Performance of ion surfing rf-carpet for high-energy RI beam gas catcher

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High-energy radioactive isotopes have been used in ion trap-based precision experiments after being stopped in a large gas cell. The stopped ions of these isotopes can be extracted from the large gas cell as a low-energy ion beam. To transport and extract these ions quickly and efficiently, electric fields are required to guide them. In this respect, an rf-carpet (RFC) method utilizing a dc potential gradient is a standard technique.[1)] However, such a method is restricted to longer half-life isotopes because of the transport time owing to the upper limit on the dc gradient that can be supported before electric discharges occur in the large gas cell. To study short half-life isotopes, an RFC featuring faster transport is required. Recently, a hybrid technique wherein the dc gradient is replaced by a traveling potential wave was proposed, called ion surfing.[2)]

Recently, we have demonstrated the transport and extraction of K^+ ions using a circular RFC in 20 mbar of He gas pressure.[3)] However, in a practical gas cell, the gas pressure is higher by one order of magnitude.

In this study, the transport and extraction of K^+ and Cs^+ ions with the ion surfing method were tested in high pressure He gas using a 100 mm cylinder electrode to create a push electric field E_{push} and a circular RFC of 80 mm diameter. In addition, we compared the effect of an RFC of a fine pitch with one of a rough pitch. The fine pitch RFC consists of 0.08 mm wide ring electrodes with 0.16 mm pitch and 0.32 mm diameter orifice, whereas the rough pitch RFC consists of 0.16 mm wide ring electrodes with 0.32 mm pitch and 0.64 mm diameter orifice.

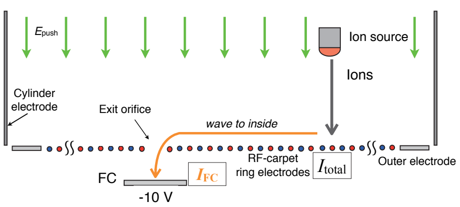

Fig. 1. Sketch of the transport and extraction efficiency measurement scheme. An rf frequency of 9.3 MHz and rf amplitude of 104 V_{pp} are typical operating conditions.

Figure 1 illustrates the scheme used to test the efficiency of this method. The study required measuring two ion currents: the current reaching the RFC electrodes (with rf off), I_{RFC} and the ion current reaching a Faraday Cup (FC), I_{FC}. The FC was biased at −10 V to pull ions out from the extraction orifice.

We define the combined transport and extraction efficiency as $I_{\mathrm{FC}}/I_{\mathrm{RFC}}$. Figure 2 shows the efficiency for K^+ and Cs^+ ions with the fine pitch RFC and the rough pitch RFC as functions of the He gas pressure P_{He}. Above a maximum pressure, the efficiency decreases with increasing pressure because the effective repelling force decreases because of stronger damping effect at high He gas pressures; the push electric field then exceeds the effective repelling field of the RFC causing ions to hit the RFC. The efficiency for Cs^+ is always higher than for K^+ because the effective repelling force scales with the mass-to-charge ratio. The fine pitch RFC is more efficient than the rough pitch RFC at higher He gas pressures. This indicates that the effective repelling force is stronger for finer pitch at higher He gas pressures.

We obtained an ion collection efficiency up to nearly 100% within a wide range of He gas pressures. To allow operation at higher P_{He}, a larger effective repelling force is needed.

We applied the ion surfing RFC to a superheavy element gas cell. The results are presented elsewhere in this journal[4)].

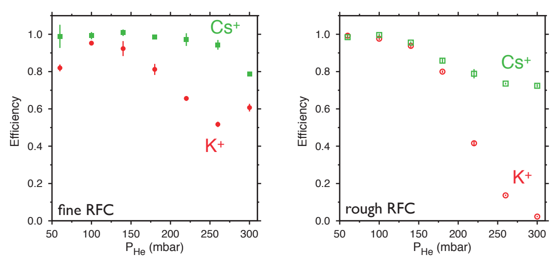

Fig. 2. The efficiency of K^+ and Cs^+ ions as a function of the He gas pressure P_{He} with fine RFC (left) and rough RFC (right).

References

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