Development of cryogenic helium gas cell at KISS

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We have developed a cryogenic helium gas cell to efficiently extract unstable nuclei produced by multi-nucleon transfer (MNT) reactions of ^{136}Xe beam impinging a ^{198}Pt target at the KEK Isotope Separation System (KISS).[1] Unstable nuclei implanted in such a helium (ionization potential (IP): 24.6 eV) gas cell can survive as singly or doubly charged ions depending on their ionization potential. In contrast to the laser ionization used with the present argon (IP: 15.8 eV)-filled KISS gas cell, a helium gas cell offers faster, more efficient, and element-independent extraction of ions. Delivering such wide isobaric cocktail beams to the existing multi-reflection time-of-flight mass spectrograph (MRTOF-MS) will allow for high-efficacy mass measurements as the device can simultaneously analyze numerous ion species. For example, in decay studies, the MRTOF-MS could be used to provide an isobarically (or even isomerically) pure sample. Therefore, the use of a helium gas cell could provide at least one order of magnitude improvement in experimental efficacy over the existing argon gas cell.

Interactions of target-like and projectile-like MNT products and scattered primary beams, with the helium gas result in a strong plasma of He^{2+} and e^-. To efficiently transport the desired radioactive ions in such a plasma, we manufactured a radio-frequency (RF) wire-carpet unit for use with a 4-phase RF traveling wave (RFTW) technique.[2] The RF wire carpet unit consists of 224 beryllium-copper wires (100 μm in diameter) with 600 μm pitch arranged in a plane. A negative DC bias applied to the wire carpet accumulates ions near the wires, while a superposed 4-phase RFTW moves the ions across the structure. Figure 1 shows a cross-sectional view of the helium gas cell installed at KISS. In the helium gas cell, a system of two RF wire carpet units accumulates and transports ions to a RF carpet on a Kapton substrate from which the ions are extracted from the gas cell. The gas cell was cooled to $T \approx 70$ K to freeze out unwanted impurities by combining a cryo-cooler and liquid nitrogen.

We performed initial offline tests to optimize the DC and RF conditions using stable $^{85}Rb^+$ emitted from an alkali ion source installed in the gas cell. The performance was then confirmed in online tests by extracting the MNT products implanted in the gas cell under the dense plasma condition. We measured the extraction yield as a function of the primary beam intensity, as shown in Fig. 2, using the MRTOF-MS to identify and count $^{198}Pt^{2+}$ ions extracted from the gas cell. The extraction efficiency from the gas cell was determined to be approximately 1%, indicating more than one order of magnitude improvement over the argon gas cell. Futhermore, the extraction yield increased linearly in proportion to the primary beam intensity up to at least 100 particle nA, in contrast with the performance of the argon gas cell wherein yields typically saturate above 50 particle nA. In total, we expect more than a 20-fold gain in extraction yield by using the helium gas cell. We plan to measure the masses of unstable nuclei in the vicinity of $N = 126$ with this system in the near future.

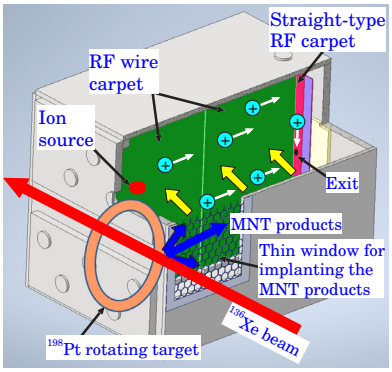

Fig. 1. Cross-sectional view of the helium gas cell. MNT products (blue lines) are implanted into the gas cell through a thin window. The flow of ions toward the gas cell exit by DC field and RFTW is shown by yellow and white arrows, respectively.

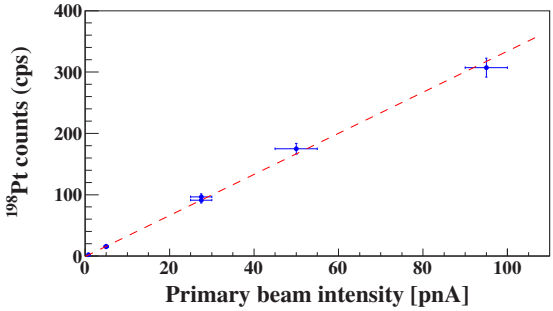

Fig. 2. Measured extraction yield of $^{198}Pt^+$ as a function of the primary beam intensity.

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References

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