Status of the Heidelberg High Current Injector

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Abstract

Many experiments at the Test Storage Ring TSR are limited by the weak currents, delivered from the tandem-post-accelerator-combination. A high current injector, which will provide 2-3 orders of magnitude higher intensities is under construction. The high current injector will consist in its first version of an ion source for singly charged ions, two RFQ-resonators and eight 7-gap-resonators. The final energy of 1.8 MeV/u is adapted to the acceptance of the post-accelerator. By adding an ECR- or EBIS-source the new system will be able to deliver beams up to uranium with energies above the Coulomb barrier of the heaviest elements. This paper describes the status of the project.

1 INTRODUCTION

Laser cooling experiments at the TSR with ultra cold beams [1] of $^9Be^+$ and $^7Li^+$ are limited by the low currents delivered from the tandem accelerator. A new injector will increase the beam currents for these two ion species by factors up to 1000. The proposed high current injector will consist, in its first phase, of a commercial CHORDIS ion source[4], two RFQs [3] and eight 7-gap resonators [2].

Moreover, also experiments with highly charged ions are frequently limited by low beam currents due to losses from multiple stripping. Therefore an ECR- or EBIS- source will be added in a second phase to increase also currents for highly charged heavy ions.

In figure 1 the schematic layout of the new injector is shown. The injector will be placed parallel to the Tandem and the $^7Li^+$ - or $^9Be^+$-beams will be injected directly into the postaccelerator which is just used as a transfer line. For the second phase, to take advantage of higher charge states, a stripping process will be used behind the last of the seven-gap resonators and the proper charge state will be sorted out by a separator consisting of 4 60°-magnets. The new injector also works at 108.48 MHz like the existing post accelerator to facilitate synchronism. The ion velocity of $\beta = v/c = 6\%$ after the high current injector is well adapted to the post accelerator and final energies higher than 5 MeV/u can be reached for all ion species.

2 THE ION SOURCE

For the production of high currents of Li^+ and Be^+ with low duty factor (5 Hz, 500μs) the commercial ion source CHORDIS [4] is used. The construction of the ion source section consisting of the source on a platform, a 60° magnet for isotope selection and a quadrupole triplet to match the beam to the RFQ section has been finished and first beam tests have been done. To study the properties of the source and to learn how to handle it in routine operation, tests in gas and sputter regimes have been carried out. Table 1 shows a list of all ion species produced so far and the intensities of the analyzed currents in CW mode. Also the extraction voltage U_{ex} is given. We used the ion source for both Be^+ and Li^+ in the sputter version to avoid having to clean the source from toxic material.

Table 1: *List of ion species and current intensities produced so far with the CHORDIS-source in CW mode*

ion type	regime	U_{ex}[kV]	I [mA]
^{4}He	gas	17.5	2.5
^{7}Li	sputter	17.5	2.0
^{9}Be	sputter	30	0.21
^{40}Ar	gas	17.5	2.5
		25	6.0
		30	9.0
^{48}Ti	sputter	30	0.37
^{53}Cr	sputter	30	0.17
^{56}Fe	sputter	30	0.46

As far as Li^+ is concerned the design value of 2 mA was achieved with stable operating conditions. Higher currents were reached and will be stably produced by using an additional cooling equipment of the sputter cathodes. For the Be^+-source we used an alloy with a Beryllium content of only 2% to avoid toxic contamination of the source. The intensity of 0.2 mA is satisfactory for all tests. Higher currents can then be achieved with cathodes made from pure Beryllium.

