First Experiments with the Greifswald EBIT

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Abstract. The former Berlin electron-beam ion trap (EBIT) has been moved to Greifswald. In addition to X-ray studies the setup will be used for the investigation of interaction processes between highly-charged ions and atomic clusters such as charge exchange and fragmentation. The EBIT setup has been reassembled and highly-charged ions have been produced from Xe-Ar gas mixtures to study the "sawtooth effect". In addition, the layout of the extraction beamline, interaction region and product analysis for the interaction studies with highly-charged ions are presented.

1. Introduction

The Berlin electron-beam ion trap (EBIT) [1] which had been operated between 1996 and 2009 was moved to the University of Greifswald and reassembled in 2011. After an extensive search for a "cold leak", the system is back in operation since December 2011. The first measurements have been dedicated to the further study of the sawtooth phenomenon of ensembles of mixed highly-charged ions. Presently, the setup is extended by adding an extraction beamline which includes an ion selector, a reaction chamber and further segments for product diagnostics with the aim of studying the interaction of highly-charged ions with atomic clusters.

2. The EBIT parameters and observation of the sawtooth behavior

No changes have been made with respect to the EBIT itself. Thus, it has a magnetic field strength of 3 Tesla, a maximum electron beam current of 150 mA, a maximum electron density of $5 \cdot 10^{12}/cm^3$ and a maximum drift-tube voltage of 30 kV [1,2]. With a maximum electron-beam energy of up to 30 keV the highest ion charge state that has be produced in Berlin is beryllium-like W^{70+} [2]. Operating at an electron-beam energy of around 8 keV, X-ray spectra from highly-charged argon ions were observed in the first test measurements after installation.
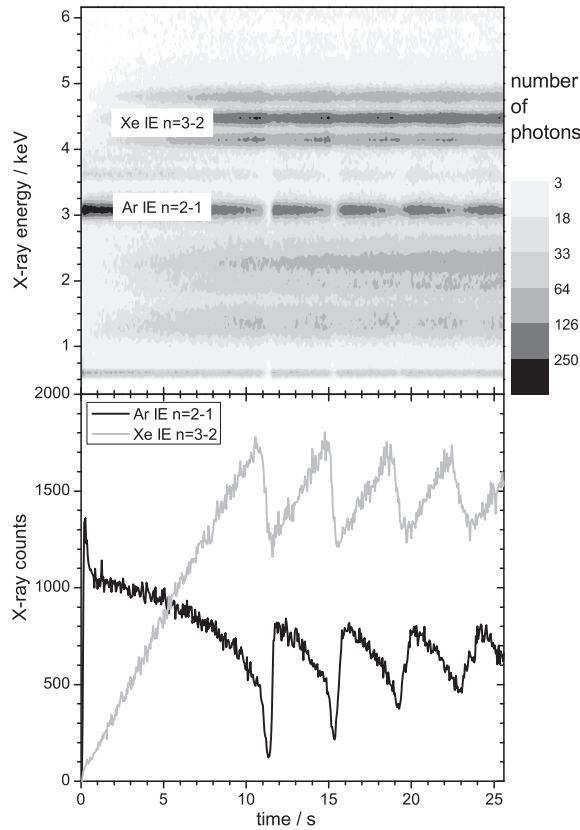
Figure 1. X-ray emission of the trap content as a function of time at an electron-beam energy of $5\,\mathrm{keV}$, an electron current of $40\,\mathrm{mA}$ and an Xe-Ar gas-mixing ratio of 1:6. Top: Scatter plot with energy on y-axis. Bottom: Intensity of Ar n$= 2 \rightarrow 1$ and Xe n$= 3 \rightarrow 2$ transition (after electron-impact excitation).

