Current status of the gas cell ion beam cooler-buncher at SLOWRI

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Conversion of a continuous ion beam to a pulsed ion beam will be an essential process for various precision experiments at the SLOWRI facility[1]. Continuous ion beams from SLOWRI gas cells can be stopped and provided as low-emittance pulsed ion beams with a gas cell ion beam cooler-buncher (GCCB)[2]. The GCCB consists of a gas cell with an RF carpet (RFC), an RF quadrupole ion guide, and a flat trap[3]. Ion beams of energy as high as 30 keV will be injected into a low-pressure He gas cell, and then decelerated and thermalized solely by gas collisions. The ions will then be efficiently transported by the RFC and the RFQ ion guide to the flat trap, and then bunched and cooled.

In this process, there was a concern regarding the performance of the RF carpet at such unusually low pressure – as low as 2 mbar. Simulations indicated that a rough-pitch RFC could transport ions more efficiently than a fine-pitch RFC[4]. The transport and extraction efficiency was investigated experimentally using an RFC with a pitch of 0.32 mm and an exit hole with a diameter of 0.64 mm with K^+ ions. Here the pitch was twice as large as the fine-pitch RFC used in high pressure gas cells. The experimental parameters were optimized to achieve a high efficiency (described in Fig. 1), which is defined as the ratio of the ion current leaving the exit hole measured by a Faraday cup placed after the RFC to the ion current measured on the RFC electrodes when the RF and AF voltages are turned off.

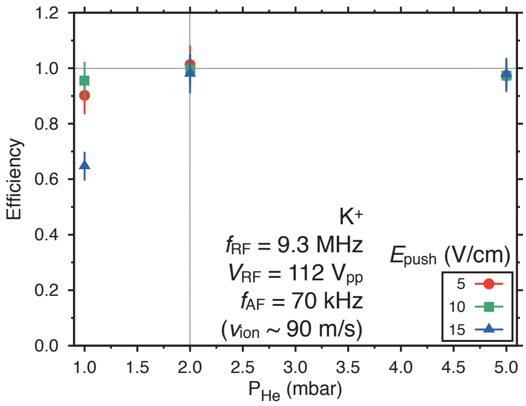

Fig. 1. Transport and extraction efficiency as a function of the He gas pressure for several $E_{\rm push}$ values.

As shown in Fig. 1, at He gas pressures higher than 2 mbar, efficiencies of ≈100% were obtained for a wide range of push electric field strengths. For an even lower gas pressure, such as 1 mbar, the efficiency slightly decreased; efficiencies of more than 60% were achieved even with the highest push electric field strengths. Compared to the efficiency of 22% seen with a fine-pitch RFC at 5 mbar, a rougher pitch can be expected to make the GCCB highly efficient.

Another concern was the injection of a 30 keV beam into the gas cell. The gas cell has no window to transport the low-energy ion beam, and thus all elements can be injected into the gas cell. However the incoming beam might be scattered due to the leak gas around the entrance. As a complementary idea, we are considering using nm-thick windows for the entrance. One option is a SiN membrane and the other is a Acetylcellulose membrane. The minimum thicknesses of SiN and Acetylcellulose membranes are 10 nm with 5×5 $\rm mm^2$ area and 10 nm with ∼10 mm diameter, respectively. The ranges for both windows were calculated by the SRIM code as shown in Fig. 2. In both cases, the ranges at 30 keV for the elements as heavy as Cs are larger than the minimum thicknesses, indicating that ions can penetrate the windows. Because the residual ion energy after the window will be much lower than the windowless case, the size of the gas cell can be much smaller, i.e., total length of <100 mm.

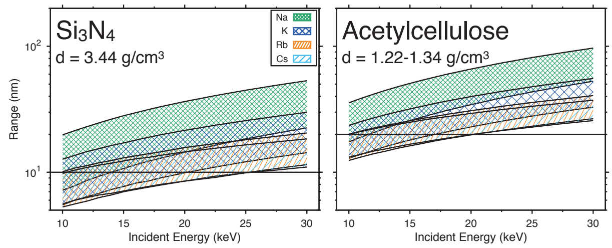

Fig. 2. Ranges as a function of the incident energy of an incoming ion beam for several elements with both SiN and Acetylcellulose membranes. The bands describe the range straggling in $\pm 1\sigma$ and the dashed lines indicate the minimum thicknesses for each material.

A performance test of these windows, i.e., a stress test for the pressure difference and the heat cycle between the room temperature and cryogenic temperature, will be performed soon. Using a 30 keV ion beam of stable nuclei, the overall efficiency of the GCCB with and without a window will be evaluated in FY2015.

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