FIRST YEAR OF OPERATION OF THE HEIDELBERG HIGH CURRENT INJECTOR

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Abstract

At the Max-Planck-Institut für Kernphysik in Heidelberg the first phase of the High Current Injector was successfully finished. The Linac, consisting of a high current source for singly charged ions, two RFQs and eight 7-gap-resonators demonstrated its performance with an accelerated He-beam (1.85 MeV/u, Q/A=1/4) and an Oxygen-beam (0.5 MeV/u, Q/A=1/9). For Coulomb explosion imaging experiments at the storage ring we were able to produce and deliver several different light molecules, singly charged, with intensities about 10 μA. In a second phase an ECR source will be added to provide the full spectrum of also highly charged ions up to uranium.

1 INTRODUCTION

To increase the intensity of various kinds of ions for the Heidelberg Heavy Ion Storage Ring TSR a High Current Injector was developed and built. In its first phase the new injector consists of a commercial CHORDIS ion source [1], two RFQs [2] and eight 7-gap resonators [3] for the variability of the end energy for Q/A$\geq$9. The CHORDIS is optimized for mainly singly charged ions. To provide also highly charged heavy ions an ECR-source, which is under installation at a test bench, will deliver the full spectrum of highly charged heavy ions in a second phase. Figure 1 shows the layout of the injector. The accelerator is installed parallel to the Tandem and beams are injected directly into the postaccelerator. In the second phase stripping will be used behind the last seven gap resonator and the proper charge state will be selected by an achromatic separator consisting of four 60^0-magnets. Like the existing post accelerator the new injector operates at 108.48 MHz. The ion velocity of β=v/c=6% after the High Current injector is well adapted to the post accelerator and final energies higher than 5 MeV/u will be achieved for all ion species in a pulsed mode operation with up to 25% duty cycle.

1.1 The CHORDIS-Ion Source

The first section consists in the first phase of two CHORDIS ion sources, designed and optimized for the production of singly charged ions. One is used for all ions except Beryllium, the second is reserved for Beryllium beams because of the toxicity of the material. Running up to 36 kV the CHORDIS achieves all voltages required for the fixed input energy of the RFQ of 4 keV/u. The source can be operated in DC as well as in pulsed mode. Alternatively, the DC beam from the source can be chopped before the RFQ by an electric deflector.

1.2 The RFQ

The second section consists of two directly coupled 4-rod-RFQ resonators [2] optimized for a charge to mass ratio Q/A $\geq$1/9. The operation frequency is 108.48 MHz. At 80 kW rf power with a duty cycle of 25% about 7 kW are dissipated in the four rods. Therefore a new design for sufficient cooling was optimized, resulting in the construction of so called mini vanes. In Fig. 3 a view inside the RFQ in beam direction is given. One can see the minivane structure as well as the stems and the tuning plates to adjust the frequency of 108.48 MHz and to optimize the flatness of the voltage.

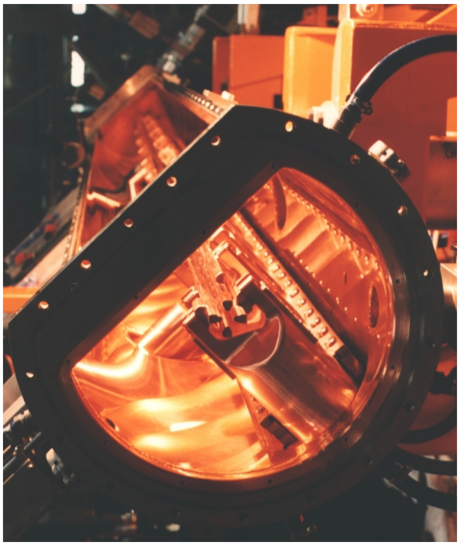

Figure 2: A view in beam direction into the Þrst RFQ. The stems are carrying the so called mini vanes with an electrode voltage of up to 60 kV with a minimum aperture of 2 mm. The tuning plates at the bottom optimize the Þeld ßatness at the resonance frequency.

