Development of a Hybrid Structures for Lossless Ion Manipulations (SLIM) Ion Mobility/Time-of-Flight Mass Spectrometer

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Overview

- The performance and optimization of a Structures for Lossless Ion Manipulations (SLIM) printed circuit board-based ion mobility mass spectrometry system is presented.
- High sensitivity has been demonstrated, enabling lossless ion mobility and mass spectrometric measurements.
- Ions can be moved in linear paths or turned 90º in various SLIM segments.

Introduction

- Ion Mobility Spectrometry/Mass Spectrometry (IMS/MS) is a powerful separations technique that separates gas phase ions by shape/charge and mass/charge ratios.[1]
- High IMS resolving power coupled to high sensitivity IMS/MS measurements allows for increased peak capacity and improved separations of conformer and isomer ions, and also enabling enhanced signal-to-noise high throughput measurements of complex e.g. global pan-omics systems.
- IMS resolving power can be improved by several methods for a given ion pulse length and ion charge:
  1. Increasing pressure and electric field while optimizing E/N.
  2. Decreasing temperature.
  3. Increasing drift cell length.
- Practical considerations make increasing pressure and decreasing temperature while maintaining lossless transmission difficult.
- Clemmer et al. have demonstrated >1000 resolving power by using a "mobility cyclotron" and multiple injections by increasing the effective drift cell length to 182.86 m.[2]
- Development of linear and T segments with printed circuit board (PCB) technology allows for development of a PCB rectangular continuous drift geometry and other exotic but analytically useful ion manipulations with high sensitivity.

