Performance of an ion surfing rf-carpet in high gas pressure for application in a high energy RI beam gas catcher

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High-energy radioactive isotopes produced in-flight by fragmentation or fission are used in ion trap-based precision experiments after being stopped in a large gas cell. The stopped ions can be extracted from the large gas cell as a low-energy ion beam. In order to transport and extract 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 by the transport time to longer half-life isotopes owing to the upper limit on the dc gradient that can be supported before electric discharges occur in the large gas cell. For studying 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 as illustrated in Fig. 1(a), called "ion surfing"[2]. This technique has recently been experimentally verified with a linear RFC[3].

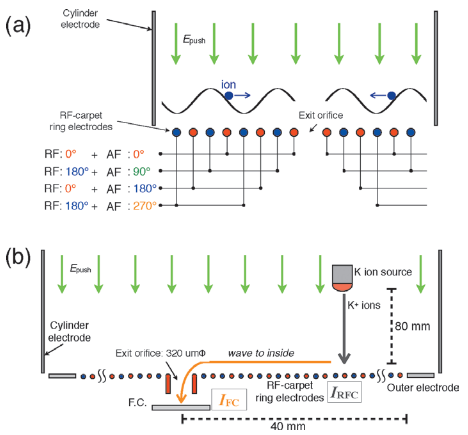

Fig. 1. (a) Concept of ion surfing with schematic of the applied rf and AF signal phases. (b) The efficiency measurement method. An rf frequency of 9.3 MHz and rf amplitude of 104 V_{pp} were used.

As in the standard method, rf signals are applied to the electrodes such that adjacent electrodes are 180° out of phase, creating an effective repelling force for the ions. In the "ion surfing" method, in order to keep the ion just above the RFC surface, the repelling force needs to be balanced by a push force, which is created by a push electric field E_{push}. The confined ions can be transported along the RFC surface by superimposing a weak audio-frequency (AF) signal such that adjacent electrodes are 90° out of phase, forming a traveling potential wave. Under optimal conditions, the ion speed approaches the wave's speed, which is proportional to the AF frequency f_{AF}[2)3)].

Recently, we have demonstrated the transport and extraction of K^+ ions using a circular RFC in 2 kPa of He gas pressure[4]. However, in the practical gas cell, the gas pressure is higher than this value.

In this study, the transport and extraction of K^+ ions were tested in high He gas pressure using a 160 mm cylinder electrode, which created a push electric field E_{push} and circular RFC with 0.32 mm diameter orifice. The RFC consists of 245 ring electrodes, each 0.08 mm with 0.16 mm pitch. Fig. 1 (b) shows the efficiency measurement method. The study required the measurement of two ion currents: the current reaching the RFC electrodes (with rf off) I_{RFC} and the ion current reaching the 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 $\varepsilon_{ext} = I_{FC}/I_{RFC}$.

Fig. 2 shows the ε_{ext} as functions of the gas pressure P_{He}. At E_{push} = 5 V/cm, more than 90% ε_{ext} was obtained. However, at E_{push} = 10 V/cm, ε_{ext} dropped in high pressure. For higher pressure, the effective repelling force becomes small. As a result, E_{push} exceeds the effective repeller field of the RFC and causes ions to hit the RFC electrodes. To allow operation at higher pressures and E_{push}, a larger effective repelling force is needed.

We intend to apply the ion surfing transport method to the SLOWRI gas cell with improved geometry.

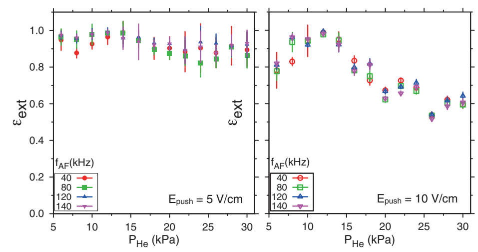

Fig. 2. ε_{ext} as a function of the gas pressure P_{He} for each AF frequency f_{AF} at a push electric field E_{push} of 5 V/cm (left) and 10 V/cm (right).

References
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