Electron-Ion Coincidence Experiments on Gas-Phase Atoms and Molecules using the CAMP Instrument

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The Max Planck Advanced Study Group (ASG) at the Center for Free Electron Laser Science (CFEL) at DESY is operating a multi-purpose experimental chamber (**C**FEL-**A**SG **M**ulti-**P**urpose instrument - CAMP) [1] especially designed for experiments at the Free Electron Lasers FLASH, LCLS and SCSS (and potentially XFEL in the future). A copy of this instrument (without the pnCCD detectors) has now been set up at the ASG lab at DESY for experiments and tests using a femtosecond Ti:Sa laser as well as synchrotron radiation from the DORIS storage ring. The chamber is equipped with various charged-particle spectrometers based on the reaction microscope [2] or a modified velocity map imaging technique [3]. Electrons and ions produced by the interaction of intense laser light or synchrotron radiation with atoms or molecules introduced into the vacuum through either an effusive or a supersonic atomic or molecular jet are detected on two 80mm Roentdek delay-line MCP detectors. The MCP and delay-line signals are recorded via an Acqiris digitizer and further processed by software that reconstructs the time of flight and hit position of each detected particle.

During our beamtime at beamline BW3 at DORIS in November 2010, two new spectrometers and a new sample delivery system for liquid samples (e.g. methanol, ethanol, methylselenol) were tested which were then used during two beamtimes at LCLS in January 2011. In addition, we performed electron-ion coincidence experiments on dibromobenzene molecules in order to determine the molecular-frame photoelectron angular distribution of the bromine 3p electrons (see e.g. [4] for further details regarding the determination of molecular-frame electron angular distribution of “fixed-in-space” molecules via electron-ion coincidences). This measurement complements an experiment performed at LCLS in May 2010, where the molecular-frame photoelectron angular distribution of the bromine 2p electrons was measured for laser-aligned molecules. It also prepares a time-resolved photoelectron diffraction experiment on laser-aligned molecules at FLASH scheduled for August 2011.

For the BW3 experiment, dibromobenzene molecules were introduced into the CAMP chamber through a doubly-skimmed supersonic jet operated with helium as carrier gas at a backing pressure of 2 bar, which passed through a resistively heated reservoir containing the dibromobenzene powder before the supersonic expansion through a 30 micron orifice. The jet crossed the monochromatized synchrotron radiation in the center of the double-sided VMI spectrometer and the bromine 3p electrons and all fragment ions were detected in coincidence. A typical ion time-of-flight spectrum and the 2D-momentum image (raw VMI image) of the Br^+ fragments are shown in Fig. 1. Further data analysis and in particular the determination of the molecular-frame angular distributions of the Br(3p)-photoelectrons is under way. These molecular-frame photoelectron angular distributions not only represent important reference data for the time-resolved FEL experiments on dibromobenzene but also contain rich information on the molecular photoionization process such as the localization of charges [5] and core holes [6], double-slit interference [7], and photoelectron diffraction [8,9].

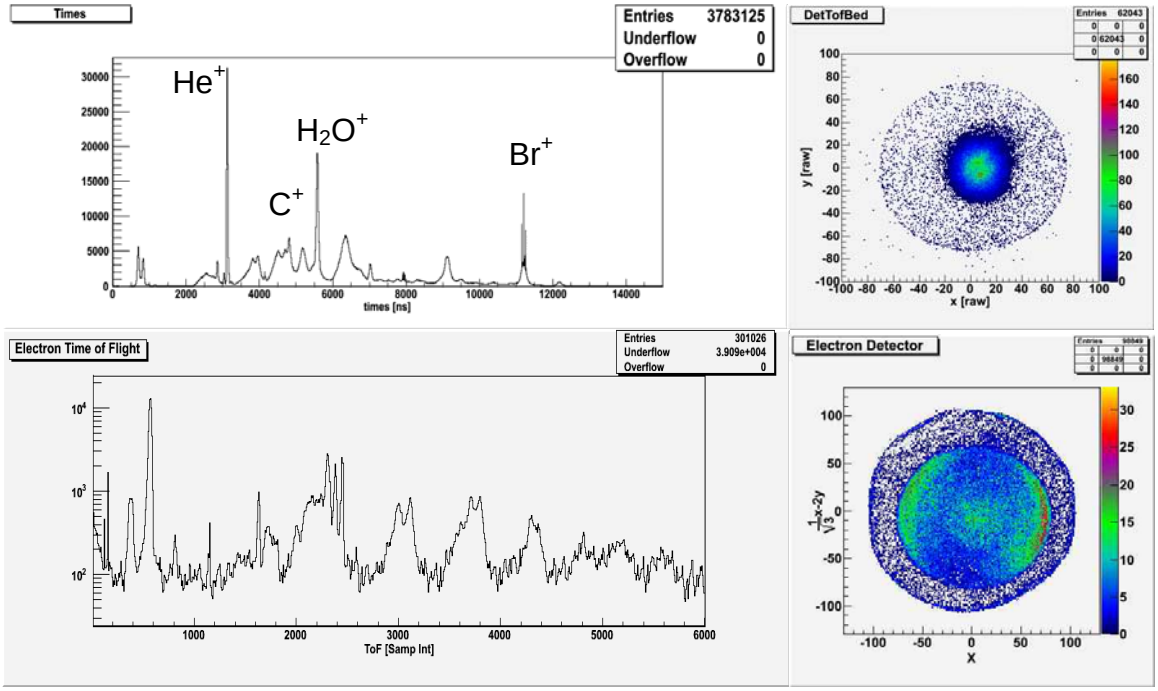

Figure 1: Preliminary data from our BW3 beamtime in November 2010. Top left: Ion time-of-flight spectrum of dibromobenzene after Br(3p)-ionization. Top right: Corresponding Br^+ fragment ion momentum distribution (raw VMI image). Bottom left: Ion time-of-flight spectrum of methylselenol after Se(3p)-ionization. Bottom right: Photoelectron angular distribution (raw VMI image) of N_2(1s) electrons recorded at 430eV for calibration purposes. Further data analysis (e.g. of the molecular-frame photoelectron angular distributions of the Br(3p)-electrons) is under way.

References

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