THE HIGH CURRENT SPIRAL-RFQ PROTOTYPE*

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Abstract

A new high current injector (HSI) for all ions up to uranium is planned at GSI [1,2]. The Radio Frequency Quadrupole (RFQ) accelerator can provide low energy, high current beams at low charge states (U^{2+}) at an operating frequency of 27 MHz. Results of particle dynamics calculations and structure development for a prototype of the first part of the HSI-RFQ are presented together with results of rf-measurements.

Introduction

The GSI upgrading program [3,4] consists of the new heavy ion synchrotron SIS, the experimental storage ring ESR and two new injectors, a high charge state injector HLI and a high current injector HSI. With these new components and the UNILAC it is possible to accelerate all elements up to uranium to energies above 1 GeV/u. Fig. 1 shows the plan view of the extended GSI accelerator facility. The SIS and the ESR are operational now for more than a year.

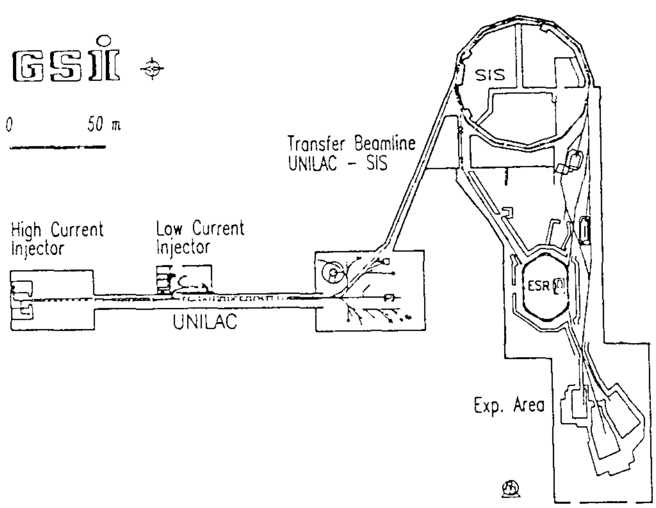

Fig. 1 Plan view of the extended GSI accelerator facilities

The new HLI [5] injector, for the nuclear physics research program at the UNILAC, is also succesfully working now. It consists of a combination of an ECR ion source, a 4 Rod RFQ [6] and an IH-structure [7], both operating at a frequency of 108.5 MHz. The HLI enables direct injection of U^{28+} into the Alvarez part of the UNILAC at an energy of 1.4 MeV/u without stripping. This injector is designed for a beam current of 5 μA at a duty cycle of up to 50 %.

The HSI is designed to fill the SIS up to the space charge limit, and will accept e.g. U^{2+} beams with currents as high as 25 mA at low initial particle energies of 2.2 keV/u. It operates at 27 MHz (Wideroe frequency) at a duty cycle of 1 %. A gas stripper at 216 keV/u produces a reasonable fraction of the necessary charge state of U^{10+} for acceleration in the second Wideroe part of the UNILAC. The second gas stripper at 1.4 MeV/u between the Wideroe and the Alvarez part provides the U^{28+} beam for postacceleration and injection into the SIS.

The Spiral RFQ

A 4 Rod RFQ structure with spiral shaped supports (spiral length 1180 mm, heigth 450 mm) as developed in Frankfurt is well suited to built a compact RFQ accelerator [8] operating at the same frequency of 27 MHz as the GSI Wideroe. Fig. 2 shows a scheme of the spiral structure.

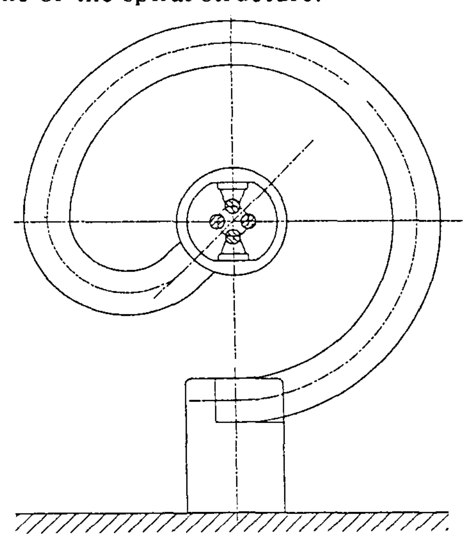

Fig. 2 Scheme of the spiral structure

The whole HSI-RFQ will have an overall length of about 35 m to reach an ion velocity corresponding to an accelerator voltage of 26 MV. To achieve the space charge limit of 0.2 mA times the ratio mass over charge state the electrode voltage has to be 180 kV. A short test resonator [9] of 1 m length has been operated with even higher voltages.

