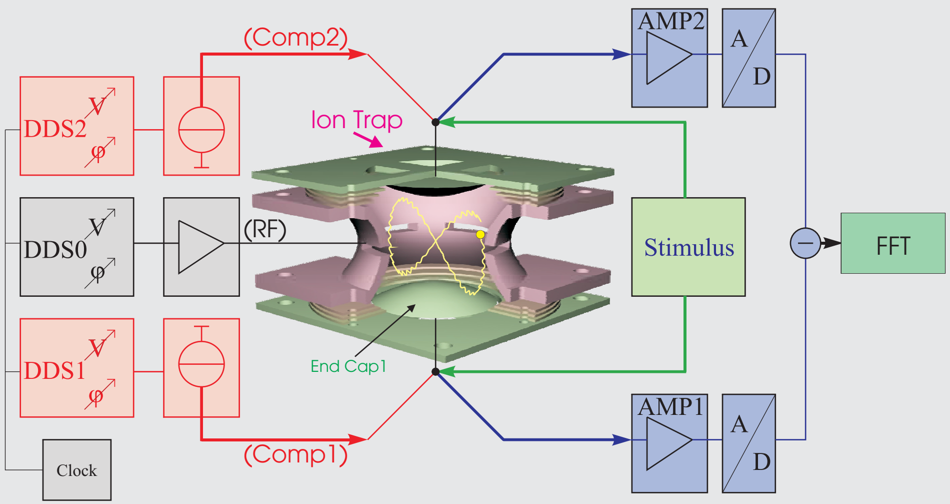
Analysis of the Linear Quadrupole Ion Trap for Fourier Transform Mass Spectrometry (FTMS)

Albrecht Glasmachers, Alexander Laue; University of Wuppertal, Germany

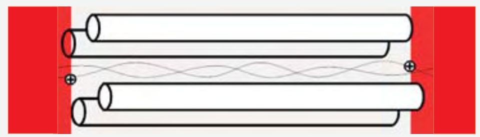
Design goals: Linear trap with improved ion storage capacity and reduced space charge density

Application Fields: Aerospace, Environmental Monitoring, Bio-Medical Analysis, etc.

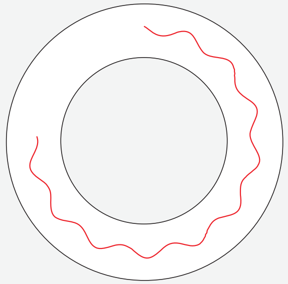
Block-Diagram of the Ion Trap Electronic



Possible versions of linear trap mass analyzers



linear trap with ion reflector



curved linear trap (toroid)

Introduction

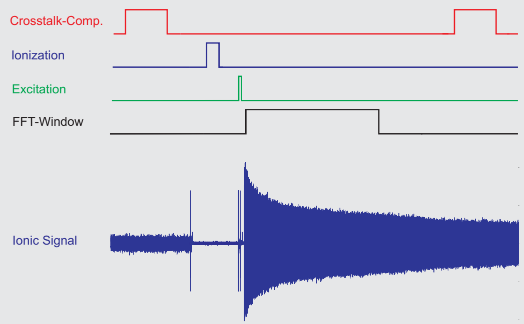
With the 3D Paul ion trap Fourier Transform mass spectroscopy was successfully performed due to a special cell design and a low noise crosstalk compensation technique. In this work we analyse whether linear quadrupole traps in form of the straight linear trap with reflectors and in form of the "curved linear trap (toroid)" can be operated in the same way. Possible benefits are higher ion storage volume, lower space charge density and therefore higher dynamic range.

Applied Methods

- Modified ion trap with split electrode geometry keeps the field accuracy high and reduces the crosstalk of the RF storage field.
- Active RF-HV crosstalk compensation based on Direct Digital Synthesis (DDS) techniques
- Numerical field and ion trajectory calculation by SIMION
- Experimental setup with electron beam ionization of gas molecules within the trap

Measuring setup

Test Conditions	
residual gas pressure:	1 x 10^{-8} mbar
testgas partial pressure	> 5 x 10^{-8} mbar
electron beam ionization:	
- current	2 μA for 10 ms
- energy	> 80 eV
RF-HV storage field:	
- frequency	1 MHz
- amplitude	50 ... 300 Vpp
excitation level (stimulus)	1 Vμs ... 25 Vμs

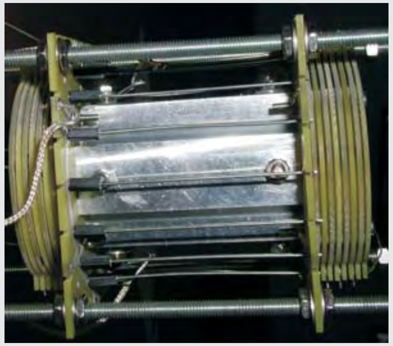


Measurement Timing Diagram

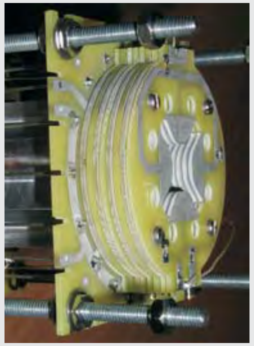
Albrecht Glasmachers, Alexander Laue; University of Wuppertal, Germany

