Offline commissioning of an iso-A/q mass reference ion source with an MRTOF-MS

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Precision mass measurements of radioactive nuclei using a multi-reflection time-of-flight mass spectrograph (MRTOF-MS) have become increasingly standard in recent years for exploring nuclear physics. MRTOF-MS enables fast and wide-band mass measurement with high resolving powers, as demonstrated in recent studies.[1–3] Precise and accurate mass determination with MRTOF-MS requires at least one well-known mass reference in the same number of laps for calibration. An iso-A/q mass reference ion is an ideal solution to minimize systematic uncertainty dependent on both mass and lap differences.[3,4]

For this purpose, an Iso-A/q mass Reference Ion Source (IRIS) has been developed using the pulsed laser ablation technique. In this technique, an ablation target made of any metal is irradiated by an intense pulsed laser to vaporize the target material, resulting in the production of singly and multiply charged ions. This facilitates the obtainment of a wide A/q range of ions, covering all isotopes in the nuclear chart.

Figure 1 shows the setup of IRIS connected to the MRTOF-MS ion trap system.[2] IRIS comprises a pulsed laser (Nd:YAG, 532 nm, ≈2.5 mJ, 10 Hz), rotating target, quadrupole ion deflector (QID), and two radiofrequency quadrupole (RFQ) ion guides: the backgammon RFQ (BG-RFQ), capable of trapping and cooling ions as an option, and the beam-transport-line RFQ (BTL-RFQ), dedicated to ion transport. Following BTL-RFQ, a diagonal steerer and an einzel lens are installed across the gate valve to efficiently inject ion beams into the pre-cooler RFQ.

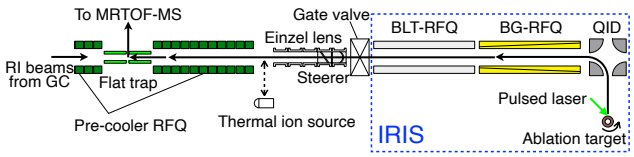

Fig. 1. Schematic of IRIS and the ion trap system on MRTOF-MS.

During the commissioning, a Mo target was used to produce a variety of isotopes and to validate the capability of using a high-melting-point metal with sufficient intensity at MRTOF-MS. The target was rotated at 5 rpm to prevent repeated ablation at the same spot and to stabilize the ion rate. Additionally, a bias voltage of 200 V was applied to the target to accelerate the produced ions. Subsequently, the ions were deflected by 90° at QID and transported through the RFQs. Subsequently, they were then steered and focused into the pre-cooler RFQ using the steerer and einzel lens. Between the einzel lens and the pre-cooler RFQ, a conventional thermal ion source (TIS) can be inserted to provide alkali ions. Certain ion beams from IRIS were transported to the gas-cell (GC) side pre-cooler RFQ through the flat trap to obtain ion signals on both measurement cycles of the concomitant method.[3] From the GC, radioactive ion (RI) beams from ^{252}Cf fission source were obtained.

Figure 2 shows the time-of-flight (TOF) spectra obtained with MRTOF-MS. At 2 laps, Mo^+ ions, molecular ions (oxide, fluoride, and dioxide), and Rb^+ ions were observed in order. At 511 laps for $^{98}Mo^+$, corresponding to the highest resolving power ($R_m \approx$ 500,000), peaks were well-separated and unambiguously identified, although those peaks were not in the order of m/q anymore. From the GC side, $^{98}Mo^+$ ions transported to the GC side pre-cooler RFQ were also

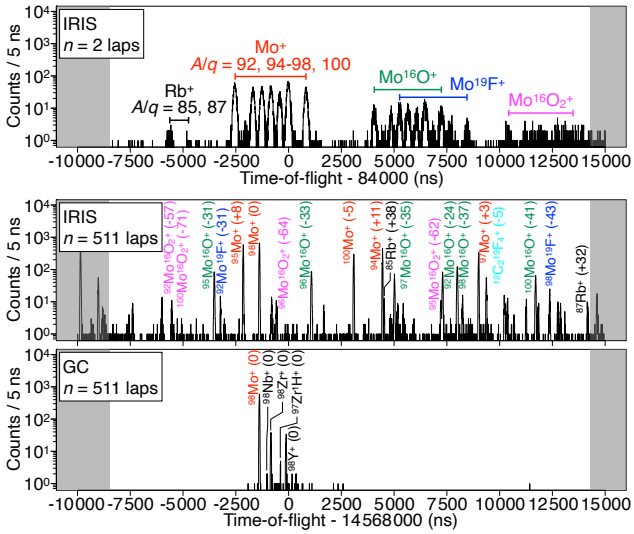

Fig. 2. TOF spectra obtained with MRTOF-MS. Top: At 2 laps from the IRIS side. Middle and Bottom: At 511 laps for $^{98}Mo^+$ from the IRIS side and the GC side with only $A/q = 98$ ions selected by an in-MRTOF deflector, with peak assignments for major peaks. The lap differences for those peaks from 511 laps are described in brackets. The gray regions are disturbed by high-voltage switching.

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transported in the measurement cycle of the GC side; therefore, they were observed in the spectrum together with RIs, $^{98}Nb^{+}$, $^{98}Zr^{+}$, $^{97}Zr^{1}H^{+}$, and $^{98}Y^{+}$.

Ions such as MoO^{+} and MoO_2^{+} are likely formed from the oxide metal surface on the target, whereas the formation of MoF^{+} ions is unlikely. MoF^{+} ions may be produced through a mechanism involving high-energy ions hitting the electrodes of the pre-cooler RFQ. During the long-term operation of the TIS thus far, stray ions could interact with fluorine atoms evaporatively deposited from a polytetrafluoroethylene (PTFE) insulator around the TIS onto the electrodes during the long-term operation of the TIS thus far, leading to the formation of molecular ions. This inference is supported by the observation of $^{12}C_2{}^{19}F_4^{+}$ ions, which are monomers of PTFE (Fig. 2, Middle). Similarly, it is presumed that Rb^{+} ions could also be produced by charge exchange with Rb atoms deposited on the electrodes. Regardless of the mechanism, these molecular ions serve as mass references.

The commissioning has shown that IRIS can provide a wide range of iso-A/q ions simultaneously. Further investigation will explore other target materials and the production of cluster ions.

References

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