Simultaneous and co-located dual polarity ion confinement and mobility separation in traveling wave-based structures for lossless ion manipulations (SLIM)

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Overview

- Structures for lossless ion manipulations (SLIM) achieve high resolution ion mobility (IM) separations.
- Ion trajectory modeling shows simultaneous confinement and analysis of positive and negative ions.

Introduction

- Mass spectrometric analysis has benefited from the ability to study both positive and negative ions.
- Polarity switching can cause unstable performance due to issues with ion source stability, subtle changes in experimental and instrumental conditions, duty cycles, etc.
- SLIM technology [1-3] uses travelling waves (TW) to transport ions enabling simultaneous transport of both positive and negative ions. However, the presence of DC guard confining fields leads to loss of ions of the opposite polarity.
- Here, we present the initial design of the RF guard-SLIM to simultaneously confine, transport and separate co-located cations and anions.

Methods

- SIMION [4] was used to simulate confinement and transport of ions in SLIM. Ion-neutral collisions modelled using the Statistical Diffusion Simulation (SDS) collision model at 4 Torr of N_2.
- MATLAB software package and OpenFoam 4.0, (open source) were used to calculate ion potentials by solving Laplace equation.
- Conditions ; 32 cm SLIM device, 3.2mm board gap, 30 Vpp TW voltage, RF: 320 Vpp at 0.8 MHz. Transmission, 250 ions per polarity. Resolution, 1000 ions polarity.

Results

Comparing the Performance of the DC and RF Guards

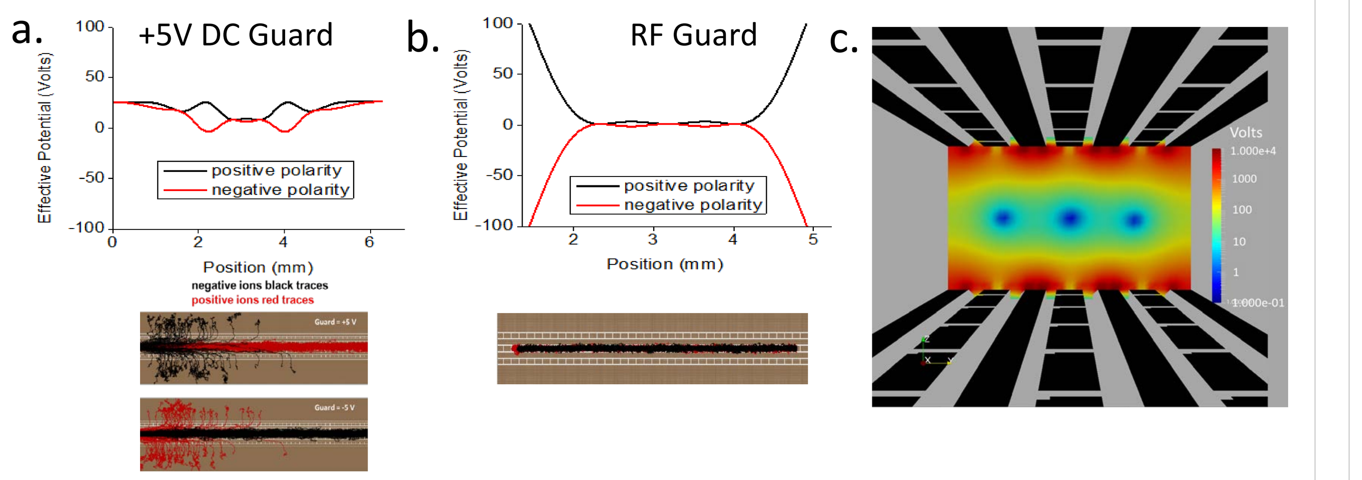

Figure 1: (a) Plot showing the potential experienced by ions between the DC Guard-SLIM boards and ion trajectories for positive ions (red traces) and negative ions (black traces), (b) plot showing the potential between the RF guard SLIM surfaces and ion trajectory showing lossless transmission of both positive and negative ions, (c) the iso-surface of the potentials between the SLIM surfaces with RF guards.