After very efficient optimizing routines for the amplifier power to reach the design electrode voltage we successfully put both RFQs into operation. The shunt impedances could be determined by these first beam tests to 121 kΩm for the first and 131 kΩm for the second one, respectively. The following table 1 summarizes the important parameters of the RFQs.

1.3 The 7-gap linac

The last section consists of eight 7-gap resonators, developed at the MPI fur Kernphysik. Figure 3 shows an opened 7-gap resonator with a view to the resonance structure and the tuning plate. The resonance structure consists

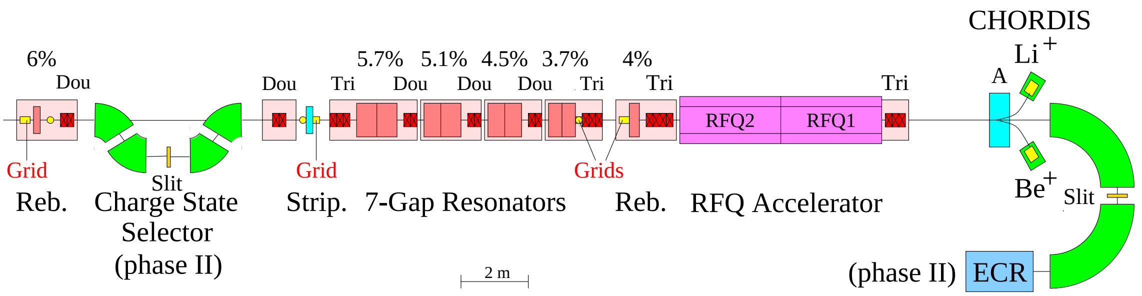

Figure 1: In its first phase the High Current Injector consists of a CHORDIS source, two RFQ and eight 7-gap resonators. For the second phase and ECR is bought an under installation at a test bench. For this phase a charge state selector will be added due to stripping processes behind the last 7-gap resonator.

Table 1: Measured parameters for the 2 RFQs, f = frequency, Z = shunt impedance, = electrode voltage.

Parameter	RFQ1	RFQ2
f [MHz]	108.48	108.48
Q–value	4450	4500
Z [kΩm] at 80 kW	121	131
U_0 [KV]	60	60
Final energy [MeV/u]	0.248	0.478

of a curved copper plate and 3 arms attacked to both sides. Each arm consists of two hollow profiles, surrounding the drift tubes and carrying the cooling water. Driven in push pull mode, consecutive drift tubes have opposite potentials. With about 1.7 MV resonator voltage at 80 kW rf power the resonators are much more efficient than the RFQ to convert the rf power to accelerating voltage. The final energy of the last resonator corresponds to the designed injection energy of the post accelerator. The 7-gap resonators accelerate the beam from 0.48 MeV/u after the RFQ to an exit energy between 1.7 and 2 MeV/u depending on the charge to mass ratio. The resonator voltages were determined by acceleration tests with velocity adapted beams. The energy gain was measured with a bending magnet and resulted in resonator voltages between 1.7 and 1.8 MV at 80 kW rf power. Table 2 summarizes the measured resonator voltages of all 8 resonators.