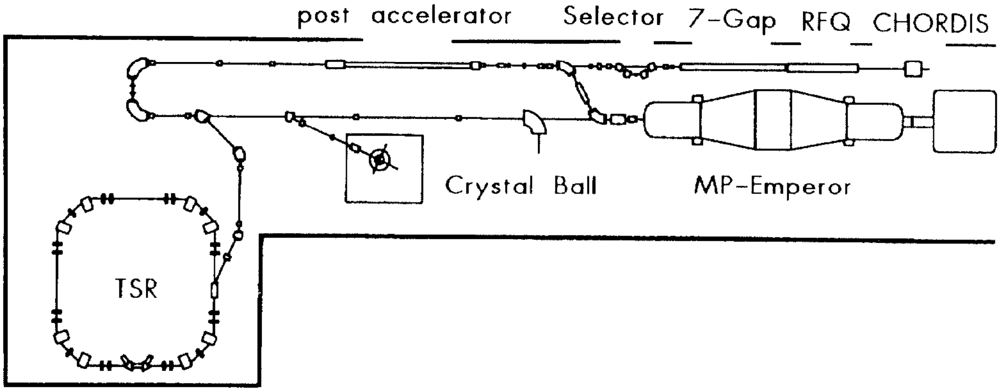

Figure 1: The new high current injector will be placed parallel to the Tandem. The ion source for highly charged ions (ECR or EBIS), planned for the second construction phase, will be located one floor below.

3 THE RFQ-ACCELERATOR

The second section of the high current injector consists of two 4-rod-RFQ resonators [3] operating at a charge to mass ratio $Q/A \geq 1/9$ as required for Be^+. The two vacuum tanks were machined from stainless steel tubes of 32 cm diameter and 3 m length. The copper plating has been done at GSI. The requirements in the mechanical tolerance ($\pm 1/100$ mm) and the adjustment ($\pm 1/10$ mm) of the 3 m long electrodes are very high. Moreover, the mechanical stability is as important as a sufficient cooling diameter, because 30% of the rf power has to be dissipated by the electrodes. However, the maximum diameter of the rods is limited by the capacity between the electrodes to ensure a high shunt impedance. In 1993 we developed a construction method which allows the production of the electrodes with high precision in the mechanical workshops of MPI. A custom made hollow profile from a copper-tin-alloy combines easy machining and high mechanical stability. To investigate the newly designed electrodes in more detail, 1 m long test electrodes were built (Figure 2) and mounted into one of the RFQ-resonators.

We were able to run the RFQ prototype at a power level of 15 kW in CW mode, which is more than a factor of two higher than the design value. Without any problems with respect to mechanical stability or sparking between the electrodes the resonator was operated for about 3 weeks. Moreover, bunching and accelerating tests were performed with the prototype resonator, detecting the accelerated bunches (Figure 3) with a fast Faraday-cup.

After the successful tests with the prototype electrodes the construction of the 3 m rods has been started. They will be finished in summer 94, so that first beam tests with the RFQ can take place later this year.

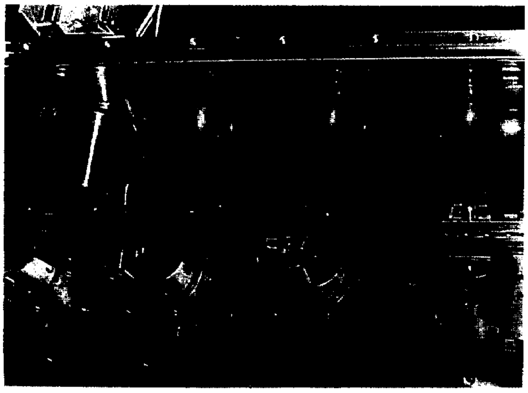

Figure 2: *View into the vacuum chamber with the 1 m long prototype electrodes*

4 THE SEVEN-GAP ACCELERATOR

With increasing ion velocity, RFQ acceleration becomes less efficient and other accelerating structures such as the seven-gap resonator, developed at the MPI für Kernphysik [2] are getting superiour.

To simplify the construction, the resonators are designed as four pairs of identical resonators for β=3.7, 4.5, 5.1 and 5.7% following the velocity profile of the accelerated ions. Based on measurements for the high velocity prototype of a seven-gap resonator, an effective accelerating voltage of 1.4 MV is expected for a low β-resonator, which operats at 80 kW rf power with 25% duty cycle.

