Electron spectroscopy on an ion beam at FLASH

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Ion beams allow to investigate mass selected cluster species, such as $(H_2O)_2H^+$, and are essential for experiments on ions for which a neutral isonuclear system is inexistent, such as HeH^+. As ion beams have a density which is inevitably orders of magnitudes lower than the one of neutral gas jets, numerous experiments on photon induced processes are only viable at a free electron laser. Examples are photoelectron spectroscopy and momentum spectroscopy of nuclear fragments. We use the Trapped Ion Facility at FLASH (TIFF) [1] to investigate the dynamics of photofragmentation after ionization with the FLASH beam. In 2009, we have added an extension of TIFF towards the PG2 platform, which allows to probe the same ion beam in a second centre of interaction (Fig. 1). Here, we have placed a magnetic bottle electron spectrometer to record electron spectra from photoionization of the ion beam. Using ten shifts of FLASH beamtime in 2009, we have determined the photofragmentation patterns of the smallest protonated water clusters, $(H_2O)_{2,3}H^+$ (see separate report), and have demonstrated the feasibility of electron spectroscopy on a beam of Ne^+ ions.
In a magnetic bottle spectrometer, an anisotropic magnetic field is used to bend electrons around a set of magnetic field lines, which guide them towards the detector. This spectrometer achieves electron detection from a large solid angle (up to 4π sR) and with good to moderate energy resolution. Momentum information is lost though. The instrument used in 2009 is similar to an earlier design [2], but incorporates some modifications for the use at FLASH. Most importantly, the length of the drift tube has been shortened to 60 cm. The strong magnetic field at the point of interaction is produced by permanent magnets and further concentrated by a conical iron tip. For the set-up at FLASH, a holder was constructed which allows to remove the magnets from the interaction chamber during baking.

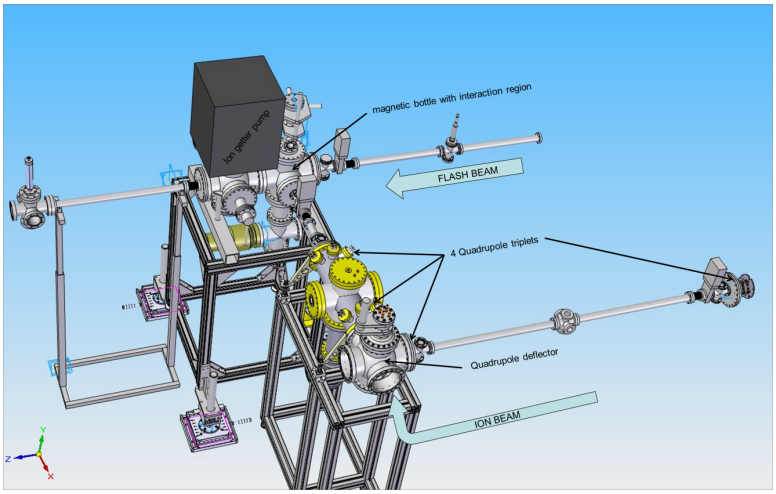

Figure 1: Sketch of the TIFF extension (TIFF Jr.), and the magnetic bottle type electron spectrometer as used at FLASH.

Figure 2 shows the electron spectrum recorded from a free Ne^+ ion beam in the magnetic bottle spectrometer. As the signal (at a chamber background pressure of 6×10^{-10} mbar) was dominated by outer valence ionization of the residual gas, a spectrum with ion beam switched off was

subtracted. In an acquisition time of 1200 s we have recorded roughly 1200 events from the ion beam. At kinetic energies between approx. 45 to 52 eV, the signal from ionization into the first three doubly ionized states of Ne is expected. Figure 2 shows significant structure in this energy region. The signal at higher kinetic energies was identified as FLASH ionization of residual water desorbed from apparatus parts by the ion beam.

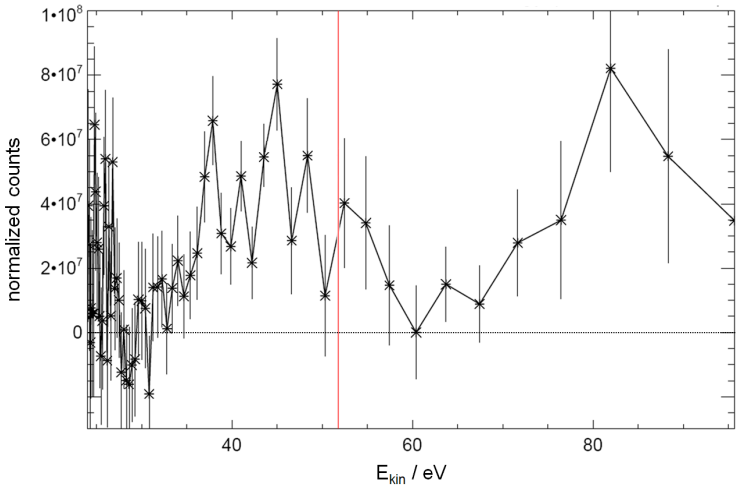

Figure 2: Electron spectra from a Ne^+ ion beam recorded with a magnetic bottle spectrometer at FLASH ($h\nu$ = 92 eV). The red line shows the expected kinetic energy for photoelectrons from ionization into the Ne^{2+} ground state.

Further improvements to this set-up were done after the FLASH shutdown. A new magnetic bottle spectrometer was constructed, which incorporates several improvements as compared to the earlier instrument. The region of high magnetic field around the interaction region has been reduced, in order to record less events from residual gas ionized along the path of the FEL beam. The coil producing the guiding field is now placed outside of the vacuum chamber. A new detector behind the interaction region was installed to allow monitoring of the ion beam as well as the measurement of neutral - electron coincidences to further reduce the background signal.
Tests of this instrument were carried out with a beam of OH^- anions, and an optical laser system (Continuum Surelight III-10, 532 nm and 266 nm with 10 mJ and 700 μJ pulse energy, resp.). Firsts results corroborate our initial count rate estimates for photoelectron spectra recorded with the FLASH beam. These are approximately a factor of 15 higher than the count rates represented in Fig. 2. We attribute this currently to an imperfect overlap between the ion and FEL beams.
Experiments aimed for are the experimental proof of non-local autoionization (Intermolecular Coulombic Decay, [3, 4]) after inner-valence ionization of anionic deprotonated water clusters, $(H_2O)_nOH^-$, and valence ionization of anionic water clusters containing a hydrated electron $(H_2O)_n^-$.

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