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Spiral RFQ Prototype

A 4 m prototype of the 4 Rod Spiral RFQ, with 220 cells, which covers the crucial low energy part of the HSI-RFQ, where the dc beam is converted into a bunched beam, has been built both for rf- and beam-tests. Fig. 3 shows the beam dynamics layout for an RFQ consisting of 550 cells, corresponding to a length of 20.5 m and a final energy of 130 keV/u. Fig. 5 shows an example from PARMTEQ calculations [10] for this RFQ, which were done for the design current of 25 mA and show that the beam formation takes mainly place in the first part of the RFQ. Therefore the short prototype can give already relevant information from beam measurements.

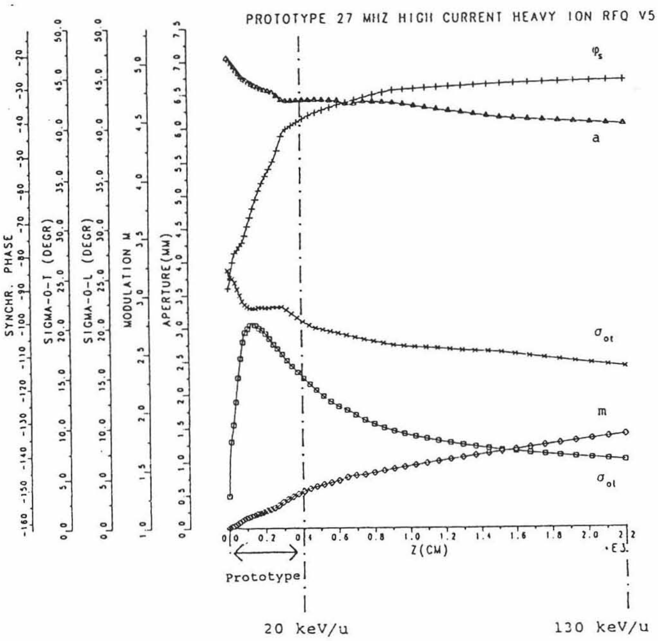

Fig. 3 Beam dynamics layout

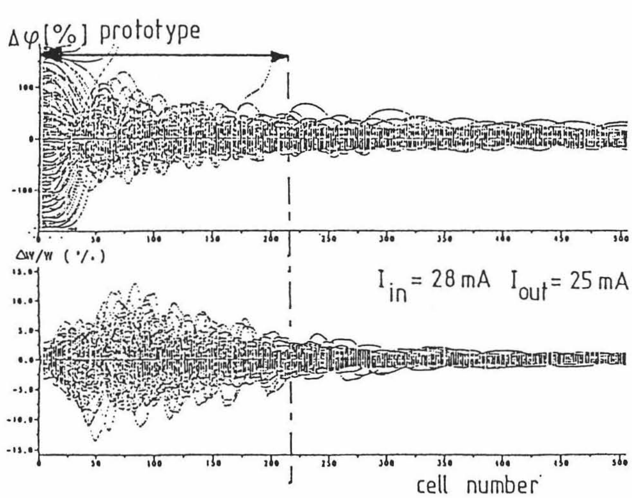

Fig. 4 Longitudinal beam behaviour along the RFQ

In table 1 the main parameters of the prototype RFQ are listed.

TABLE 1
Main Parameters of the RFQ Prototype

f	27.1[MHz]	length	3,95[m]
cells	231	spirals	20
T_{in}	2.2[keV/u]	T_{out}	17.8[keV/u]
φ_s	-90 to -39[°]	a	7.0-6.02[mm]
m	1 - 1.458	$\dot{\alpha}_{synchr}$(norm)	1π[mm mrad]
ε_{in}(norm)	0.3π[mm mrad]	I_{max}	0.23 A/ξ[mA]
U_{el}	1.51 A/ξ [kV]	A/ξ_{max}	130

For the prototype RFQ a rectangular vacuum chamber, made of aluminium, has been chosen. Fig. 5 shows a view of the prototype RFQ.

