# Precise timing for time-of-flight mass spectrometry

## The Innsbruck 22 pole ion trap experiment

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**The dynamic properties of cold molecular ions are an issue in several areas of fundamental research, so e.g. in astrophysics for a better understanding of generation of the observed appearance of matter in interstellar media. According theories mostly rely on simulations and assumptions. The benefit of the experimental analysis of generation and dynamics of cold molecular ions to verify these theories can not be overestimated.**

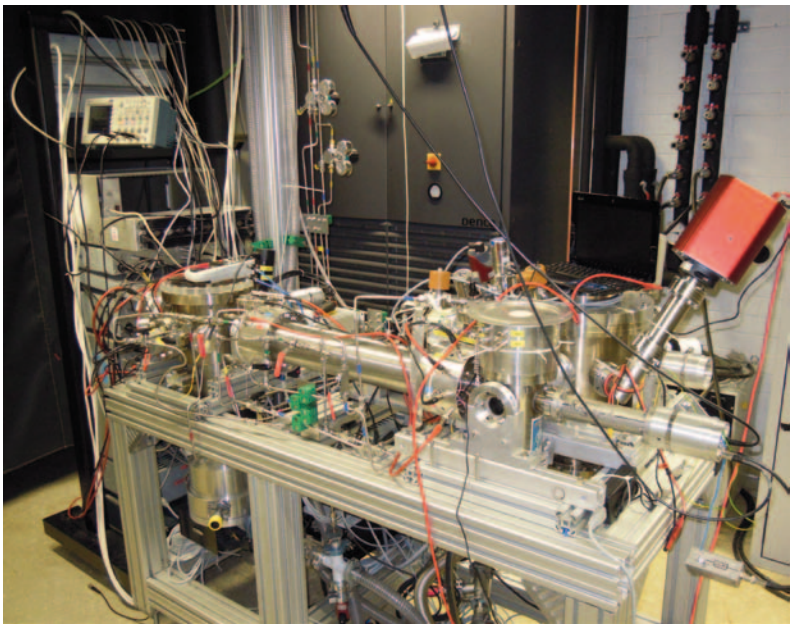

**Fig. 1** The experimental set-up

For the purpose of studying the dynamical properties of cold molecular ions we are using a radio frequency ion trap setup, combined with high resolution mass spectrometry. The range of applications of the setup covers gas phase chemical reactions, cluster experiments and spectroscopic studies of different ionic species [1].

The major components of the experimental setup are a pulsed ion source, a 22-pole radio-frequency ion trap, and a mass-selective ion detection system based on time-of-flight (TOF) **(Fig. 1+2)** [2]. Buffer gas and suitable reaction gases can be applied at well-defined densities in the trap. The trap temperature may be varied in the range from 8 K to 300 K as the trap housing is mounted on a helium cryostat.

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Typically multipole ion traps are combined with quadrupole ion guides and quadrupole mass filters in order to trap only selected masses and to reach a good mass resolution. In contrast, our trap setup is operated in a tandem TOF configuration, which means TOF mass spectrometry is used for loading selected ions into the trap, as well as for analyzing ions extracted from the trap. One of the advantages is, that a full mass spectrum (e.g. of ionic products of a chemical reaction) can be recorded at once, rendering measurements immune against slow drifts in ion source conditions.

Recently the setup has been upgraded by a multi-cycle reflectron. This device consists of electrostatic ion mirrors and its functionality can be compared to an optical resonator. Ions can be reflected multiple times between the mirrors, which enhances the TOF mass resolution to $m/\Delta m > 5000$.

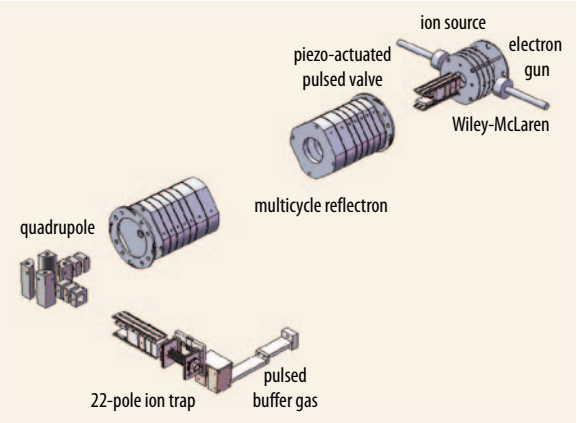


**Fig. 2** The experimental setup of the ion trap experiment, consisting of a pulsed ion source, a 22-pole radio frequency ion trap and a reflectron for high resolution mass analysis

## Ion source operation and mass selection

Two 8-channel pulse delay generators are used to run the experiment. The Quantum Composers 9528 **(Fig. 3)** are ideally suitable here as the units deliver 8 pulses with individual width and delay and can easily be synchronized to drive the here needed 12 independent timing events with an accuracy below a nanosecond. The ion source runs

 