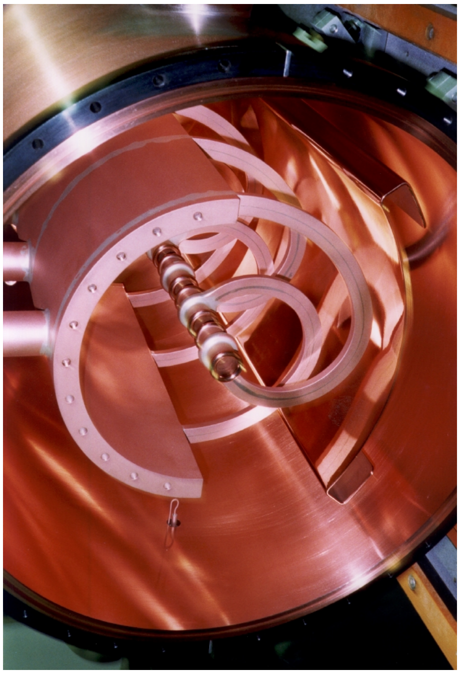

Figure 3: A view into a 7-gap resonator. The resonace structure is connected to the tank with 3 stems, the tuning plate corrects the resonce frequency due to temperature effects.

2 THE DESIGN PARAMETERS

To prove the design parameters of the injector, beam times with Helium and Oxygen were performed. With the Oxygen-beam, $^{18}O^{2+}$, the charge to mass ratio of 1/9 could be demonstrated. With an input energy of 4 keV/u into the RFQs, a beam energy after the RFQ of 8.6 MeV was measured with a bending magnet. Therefore the 0.478 MeV/u of the two coupled RFQs were achieved. The rf power in pulsed mode was 88 kW of the first and about 80 kW of the second RFQ. To prove the output energy of the linac we run the machine with Helium He^+. With a charge to mass ratio of 1/4 the machine can be operated in CW mode. The He-ions were accelerated up to 7.5 MeV which is above the design value of 1.7 MeV/u.

3 FIRST USER BEAM TIMES

In the first year of operation the main demands of the user community were concentrated on the production of molecules. As shown in table 3 various ions and molecules could be produced and accelerated.

A lot of conditioning and optimizing as well as test beam times were performed with Helium. The simplicity of pro-

Table 2: Measured resonator voltages for all eight 7-gap resonators

Resonator	Design velocity [%]	Voltage [MV] at 80 kW
1	3.7	1.73
2	3.7	1.67
3	4.5	1.79
4	4.5	1.73
5	5.1	1.69
6	5.1	1.74
7	5.7	1.70
8	5.7	1.71

Table 3: List of all accelerated ions and molecules produced until now. U_{ex} is the extraction voltage of the source, adapted to 4 keV/u input energy of the RFQ, I_{FC-RFQ} the measured beam intensity after both RFQs and E the energy determined with an analyzing magnet .

Ions	U_{ex} [kV]	I_{FC-RFQ}	E [MeV]
$^{4}He^{+}$	16	1.0 mA	2.0-7.5
$^{18}O^{2+}$	36	200 nA	8.6
$^{24}Mg^{+}$	30	5.0 μA	0.03
H_3^+	20	50 μA	1.5
D_2^+	16	5.0 μA	2.0
D_2H^+	20	5.0 μA	2.37
$^{4}HeH^{+}$	20	5.0 μA	2.37
$^{3}HeD^{+}$	20	5.0 μA	2.37

duction and the low charge to mass ratio makes it to a good tool for test purposes. The only disadvantage was the fact that Helium can not be pumped efficiently with our cryo pumping units at the RFQs, which results in short periods to regenerate the cryo pumps. By using the Oxygen-beam the design value of the charge to mass ratio of 1/9 could be proved. Due to the life time of the filaments of the source we produced only very low beam intensities. For Magnesium a very low energy was required. Thus it could be demonstrated that the RFQs can be operated as a beam transport system for a DC beam without acceleration. Using a few kW rf power in both RFQ tanks and a detuned phase setting between them the transmission efficiency was improved from 0.5% without rf up to 10%. All molecules produced so far had the requirements of low energy and intensities of about a few μAs. They were injected into the Storage Ring at MPI for Coulomb Explosion Imaging Experiments [4]. Typical transmission of all beam times are about 80 to 90% from the source to the RFQ at intensities of a few 100 μA, through the RFQ also about 80 to 90% and through the Linac about 80%.

4 REFERENCES

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