An Efficient Pressure Reduction Interface Based on a Miniature Quadrupole Ion Guide

Albrecht Glasmachers; Alexander Laue; Albrecht Brockhaus (University of Wuppertal, Germany)
Michel Aliman (Carl Zeiss NTS GmbH, Oberkochen, Germany)

University of Wuppertal, Germany
Institute for Pure and Applied Mass Spectrometry

Introduction

Within a mass spectrometer ions have to pass through regions of different pressures e.g., high pressure regions (atmospheric down to 10^{-2} mbar) for ionization, cooling or fragmentation and low pressure regions (down to 10^{-10} mbar) for mass analysis. The interface between these regions should block the neutral components (e.g., buffer gas). For the ions a high transparency within the mass range of interest and a controlled transfer without velocity/mass dispersion is often required. For the conception of mass spectrometers such pressure interfaces should be available as building blocks which integrate the required mechanical and electrical parts in a compact and robust design.

Methods

Effective barriers for neutral particles can be provided by thin long capillaries with high aspect ratio, but these devices block ions, too. On the other hand well known solutions for a guided ion transfer like ion funnels or multipole ion guides are not a good barrier for neutral particles.

To fulfill both tasks we present a new sealed miniature quadrupole ion guide. The sealed inner part between the quadrupole rods works as a capillary with low transparency for neutrals, while the quadrupole fields in combination with travelling potential wells guide the ions with high efficiency.

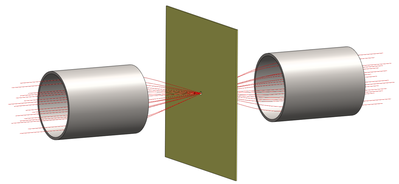
For small diameters the realization of such a system is a technological challenge for which we present new solutions based on planar technologies.

Principles of Pressure Reduction Interfaces

What we want to have

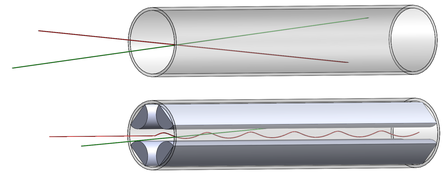
for neutrals for ions

Pressure interface with hole and lenses



- mass dependent
- energy dependent
- low acceptance angle

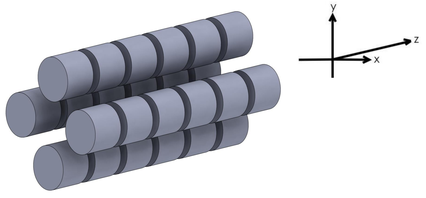
Pressure interface with capillary and ion guide



Effects of a capillary (top) and a capillary with ion guide (bottom) on ions and neutrals

Ion Transfer

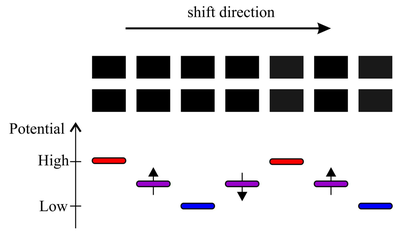
Capillary formed by quadrupole rods



segmented rods with

- RF quadrupole field in xy-plane
- Transport field in z direction

Shift pattern



- periodic pattern with 4 phases
- phase periods: adjustable 50 µs to 500 µs
- potential wells: adjustable 1V to 5V

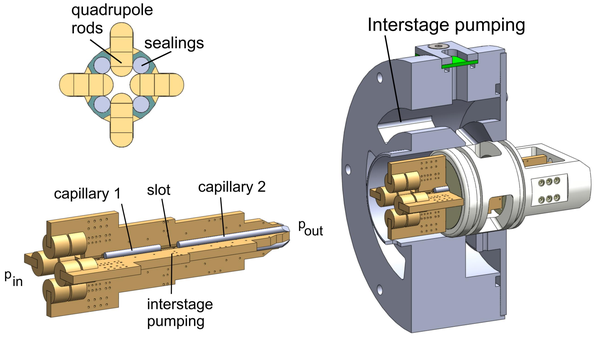
Shift performance

- top: shift signal
  left pulse: „smooth“ shift
  right pulse: „abrupt“ shift
- bottom: output charge

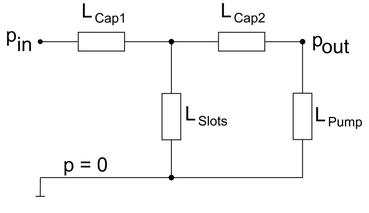
- Ions do not hit the capillary walls because of quadrupole fields
- Transfer along the capillary by traveling potential well
- Qudrupole radius: 0.8mm
- transfer efficiency: > 50%

Barrier for Neutrals

Experimental setup



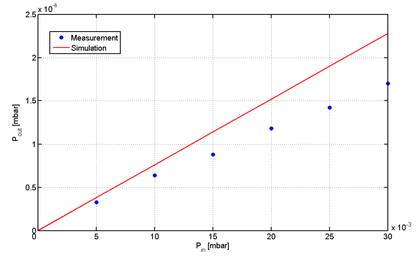
Model of pressure interface



$L_{CAP1} = 3.5 * 10^{-5}$ m³/s
$L_{CAP2} = 1.7 * 10^{-5}$ m³/s
$L_{slots} = 1.16 * 10^{-3}$ m³/s
$L_{pump} = 67 * 10^{-3}$ m³/s (N_2)
$L_{pump} = 58 * 10^{-3}$ m³/s (He)

$p_{out}/p_{in} = 7.6 * 10^{-5}$ for N_2
$p_{out}/p_{in} = 2.4 * 10^{-4}$ for He

Results



Conclusions

- Two capillaries with interstage pumping provide an effective barrier for neutrals
- Effective capillary radius of 0.8 mm
- Pressure reduction of
  7.6 * 10-5 for N2
  2.4 * 10-4 for He
- Ion transfer with high efficiency (> 50%) by quadrupole wave guide
- Realization by planar technologies

Final Design