Methods

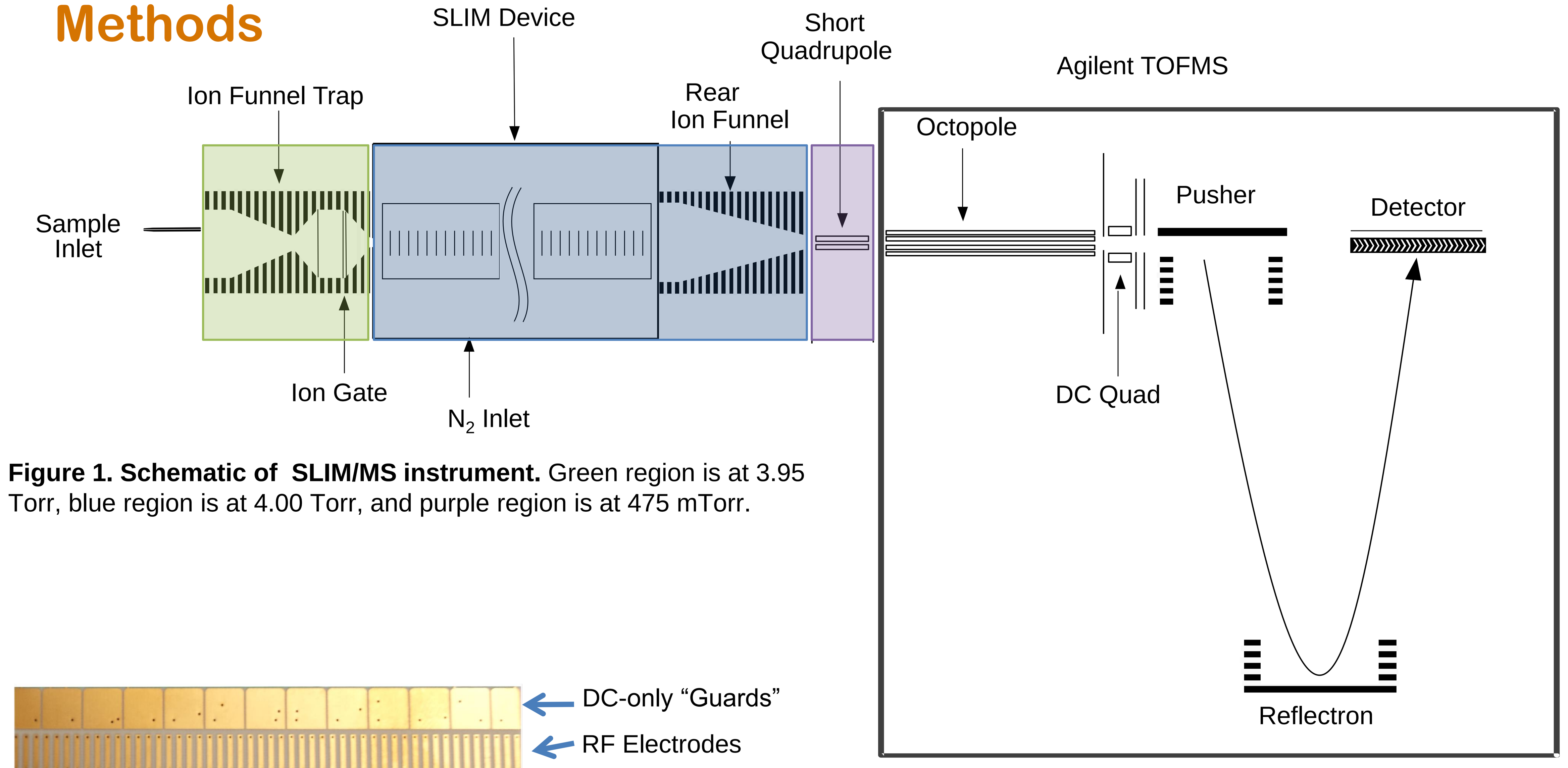

Figure 1. Schematic of SLIM/MS instrument. Green region is at 3.95 Torr, blue region is at 4.00 Torr, and purple region is at 475 mTorr.

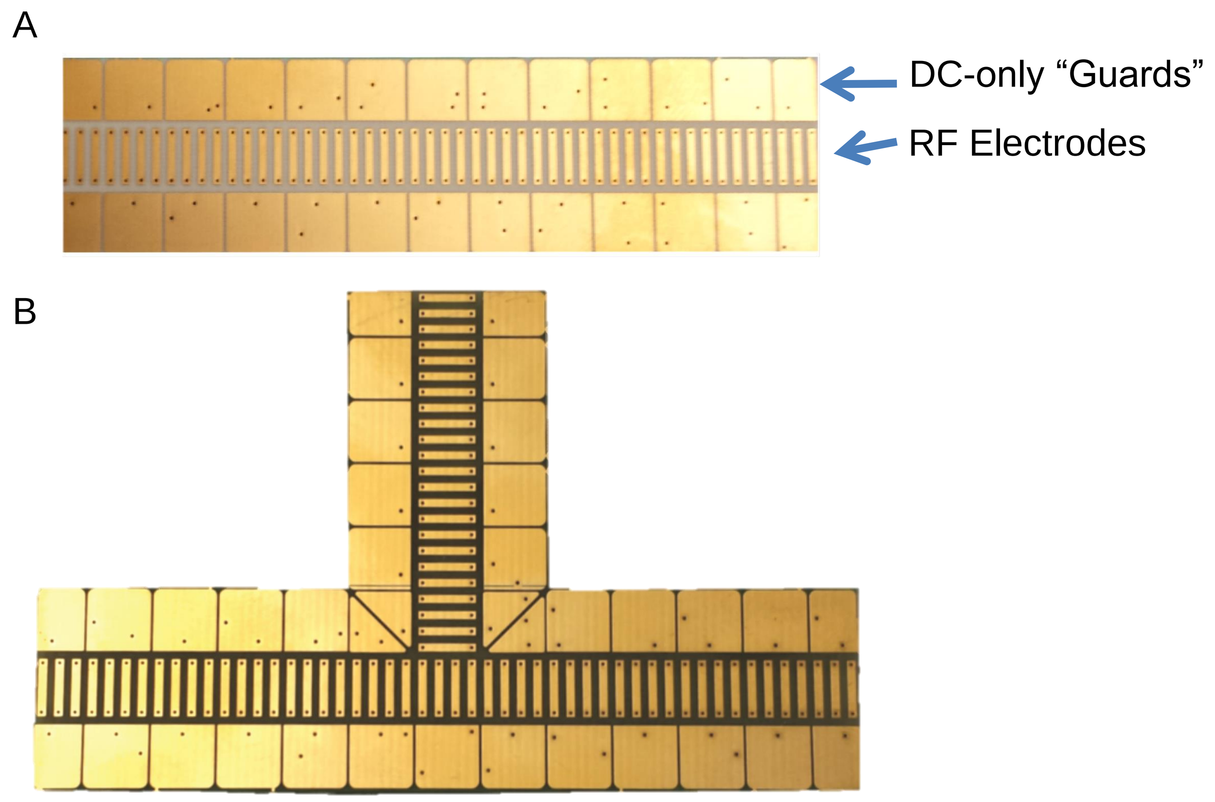

Figure 2. Pictures of SLIM PCB segments. Two 7.62 mm x 7.62 mm SLIM segments including a (A) linear segment and (B) T segment. Individual segments are connected to form complex geometries.

