BERGISCHE UNIVERSITÄT WUPPERTAL

Physical & Theoretical Chemistry

University of Wuppertal

Revving up the Ion Highway

A Novel Method for the Sampling of Native Ions from a Distant Location

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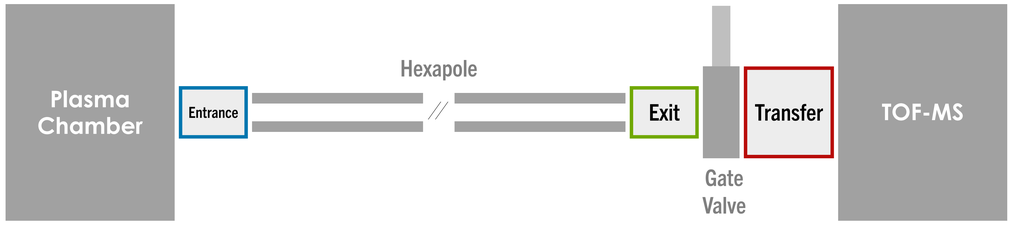
Introduction



An ion optical transfer system is necessary to efficiently sample "distant" ions. In this work, **a distance of 150 cm** between a plasma chamber and a time-of-flight mass spectrometer (TOF-MS) is linked by employing a segmented **hexapole** equipped with matching upstream apertures (**entrance**), downstream ion optics (**exit**), to facilitate ion transport through a gate valve into the TOF-MS (**transfer**). The latter became mandatory due to chamber regulations and to allow swift access to the TOF without interfering plasma chamber operation.

Methods

Simulations

The entire transfer stage was simulated with the SIMION program package[1]. Gas flow simulations were performed using the SPARTA program package[2].

[1] D. A. Dahl, Int. J. Mass Spectrom., 200, 3, 3–25 (2000)
[2] S. J. Plimpton *et. al*, Physics of Fluids, 31, 086101 (2019)

Experimental

Pressure and capacitance measurements for the final hexapole design were performed in-house using a stainless-steel mock-up stage with the same dimensions as used in the final design.
The gradient lens stack and the Einzel lens along with the electronics are manufactured in-house. The segmented hexapole is designed and manufactured by Fasmatech (Athens, Greece).

Entrance

An **Einzel lens** consisting of three electrodes focusing ions into the hexapole, simultaneously acting as gas flow restriction through the 1st Electrode with ⌀ 0.2 mm to keep the pressure < $1 \cdot 10^{-4}$ mbar with in the transfer.

Hexapole

A **hexapole** consisting of 5 segments, each 30 cm long, with decreasing DC bias voltages (-4 V → -40 V). Active ion guiding through almost the entire travel path ensures sufficient ion transport along the hexapole axis.

Exit

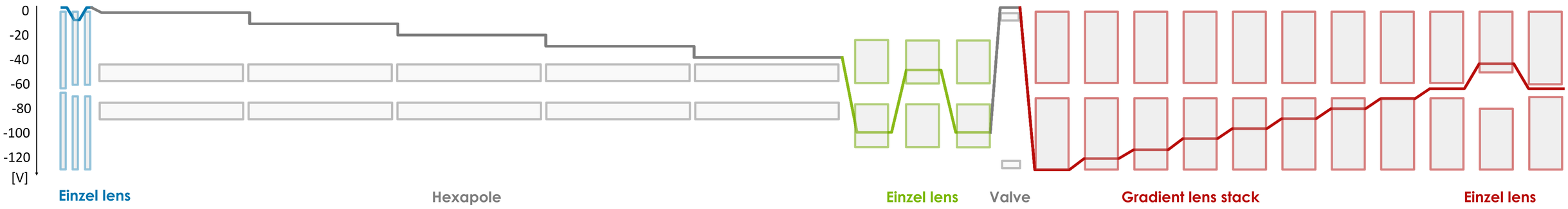
An **Einzel lens** consisting of three electrodes accelerates transferred ions from the hexapole and focuses them to efficiently traverse the unguided 30 mm long region within the gate valve.

Gate Valve

Allows swift separation of the two systems for maintenance or in case of unexpected behavior (e.g., pressure increase, run-off situations).

Transfer

A **gradient lens stack** with integrated **Einzel lens** collecting ions downstream of the gate valve. Mandatory reduction of the kinetic energy of the ions prior to mass analyzer entry.



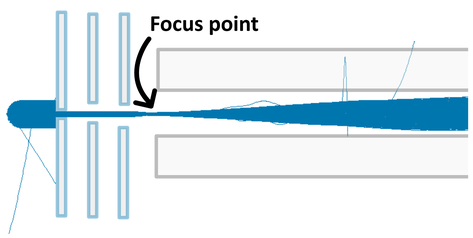
Ion Trajectories

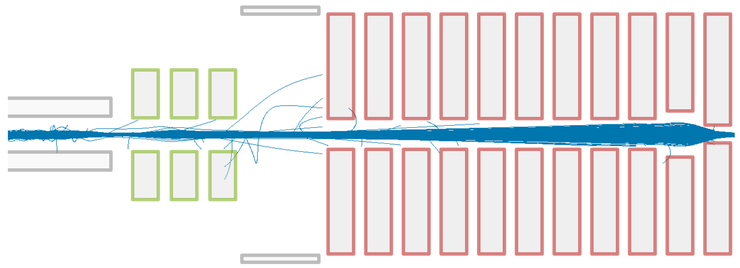
Entrance

- Anisotropically distributed ions are focused to a focus point ≈1 mm downstream of the last electrode of the Einzel lens
- Axial acceleration towards TOF-MS

Hexapole

- Guided multipole motion





Exit

- Ion focusing with Einzel lens
- Acceleration of ions, see below.
- Focus point *downstream* of gate valve: **33 eV → 60 eV resp. 85 eV in focus point**

Gate valve

- Due to high ion velocity and downstream focus almost lossless transport of ions through this region is achieved

Gradient Lens Stack

- Broadening of ion beam and simultaneous deceleration of ions in gradient lens stack **85 eV → 18 eV**
- Refocusing of ion beam in Einzel lens into TOF-MS source/analyzer region (not shown here)
- **18 eV → 25 eV**