Photofragment characterization using electrostatic traps and storage rings

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Photofragmentation experiments on molecular ions have a wide range of applications from fundamental molecular physics over cluster- and biophysics to atmospheric and interstellar chemistry. They can be performed as direct laboratory studies of processes important in these fields, as a tool for studying absorption properties by action spectroscopy, or as a probe for the electronic and geometric structure of molecular systems.

The use of fast ion beams allows for mass selection of the parent ions as well as efficient detection and characterization of all emerging fragments. Additionally, employing storage devices such as traps or storage rings enables the preparation of internal molecular states, the investigation of delayed photo-processes, as well as an increase of the reaction rate by bunching and recycling of the target ions. On the photon side, techniques range from visible lasers for studying biomolecules to large-scale facilities like synchrotrons and free electron lasers addressing highly excited states with energetic photons.

An apparatus designed for crossed-beams photofragmentation experiments on keV molecular ions is the TIFF setup (Trapped Ion Fragmentation at an FEL) installed at the free electron laser FLASH in Hamburg, Germany. Using this machine, we have performed a number of studies on small to medium-sized molecular ions, e.g. HeH^+, $H^+(H_2O)_{n=1–4}$, using photon energies in the 35–90 eV range. The setup allows the identification of fragmentation channels through a biased interaction region, the measurement of breakup energies and geometries through 3D single-particle imaging and the preparation of ions in a rovibrationally relaxed state in an electrostatic ion beam trap. In parallel with the ongoing activities at FLASH, a number of newly developed instruments are currently under construction:

- An electrostatic saddle point electron spectrometer can be inserted at the TIFF interaction point or used as a standalone experiment in connection with other light sources. This device allows the detection and characterization of photoelectrons in coincidence with the atomic or molecular fragments produced. An integrated ion beam trap facilitates these experiments on stored ion beams.
- Furthermore, a new compact, modular electrostatic storage ring is under construction, which offers additional possibilities regarding insertable instruments, ion beam bunching and fragment mass spectroscopy by selective storage of specific breakup products.
- For cooling of ions beyond the possibilities of radiative relaxation, a radio frequency ion trap is being built which will trap molecular ions at rest and thus allow buffer gas cooling.

The talk will give an overview of the currently employed techniques, recent scientific results and ongoing developments.

References

[1] H.B. Pedersen *et al.*, Phys. Rev. A **82**, 023415 (2010)
[2] L. Lammich *et al.*, Phys. Rev. Lett. **105**, 253003 (2010)
[3] A. Wolf *et al.*, J. Phys. B: At. Mol. Opt. Phys. **43,** 194007 (2010)

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