Commissioning of the New Heavy Ion Injector at GSI

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Abstract

The Unilac has been upgraded by a new injector linac. It consists of an ECR source, a 108 MHz RFQ linac and an interdigital H-type accelerator structure. Highly charged ions (as U^{28+}) are extracted from the ion source and accelerated by the RFQ structure up to 300 keV/u. The IH tank accelerates with a very high rf efficiency up to the energy of 1.4 MeV/u. The commissioning of the new injector will be reported.

Introduction

The new GSI synchrotron SIS and storage ring ESR are in routine operation now. The Unilac is simultaneously used as injector for the SIS and to serve the low energy physics experimental area. To meet the different demands of the high and low energy experiments and to operate the accelerator facility efficiently, the scheme of time share operation has been adopted for the Unilac: beams of different ion species and currents are extracted from two injectors and accelerated to different energies on a pulse-to-pulse basis[1].

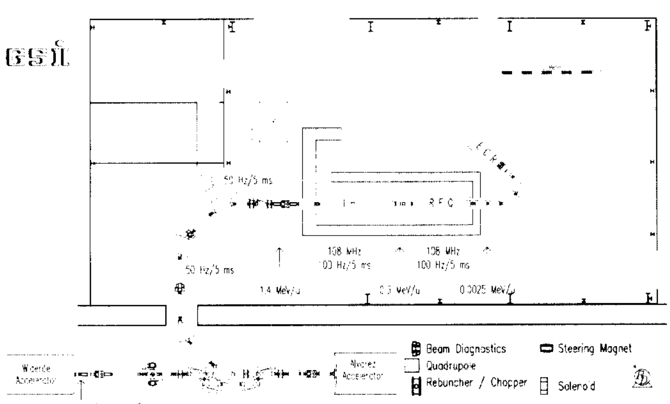

Fig. 1: Plan view of the new injector

A high charge state ion injector[2] (HLI, Hochladungsinjektor) is being commissioned presently. It is foreseen to serve low energy physics experiments and consists of an ECR (Electron-Cyclotron-Resonance) source[3], followed by a 108 MHz four rod RFQ-tank[4] and a 108 MHz interdigital H-type structure[5]. Intermediate stripping is not any longer necessary. The new injector is much shorter, has less components and needs less power than the old Wideröe accelerator and will therefore be more reliable. But it is not designed for higher beam currents.
For this reason it is planned to rebuild the old Unilac injector in order to produce higher beam currents by up to three orders of magnitude to utilize the SIS current limit.
The concept of this high current injector[6] favours a CORDIS- or a MEVVA-type ion source for single or double charged particles to be accelerated. A new 27 MHz RFQ linac substitutes the Wideröe tank 1. Due to stripping of the beam, tanks 2, 3 and 4 can be used on.

The High Charge State Injector

An ECR source[3] operating at 14.5 GHz has been developed at CEN Grenoble to deliver the same charge states of heavy ions which have been generated so far by gas stripping at 1.4 MeV/u. Test runs of the source have shown that the expectable beam currents are comparable or even higher than delivered by the existing prestripper linac (e.g. U^{28+}: 5 eμA, Pb^{25+}: 6 eμA, Xe^{17+}: 27 eμA, Ni^{8+}: 20 eμA). Such high charge states allowed an accelerator design with very efficient acceleration up to 1.4 MeV/u by application of a four rod RFQ-structure and an IH-structure (Fig. 1).
The Alvarez rf amplitude limitation conform to U^{25+} results in an extraction voltage of 23.8 kV of the ECR source to reach the input energy of 2.5 keV/u of

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the RFQ-structure. The expected unnormalized emittance is 200 π•mm•mrad for both planes.