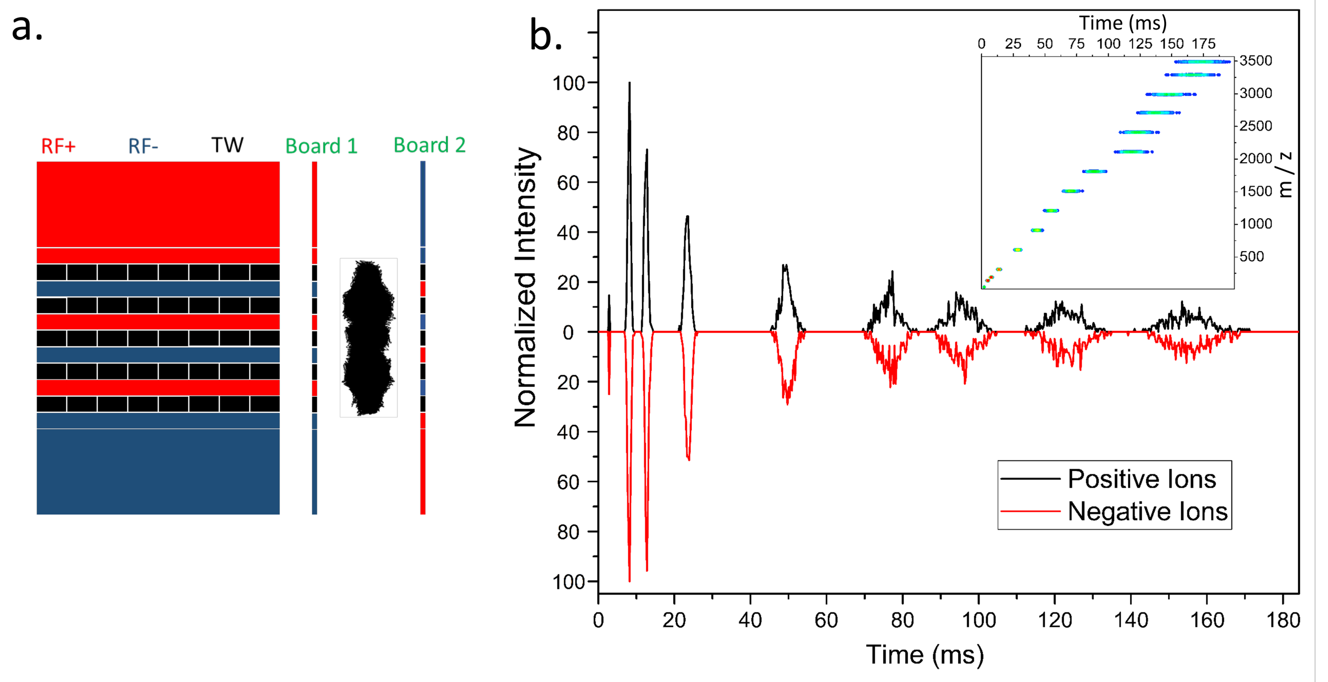

Figure 2: (a) RF guard SLIM configuration, optimized for dual ion polarity confinement and transport, (b) Simulated arrival time distributions (ATDs) of positive ions (black traces) and negative ions (red traces) through SLIM. Inset shows simulated nested IMS spectrum showing ATDs of both positive and negative ions as a function of *m/z*.

