Controlled interaction of ions with high-intensity laser light

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We are currently preparing an experimental setup which features a Penning trap for preparation and control of suitable ion targets for irradiation with high-intensity laser light and study of subsequent reactions. Of particular interest is the detailed investigation of multiphoton-ionisation of confined particles by highly intense laser light. One important aspect is control over the confined particles' mass, charge, density, localization and optimized overlap with the laser light by Penning trap techniques like the use of trap electrodes as 'electrostatic tweezers' and by application of a 'rotating wall', respectively. Also, the non-destructive detection of reaction products is a central property. The Penning trap setup is designed in a portable fashion, such that it can be attached to existing laser systems easily [1].

The interaction of highly intense radiation with matter and the corresponding non-linear effects have been subject of lively research, both theoretical and experimental, especially in the infrared and visible photon energy regimes. Laser systems capable of producing high intensities also at photon energies in the extreme ultra-violet (EUV) and (soft) X-ray regime open access to novel effects like non-linear Compton effects or simultaneous elastic and inelastic photon scattering, and allow multiphoton-ionisation experiments in a new domain. However, experiments have so far not been able to prepare and investigate well-defined particle ensembles and to non-destructively analyse the reaction products with high accuracy, nor were they able to select or prepare products for further studies in a well-defined way.

The particles (atomic or molecular ions) are confined in the Penning trap following in-trap production or capture of externally produced ions. Confined ions can be cooled, compressed, positioned and selected with respect to their mass and charge prior to laser irradiation. The reaction products are analysed by non-destructive methods and hence remain confined for further studies. Such measurements are, for example, able to determine cross sections for multiphoton-ionisation in an energy- and intensity- regime so far not or not sufficiently examined. Additionally, the created electrons may be extracted from the trap and analysed externally. Hence, the reaction energetics may be reconstructed as completely as possible.

Figure 1 shows an example of a multiphoton ionization study using these techniques: ions are dynamically loaded into the trap from external sources or produced in the trap by electron impact or laser ionization (A). One or more specific ion species are selected (B), these ions are then cooled, compressed by a rotating wall and positioned. Thus, the ion target is well-prepared for interaction with the high-intensity laser. During and following the laser interaction, the charge state evolution of the confined ions is monitored

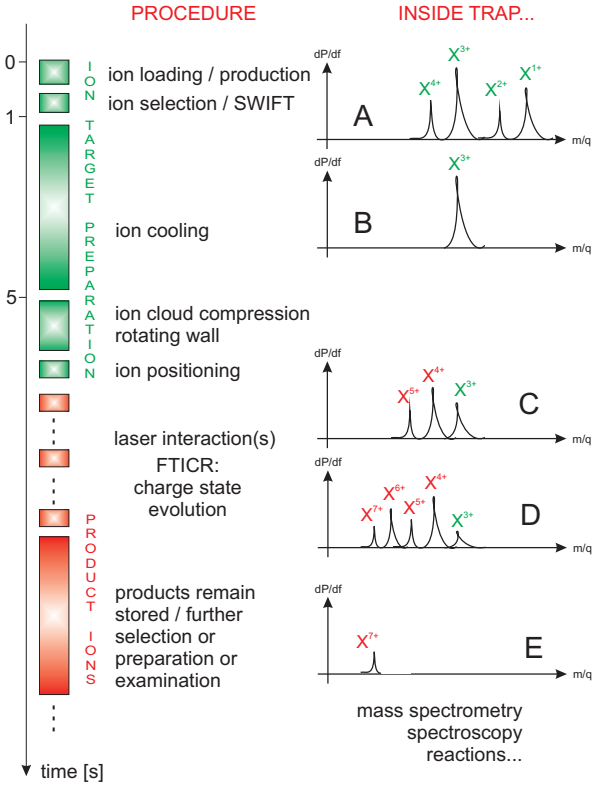

Figure 1: Example of an experimental timing scheme for a study of multiphoton ionization. The individual durations are meant to reflect the typical order of magnitude. The right hand side shows the corresponding mass-to-charge spectra of the trap content, for details see text.

by FT-ICR-spectrometry (C and D). Specific product ions can be selected and remain stored for further use (E).

Ion positioning along the experimental axis has some interesting features when a focused laser is considered since it allows to determine the position of the focus with high resolution. At the same time, especially for strongly focused lasers, ion positions can be chosen such that the reaction takes place at different field intensities and thus allows a study of the reaction as a function of laser field intensity without the need to change laser parameters.

References

[1] M. Vogel, W. Quint, Th. Stöhlker and G.G. Paulus, Nucl. Inst. Meth. B **285**, 65 (2012).