PERFORMANCE OF THE GSI HLI-RFQ[×]

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Abstract

At GSI, the new "High Charge State Injector (HLI)", a combination of an ECR ion source, a four-rod RFQ, and an IH structure, has been successfully put into operation. The HLI-RFQ is designed for the acceleration of U^{28+} from 2.5 to 300 keV/u with a high duty factor of up to 50%. Properties of the RFQ resonator and results of beam tests will be presented.

Introduction

The GSI accelerator facility consists of the UNILAC, the heavy ion synchrotron SIS, and the storage ring ESR. The new HLI-injector for the UNILAC has been built to provide 2 to 20MeV/u beams for the low energy program of GSI [1,2]. Fig. 1 shows the arrangement of the HLI, which consists of an ECR source, an RFQ accelerator, and an IH structure [3,4,5].

The four-rod RFQ accelerator is designed to accelerate heavy ions with a charge to mass ratio of $q/A \geq 0.117$ (U^{28+}) from 2.5keV/u to 300keV/u [6]. The IH-structure accelerates the beam to 1.4 MeV/u which is the proper energy for the injection into the Alvarez part of the UNILAC.

The four-rod RFQ

The resonator consists of four rods arranged as a quadrupole. Opposite rods are connected by a row of support stems as shown in fig.2. The quadrupole field between the electrodes is achieved by a π - $\lambda/2$ mode.

When the structure frequency and electrode voltage have been chosen to give good focussing properties, the length has to be optimized with respect e.g. to the resulting emittance, the power consumption and the transmission, which is the ratio of d.c. input beam versus output beam.

The mechanical design of this type of accelerator structure allows cooling of all components. The stems, the electrodes, and the tuning blocks are screwed into the tank to be able to change components in case of problems with high duty factor operation, which is required for the HLI-RFQ. Fig. 3 shows the final particle design parameters along the RFQ structure. Table I summarizes characteristic parameters. The slow increase of the ion energie T as function of RFQ cell number N is demonstrating the fact that a significinant part of the structure is required for bunching.

Results and Beam Tests

The RFQ was assembled, aligned and tuned at GSI. Before the RFQ went into operation its field flatness was examined and optimized under low power conditions. The field variation along the axis was ± 5% as shown in the solid line in fig.4. PARMTEQ calculations on the effects of this unflatness on the output emittance show that

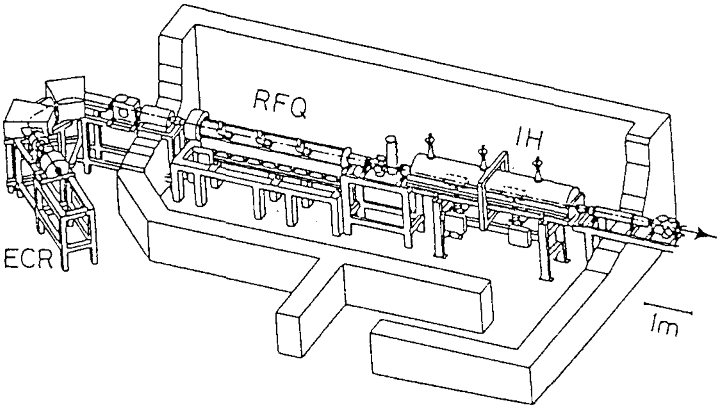

Fig. 1 Layout of the "High Charge State Injector" HLI

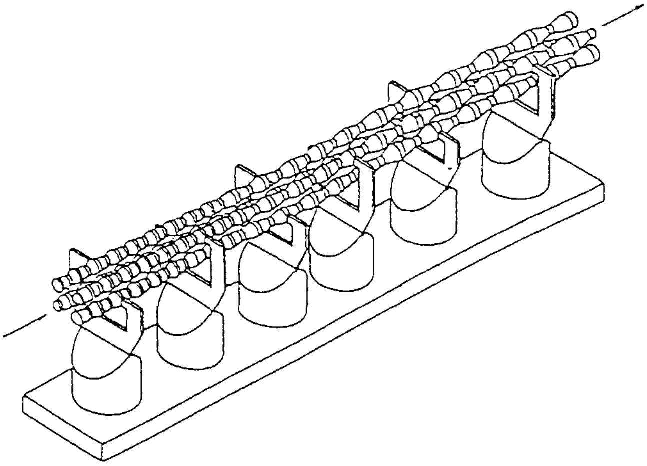

Fig. 2 Scheme of the Four-Rod RFQ structure

[×] supported by the BMFT and GSI

the beam shows nearly no difference compared to the structure with ideal field flatness [7]. Also for the maximum tilt one can achieve by asymmetrically positioning of tuners (fig.4(2,3)) the effect is very small.

Fig. 5 shows the ratio of voltage on x and y electrodes which have an asymmetry in the first and last cells of the RFQ, because for rf-termination the end cap capacity has not been matched.

The first beam tests showed encouraging results. The output beam had the proper bunch structure and ion energy. Fig. 6 shows a signal of the phase probe. The width of the bunch, estimated by time of flight measurements with two probes, was less than 1 nsec. The radial emittance was in good agreement with the theory, as demonstrated in fig. 8.

