Deceleration of ions in the HITRAP facility

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The major challenge for experiments with low-energy highly charged ions (HCI) remains their preparation in sufficient quantities. As the only facility of its kind in the world, HITRAP aims to take advantage of the high intensities of HCI production by in-flight stripping of electrons in an accelerator facility for low-energy experiments. By reducing the energy in several steps from production at 400 down to 4 MeV/u and finally to sub-eV in a trap, a bunch of some 10^5 cold HCI can be forwarded with a chosen transport energy to different experiments.

The first stage of the linear decelerator, an interdigital H-type structure (IH), decelerates ions from 4 to 0.5 MeV/u and was successfully commissioned several years ago with deceleration efficiencies close to the theoretical maximum [1]. The commissioning of the second deceleration stage, the radio-frequency quadrupole (RFQ), has proven to be more challenging because of the very large parameter space combined with a relatively low acceptance of the device. An attempt to improve on this brought a new design of the electrodes [2] and offline tests at MPIK in Heidelberg [3]. The modified RFQ was reinstalled at GSI and commissioned during three beamtimes in 2014. Figure 1 shows the signal of the HCI decelerated from 500 to 6 keV by the RFQ, obtained after systematic scans and optimization of the system parameters during the first two beamtimes. The ions leaving the RFQ were sent through a magnetic field of a permanent magnet with integrated slits. As a result, the ions with smaller energy get a larger deflection angle (the left peak in Fig. 1) and can be distinguished from the non-decelerated ions. The last HITRAP beamtime of the year was used for systematic tests of deceleration, as well as to transport the decelerated ions through the low energy beamline towards the cooling trap.

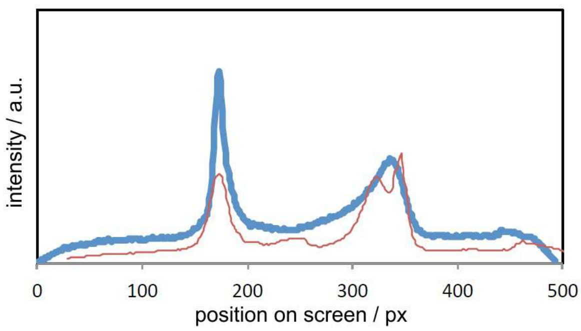

Figure 1: The ion beam from the RFQ after the energy analyser. The thin, red line is the reference signal from the offline tests and the thick, blue line is the online signal from July 2014. The low energy part, i.e. the decelerated ions' signal is the peak to the left. The peak to the right is the undecelerated part of the beam.

The synchrotron cooling of trapped electrons for electron cooling was investigated for the last deceleration stage of HITRAP, the cooling trap. Electrons emitted from a GaAs surface after irradiation with UV light were guided to the trap and stored for extended amounts of time. The cooling effect by synchrotron radiation in the strong magnetic field of the trap was experimentally verified [4]. Further improvements include improvements of the vacuum, the optimization of the ion and electron capture process as well as their mixing and cooling. Detailed simulations of the trapping and the cooling process in the cooling trap have been conducted to that end and show promising results [5].

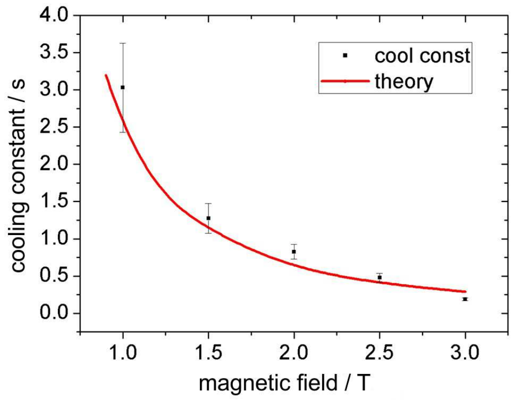

Figure 2: Synchrotron cooling of electrons in the cooling trap. The measured cooling constant of the trapped electrons reduces with the increasing magnetic field. The full, red line shows the value expected from theory.

References

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