Improvement of gas inlet system for FRAC at SCRIT facility

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At the SCRIT facility,[1)] we have been studying the charge density distribution of unstable nuclei using the electron scattering method. To perform electron scattering with radioactive isotopes at a low production rate, it is necessary to convert the ions generated continuously by the ISOL-type ion separator, the electron-beam-driven RI separator for SCRIT (ERIS),[2)] to a pulsed beam with an efficiency as high as possible. A fringing-RF-field-activated dc-to-pulse converter (FRAC)[3)] is a gas-filled beam cooler buncher developed for this purpose and achieves an accumulation of 10^7 ions with an efficiency of approximately 90%.[4,5)] However, a decrease was observed in the accumulation efficiency with a longer stacking time (see the blue squares in Fig. 2), and there were concerns that contaminants with small ionization potential in the noble gas could neutralize and molecularize the target ions. Therefore, a buffer gas purification system was introduced in the FRAC.

Figure 1 presents a schematic of the newly modified gas inlet system. Neon gas was purified to the ppb level or less of impurities using a filter (IG-105-200630, ARM Purification) and flowed into the FRAC, where the gas pressure was controlled to $\sim 10^{-3}$ Pa through differential pumping. A further improvement was the installation of a variable leak valve (951-7170, Canon ANELVA) instead of the needle valves. This valve enabled microflow control and significantly contributed to optimizing the gas pressure in the FRAC. Following assembly, all the gas lines were evacuated and baked at 110°C for nearly a day to eliminate as much residual impurity as possible.

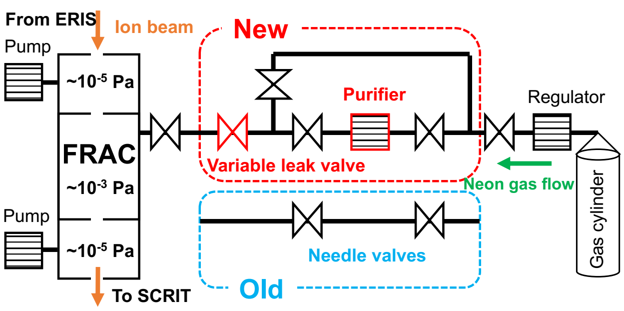

Fig. 1. Schematic of the gas inlet system before (blue frame) and after (red frame) modification. Neon gas was regulated at 0.11 MPa before the variable leak valve, and the microflow rate was controlled and introduced downstream of the valve to the FRAC.

Offline experiments were performed to evaluate the improved efficiency. The $^{132}Xe^+$ ion beam delivered from ERIS was injected into the FRAC for 0.4 ms at 1 Hz ($\sim 10^7$ ions/cycle), trapped and cooled (for 1–1000 ms), and subsequently ejected into a Faraday cup located downstream of the FRAC to measure the ion current. The FRAC was operated with a 1.8 MHz, 1 kV_{pp} RF field and a DC potential of depth 30 V along the beam axis at a neon gas pressure of 2.0×10^{-4} Pa.

Figure 2 presents the offline test results of the stacking time dependence of the accumulation efficiency with and without the purifier. The efficiencies were defined as the ratio of the ion current to that without stacking in the FRAC. Before the improvement, the efficiency started decreasing after 10 ms of stacking and dropped to approximately 66% at 500 ms, whereas the introduction of gas purification enabled the efficiency to be maintained at over 90% for more than 1 s.

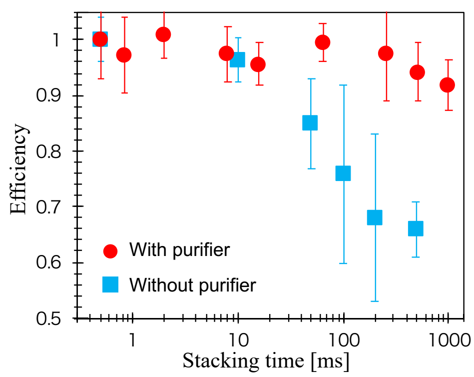

Fig. 2. Dependence of stacking time on FRAC efficiency with (red solid circles) and without (blue solid squares) purifier.

This study has established the significance of buffer gas purity, and the possibility of longer accumulation times and more efficient cooling at higher pressures has indicated the possibility of the electron scattering of exotic nuclei with small production yields in the future.

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References

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