A gas-cell ion cooler and buncher for SLOWRI

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For future experiments at SLOWRI, ion cooling and bunching will be indispensable for various experiments such as collinear laser spectroscopy, and for all ion trap experiments. The ion beams from SLOWRI gas catchers will be continuous with a beam energy of 30 keV. They must be decelerated and cooled in an ion trap for bunched ions. In general, linear RF quadrupole (RFQ) traps have been used for such a purpose after electrostatic deceleration. Such systems typically use He gas at a pressure of the order of 10^{-2} mbar to cool ions in a ∼1 m length RFQ. Due to the limited acceptance of the RFQ, the typical efficiency of such cooler and buncher is a few ten percent[1)2)].

We propose here a new gas-cell cooler and buncher (GCCB) scheme (Fig. 1). It consists of a gas cell (GC) with an RF carpet (RFC) and a flat trap (see Fig. 1). The GCCB will be filled with He gas at up to 2 mbar – much less than the ∼100 mbar used in conventional GC – and cryogenically cooled to <77 K. According to calculations with TRIM, a stopping efficiency of ≈100% can be obtained for any 30 keV beams with $Z > 3$ if the GCCB is at least 420 mm long.

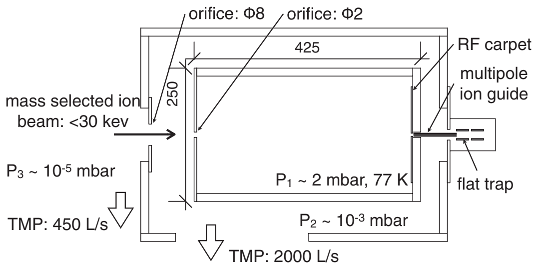

Fig. 1. Schematic diagram of the GCCB. Continuous ion beams will be cooled in the grounded GCCB, transferred to the flat trap, and extracted as a pulsed beam[3)].

The RF carpet is a proven technique for efficient and fast ion transport. Recently, the so-called ion surfing method, in which a traveling potential wave is superimposed on the RF, has been developed for faster transport[4)]. The transport speed was as high as 75 m/s with a linear RFC[4)] and an extraction efficiency of ≈100% was obtained using a circular RF-carpet[5)]. However, it has yet to be used at pressures as low as 2 mbar.

To verify the performance of the RFC at low pressures, the extraction efficiency of the RFC was investigated with a fine-RFC that has an electrode pitch of 0.16 mm and 0.08 mm^2 exit hole. The experimental parameters were optimized to achieve high efficiency using an RF frequency of f_{RF} = 5 MHz. However, when operated at 2 mbar, few ions could be extracted from the GC; at 5 mbar, the efficiency was 22%.

Simulations with SIMION indicated that the low efficiency was the result of unstable ion motion arising from the ions moving between adjacent electrodes in fewer RF periods than required for the validity of the pseudo-potential approximation (see Fig. 2). By increasing the RF frequency to 12 MHz, the simulation indicated that the ion motion would become stable and a high extraction efficiency could be achieved.

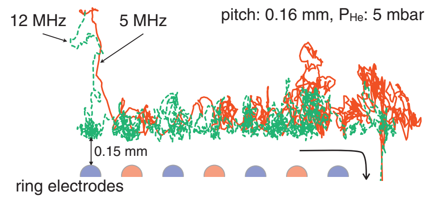

Fig. 2. Comparison of ion motions for f_{RF} = 5 MHz and 12 MHz.

Since the resonance RF frequency is, however, limited by the impedance of the system, such higher frequency is difficult to obtain; however, increasing the electrode pitch should yield a similar effect. In simulation, doubling the electrode pitch and the exit hole diameter yielded near unity extraction efficiency with 2 mbar He for f_{RF} = 5 MHz (see Fig. 3). Taking into account the transport and trapping efficiencies of a multipole ion guide and a flat trap[3)] after the GC, the overall efficiency of the GCCB is expected to be >50%. Such a larger-pitch RF-carpet is being manufactured and will be tested soon. An offline test using 30 keV ion beam counpled to a multi-pole ion guide and the flat trap[3)] will be performed in early FY2014.

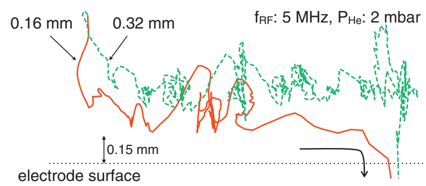

Fig. 3. Comparison of ion motions in 2 mbar He using 0.16 mm and 0.32 mm pitch.

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