Transport of Plasma generated Ions into a Fourier Transform Quadrupole Ion Trap using viscous gas flows

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Introduction

Quadrupole Ion Traps (QITs) are frequently used mass analyzer systems. Mass spectra are either obtained by sequential ejection of trapped ions with external ion detection or by ion excitation and subsequent Fourier Transformation (FT) of the recorded transient frequency response caused by the ion oscillation. Generally, ionization can take place within the volume of the QIT or ions can be generated externally and then transferred into the trap, e.g., via a capillary.
The gas flow through capillaries depends on the capillary temperature (i.e., gas viscosity) and the pressure difference between the entrance and exit port. In the present work the transport of externally generated ions by means of viscous flow into a FT-QIT is investigated.

Methods

A Zeiss (Oberkochen, Germany) FT-QIT test setup is used. It was designed to generate ions *within* the trap by electron ionization (EI).
Here, a Helium DC-plasma is employed for *external* generation of ions. The Helium gas flow is controlled with a flow controller (MKS Instruments, USA) to approx. 1.5 mL/min. The primary Helium plasma is generated in a plasma chamber, which is connected to a reaction chamber by a small orifice. A gas mixture of benzene, toluene, and xylene (BTX) in N_2 is used as sample at a pressure of approx. 2 mbar, which is fed into the reaction chamber. Here, Penning ionization of mostly N_2 by metastable helium atoms takes place. Subsequently, BTX molecules are ionized by N_2^+.

All plasma generated ions are transported via a CS-Fused-Silica GC column with 0.53 mm inner diameter and approx. 3 cm length into the QIT volume. Ion transmission is determined with an electrometer connected to the QIT ring electrode.

FT-QIT Demo Tool

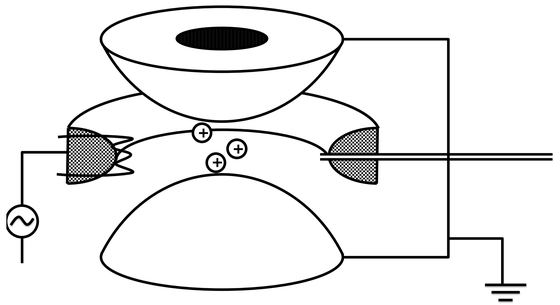
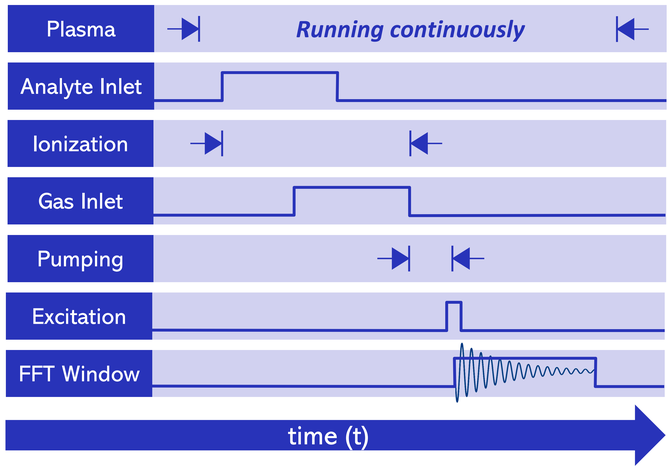


Fig. 1: Schematic of the used FT-QIT

The FT-QIT setup was originally designed to generate ions within the QIT volume via EI. The endcaps are tied to ground potential and incorporate the detector electrodes. An RF trapping voltage with a frequency of approx. 1 MHz is applied to the ring electrode. In this work, ions are guided into the QIT volume via a capillary penetrating through the ring electrode.

Typical Measurement Sequence



External Ionization

The challenging task of this work was to proof that ions can penetrate the oscillating RF potential barrier of the ring electrode. There is no evidence in the literature that thermal kinetic energy of the ions is sufficient to pass this barrier. To demonstrate that thermal ions can *principally* be guided through a capillary into the QIT via viscous gas flow, an electrometer was connected to the ring electrode.

