A carbon cluster ion source for absolute mass calibration at TRIGA-TRAP

C. Smorra[1,2], K. Eberhardt[1], M. Eibach[5], J. Ketelaer[5], J. Ketter[5], K. Knuth[5], Sz. Nagy[3], W. Nörtershäuser[1,4], K. Blaum[2,3]

[1]Institut für Kernchemie, Johannes Gutenberg-Universität, D-55128 Mainz; [2]Physikalisches Institut, Ruprecht-Karls-Universität, D-69120 Heidelberg; [3]Max-Planck-Institut für Kernphysik, D-69117 Heidelberg; [4]GSI Helmholtzzentrum für Schwerionenforschung, D-64291 Darmstadt; [5]Institut für Physik, Johannes Gutenberg-Universität, D-55128 Mainz;

Introduction and motivation: Penning trap mass spectrometers are leading devices to determine one of the most fundamental property of a nucleus: its mass [1]. To this end, the cyclotron frequency $\nu_c = q\,B\,/\,(2\,\pi\,m)$ of a stored ion is measured, where q denotes the charge, m the mass of the ion, and B the magnetic field strength, which is obtained from a calibration with a reference ion of well-known mass. A new laser ablation ion source was developed for TRIGA-TRAP [2] to produce carbon cluster reference ions, facilitating absolute mass measurements, since carbon clusters are integer multiples of the atomic mass unit. Systematic studies of the accuracy of the mass spectrometer can be performed by carbon cluster cross-reference measurements [3], in which the well known frequency ratio of two different carbon cluster ions is determined. Furthermore, since a large variety of reference ions with well-known mass is provided, a reference ion species with a cyclotron frequency similar to the ion of interest can be selected in order to minimize systematic mass dependent uncertainties.

Experimental setup and results: Laser ablation is the common approach to generate carbon clusters for mass spectrometry purposes. At TRIGA-TRAP a pulse from a frequency-doubled Continuum Minilite Nd:YAG laser at a wavelength of λ = 532 nm, with a pulse width of τ = 5 ns, and a repetition rate below 1 Hz is guided into a vacuum chamber and focussed on a Sigradur® target with an energy density of 120 to 250 MW/cm^2. Thereby, carbon is removed from the target surface, and a plasma is formed, in which carbon clusters are created and ionized. Afterwards, they are extracted by an electrode of Pierce geometry, focussed by an Einzel lens and after a 90° deflection guided by conventional ion optics into the Penning traps. A detailed description of the ion source is found in [4, 5].

The laser ablation ion source produces an ion pulse composed of a mixture of ions of a broad mass range. In order to analyse the mass spectrum, the ions were stored in a Penning trap, where their initial energy spread is reduced by collisions with helium buffer gas. Subsequently, the cooled ions are ejected from the trap and detected with a channeltron-type electron multiplier detector. Ions of different masses are distinguished by their time of flight, as shown in figure 1. Clusters up to C_{24}^+ (mass 288 u) were successfully produced, thus the entire nuclide chart can be covered with reference ions. The desired cluster species is selected by applying a mass selective buffer-gas cooling technique in the preparation trap, so that a clean ion bunch is available for the actual measurement in the precision trap.

The same source has been used to produce a sufficient amount of gadolinium monoxide ions and americium monoxide ions for a first off-line mass measurement.

Conclusion and outlook: A laser ablation ion source for the production of carbon cluster ions was developed, tested and brought into operation at the TRIGA-TRAP facility. Reference ions for absolute mass calibration are thus available, and the stability of the source was demonstrated by 14 hours continuous operation without any maintenance. Mass measurements on lanthanoide and actinoide elements are currently in progress.

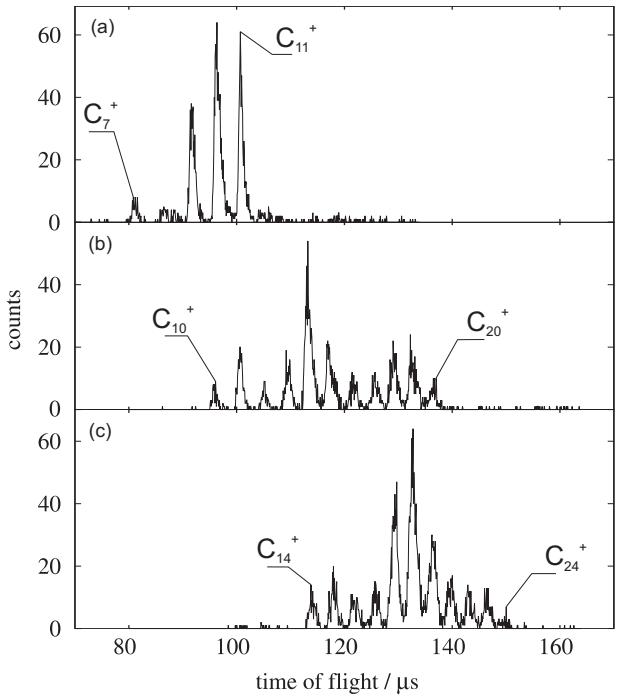

Figure 1. Time-of-flight spectra recorded after ejection of carbon clusters from the preparation Penning trap in order to identify the ion species. Different fractions of the mass spectrum produced by the ion source were sampled.

References

[1] Blaum K. Phys. Rep. 425 1-78, 2006.
[2] Ketelaer J. *et al.* Nucl. Instrum. Meth. A 594 162-177, 2008.
[3] Kellerbauer A. *et al.* Int. J. Mass Spectr. 229 107-115, 2003.
[4] Smorra C. Diploma thesis, Johannes Gutenberg-Universität Mainz, 2008.
[5] Smorra C. et al., submitted to J. Phys. B (2009)

Acknowledgements

Financial support is acknowledged from the Helmholtz Association for National Research Centers (HGF) under Contract VH-NG-037 and VH-NG-148 as well as by the Stiftung Rheinland-Pfalz für Innovation under Contract 854. Sz. Nagy acknowledges the support of the Alliance Program of the Helmholtz Association. We also thank P. Thörle-Pospiech and the technical staff of the TRIGA Mainz reactor. D. Beck and F. Herfurth from GSI/Darmstadt, and the CS development team are acknowledged for their support.