Development of the HITRAP experimental facility

Z. Andelkovic[1], *S. Fedotova*[1], *F. Herfurth*[1], *N. Kotovskiy*[1], *B. Maaß*[2], *J. Steinmann*[3], *and G. Vorobjev*[1]
[1]GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt; [2]TU Darmstadt; [3]Hochschule Darmstadt

Heavy few-electron ions are relatively simple systems in terms of electron structure which offer unique opportunities to conduct experiments under extremely large electromagnetic fields that exist around their cores. This makes them perfectly suited for various experiments including, but not limited to, tests of quantum electrodynamics at the strong field limit, multiple electron transfer or interaction of highly charged ions (HCI) with surfaces. In the recent decades the theory has advanced enough to be able to calculate quantities such as the g-factor of bound electrons or electron energy levels with high precision. Thus, the major challenge for such kind of experiments has remained the preparation of such highly charged ions.

As an extension of the existing GSI accelerator facility, the heavy ion trap (HITRAP) facility was conceived as the final deceleration stage for HCI. It is designed to provide cold bunches of up to 10^5 ions with charge states as high as bare uranium. The HITRAP decelerator consists of several stages designed to bring the energy of HCI from the initial 4 MeV per nucleon stepwise down into the sub-eV range. After the successful offline tests of the modified radio-frequency quadrupole (RFQ) - the second deceleration stage - it was installed back into the main beamline and equipped with diaphragms at the ion input and output. They will ensure ion beam injection on axis of the 4-rod structure, which was found to be crucial for the deceleration efficiency during the offline tests.

The final deceleration stage - the cooling trap - has seen some modifications for better high voltage stability and suppression of unwanted electron emission processes. After successful trapping of HCI from the EBIT in the year before, the ongoing work at the moment is to prepare the trap for the ions at 6 keV/u decelerated from the RFQ. A detailed simulation study of the resistive cooling process is carried out at the same time [1]. Together with electron cooling, this method will reduce the ion energy to the sub-eV level and prepare a cold bunch of heavy HCI for distribution to different experiments.

The HITRAP facility on the experimental platform included so far a Dresden EBIT and a transfer beamline connecting it to the cooling trap. In 2013 the branch connecting the EBIT and the HITRAP decelerator with various experiments has been completed, thus extending the low-energy beamline by some 15 m, as shown in the figure below. The new section includes nine quadrupole doublets, two 90° deflectors, four diagnostics chambers and an appropriate number of UHV pumps for reaching a residual gas pressure of 10^{-10} mbar. Ion bunches, including highly charged O, Xe and Ar ions have been successfully transported along the full beamline length. This result enables the planned laser spectroscopy experiments in the SpecTrap Penning trap [2], and also paves the way for other experiments associated with HITRAP, like the measurements of the bound-electron *g*-factor [3] and study of multiple electron transfer in cold atom-HCI collisions [4].

As an addition to the Dresden EBIT, plans and preparations were made for an installation of the high-energy S-EBIT [5]. Consigned to GSI as a loan from the Helmholtz Institut Jena, it currently being installed on the HITRAP experimental platform and connected with the existing infrastructure. This accelerator-independent source of heavy, highly charged ions will help bridge the shutdown time of the GSI accelerator complex during the preparation for FAIR and supply heavy HCI to the experimental stations.

References

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