Modification of dc-to-pulse converter FRAC

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At the SCRIT electron scattering facility,[1)] we aim at realizing world's first electron scattering experiment for unstable nuclei, after succeeding in the principle verification experiment using stable nuclei ^{132}Xe.[2)] In order to perform electron scattering with an unstable nuclei with a small production rate, it is important to accumulate and inject ions efficiently into the SCRIT device. For this purpose, it is necessary to convert a continuous ion beam from the ISOL-type ion separator, ERIS (Electron-beam-driven RI separater for SCRIT),[3)] to a pulsed beam with a pulse duration of 300–500 μs. We developed a dc-to-pulse converter, FRAC (Fringing-Rf-field-Activated dc-to-pulse Converter),[4)] based on an RFQ linear ion trap, with a conversion efficiency of 5.6%. In this article, we report about the modification applied to further improve the efficiency and the latest performance of the FRAC.

The first modification is to enable cooling of the accumulated ions with a buffer gas. Ions lose their kinetic energy by collision with the buffer gas and accumulate in a longitudinal potential well created by the DC potential applied to the RFQ rod and a barrier electrode at both ends of the rods. The ions are injected for several seconds, stacked, and consequently ejected as a high-intensity pulsed beam. Ion beam cooler-buncher technology with a buffer gas of ∼1 Pa is widely used in the world. However, since the SCRIT device operates under a high vacuum of $\sim 10^{-8}$ Pa, it cannot be used in our beam line. Therefore, we tried to maintain the pressure inside the FRAC as high as possible while keeping the beam line vacuum at $\sim 10^{-5}$ Pa by differential pumping between the FRAC and beam line. As a result, the vacuum of the FRAC was achieved as $\sim 10^{-3}$ Pa. Cooling with low-pressure buffer gas requires a long cooling time of several tens of milliseconds, which causes a decrease in efficiency, however, that can be prevented by operating the FRAC in the SPI (Synchronous Pulse Injection) mode,[4)] in which the injection barrier potential is switched open and close synchronously with the arrival of the pre-pulsed beam from ERIS.

The second modification is to enable the application of an electric field gradient in the longitudinal direction of the FRAC. When the potential of the cooling region is uniform, it takes several milliseconds to extract all the cooled ions because they are widely distributed in the entire cooling area with low velocity. Therefore, the RFQ was physically divided into six segments, and descending DC potentials were applied and the potential dropped toward the exit. Consequently, the cooled ions were locally accumulated in the vicinity of the exit, and as a result, it is possible to extract as a narrow pulse beam.

Table 1. Conversion efficiency.

V_{d} \ f_{inj}	5 Hz	10 Hz	20 Hz	50 Hz	100 Hz
0 V	92.2%	88.1%	76.4%	66.7%	60.9%
5 V	92.4%	87.2%	81.8%	74.1%	69.8%
10 V	85.4%	79.1%	73.3%	63.4%	64.2%
15 V	-	-	-	-	53.5%

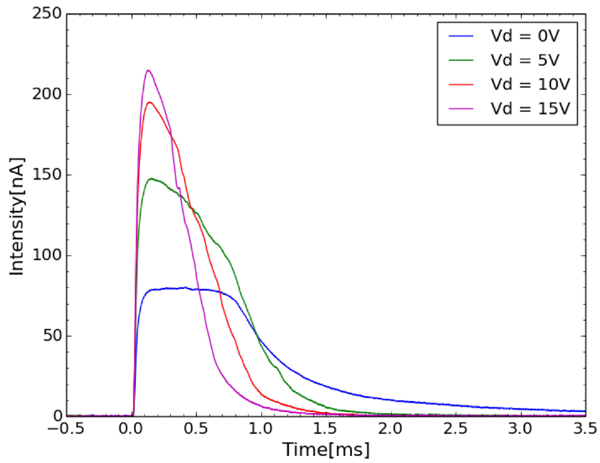

Fig. 1. Waveforms of the output pulsed beam obtained at different V_{d}.

In the measurement, the electric field gradient was set to be linear. The potential difference between the entrance and the exit, V_{d}, and the injection frequency of the pre-pulsed beam, f_{inj}, were used as measurement parameters. The conversion efficiency was greatly improved by the present modification. Table 1 shows the conversion efficiency with each measurement parameter. Figure 1 shows the waveform of the extracted pulsed beam when the pre-pulsed beam is injected at 100 Hz, with an ejection cycle of 0.5 Hz. As can be seen in Fig. 1, the pulse width narrows as V_{d} increases, and the FWHM is reduced to 418.5 μs at $V_{\mathrm{d}} = 15$ V. At the same time, however, the conversion efficiency is relatively small. Methods to solve this problems are currently under development.

References

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