**Fig. 3** The Pulse generator 9528 from Quantum Composers

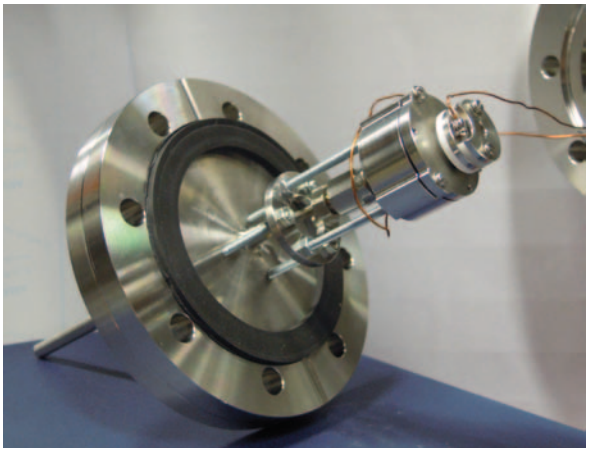

**Fig. 4** The piezo-actuated pulsed valve

on a repetition rate of 10-20 Hz in cw mode. The ion trapping and detection is operated by a second box. As the ion trapping occurs on a variable time scale a logic unit is used to synchronize the source with the ion trap.

Ions are produced in a pulsed-beam ion source. A homemade piezoelectric valve **(Fig. 4)** emits a supersonic gas jet of typically 120 µs (Timing Channel A1). The gas propagates through a set of ring electrodes that are switched on a potential of 500 V for ~10 µs (B1). This pulse leads to a plasma ignition in the gas jet. The ions of interest are produced in this plasma. For stability reasons, the plasma is seeded with a short counter propagating 1 keV electron beam from a home made electron gun (C1). The ions of the plasma travel downstream and enter the field plates of a Wiley-McLaren TOF mass spectrometer. At this moment these plates have to be switched to their operating voltages (~500 V) to accelerate the ions perpendicularly out of the gas jet (D1). This switching is performed using Behlke high voltage switches that feature a sharp voltage rise time of about 40 ns. The timing of this process is crucial for the focussing properties of the ion source. As the ions leave the source region, the ion beam is steered using electrostatic deflectors and lenses, before being bent 90° in quadrupole deflector system. The ions can then be mass selected by gating one of the deflection electrodes (E1) before they enter the rf ion trap (F1).

## Ion trapping and mass analysis

The trap consists of 22 metal rods to which an oscillating voltage of up to ±300 V can be applied. This confines the ions in radial direction, whereas the axial trapping is done by a set of ring electrodes (endcaps). In order to catch the ions out of the beam these electrodes have to be accurately switched to the trapping configuration (e.g. a repulsive potential) once the ions are inside the trap (A2). A short but intense pulse of buffer gas out of a piezo electric valve is applied to stop the ion beam as it enters the trap (C2). After a variable storage time (1 ms – hundreds of seconds) one of the endcaps is switched to an attractive potential to drag the ions out of the trapping region (B2). This acceleration again initializes a TOF mass separation.

To enhance the mass resolution, the ions can be sent to the multi-cycle reflectron. The ion package is trapped between the mirrors as they are switched to their reflective configuration (D2, E2). After a well defined number of round trips ($\sim n \cdot 10$ µs), one side of the reflectron is opened to release the ion package, which is then detected on a micro channel plate. The trap is now ready to accept another ion package (F2) and waits for the next ion shot out of the source. The experimental setup allows for the first time to verify in quality and quantity existing theories on the chemical dynamics of cold molecular gases **(Fig. 5)**.

### References

[1] *R. Wester*, J. Phys. B **42**, 154001 (2009)
[2] *J. Mikosch*, *U. Frühling*, *S. Trippel*, *R. Otto*, *P. Hlavenka*, *D. Schwalm*, *M. Weidemüller*, *R. Wester*, Phys. Rev. A **78**, 023402 (2008)

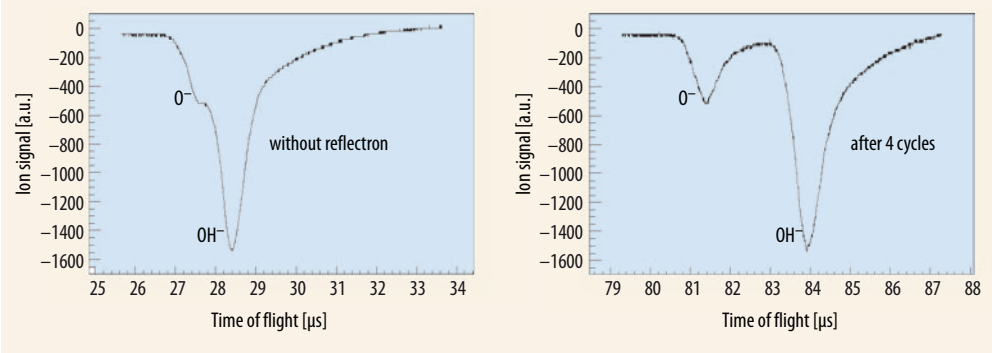


**Fig. 5** The laboratory setup with the "ns timing heartbeat"