- SLIM segments utilize 180º out of phase RF on neighboring RF electrodes to provide pseudopotential wells for lossless ion transmission.
- SLIM geometries included six linear segments and three linear segments followed by a T segment followed by two additional linear segments.

Results

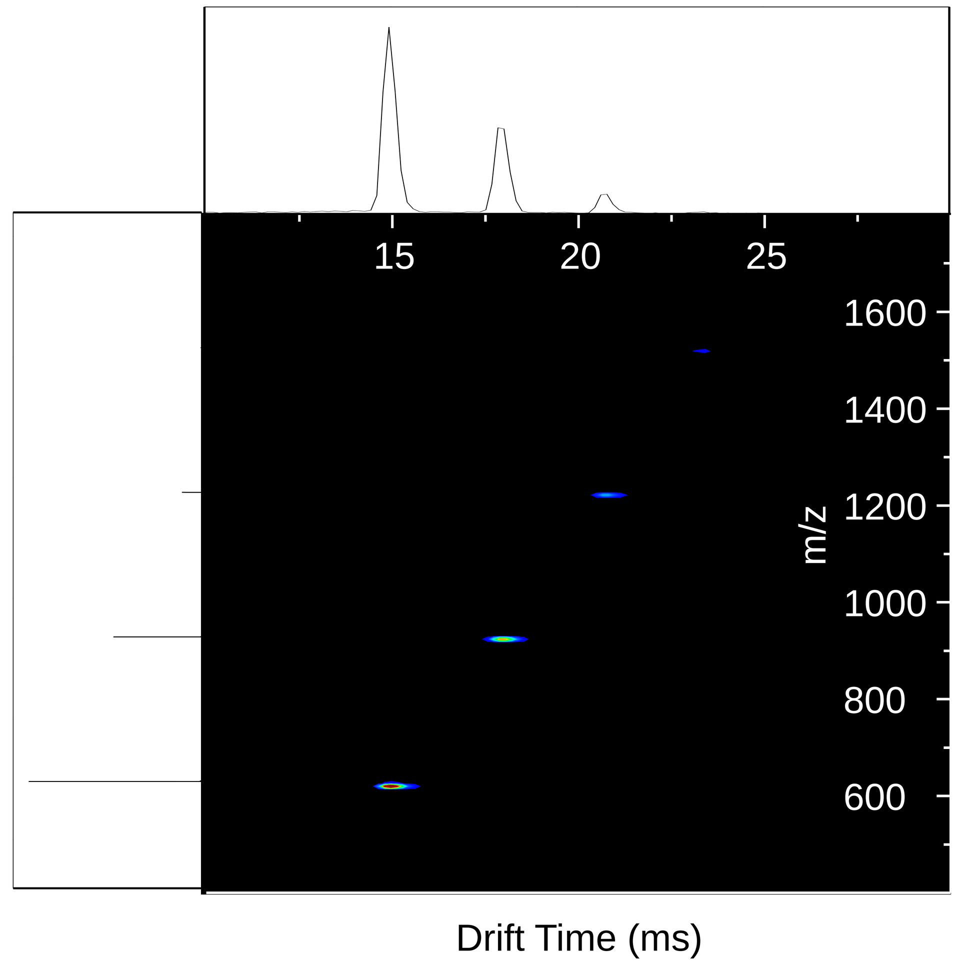

Figure 3. Example of a SLIM spectrum. Nested IMS/MS spectrum of Agilent Tune Mix, *m/z* 622-1522. with linear geometry. Each component is drift time resolved.