Fig. 2 displays the transverse beam envelopes of the ion spectrometer. The split pole analyzing magnet has a total deflection angle of 135 degree, the angles of all pole face rotations are 25 degree vertical focusing. The inner field boundaries have a radius of 2.7 m to compensate the second order distortions. A momentum resolution of $1.3 \cdot 10^{-3}$ was obtained, Pb isotopes can be completely separated. An electrostatic chopper with a deflection voltage of 16 kV and a rise time of 10 μs converts the beam from dc to 100 Hz pulses with a duty cycle up to 50 %.

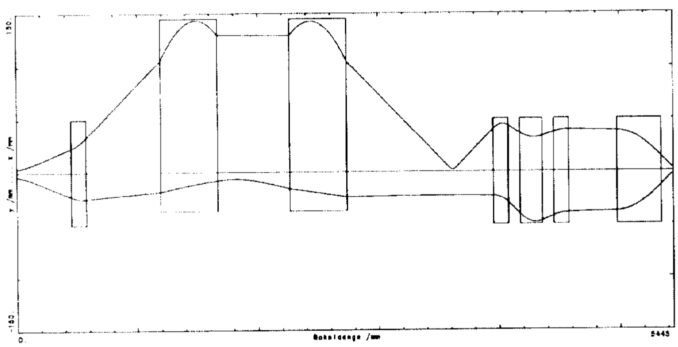

Fig. 2: Spectrometer beam envelope

The RFQ tank is about 3 m long and has a diameter of 0.5 m. For U^{25+} the maximum voltage is 78 kV (125 kW rf power) for acceleration to 0.3 MeV/u. The radial acceptance has 50 % reserve compared to the source values. The expected longitudinal emittance is 30 π•keV/u•deg at the exit.

The length of the IH-structure is 3.55 m, the diameter is 0.63 m. It contains two magnetic quadrupole tripletts, the particle output energy is 1.4 MeV/u. The very high shuntimpedance of 320 MΩ/m yields an effective voltage gain of 10.5 MV with an rf power of 109 kW. The radial acceptance is 60 π•mm•mrad unnormalized, the longitudinal acceptance 150 π•keV/u•deg.

The 180 degree beam transport line is equipped with two λ/4 coaxial type bunchers. The transverse beam optics are designed as an achromatic system. An 11 degree switching magnet with a rise time of 5 ms can deflect each other of the 100 Hz pulses for local experiments. With a 30 degree bending magnet of 35 ms field rise time one of two injector beams may be chosen for further acceleration in the Alvarez tanks working at 50 Hz pulse repetition rate.

Commissioning of the HLI

All components of the HLI are installed. Cooling water, electrical supplies, cables, RF power lines are in place. The extensively computerized controls are essentially in operating condition.

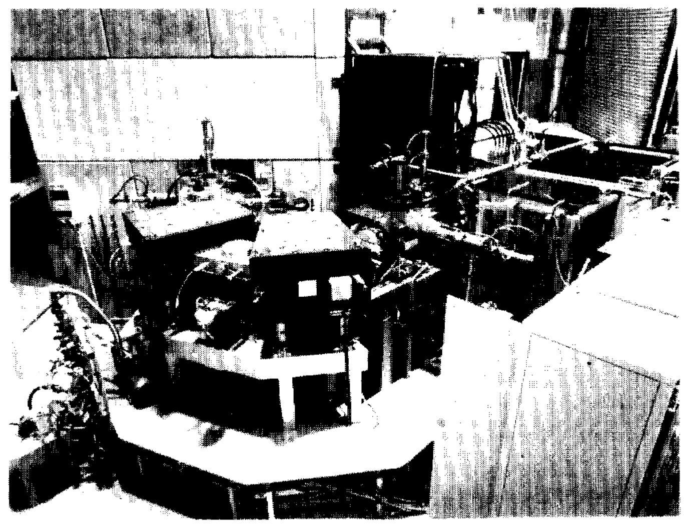

Fig. 3: Photograph of the injection beam line

The commissioning of the ECR source itself took place in Grenoble and at GSI[3]. Fig. 3 shows the source and the low energy transport system. The Xe spectrum (Fig. 4) is recorded with the new spectrometer. The isotopes are completely separated. The measured beam half width of 4 mm fits the calculations. In these tests the extraction voltage was set only to half the nominal value to avoid conditioning problems. Due to this restriction an improvement of the resolution can be expected and the designed resolution of Pb isotopes will be reached. The dispersion of the spectrometer was measured as D = 23.2 mm/%(Δp/p). The analyzed beam was transported through the following lenses and measured by an emittance measurement device. The beam properties fit the RFQ structure acceptance very well.