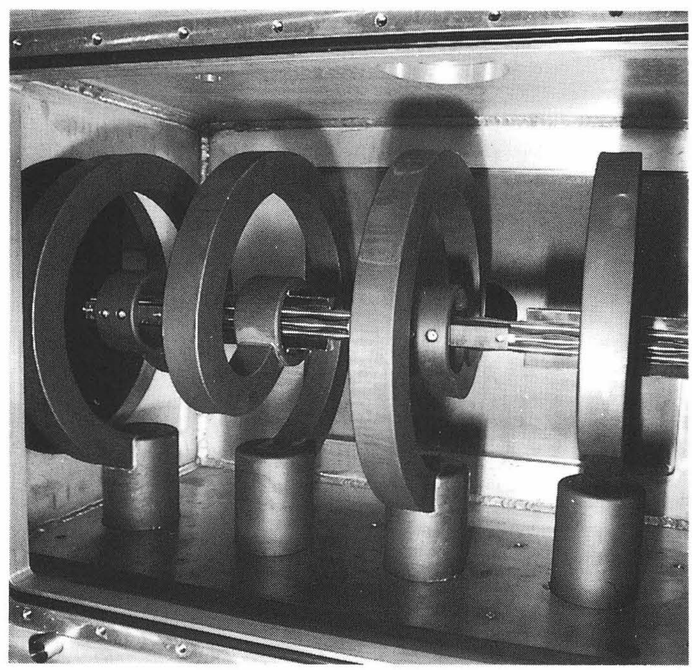

Fig. 5 View of the RFQ prototype

Alignment of the prototype

The big lids of the rectangular vacuum chamber simplify the mounting and adjustment of the RFQ structure. The spiral supports are installed on a copper ground plate and aligned with an opto-mechanical system. For the reason of manufacturing each 4 m electrode consists of 21 pieces. For a high stability they are fixed and brazed on ten electrode carriers each about 100 mm long. The gap distance between the electrodes is adjusted by washers with the alignment-system, too. The precision of the electrode alignment is better than 1/10 mm, that means an error less than 3 % of the aperture radius. Fig. 6 shows the results of the electrode alignement.

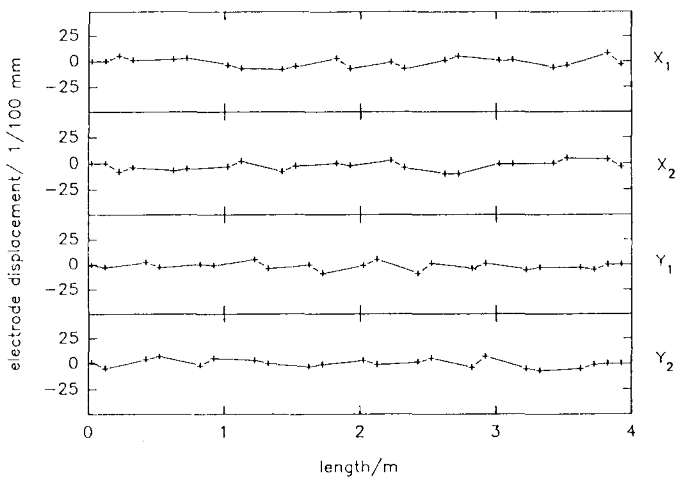

Fig. 6 Measured electrode alignment

Rf-Measurements

The measured Q-value of the prototype is Q = 4200. This is, compared with the sparking test resonator, an enhancement of 30 % due to the enlargement of the square length of the spiral supports from 25 mm to 45 mm. A low level measurement of the shunt impedance yields Rp = 500 kΩm. For a good beam quality it is important to get a constant field distribution along the beam axis. The field distribution can be changed by detuning of rf-cells with tuning plates. Fig. 7 shows a field distribution measurement of the RFQ prototype without any correction. The maximum deviation is less than 2 %.

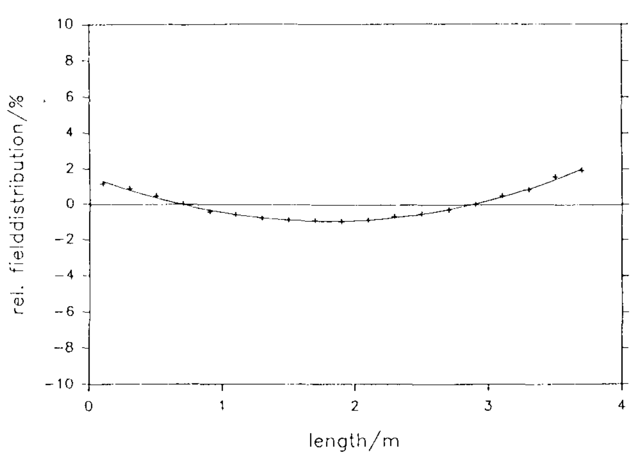

Fig. 7 Field distribution along the RFQ prototype

Status and Schedule

The vacuum tests are finished. The rf-matching has been done and the resonator is now in the conditioning phase. First high power tests and beam tests with He^+ at an electrode voltage of only 6 kV are planned for September in our institute. If these experiments are finished, the RFQ will be operated at the high current injector test stand at GSI with Xe^+ and U^{2+} at an electrode voltage up to 180 kV.

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