Doughnut-shaped gas cell for KEK Isotope Separation System[†]

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We have developed the KEK Isotope Separation System (KISS)[1] to study the β-decay properties of neutron-rich isotopes with neutron numbers around $N = 126$ for astrophysics research.[2] KISS uses a laser ion source to produce pure low-energy ion beams of neutron-rich isotopes in the region around $N = 126$, which are produced in multi-nucleon transfer reactions by impinging a stable ^{136}Xe beam with an energy of approximately 10 MeV/nucleon on a ^{198}Pt target.[3] The extraction efficiency from the laser ion source, namely an argon gas cell, was as low as 0.01%. The low extraction efficiency stems from the plasma induced by the primary beam injection into the gas cell, which is believed to reduce the ionization efficiency and selectivity of the laser ionized atoms.

It is straightforward to increase the production yields of unstable nuclei by increasing the primary beam intensity. However, the plasma effect obstructs the increase of beam intensity. To overcome the difficulty, we have developed a doughnut-shaped argon gas cell with a rotating target. Figure 1 shows a schematic 3D view of the doughnut-shaped gas cell. The doughnut-shaped gas cell has an aperture for transporting the primary beam without entering the gas cell and a large window (polyimide foil 5 μm in thickness) for implanting the target-like fragments (TLFs) recoiling out of a rotating ^{198}Pt target. Owing to the characteristic large emission angles of TLFs, the TLFs could be injected into the gas cell with high efficiency.

To study the performance of the doughnut-shaped gas cell with a rotating target, we performed on-line experiments using a ^{136}Xe^{20+} beam with 10.75 MeV/nucleon and a maximum intensity of 60 pnA. Figure 2 shows the measured extraction yield of ^{199}Pt^{+} as a function of primary beam intensity. The black square and red circles in Fig. 2 indicate the measured extraction yields with the use of the old and new gas cells, respectively. The extraction yields were approximately 20 pps at 20 pnA with the use of the old gas cell and approximately 260 pps at 50 pnA with the use of the new doughnut-shaped gas cell. These results clearly indicate that the doughnut-shaped gas cell increased the extraction efficiency by suppressing the plasma effect. Moreover, we could increase the extraction yields by increasing the primary beam intensity up to 50 pnA owing to the new gas cell. However, we observed a decrease of the extraction yield as the primary beam intensity was increased beyond 60 pnA. This result indicates that we could not completely suppress the plasma effect, and further improvements are required to the KISS gas cell system. This will be the focus of our future research.

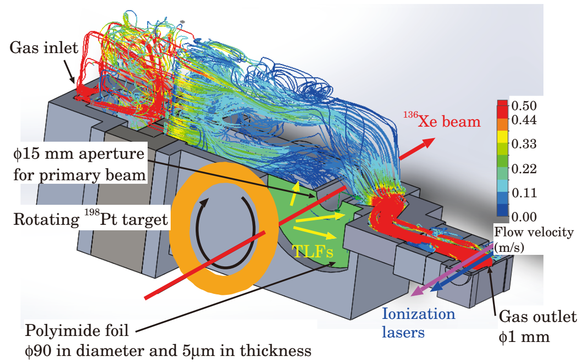

Fig. 1. Schematic view of the doughnut-shaped gas cell. The colored lines indicate the calculated argon gas flow trajectories connected to the gas outlet, based on the exact geometry. The color code indicates the calculated velocity (m/s) of the argon gas flow. Here, the pressure of the argon gas was 88 kPa.

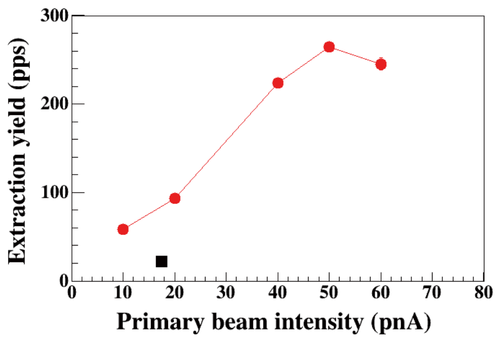

Fig. 2. Measured extraction yields as a function of primary beam intensity with the use of the old and new gas cells. Statistical error bars are smaller than the symbols.

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