A closer inspection of the output beam showed an angular offset of appr. 1^{0} and more important a smaller transmission than predicted. Only 40-50% of the beam current behind the spectrometer were measured at the RFQ [2].

We have checked the field flatness and operated with a field tilt by intentionally mis-positioning of the tuners but the output beam remained unchanged. Also possible dipole components in the RFQ were checked, but their value was determined to be less than 2%.

The input matching was modified by shifting the matching solenoid closer to the RFQ and by increasing the gap between the electrode and the beam entrance flange but this had also no effect on the transmission. Experiments with reduced input emittance and with helium at increased electrode voltage resulted in the required transmissions value of 90% [2].

Inspection of the electrode positions with a telescope showed misalignements of greater than 0.5mm, which in Parmteq simulations strongly reduced transmission [9].

After realignment of the electrodes (fig.9 shows the measured apertures) the transmission was improved. For an input emittance of 130 π mm×mrad the transmission was 92%, which is illustrated in fig. 10. For the experiment the emittance was changed by an aperture in the injection beam line [10].

RF operation was very stable with very little multipacting at low levels and a quick thermal equilibrium at power levels up to 130 kW (25% d.c.). Unexpected difficulties were encountered at high power levels due to a rf modulation caused by ponderomotoric forces, qualitatively similar to the effects studied at spiral loaded cavities [8]. This effect has been characterized as a mechanical oscillation of the electrode ends,

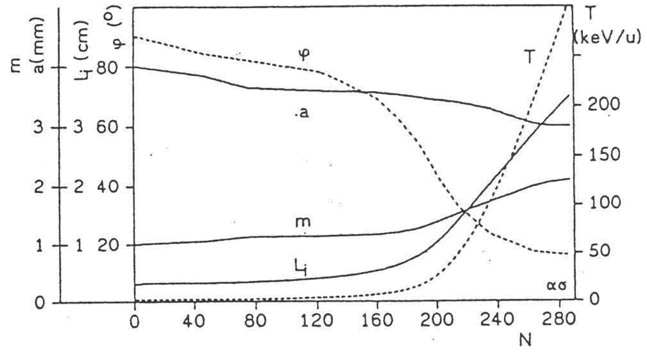

Fig. 3 RFQ parameters vs. cell number N

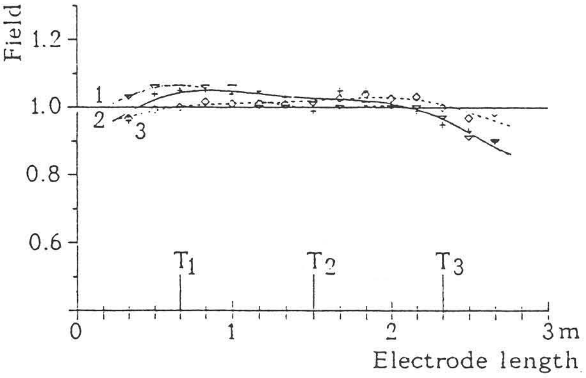

Fig. 4 Measured voltage distribution along the RFQ electrodes for different tuner positions

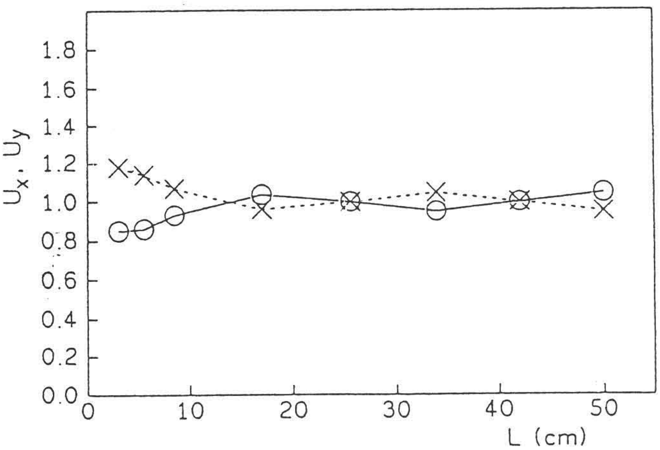

Fig. 5 Ratio of voltage on x and y electrodes

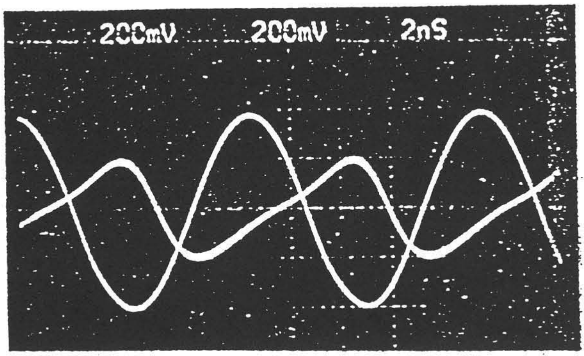

Fig. 6 Phase probe signal of the bunched beam

which was excited at the pulse repetition frequency. Its resonance is at 178 Hz at which it shows strong amplitude resp. foreward power modulation (fig. 11) if the tank amplitude is kept constant during the pulse by the control system. Even the pertubation is small at the design values (50 Hz rep. rate, duty cycle of 25%) this effect will make it difficult to achieve 50% at 50Hz without additional mechanical stabilisation of the electrodes.

