HITRAP – Status of On-Line Commissioning and Installations

F. Herfurth[1], W. Barth[1], G. Clemente[1], L. A. Dahl[1], P. Gerhard[1], O. K. Kester[1], H.-J. Kluge[1], C. Krantz[2], N. Kotovskiy[1], C. Kozhuharov[1], M. Maier[1], D. Neidherr[1], W. Quint[1], U. Ratzinger[3], A. Reiter[1], A. Schempp[3], A. Sokolov[1], Th. Stöhlker[1], H. Vormann[1], G. Vorobjev[1], A. Wolf[2], and S. Yaramishev[1]

[1]GSI, Darmstadt, Germany; [2]MPI-K, Heidelberg, Germany, [3]IAP Uni-Frankfurt, Germany

Heavy, highly charged ions (HCI) are interesting systems for many different experiments as for instance precision tests of the theory of quantum electrodynamics (QED). In order to transform heavy HCI produced at 400 MeV/u to stored and cooled HCI at low energy the linear decelerator facility HITRAP has been conceived behind the experimental storage ring (ESR). Its setup has been started in 2006 and commissioning is underway [1].

In the ESR ions are decelerated from 400 to 4 MeV/nucleon, cooled and extracted; meanwhile a routine operation. Up to ten million ions can be extracted at 4 MeV/nucleon and sent to HITRAP.

The ions are then matched to an interdigital H-type structure (IH) using a double drift buncher, decelerated from 4 to 0.5 MeV/nucleon in the IH, and then down to 6 keV/nucleon in a radio frequency quadrupole (RFQ).

About one million highly charged ions are typically decelerated with the IH from 400 MeV/nucleon to about 0.5 MeV/nucleon per cycle. However, the optimization of the combination of two bunchers (combined in the double drift buncher) and the IH is still difficult and not completely understood. The large parameter space given by three RF amplitudes and two phases requires the investigation of many different settings.

In 2012, the rebuncher between IH and RFQ structures was taken into operation. With a measured loaded Q-value of about 5000 and an effective impedance of 29 MΩ it yields a gap voltage of 100 kV for A/q=3. For $^{50}Ti^{22+}$ ions the effective gap voltage of 80 kV corresponds to a change in energy of less than 35 keV/nucleon.

To measure the action of the buncher on the beam, the phase of the rebuncher RF was changed relative to the master oscillator driving the IH radio frequency (fig. 1). Effectively, this makes the ions experience different gap voltages. The largest measured dispersion on the energy analysing detector of about 0.8 mm corresponds to an approximate change in energy of 40 keV/nucleon, pretty close to the expected value.

The full-width-half-maximum of the peak on the detector is 45 keV/nucleon. This is the result of a convolution of geometrical spread due to imaging, slit size and camera issues with the actual energy spread of the ion beam. This has not yet been disentangled, but first estimates show that at least half of that spread is due to the energy spread.

All efforts to decelerate the beam further with the RFQ structure failed so far. The most probable reason is a slight mismatch of the IH output energy distribution and the energy range accepted by the RFQ. This was found in recently updated simulations of the RFQ structure using the code DYNAMION accompanied by detailed 3D measurements of the electrodes and verified in off-line test. Consequently, a new electrode set has been designed, built and tested off-line [2,3,4] with an on-line test pending autumn 2013.

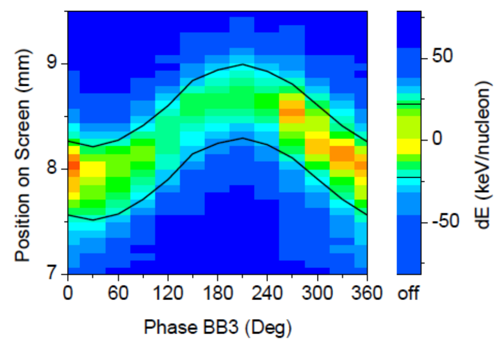

Figure 1: Commissioning of the spiral rebuncher between IH and RFQ. Shown are position on the screen, corresponding energy shift, and intensity (in arbitrary units) of the beam on the energy analysing detector versus the phase of the radio frequency driving the buncher cavity. A power of 1.1 kW was used for all phases. The lines are the FWHM limits of a Gaussian fit of the beam profile at each phase.

The cooler Penning trap was tested offline with deuterium ions from a cross beam ion source, an electron source to provide the electrons for the electron cooling scheme and medium heavy, highly charged ions from a compact, room temperature electron beam ion trap (EBIT) [5]. Finally, O^{8+} ions have been stored for an extended period of time. The simultaneous storage of ions and electrons is the next item on the test schedule.

References

[1] F. Herfurth *et al.*, “The HITRAP Decelerator and Beam Instrumentation”, HIAT’12, Chicago, July 2012, p. 217, http://www.jacow.org.

[2] S. Yaramyshev *et al.*, “A new Design of the RFQ-Decelerator for HITRAP”, this annual report.

[3] K. Dermati *et al.*, “Manufacturing and Assembly of the Electrode Structure of the HITRAP RFQ”, this annual report.

[4] M. Maier *et al.*, “Offline commissioning of the old and new HITRAP RFQ”, this annual report.

[5] A Sokolov *et al.*, “SPARC EBIT — a charge breeder for the HITRAP project”, J. Instrum. 5 (2010), C11001.