Scaled down models for the four different resonators have been used to optimize field distribution and shunt impedances. Based on these measurements seven out of eight seven-gap resonators have been fabricated up to now [5].

In figure 4 a seven-gap resonator with a flange removed is shown. Segments on both sides of the half shell allow to tune the resonator to the required eigenfrequency of 108.48 MHz. The tuning plate, protruding into the resonator from below, is clearly visibel. The rf power is coupled into the resonator near one of the three legs which connect the resonance structure to the tank and where the magnetic field is maximal.

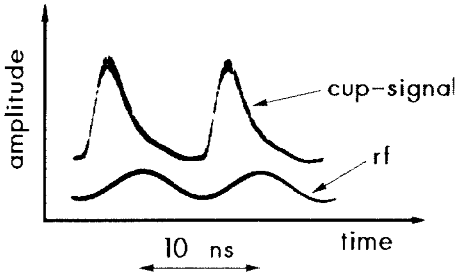

Figure 3: Cup signal of H_2^+- bunches, accelerated in the RFQ- prototype.

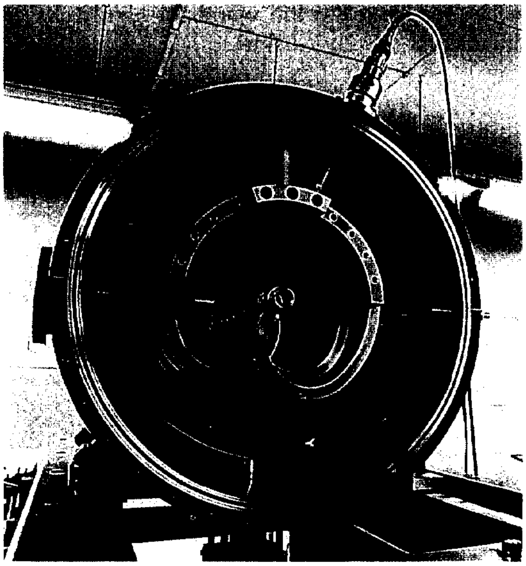

Figure 4: *The 7-gap power resonator (β=3.7%)*

From bead perturbation measurements of the power resonators a maximum voltage of 1.7 to 1.9 MV for an input power of 80 kW was calculated. Beam acceleration tests have been made by injecting an ion beam with synchronous velocity into the resonator and using a 90°- magnet to measure the energy distribution versus magnetic field. From the energy distributions the resonator voltages could be derived and were found in good agreement with the bead perturbation measurements. The results are presented in table 2. The shunt impedance Z is defined by $Z=\frac{U_o^2}{NL}$, where U_o is the resonator voltage, N the incoupled rf power and L the lenght of the resonator.

For the 5.1% and the 5.7% resonators beam and power tests are in preparation. Additional power tests of the 3.7% and 4.5% resonators were carried out with up to 100 kW rf power at a duty cycle of 25%. Neither mechanical vibrations due to ponderomotive forces nor multipactoring problems have been observed.

Table 2: *Comparison between the resonator voltages measured with the bead perturbation method (U_o^*) and by accelerating a beam (U_o). The shunt impedance Z is calculated from U_o*

β[%]	U_o^*[MV]	U_o[MV]	Z [MΩ/m]
3.7	1.70	1.74	99.6
4.5	1.90	1.84	94
5.1	1.84	—	—
5.7	1.91	—	—

5 OUTLOOK

Since all accelerator components should be ready by the end of this year, the new high current injector will be set up right after the small reconstruction of the accelerator building, which is scheduled for July and August of this year. So the first beams from the high current injector in its first phase is expected to be available in 1995.

The combination of the capability of the RFQ of accelerating slow heavy ion beams and the flexibility both in input and in output energy of the seven-gap resonators might find a new application in a proposed project at CERN concerning the acceleration of radioactive beams at ISOLDE.

6 ACKNOWLEDGEMENT

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