The high duty factor operation revealed some weak points of the HLI RFQ structure design. The electrodes like all parts of the resonator are bolted together, which is not as stable as being fixed by welding or brazing. The electrodes have to be stiffened and the power losses and temperature distribution on electrodes, stems, base plate, and tank has to be measured to further improve operational properties.

Acknowledgement

We thank those who helped and hope that those who are waiting for the completion have some confidence now that soon everything will work as expected.

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TABLE 1
Parameters of the HLI-RFQ

Injection/final energy	2.5 / 300 keV/u
Charge to mass ratio	28/238 - 1
Frequency, electrode voltag :	108.5 MHz /80kV
Duty cycle - rep. rate	25-50% , 50-100 Hz
Tank diameter, length	35 cm / 3.0m
Input/output emittance	0.5/0.55 π mm mrad
Longitudinal emittance r.m.s. (100%)	10° keV/u

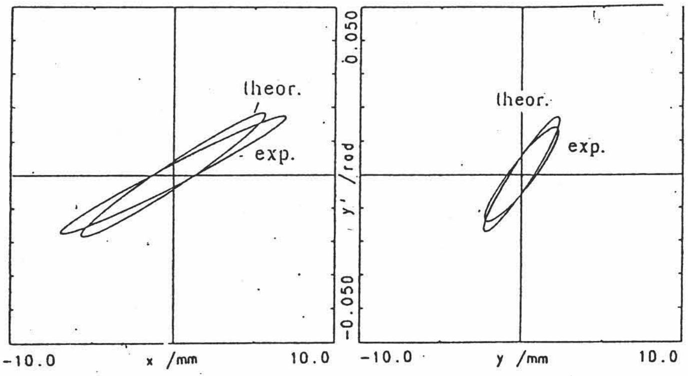

Fig. 8 Measured and calculated beam emittances

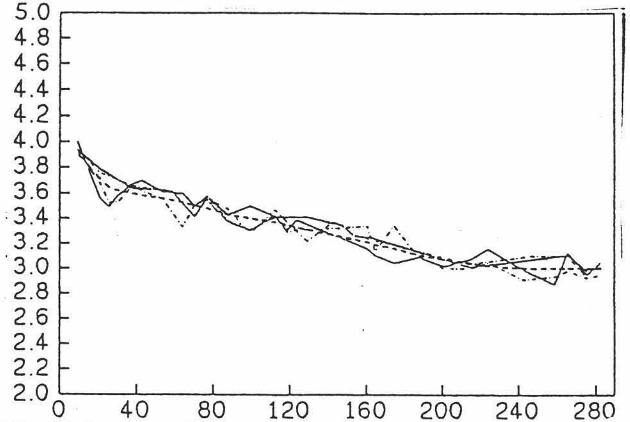

Fig. 9 Measured apertures after realignement

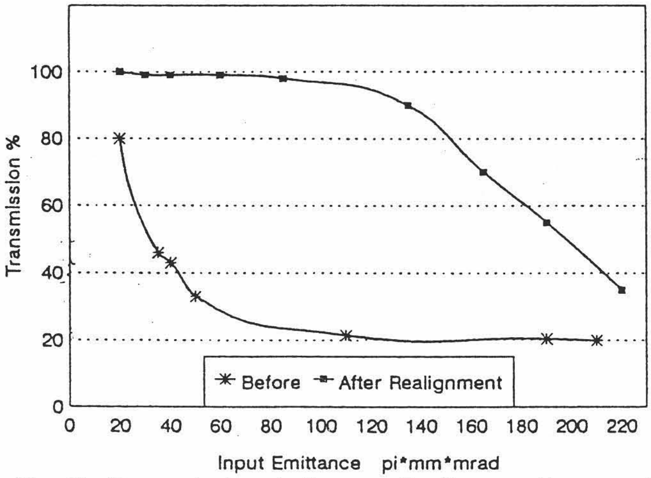

Fig 10 Transmission before and after realignement of the electrodes

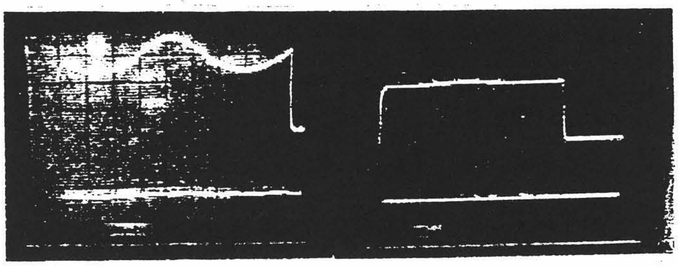

Fig. 11 Input power modulation for rf pulses with 178Hz / 4.4msec and 50Hz / 3.5msec