Development of a buffer gas-free Buncher for SCRIT experiments

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We developed low-energy–ion beam buncher[1)] for ion beam injection into the SCRIT device at the Self-Confinig Radioactive isotope Ion Target (SCRIT)[2)] facility. This apparatus makes it possible to convert a continuous beam from Electron-beam-driven RI separator for SCRIT (ERIS)[3)] to a pulsed beam with 500 μs duration. This buncher is based on a linear radio-frequency quadrupole (RFQ) buncher widely used in the world. However no buffer gas is used and this buncher works in ultra-high vacuum condition. The new-type buncher we have developed stacks continuously injected ions using RF fringing fields created at both ends of the RFQ electrodes, and extracts them as a pulsed beam. In off-line test experiments, we found the DC to pulse conversion efficiency. We also found that the efficiency is greatly improved by combining with pre-bunching at the ion source using grid action.

Figure 1 shows the schematics of the off-line experimental setup of the system together with the longitudinal potential diagrams. This consists of an ion source with a grid, RFQ electrode with barrier electrodes as both ends, and the analyzing magnet. Three Faraday cups were used as beam diagnostic device as shown in the figure. The RFQ has a total length of 914 mm and a bore radius of r_0 = 8.0 mm. RF field with less than 500-V amplitude is supplied in the frequency range from 0.3 MHz to 3 MHz from an LC resonance circuit. The ion source is a surface ionization type, and it provides alkali metal ions ($^{133}Cs^+$, $^{85\text{-}87}Rb^+$, $^{39\text{-}41}K^+$, and $^{23}Na^+$) beam. Accelerating voltage V_{Acc} = 6.0 kV. The voltage V_{Bar} applied to barriers 1 and 2 was slightly lower than V_{Acc}, $V_{Acc} - V_{Bar}$ = 1.5 V, and higher than the DC voltage V_{DC} applied to the RFQ electrodes, $V_{Bar} - V_{DC}$ = 5~10 V. With this condition, continuously injected ions are decelerated by the RF fringing field in between the barrier and the RFQ. Stacked ions are extracted from the buncher when the potential of the barrier electrode 2 is switched to V_{DC} – 120 V. This operation was repeated with appropriate frequency.

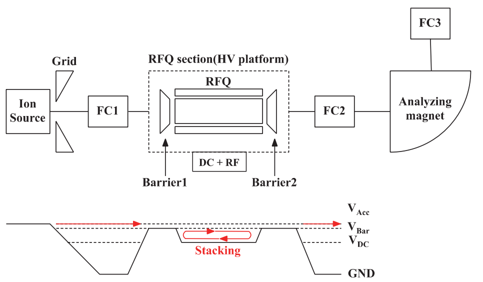

Fig.1. Experimental setup of the buncher system together with the longitudinal potential diagram (DC injection).

From the observed waveforms at FC1-3, we estimated the number of ions at each position. The stacking efficiency is defined as the ratio between the number of ions injected in the operation period (N_{inj}) and the extracted yields of pulsed beam (N_{ext}), $\varepsilon = N_{ext}/N_{inj}$. Figure 2 shows example of waveforms of pulsed Cs ion beams observed at FC3 at the operation frequency of 2 Hz. Red and green lines indicates cases of continuous beam injection and pre-bunched beam injection respectively. Pre-bunching enhances the yield of the pulsed beam by approximately three times. Estimated DC-pulse conversion efficiency is shown Fig. 3 as a function of the operation frequency. The efficiency increases with the operation frequency, and the typical value for continuous beam injection, for instance, is approximately 5% at the 2 Hz operations. The efficiency for the case of the pulsed beam is always enhanced and roughly 30% at the operation frequency of less than 10 Hz. This is due to the enhancement of the peak intensity of the pre-bunched beam and by significantly reducing the stacking time in the RFQ.

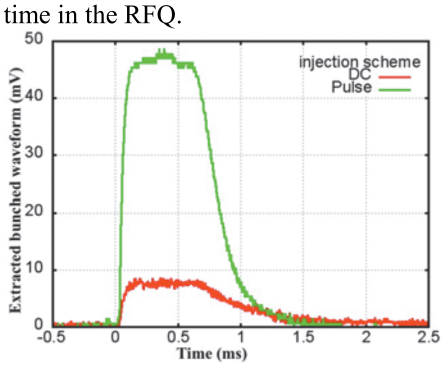

Fig. 2. Waveforms observed by FC3 for each injection schemes at the frequency of 2 Hz.

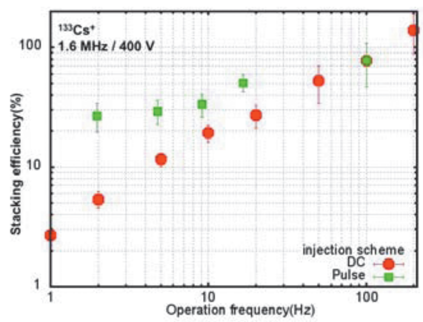

Fig. 3. Operation frequency dependence of stacking efficiency for each injection scheme.

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References

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