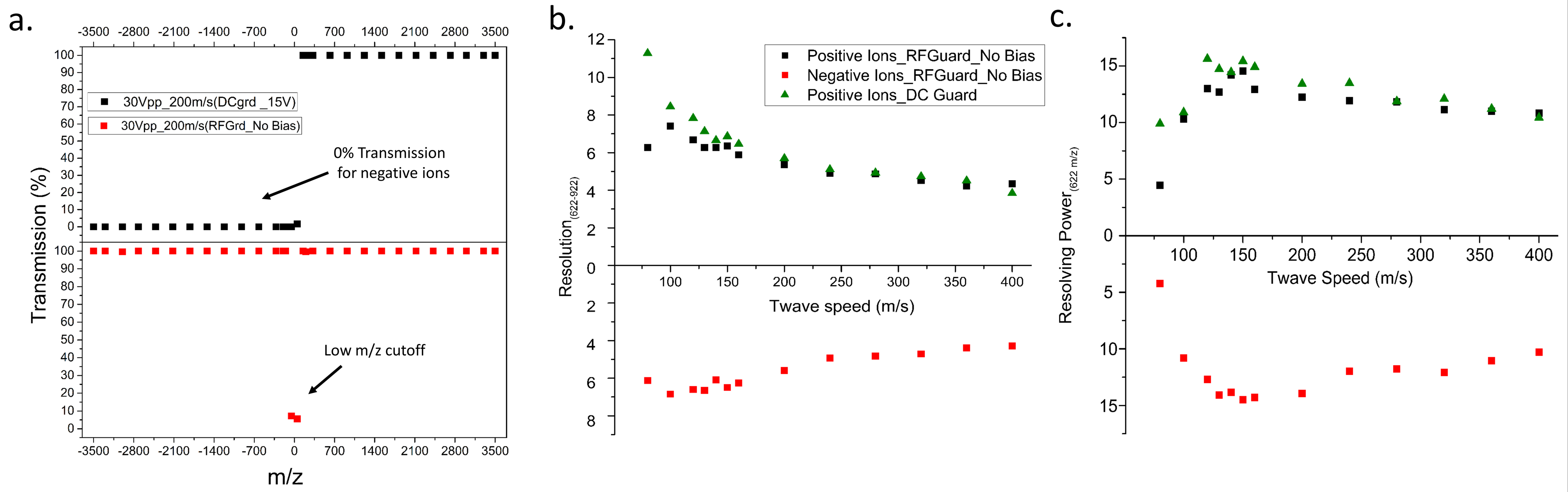

Figure 3: (a) Plot showing the transmission of positive and negative ions (m/z 50 – 3500) with the DC guard (Top) and RF Guard (Bottom) respectively, as a function of *m/z*, (b) mobility resolution for the m/z 622 and 922 peaks, (c) resolving power for m/z 622 for the 32cm SLIM. Similar transmission performance observed for 84 m/s and 400 m/s.

Minimizing Ion-Ion interaction in the Dual Polarity SLIM Device

Surfing and Separation Modes in Dual Polarity SLIM

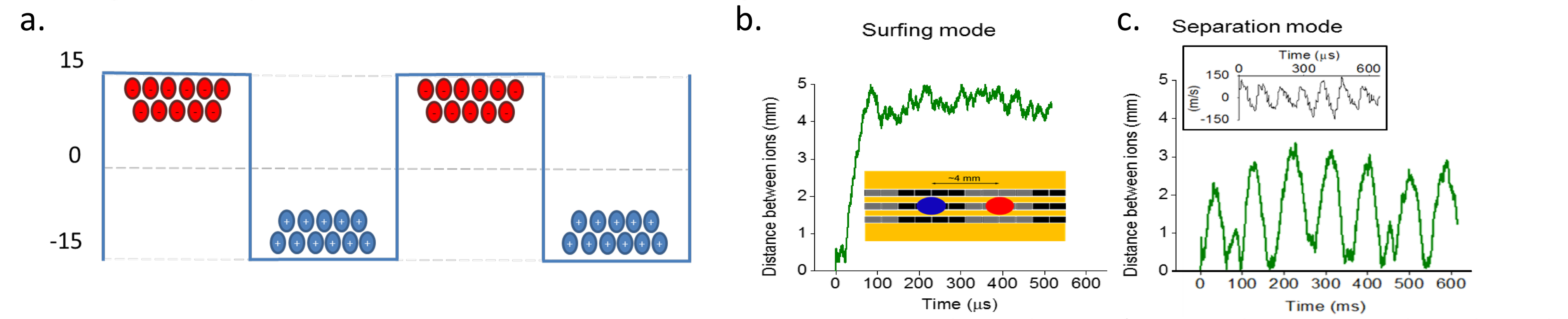

Figure 4: (a) ion polarities as transported in the wave profile of the travelling wave, (b) the evolution of distance between two hypothetical ions of same mass, mobility and opposite charge in the surfing mode where ions are confined to bins of TW, as shown in 4(a), (c) evolution of distance between polarities when they are in the separation mode. Inset shows the relative velocities between the ions (magnitude varying between 1 m/s and 150 m/s) over the course of their transport.