Optimization

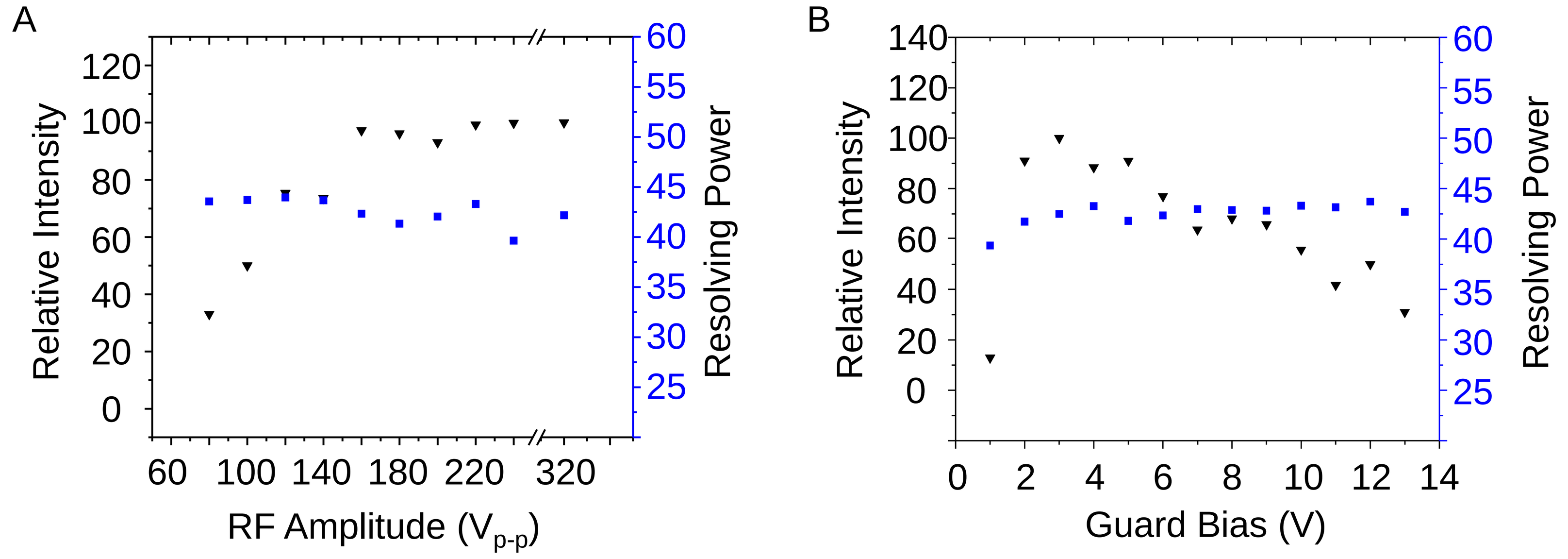

Figure 4. Optimization of the linear configuration. (A) Dependence of relative intensity and IMS resolving power on RF amplitude. E = 20 V/cm, guard bias 5 V, 750 kHz RF; (B) Dependence of relative intensity and IMS resolving power on guard bias. E = 20 V/cm, 220 V_{p-p} 750 kHz RF.

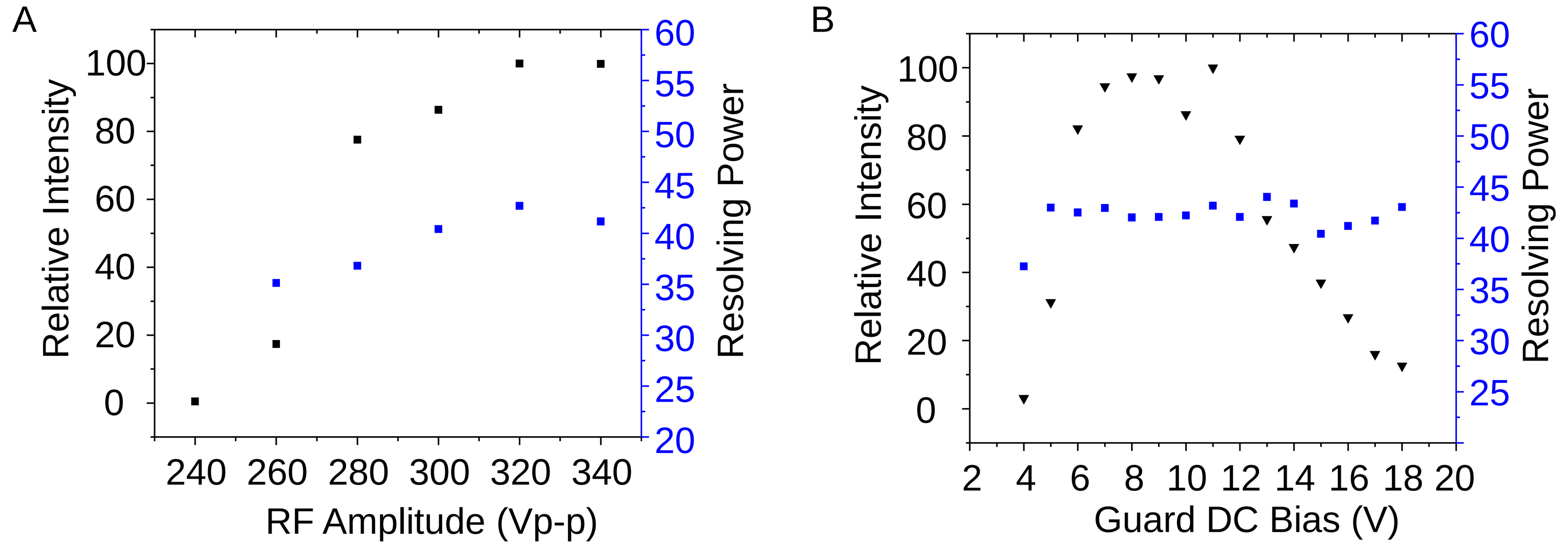

Figure 5. Optimization of the configuration including T segment. (A) Dependence of relative intensity and IMS resolving power on RF amplitude. E = 20 V/cm, guard bias 11 V, 685 kHz RF; (B) Dependence of relative intensity and IMS resolving power on guard bias. E = 20 V/cm, 320 V_{p-p} 685 kHz RF.

