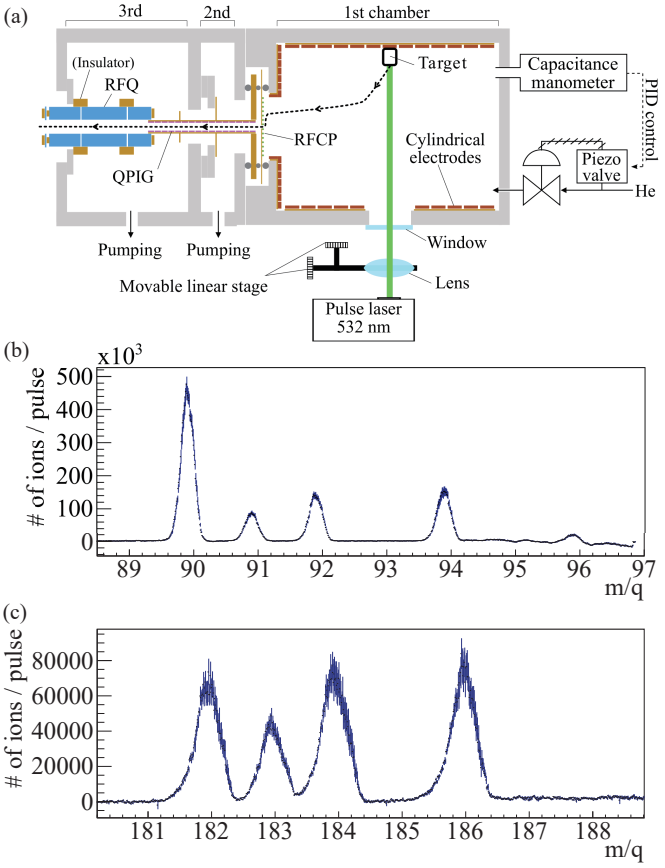

Fig. 1. (a) Sketch of the ion-source system. (b) Mass spectrum of Zr^+. (c) Mass spectrum of W^+.

system was studied separately using a Cs^+ emitter, and the transport efficiency was approximately 60–80%. The laser-intensity threshold of ion formation was 1–1.3 J/cm^2, and weak dependence on the repetition rate of laser ablation was observed. Consequently, 10^5–10^7 singly charged ions per laser pulse, consistent with the natural abundance, were successfully observed for metal targets of Ni, Ag, Zr, Ta, W, and a barium compound (BaF_2). The energy spread of the extracted ions was evaluated to be <1 eV via a comparison of the width of the obtained mass spectra with trajectory simulations assuming various initial temperatures, although direct measurements are needed for conclusive evidence.

Therefore, singly charged ion beams of one selective isotope including refractory elements are available for the reference measurement of collinear laser spectroscopy. Background reduction will be possible using a time gate in coincidence with the pulsed ablation laser.

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