The 3rd report on offline test for RF carpet transportation in RF ion guide gas cell at the SLOWRI facility

A. Takamine,[*1] S. Iimura,[*1] M. Rosenbusch,[*2] M. Wada,[*2] S. Chen,[*3] J. Liu,[*3] P. Schury,[*2] T. Sonoda,[*1] T. M. Kojima,[*1] I. Katayama,[*1] Y. X. Watanabe,[*2] H. Ueno,[*1] and H. Ishiyama[*1]

A gas catcher cell using a radio-frequency (RF) ion guide method[1)] is being developed to provide ultra-slow RI beams at the SLOWRI facility. We built a gutter-structure ion guide gas cell, which consists of two-stage RF carpets (RFCPs).[2)] We previously used strip electrodes with a pitch of 0.32 mm (electrode width of 0.16 mm and spacing of 0.16 mm) for the 1st RFCP. The transport efficiency was limited to ≈60% in 133 mbar of He gas and even lower in a higher pressure gas. We replaced the 1st RFCP with a finer pitch of 0.25 mm (electrode width of 0.1 mm and spacing of 0.15 mm) to improve the performance. However, finer-pitch RF electrodes have a larger capacitance, which would practically limit the RF resonance frequency for the RFCP. Therefore, we conducted an offline test to investigate the RF transport performance on the new 1st RFCP at different RFs by changing the resonance coil of the resonant circuit.

The offline test was performed using surface-ionization ion sources of Cs and K which were placed at the inner wall of the gas cell. The setup is shown in a figure in Ref. 2). The ions produced from the ion sources were collected onto the 1st RFCP, transported on the 1st RFCP, and collected onto the 2nd RFCP. We measured the ion currents, I_1, on the 1st RFCP and those on the 2nd RFCP, I_2, by a pA meter using each of the RFCPs as a Faraday cup. The transported efficiency was defined as I_2/I_1. It should be noted that for the measurements of I_1, the DC potential distribution was slightly different from that in the case of I_2 because we could apply a DC gradient on the on the 1st RFCP only for the measurements of I_2.

Figure 1 shows the test results in 133 mbar of He gas for (a) Cs$^+$ ions and (b) K$^+$ ions at different RF frequencies. The drag DC field on the 1st RFCP was 4 V/cm, and the extraction DC field on 2nd RFCP was 20 V/cm. We achieved a higher transport efficiency compared with the previous RFCP,[2)] although we found that it requires a correction to the efficiencies by a factor of not more than ∼0.9, which results from the DC-field distribution difference mentioned above. The results indicate that an RF frequency of ∼6 MHz was sufficient for Cs$^+$ ($m/q = 133$), although it did not saturate the K$^+$ ($m/q = 39$) transport efficiency. According to the results, we will operate the RF ion guide gas cell at 7–8 MHz in the commissioning at the end of the ZeroDegree beam line in spring FY2020.

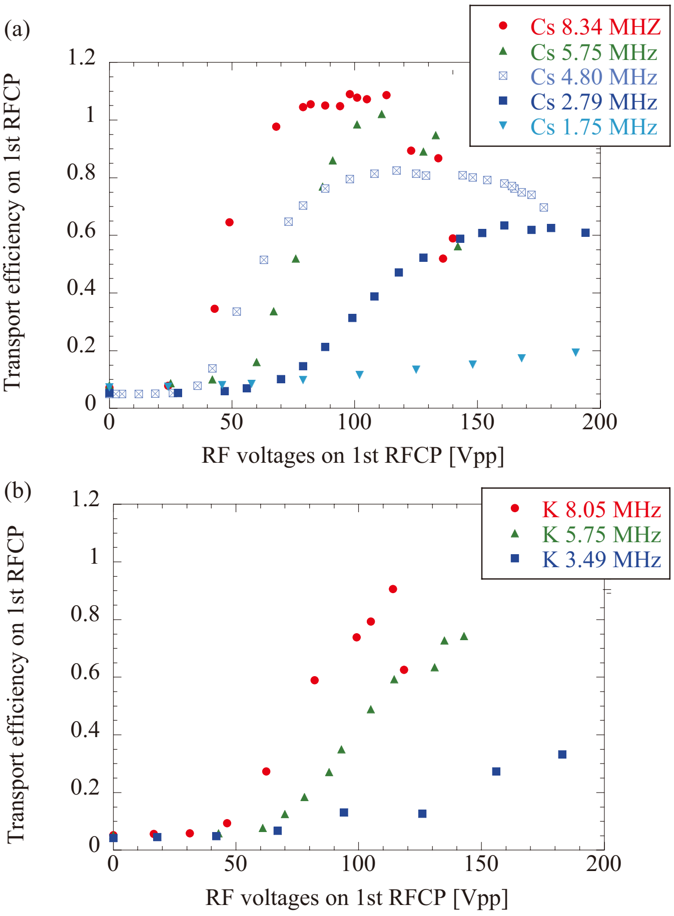

Fig. 1. RF voltage dependence of the RF transportation efficiencies for (a) Cs$^+$ and (b) K$^+$.

The plots clearly show that higher RF voltages are required to transport the lighter ions at a similar RF frequency, which can be straightforwardly interpreted from the expression of the RF repelling force.[1)] The plot (a) also shows that there exist RF voltages maximizing the transport efficiency for each RF frequency. We observed some discharge-like ion currents at a higher voltage than the efficiency peak points; consequently, the discharge seemingly disturbed the ion transport. However the transport efficiency would be different depending on the position in an RFCP stability diagram,[3)] defined by the RF and DC voltage values, which has a possibility to explain this result. An attempt at quantitative interpretation is underway.

References

1) M. Wada *et al.*, Nucl. Instrum. Methods Phys. Res. B **204**, 570 (2003).
2) A. Takamine *et al.*, RIKEN Accel. Prog. Rep. **52**, 139 (2019).
3) S. Schwarz, Int. J. Mass Spectrom. **299**, 71 (2011).

[*1] RIKEN Nishina Center
[*2] Wako Nuclear Science Center (WNSC), IPNS, KEK
[*3] Department of Physics, The University of Hong Kong