At present, earlier confinement studies [3,4] of ensembles of different ion species are being continued. Our first measurements were performed with a xenon-argon mixing ratio of about 1:6. We observe a sawtooth-like temporal X-ray intensity variation converse for both elements (figure 1). As described before [3,4] this collective behavior can be explained by periodic collapses and build-up of the ion population in the trap, which occur for large abundances of the lighter element with respect to the heavier element. However, the oscillations are very sensitive to the specific EBIT conditions, such as the trap potential, the electron-beam current, the total gas pressure and the gas-mixing ratio. The details of the influence of these conditions and the processes driving the periodic behavior are still being studied. As indicated above, we intend to further investigate the sawtooth oscillations in the X-ray intensities. These X-ray measurements will be complemented by analysis of the ions ejected during the different phases of the oscillation periods.

3. Layout of the extraction beamline

We have extended the capabilities of the Greifswald EBIT to include studies of the interaction of atomic clusters with highly-charged ions. To this end, the ions can be extracted through the top of the EBIT either in bunches or in the so-called the "leaky mode" [5]. Once extracted, the ions are guided to a reaction chamber by use of a 90-degree bender and various ion optical elements (figure 2), including electrostatic lenses and deflectors. In addition, the extracted beam is diagnosed using Faraday cups and microchannel-plate detectors (not shown in the figure). In the case where several ion
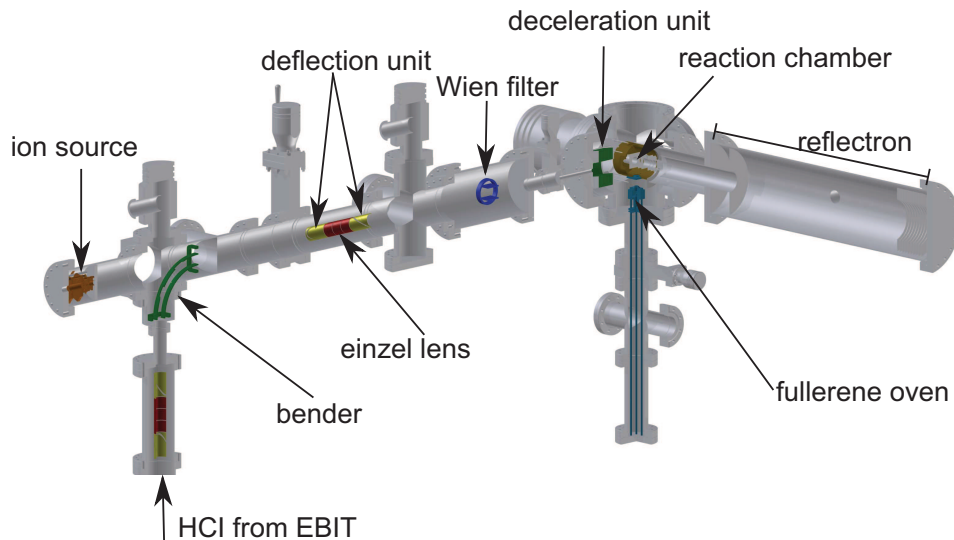

Figure 2. (Color online) Schematic of the experimental setup on top of the EBIT.

species are extracted a separation of the ions of interest can be performed with a Wien filter. In addition, before the ions enter the collision chamber, their energy can be adjusted by a deceleration stage.

To interact with the ions, clusters are delivered as a beam perpendicular to the beam of highly-charged ions. For the first collision experiments we are currently installing a fullerene oven [6]. A reflectron time-of-flight mass spectrometer, orthogonally installed with respect to both the ion-beam and cluster axes will be used to analyze the charged reaction products.

A cross beam ion source has recently been added (see top left of figure 2). This source will allow the alignment of the horizontal components without the need to produce highly-charged ions for the testing of the collision chamber and diagnostics. The new setup will allow focused studies of cluster reactions with ions of lower and higher charge states. As for fullerenes, the low-charge ions are known to produce only low-charge fragments [7] while fullerenes as highly-charged as C_{60}^{9+} were observed in charge-transfer reactions of C_{60} with highly-charged ions, such as Xe^{30+} [8]. After similar fullerene experiments we plan to perform measurements with metal clusters. They will complement ClusterTrap studies [9] where, e.g., vanadium clusters have been charged up to $z = 6+$ by electron-

impact ionization [10].

Acknowledgments

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We wish to have figure 2 kept in landscape format, i.e. extended over two columns, because otherwise important details cannot be visualized.