Development of a cryogenic linear RF ion trap for the TMU E-ring

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Synopsis We designed a linear octupole RF ion trap to store molecular ions produced by a laser ablation ion source, and to cool them by 4K He buffer-gas prior to injection to an electrostatic ion storage ring (the TMU E-ring). The bunch width is crucial in the pulse-mode ion extraction from the ion trap, because the extracted ions will be further accelerated to 10-15 keV by a pulsed high voltage for injection into the TMU E-ring. By applying an axial electric field with tapered electrodes, the stored ions are expected to be extracted rapidly, leading to a narrow bunch width. Our simulation assured that the bunch width will be shortened to less than 6 μs.

To study evolution of the internal energy distribution of molecular ions stored in an ion storage ring, it is highly desirable to inject vibrationally/rotationally cooled molecular ions to the ring in order to prepare well-defined initial conditions. We started developing a dedicated ion trap in which hot ions produced in the ion source are cooled with 4 K He-buffer-gas cooling before injection into the TMU E-ring, in parallel to a project to prepare the cooled ions for a newly built cryogenic ion storage ring RICE at RIKEN [1]. The bunch width is crucial in the pulse-mode ion extraction from the ion trap, because the bunched ions will be further accelerated to 10-15 keV for injection into the TMU E-ring by a pulsed high voltage applied to an 80 mm-long acceleration tube electrode.

Generally, the linear RF ion trap are equipped with two electrodes at the entrance and the exit to confine the ions in the axis direction, and by lowering the potential at the exit, the stored ions are extracted in a pulsed mode. According to a prototype linear octupole ion trap, the obtained bunch width was typically 200 μs in time, shown in Fig. 1(a), and a few meters in length, much longer than the condition required for efficient acceleration, because it takes long time for the ions close to the entrance to travel to the exit.

To solve this problem, we decided to insert eight tapered plate-type electrodes between the rod-shaped octupole electrodes of the ion trap, following the idea of ref. 2 [2]. The stored ions are extracted rapidly by the applied axial electric field (approximately 1 V/mm), leading to a narrow bunch. Our simulation by the SIMION 8.1 [3] assured this scenario; the bunch width for extraction will be shortened to less than 6 μs. For instance, when we store C_{10}^- ions, the bunch width is expected to be typically 5.4 μs in time (shown in Fig. 1(b)) and 50 mm in length at the position of 100 mm downstream of the exit of the ion trap. It is drastically improved in contrast to the case without the additional electrodes.

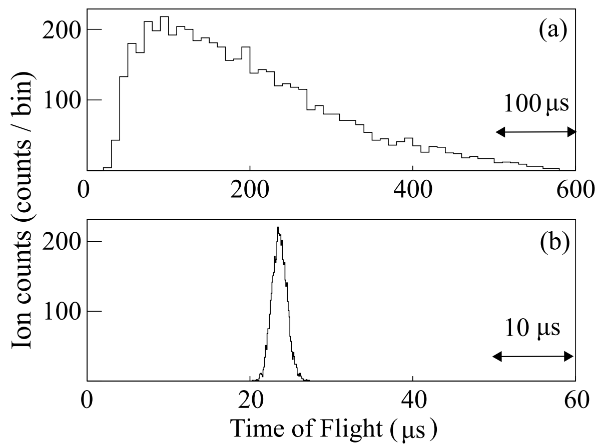

Figure 1. Simulated time of flight (ToF) of the 5000 particles of C_{10}^- ions extracted from the linear octupole ion trap, (a) without, and (b) with the tapered plate-type electrodes between the rod-shaped octupole electrodes, respectively. The ToF start is the timing when the ion extraction starts, and the ToF stop is the timing when the ions reach the detector placed 100 mm downstream of the exit of the ion trap. The bin width is (a) 10 μs and (b) 0.1 μs, respectively.

References

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