Yield development with in-gas-jet laser ionization at KISS

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We are developing the KEK Isotope Separation System (KISS)[1)] to perform experimental studies such as lifetime measurements, mass measurements, β-γ spectroscopy, and laser spectroscopy for neutron-rich nuclei around the closed neutron shell $N = 126$, which is relevant to r-process nucleosynthesis. KISS is an argon-gas-cell-based laser ion source, in which these neutron-rich nuclei are produced by multinucleon transfer (MNT) reactions between a ^{136}Xe beam and ^{198}Pt target.[2)] The beam is provided by RILAC2 + RRC with an energy of 9.4 MeV/nucleon on the target, which had a thickness of 12.5 mg/cm^2. The reaction products ejected from the target enter the gas cell through a 5-μm polyimide window placed 10 mm downstream from the target. The gas cell is filled with 1-atm argon gas, which thermalizes and neutralizes injected reaction products. They are transported to the exit of the gas cell by laminar gas flow. In or out of the gas cell, these neutral atoms are irradiated by lasers for laser resonance ionization. Two lasers are used: one is for excitation, while the other is for ionization. One specific element can be selected for ionization by tuning the wavelength of the excitation laser. These ions are transported by radio frequency (RF) ion guides and accelerated by a high voltage of 20 kV followed by a dipole electromagnet for mass separation.

Since the neutron-rich nuclei of interest around $N = 126$ are produced in rare channels of MNT reactions, their efficient extraction is essential for their measurements. Thus far, in-gas-cell laser ionization has been used, in which two lasers are irradiated into the gas cell. Recently, KU Leuven group demonstrated in-gas-jet laser ionization with efficiency more than 10 times that of in-gas-cell ionization.[3)] In-gas-jet laser ionization uses two lasers, which are irradiated on a gas jet formed by a de Laval nozzle attached at the exit of the gas cell. Low-temperature and low-pressure conditions in the supersonic jet could reduce the loss of ions caused by their collisions with dense gas atoms. For yield development at KISS, we introduced an in-gas-jet laser ionization setup, as shown in Fig. 1. In order to sufficiently irradiate two lasers on the neutral atoms of interest in the supersonic jet, the overlap among them are optimized by arranging the excitation laser collinearly with the gas jet, and the ionization laser is perpendicularly reflected several times by two mirrors. An S-shaped RF quadrupole ion guide (SRFQ) was introduced to enable the collinear injection of the excitation laser. The SRFQ was segmented along the ion transportation to apply an increasing electric potential from the upstream to the downstream because a simulation with the SIMION code for the ion transportation indicated that ions stopped in the absence of such an electric-potential gradient. The on-line experiment did not show increased extraction yields with in-gas-jet laser ionization. When the same SRFQ was used with in-gas-cell ionization, the count rates of extracted ions were the same between extraction with and without the electric-potential gradient. This result indicates that the initial ion velocities obtained from the gas jet are not correctly evaluated in the simulation. We will further investigate the SRFQ design for yield development with in-gas-jet laser ionization through a more realistic simulation.

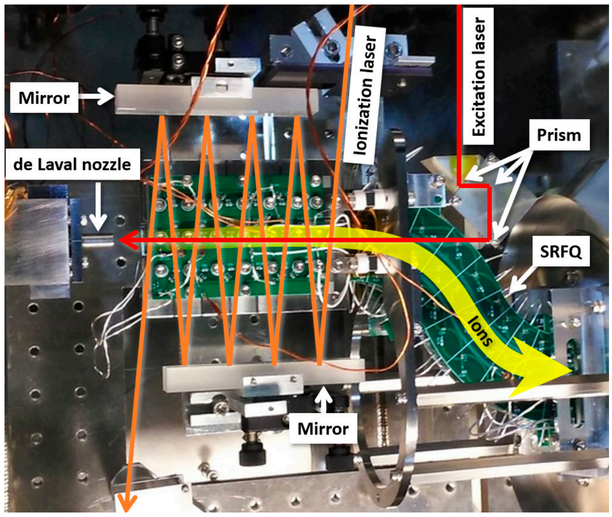

Fig. 1. KISS setup for in-gas-jet laser ionization.

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