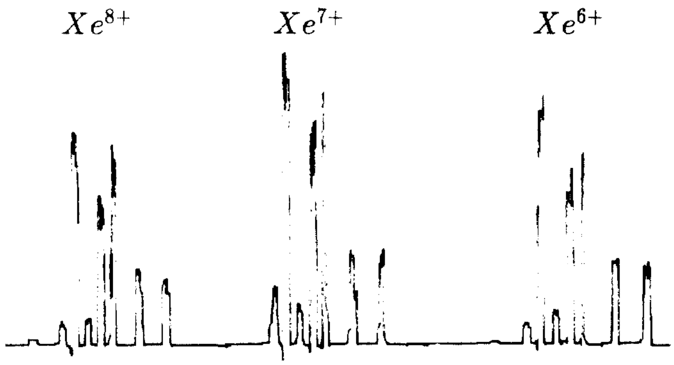

Fig. 4: Measured Xe spectrum

The RFQ structure has been developed and commissioned by the Institut für Angewandte Physik, University of Frankfurt. It is completely assembled, vacuum tested and now waiting for rf power tests. Detailed information is given in a special contribution to this conference[4]. The IH cavity was tested with low and high rf power. Fig. 5 shows the electrical field distribution recorded by a perturbation measurement. The shunt-impedance of 320 MΩ/m ± 5 % leads to a power consumption of only 109 kW for U^{25+}. The Q value is 21.500. Power tests have been carried out at following levels: P = 140 kW, 15 % duty cycle and P = 60 kW, 50 % duty cycle.

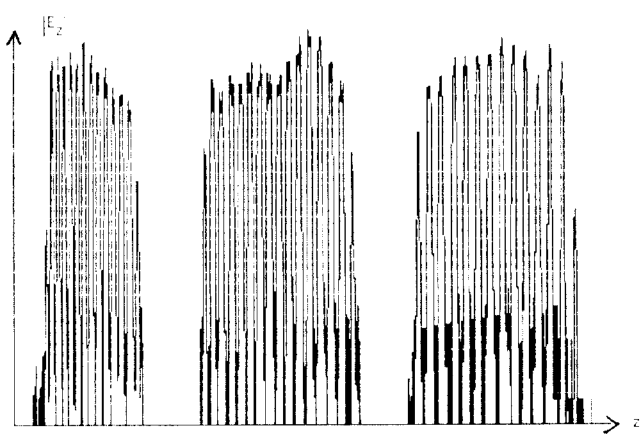

Fig. 5: Field distribution of the IH structure

For longitudinal beam matching one 108 MHz buncher cavity is installed in the intertank section and two in the 180 degree beam line. They have been tested with an rf power of 2.3 kW, 50 % duty cycle. The effective shuntimpedances are 68 and 73 MΩ/m respectively, the Q values are 6.030 and 10.050. The efficient gap voltages are 155 and 233 kV respectively.

Status and Perspectives

The HLI was scheduled to have been commissioned at the end of March. Due to other competing activities at GSI and resulting lack of manpower we are behind schedule. Commissioning of the RFQ and IH cavity with beam are now in progress, which will be followed by beam transport tests through the 180 degree bending line. Also a reproducible set of machine parameters must be worked out.
In May the rebuilding of the stripping section for pulsed operation of the matching magnets will take place. This modification will complete the efforts to establish the ion switching mode for the GSI accelerators.

References

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