Latest performance of FRAC at SCRIT facility

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The construction of the SCRIT electron scattering facility,[1)] which aims to realize the world's first electron scattering experiment for unstable nuclei, enabled measurement with $\sim 10^8$ ions/s. In order to perform electron scattering with unstable nuclei at a small production rate, it is necessary to convert the ions generated continuously by the ISOL-type ion separator, Electron-beam-driven RI separator for SCRIT(ERIS),[2)] to a pulsed beam with an efficiency as high as possible. For this purpose, we developed a dc-to-pulse converter, Fringing-Rf-field-Activated dc-to-pulse Converter(FRAC).[3)] In 2018, the dc-to-pulse conversion efficiency was greatly improved through a modification to incorporate cooling and the 2 step-bunching method.[4)] In this article, we report the optimization of the 2 step-bunching method, the latest performance, and the future plan.

In the 2 step-bunching method, pre-pulsed beams extracted from ERIS are stacked in FRAC and extracted as a high-intensity pulsed beam from FRAC. Therefore, to achieve a high dc-to-pulse conversion efficiency, the efficiencies of both ERIS and FRAC are important. The most important factor in these efficiencies is the extraction frequency of the pre-pulsed beam, f_{pre}. To determine the most appropriate f_{pre}, we performed two measurements. The first measurement was of the stacking-time dependence of the stacking efficiency of ERIS, E_{ERIS}. E_{ERIS} was $\sim$100% for stacking times up to 100 ms. The details are reported in Ref. 5). The second measurement is of the cooling time. The cooling time is the time until the ions injected into FRAC are sufficiently cooled. When ^{133}Cs was used as the ion beam and Xe gas of $\sim 10^{-3}$ Pa was used as the coolant, the cooling time was 50 ms. From these results, the appropriate time interval for extracting the pre-pulsed beam was determined to be from 50 ms to 100 ms. Therefore, 2 step-bunching was performed at $f_{\mathrm{pre}} = 10$ Hz.

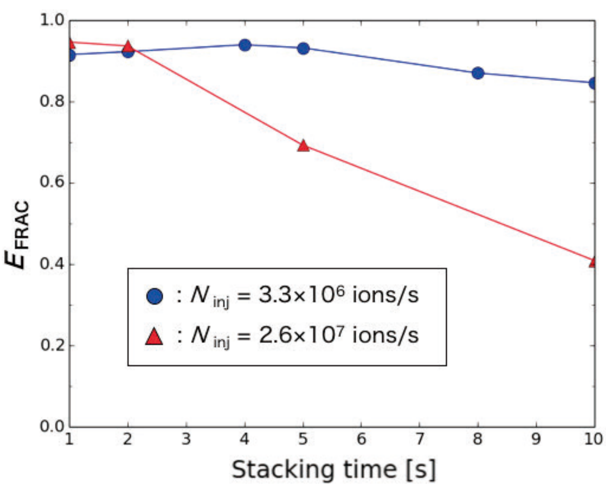

Fig. 1. Stacking-time dependence of E_{FRAC}.

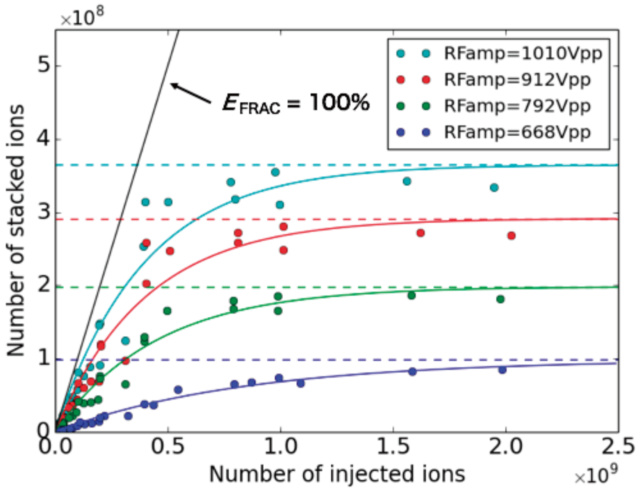

Fig. 2. RF-amplitude dependence of the number of stacked ions.

In the measurement after the optimization of 2 step-bunching, the stacking time dependence of the efficiency of FRAC, E_{FRAC}, was measured. The measurement was performed twice while changing the number of injected ions per second, N_{inj}. Figure 1 shows the results. E_{FRAC} was constant at $\sim$90% when the number of injected ions was less than 5.2×10^7. However, E_{FRAC} decreased as the number of injected ions increased further. This is considered to be due to the shallowing of the pseudo potential created by the RF electric field, which is a result of the space charge effect of the stacked ions. The ions injected thereafter cannot be stacked further.

The pseudo potential can be deepened by increasing the RF amplitude. We measured the RF-amplitude dependence of the number of stacked ions in order to explore the possibility of improving E_{FRAC} by increasing the RF amplitude. Figure 2 shows the result. As the RF amplitude increases, the number of stacked ions increases and E_{FRAC} approaches 100%. From this result, it is concluded that increasing the RF amplitude was effective. In order to stack $\sim 10^8$ ions with a higher efficiency, we are planning to increase the RF amplitude.

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