Development of light collection system for collinear laser spectroscopy

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The laser spectroscopy of atomic transitions can aid in clarifying the nuclear structures in ground and isomeric states. We are preparing for the collinear laser spectroscopy (CLS) of rare isotopes (RIs) at the upcoming thermalized RI beam facility using an He gas catcher, referred to as SLOWRI.[1] Barium isotopes were measured as a first offline demonstration of our CLS setup.[2] Thereafter, offline measurements of stable Zr isotopes were performed.[3] An unstable refractory element isotope such as a radioactive Zr isotope is a candidate for an online experiment in the intermediate mass region. As the intensity of exotic Zr isotopes is limited in the online experiment, the detection efficiency should be improved for precise measurement. This report describes a next step to improve the light collection efficiency.

We have performed CLS by changing the velocity, that is, Doppler tuning, of the ion beam using post-acceleration electrodes in the region where a photomultiplier tube (PMT) is placed as a fluorescence monitor. Figures 1(a) and (b) depict the top and side views of the primary design of the electrodes, respectively. Ion beams and the spectroscopy laser pass collinearly through them (from left to right). A post-acceleration voltage up to ±3 kV is applied on a long electrode at the center, divided by each resistor connected to each thin electrode, and grounded at both ends. A sheet of metal mesh is attached on both sides at the center. It avoids optical pumping outside of the region and enables the spectroscopy laser to be locked. Figure 1(e) presents a schematic around the center electrode. The PMT is placed in front of the mesh and a cylindrical mirror is placed on the opposite side, so that light from these two open sides can be detected.

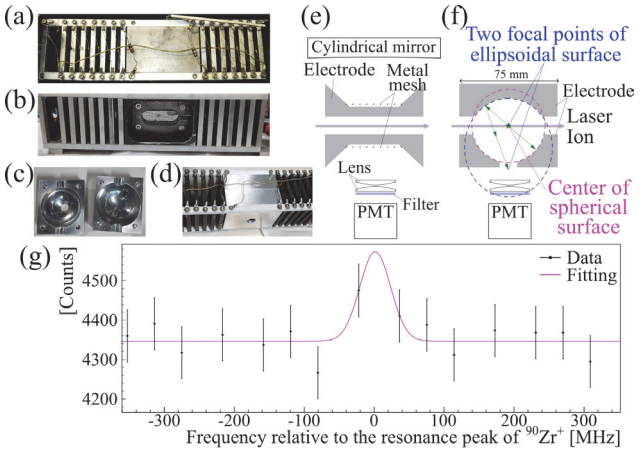

Fig. 1. Post-acceleration electrodes: (a) top and (b) side view of the old ones, (c) inner surfaces, and (d) assembled view of the new ones. Schematics of the (e) previous and (f) new design of the center electrode. (g) Observed spectrum of $^{90}Zr^{+}$ with 10^3 ions per bunch and Voigt fitting.

We constructed a new pair of mirror-shaped electrodes to improve the light collection efficiency. Figure 1(c) depicts the inner surfaces of the new electrodes: one is spherical with a hole at the center (left) and the other is ellipsoidal (right); these were originally designed by M. Baba[4] for molecular spectroscopy. They are made of aluminum, and the inner surfaces are polished. Figure 1(d) presents an integrated view with the new pair of electrodes at the center. Figure 1(f) presents a schematic where blue and magenta dashed lines correspond to the ellipsoidal and spherical surfaces, respectively. The center of the spherical surface is one of two simultaneous focal points of the ellipsoidal surface. If a point-like light source is placed at the center, reflected light on the spherical surface returns and re-passes the spherical center, and then re-reflected light on the ellipsoidal surface focuses onto the other focal point, which is observed using the PMT through the hole. It allows 90% of solid angle coverage for the pointlike source. In CLS, however, 40% of coverage is estimated when the interaction region is 4 cm in length.

We performed the CLS of $^{90}Zr^{+}$ this new apparatus. The overall efficiency is improved by a factor of 2.3 over the original detection setup. The absolute value is estimated at more than 4×10^{-6}, though it is necessary to determine the exact number of ions that contribute to the optical detection. So far, a resonance peak was observed for the intensity of down to 10^3 ions per bunch of repetition of 2 Hz, as depicted in Fig. 1(g). Further improvement such as one-to-one coincidence with ion detection is necessary to reduce the background rate for the exotic RIs with intensity lower than 100 pps. Further, the reflectivity of the surface of the electrode in this wavelength region, which is currently estimated at less than 50%, can be improved up to 60% by polishing.[5]

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