Development of an ion funnel based on printed circuit technology for ion transfer and manipulation purposes

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Introduction

State of knowledge:
Traditional ion funnels are used for efficient ion transfer between two regions of different gas pressure, and for ion focusing [2]. In these funnels the ring radius R is typically much larger than the axial distance W between the electrodes.

Challenge: a novel funnel

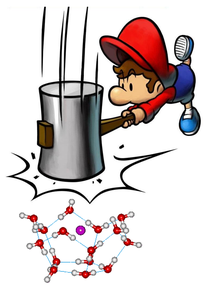
1. operating with non-vanishing axial radiofrequency fields,
2. working at elevated pressure (~ 1…10 mbar),
3. optionally allowing for time-modulated dc signals applied to the ring electrodes,
4. being able to modify the primary ion energy distribution, activate the ion population (analyte ion and/or LC solvent cluster) in a controlled way

Methods

ionization source	custom cAPCI [1] (capillary atmospheric pressure chemical ionization source) – corona discharge – background gas N_2 – water added through needle with the aid of a syringe pump
ion transfer	glass capillary – 0.6 mm int. diameter – 210 mm length – ion funnel – 30 electrodes – 5 mm int. radius – rf (875 kHz, 100Vpp) – dc gradient fields (typ. 10V to skimmer) – optional moving potential wells
MS	Hiden HPR60 (molecular beam mass spectrometer) equipped with – 2 skimmers, – 2nd pumping stage

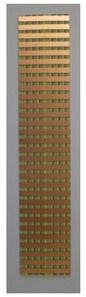
Ion funnel concept, design and experimental set-up

our dream: ion activation

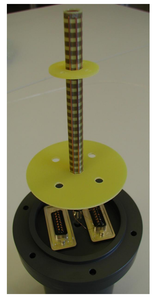


novel ion funnel:

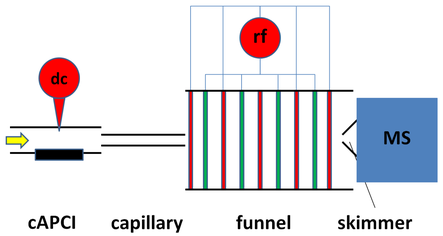
- 30 Cu electrodes of
- R = 5mm radius
- W = 5mm structure width
- rf fields in core region



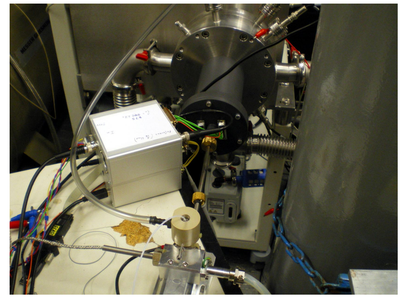
FR4 plate



ion funnel

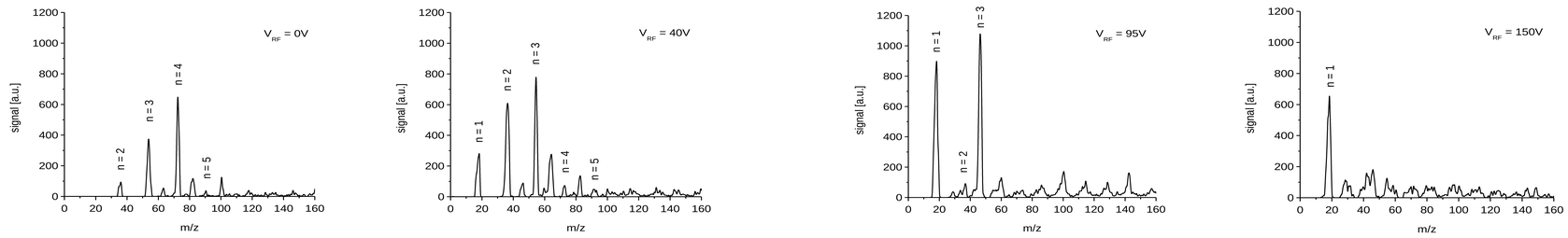


experimental set-up



ion source, funnel, and electronics

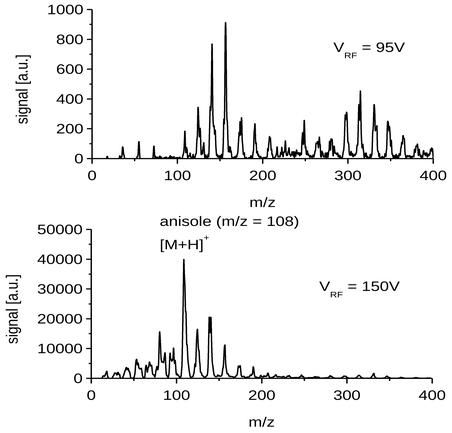
$[H+(H_2O)n]^+$ water cluster fragmentation induced by radiofrequency heating within the ion funnel



increasing rf amplitude

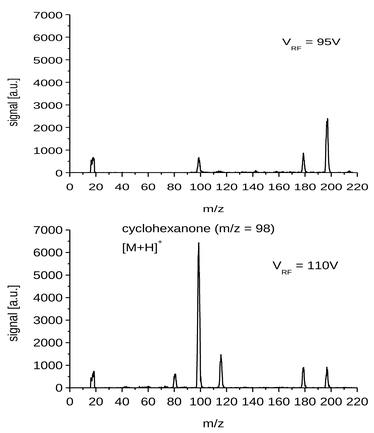
Enhanced analyte protonation and analyte ion transfer capability

Anisole protonation



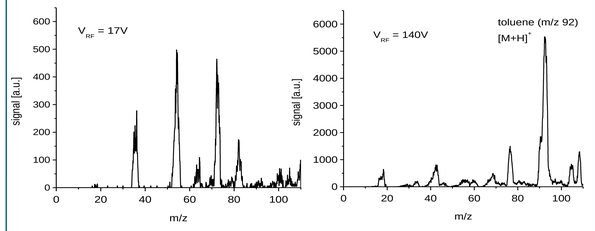
Cyclohexanone protonation

- low field: proton bound dimer formation
- increased field: activation of the ion population leading to monomer formation, increased ionization efficiency and ion transport

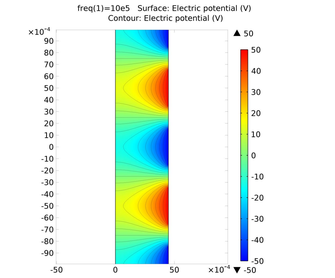


Toluene protonation

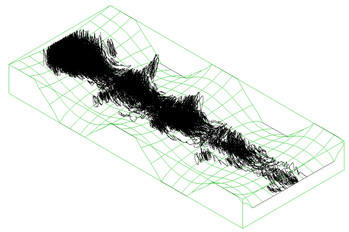
- high fragmentation/activation of water clusters
- efficient protonation



Simulation results



finite element field simulation



ion trajectories from SIMION® simulation study (including elastic collisions)

Conclusions

- Ion funnel efficiently transfers analyte ions as well as reagent ions over large distances e.g., >200 mm.
- With increasing rf amplitude the chemical equilibrium of the water cluster population is shifted to smaller clusters.
- Proton bound dimer ions as well as hydrated analyte ions are efficiently transferred into the corresponding monomers in a controlled manner.
- Efficient production of H_3O^+ leads to enhanced protonation of non-polar analytes e.g., toluene.

References

[1] S. Klee et. al., poster MP15 #274
[2] S. A. Shaffer et. al., *Rapid Communications in Mass Spectrometry* **11**, 1813 (1997)