Progress in the dc-to-pulse converter FRAC

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An appropriate dc-to-pulse converter is required at the SCRIT electron scattering facility,[1,2] where a continuous radioactive ion beam from the ISOL, called ERIS,[3] has to be converted to a pulsed beam with a duration of 300–500 μs to inject target ions into the SCRIT device. We developed a new type of a dc-to-pule converter, named fringing-Rf-field activated dc-to-pule Converter (FRAC), by utilizing the fringing RF field at both ends of RFQ rods. It is based on an RFQ linear trap technique and works under an ultra-high-vacuum condition. Ions continuously injected into FRAC are decelerated by the alternating longitudinal electric field produced in the distorted RF field appearing around both ends of the RFQ rods. They are accumulated in FRAC for a significantly long time, stacked during the FRAC operation period, and consequently ejected as a high-intensity pulsed beam. This edge effect notably appears only when the energy of incoming ions is less than several eV at the injection barrier and the energy spread is considerably small.

There are barrier electrodes with an aperture 6 mm in diameter at both ends of the RFQ rods. A slightly lower voltage, V_{BI}, compared to the ion beam energy is applied to the injection barrier electrode to accept the continuously incoming beam, and the beam is decelerated to a few eV at the injection barrier. The dc voltage, V_{RFQ}, which is lower than that at the injection barrier by typically 20 V, is applied to the RFQ rods to form a longitudinal potential well for ion confinement, and the ejection barrier voltage is set to be higher than the ion energy. The "basic operation mode" in which the continuous ion beam is injected into FRAC with the fixed DC potential structure as mentioned above, successfully contributed to the first electron scattering experiment for the ^{132}Xe iosotope.[4]

We attempted other operation modes to enhance the dc-to-pulse conversion efficiency toward the experiments for radioactive isotopes. They are two-step stacking, in which the pre-pulsed beams produced by the grid switching at the ion source are injected into FRAC and stacked again in FRAC for 1 s. The pre-pulsed beam has a duration of 200 μs, repetition rate of 500 Hz, and the duty of 0.1. The injection barrier potential is synchronously switched between open and close with the pre-pulsed beam arrival. This is a "synchronous pulse injection (SPI) mode" Since we found the energy spread of the pre-pulsed beam is doubled relative to that of the dc beam owing to the shift of the most-probable energy with time, we suppressed the energy-to-time correlation by modulating V_{BI} and V_{RFQ} to trace the energy shift when the beam is injected. This is an advancement of the SPI mode, and it is called the "modulated injection barrier (MIB) mode." Another operation mode is a "ramped RFQ voltage (RRV) mode," in which V_{RFQ} is ramped down during a FRAC operation period with a rate of 10 V/s. This procedure expands the longitudinal phase volume for the ion stacking, adiabatically moves the formerly stacked ions to a lower energy region, and provides free space for the later incoming ions. Although the energy spread of the output pulsed beam becomes wider, a higher dc-to-pulse conversion efficiency is expected.

The waveforms of the output pulsed beams in these operation modes are shown in Fig. 1. The output pulsed beam intensity was enhanced by a factor of 2.5 for the SPI mode, a factor of 4.5 for the MIB mode, and a factor of 10 for the RRV mode relative to the basic operation mode. The dc-to-pulse conversion efficiencies at an operation frequency of 1 Hz are, for instance, 0.8% in the basic operation mode, 2.1% in the SPI mode, 3.4% in the MIB mode, and 5.6% in the RRV mode. While the dc ion beam intensity was practically 4.6 nA, in this measurement, a high-intensity pulsed beam containing 1.6×10^9 ions was obtained at 1 Hz.

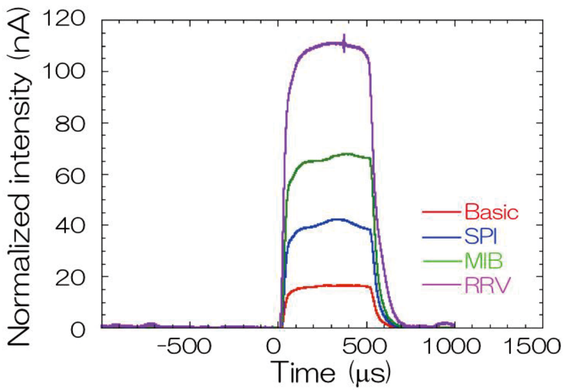

Fig. 1. Waveforms of the output pulsed beam obtained in four operation modes.

References
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