(FTMS)

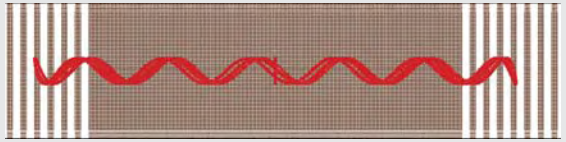
Linear trap with segmented reflectors



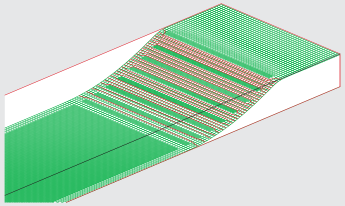
4 hyperbolic rods



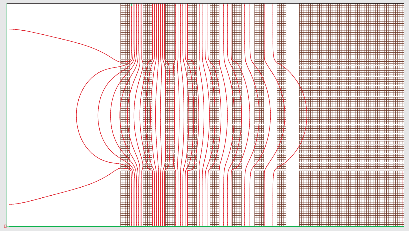
Reflector with 8 plates



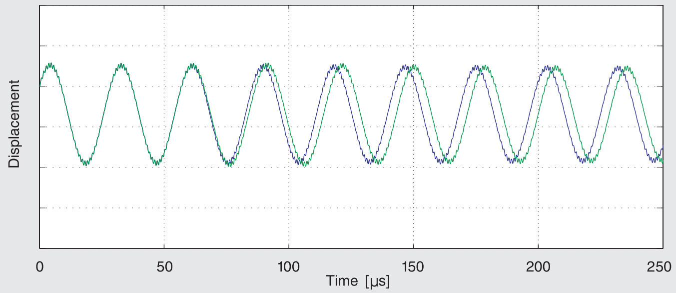
Ion motion with reflection



Quadratic DC potential rise

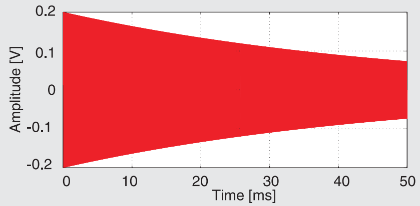


DC equipotential lines

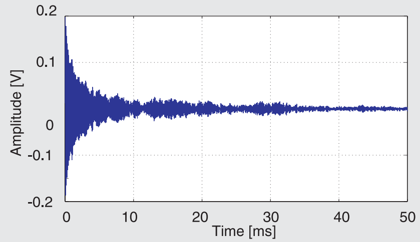


Phase error caused by reflection

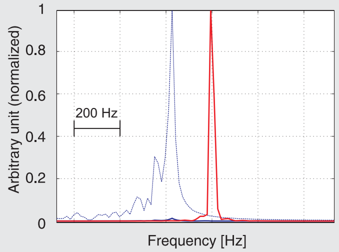
Effects of reflection phase error



Transient signal without phase error

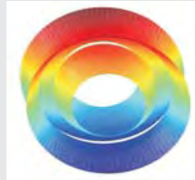


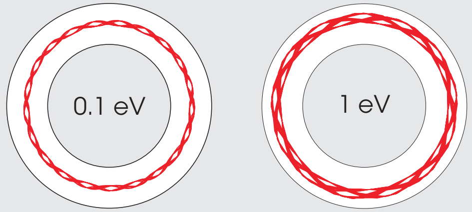
Transient signal with phase error



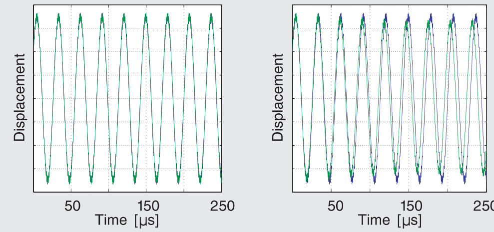
Comparison of the spectra

Curved trap (toroid)





Ion trajectories vs. circular energy



Time signals with continuous phase shift

Conclusions and outlook

For the linear trap an ion reflection at both ends of the trap is required to enable sufficient long storage time of the ions. For the reflectors superimposed dc fields or modified RF fields are required. With both solutions an effective storage of ions in a wide mass and energy range can be achieved. However, because of the transfer of energy between the different oscillation modes, a phase shift of the stimulated mass specific oscillation happens during the reflection process. This leads to very short transient signals with skewed spectral lines which can not be used for high resolution Fourier transform mass spectroscopy.

A "curved linear trap" (toroid) does not need any reflector because both ends of the "linear trap" are connected together. Therefore phase errors caused by reflectors can be completely avoided. On the other hand, the curved form produces field deviations from the ideal quadrupole system which results in frequency errors (continues phase errors) depending on the circulation speed of the ions. With corrections of the electrode shape which were published for the toroid trap these errors can be minimized. Then the toroid trap with optimized sensor geometry and active crosstalk compansation is an interesting alternative to the classical 3D Paul trap for Fourier transform mass spectrometry.