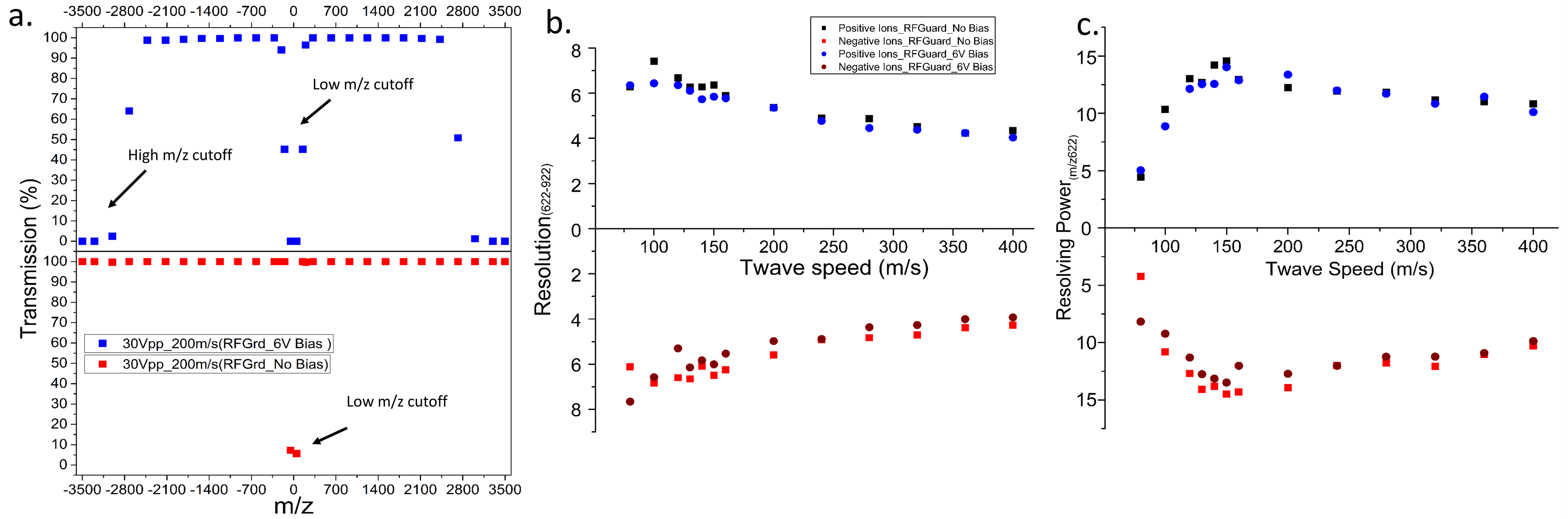

Figure 5: (a) plot showing the transmission efficiencies of positive and negative ions (m/z 50 – 3500) with the RF guard having a 6V board bias (Top) and with no board bias (Bottom) respectively, as a function of *m/z*, (b) resolution for the m/z 622 and 922 peaks, (c) resolving power for *m/z* 622. Similar transmission performance observed for 84 m/s and 400 m/s.

Effect of surface bias on spatial distribution of co-located ions

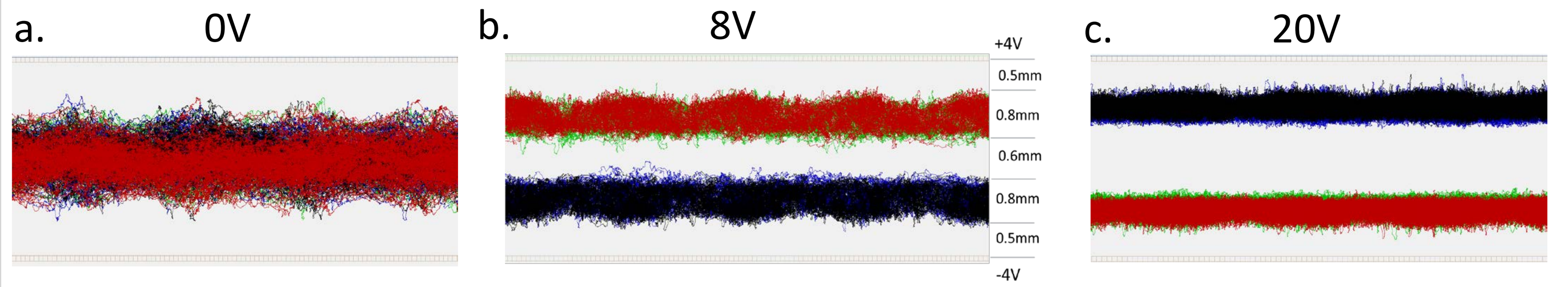

Figure 3: Simulation showing the transmission volume occupied by the two ion polarities as a function of applied bias voltage (a) 0 V, (b) +4 V and -4 V (c) +10 V and -10 V on the Top and Bottom boards, respectively.

Conclusions

- First demonstration of simultaneous positive and negative confinement and IM separation achieved by replacing the DC guards in the traditional SLIM devices with RF guards.
- Similar performance characteristics observed in the DC guard SLIM devices and RF guard SLIM.
- Ion/ion interactions can be controlled by biasing the two boards separately, to spatially separate the two ion polarities respectively.

Acknowledgements

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