Design and Performance Characteristics of a Multiple Reflection TOF-MS for space applications

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The RTOF (Reflectron Time-Of-Flight) sensor is a TOF-mass spectrometer on board of the European Space Agency (ESA) Rosetta mission to comet 46P/Wirtanen. It is one of the three ROSINA (Rosetta Orbiter Spectrometer for Ion and Neutral Analysis) sensors [1], assigned to in situ measurements of the volatile composition in a close cometary environment. RTOF will have unprecedented capabilities for in-situ measurements of the composition of neutral as well as ionized components. The performance requirements for the RTOF sensor are: Mass range 1 amu/e up to 1000 amu/e with a mass resolution m/Δm of 500 at one percent peak height. The instrument should have a high sensitivity of 10^{-4} A/mbar. The power consumption has to be less than 30 watts, while the overall mass has to stay within the limit of 13.4 kg. The performance of RTOF is demonstrated by a measurement of the isotopic abundance of residual gas. A high mass resolution of almost 5000 (FWHM) over the entire mass range is achieved. The dynamic range covers more than six orders of magnitude. Figure 1 shows a residual gas spectrum with the natural isotopic abundance of water.

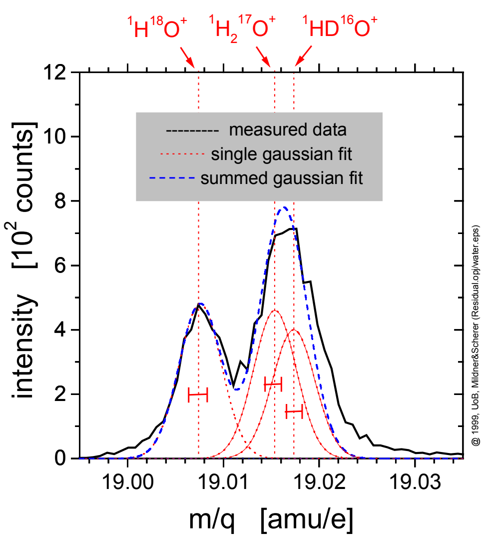

Fig. 1: Mass spectrum of residual gas for isotopic abundance of water

Isotopic ratio	Literature data	Experimental data
$\frac{^1H^{18}O^+}{^1H^{16}O^+}$	$2.0 \cdot 10^{-3}$	$2.1 \cdot 10^{-3}$
$\frac{^1HD^{16}O^+}{^1H_2{}^{16}O^+}$	$3.0 \cdot 10^{-4}$ } $= 6.7 \cdot 10^{-4}$	$6.0 \cdot 10^{-4}$
$\frac{^1H_2{}^{17}O^+}{^1H_2{}^{16}O^+}$	$3.7 \cdot 10^{-4}$	

Tab. 1: Measured isotopic abundance commensurate with the natural isotopic abundance

The solid line represents the experimental results at 19 amu/e. The accuracy in mass-per-charge determination is better than 50 ppm. Therefore, the different mass lines can be clearly identified. The mass resolution m/Δm is in the range of 4000. The peak at 19.017 amu/e consists of the sum of the water isotopes $^{1}H_2{}^{17}O^+$ and $^{1}H^{2}D^{16}O$, while the peak at 19.008 amu/e corresponds to the mass line of $^{1}H^{18}O^+$. The dashed lines are theoretical gaussian fits of the individual isotopic peaks. The summed theoretical curve for $^{1}H_2{}^{17}O^+$ and $^{1}H^{2}D^{16}O^+$ is fitting well with the experimental distribution. In the cometary environment one expects a $^{1}H_3{}^{16}O^+$ line with an intensity of a thousandth of $^{1}H_2{}^{16}O^+$, which does not form in our ion source. The main elements of the ion optics - ion sources, Hardmirror, as well as the Integrated Reflectron - were designed in a novel sophisticated ceramic-metal technique optimized for space application with respect to cleanliness and mass constraints. The Integrated Reflectron represents a novel two-stage grid free reflectron with an increased ratio of ion optical usable inner to outer diameter. A resistor helix is applied on the inner surface of the ceramic tube. The voltage drop along the helix generates the homogeneous electrostatic field for the retarding and the repelling region. The helix pitch angle is compensated by the voltage drop over the resistor helix and improves the homogeneity of the electric field at the Reflectron body periphery. The strengths of both electric fields are individually adjustable. The length of the resistor helix Reflectron is 128 mm, where 44 mm is used for the retarding and 84 mm for the repelling part. The Reflectron has an integrated electrostatic lens of 73 mm length. The total mass of the Integrated Reflectron is 723 grams and accepts an operation temperature range from -70°C up to +300°C. Simultaneously it is an integral part of the ultra-high vacuum enclosure of the RTOF sensor. The Hardmirror is an additional two-stage grid less reflecting ion optical element with integrated electrostatic lens [3]. It allows operating the RTOF sensor in a triple reflection mode by almost doubling the mass resolution. To protect the detector against excessive count rates the Hardmirror can be used in a pulsed mode to suppress selected mass. The inner diameter of the Hardmirror is 36 mm with a total length of 59 mm. The total mass of the Hardmirror is 122 grams. The orthogonal extraction ion source is assigned to measure cometary ions. For mass saving the source design consists of titanium electrodes (entrance region) and an integrated metal-ceramic body for the extraction, and the acceleration region, respectively. The number of extracted ions is investigated as a function of the tilting angle α and β according to a incoming external ion beam. Therefore, the ion source setup was adjustable in an external ion beam produced by a low energy accelerator with a beam energy of 8 ± 4 eV. The results show an acceptance angle of 3.5° FWHM in both directions.

[1] Prototype of a high sensitive Reflectron Time-of-Flight Mass Spectrometer for the ROSETTA comet rendezvous mission, S. Scherer et al., ASMS 98 (1998) in press.

[2] ROSINA Rosetta Orbiter Spectrometer for Ion and Neutral Analysis, Proposal submitted to ESA for the International Rosetta Mission, Balsiger H. et al. (1993).

[3] New Ion-Optical Element for Reflectron Time-of-Flight Mass Spectrometer, Hohl M. et al., Rev. Sci. Instr. (1999) in press.