Comparison of Linear and Turn

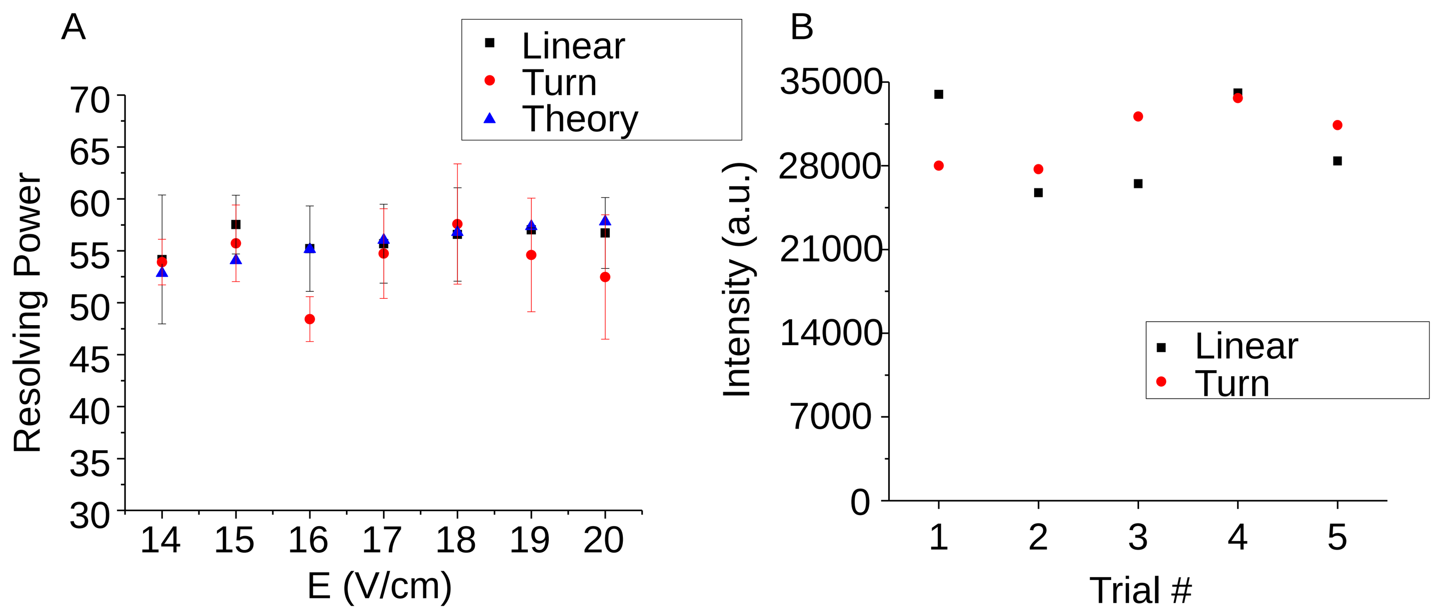

Figure 6. Comparison of linear and T performance. (A) Comparison of the dependence of IMS resolving power on electric field between linear and turn geometries and the calculated resolving power from Reference 1. Each point is the average of three replicates; (B) Comparison of absolute intensities at 20 V/cm between linear and turn geometries. Linear geometry with 5 V guard bias, 220 V_{p-p} 750 kHz RF. Turn geometry with 11 V guard bias, 320 V_{p-p} 685 kHz RF.

Conclusions

- Ion intensities and arrival time distributions have been measured using linear and 90º turn geometries.
- Intensity and IMS resolving power differences between linear and 90º turn geometries are not significant.
- The turn requires greater confining RF amplitude and guard biases for ions to turn with high sensitivity.
- IMS performance comparable to conventional drift tubes achieved in SLIM.

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2. Glaskin, R.S.; Ewing, M.A.; Clemmer, D.E.: Ion Trapping for Ion Mobility Spectrometry Measurements in a Cyclical Drift Tube, Anal. Chem. **85,** 7003-7008 (2013)

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