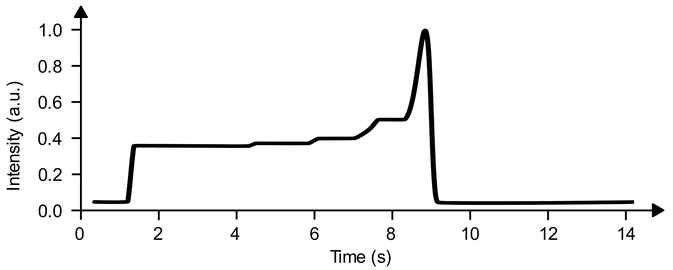


Fig. 2: Electrometer intensity in dependence of time. Trap pressure approx. 10^{-6} mbar, reaction chamber pressure approx. 200 mbar.

As the graph in Fig. 2 shows, ions are passing through the capillary and reach the QIT volume. We were also able to acquire mass spectra; however, the results were not reproducible and were time dependent as shown in Fig. 3.

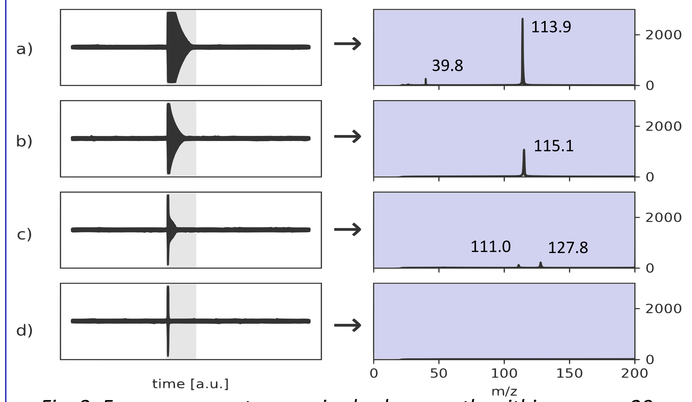


Fig. 3: Four mass spectra acquired subsequently within approx. 20 min. The plots show a decreasing signal intensity.

Conclusion

The results presented in Fig. 2 and 3 demonstrate that ion transport from an external ion source into the FT QIT volume with RF potential applied to the ring electrode is possible. The ions pass an RF potential barrier of a few hundreds volts. The well reproducible qualitative “step-like” shape of the ion signal (Fig. 2) is rationalized in terms of charging effects of the quartz capillary. This issue is well known from previous works in our lab.

The recorded mass spectra show several mass peaks depending on the experimental conditions. It is most likely that BTX ions undergo ion-molecule-reactions with neutral BTX molecules leading to the observed mass signals.

Outlook

Investigation of the phenomenon presented in Fig. 3. The main goal is a reproducible and temporally stable ion response. Furthermore it is planned to focus on the ion-molecule chemistry within the ion source reaction chamber, as well as in the QIT volume.

Literature

Brachthäuser, Y.: Development and characterization of a Fourier Transform based Quadrupole Ion Trap (FT-QIT) technique for process and residual gas analysis. Dissertation, Bergische Universität Wuppertal, Wuppertal (2017).

Brachthäuser, Y., Müller, D., Kersten, H., Brockmann, K., Benter, T., Derpmann, V., Laue, A., Reuter, R., Aliman, M.: Development and characterization of an FT-QIT with in situ electron ionization for residual and trace gas analysis. In: 64th ASMS Conference on Mass Spectrometry and Allied Topics, San Antonio, USA (2016).

Brachthäuser, Y., Müller, D., Kersten, H., Brockmann, K., Valerie, D., Aliman, M., Benter, T.: A FT 3D Ion Trap with in-trap electron ionization and pulsed gas inlet: transient pressure profile and space charge induced effects. In: 65th ASMS Conference on Mass Spectrometry and Allied Topics, Indianapolis, USA (2017).