Properties of the GSI HLI-RFQ Structure[×]

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Abstract

A "High Charge State Injector (HLI)"- RFQ for the GSI, designed for the acceleration of U^{28+} from 2.5 to 300 keV/u has been built and tuned. Properties of the RFQ structure and first experimental results will be presented.

I. INTRODUCTION

The GSI accelerator facility consists of the UNILAC, the heavy ion synchrotron SIS and the storage ring ESR. The SIS synchrotron can accelerate all elements up to uranium to energies above 1 GeV/u [1,2].

To fill the SIS up to its space charge limit and to use the full potential of the new GSI accelerator complex a new high current injector in front of the UNILAC is planned which will accelerate up to 25 emA U^{2+} ions with a small duty cycle.

The development of new sources for highly charged heavy ions but lower currents (design value e.g. 5 eμA instead of 25 emA) enable direct acceleration of U^{28+} ions in a new high charge state injector (HLI) for the Alvarez part of the UNILAC to supply independantly heavy ion beams for the physics program in the UNILAC experimental hall [3]. The HLI injector, which is shown schematically in Fig.1 and described in a separate paper [4], consist of an ECR source [5], an RFQ [6,7] and an IH-structure [8].

The 4-Rod RFQ will accelerate heavy ions with charge to mass ratio of $q/u \geq 0.117$ (U^{28+}) from 2.5 keV/u to 300 keV/u which corresponds to an energy gain of 2.5 MeV/q [9].

With this new injector uranium ions extracted from the ECR source will be accelerated to to 1.4MeV/u and injected into the Alvarez structures without passing any stripper thus replacing the Wideroe/Stripper part of the UNILAC which is then dedicated to short pulse high current acceleration for SIS injection only.

II. THE 4-ROD RFQ

The 4-Rod RFQ rf-structure consists of coupled λ/2 - oscillators in a linear arrangement of straight radial stems and circular rod electrodes as indicated in fig.2 [10]. Although the currents are concentrated on the stems the efficiency does not fall short compared with other RFQs. The resonator is very stable with respect to rf operation because neighbouring modes are clearly separated and all major current conducting parts can easily be cooled, which is important especially for high duty cycle operation as planned for the HLI-injector.

The design of the GSI RFQ follows the design succesfully applied for CRYRING-RFQ [11,12] but all parameters have been stringened.

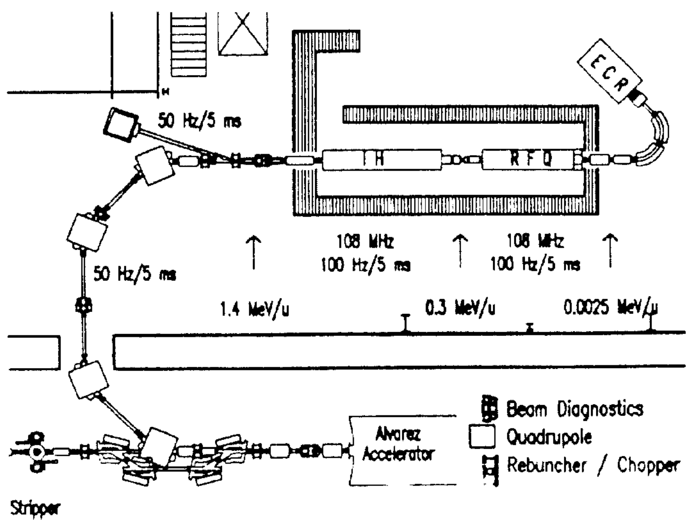

Fig. 1 Layout of the 1.4 MeV/u injector (HLI)

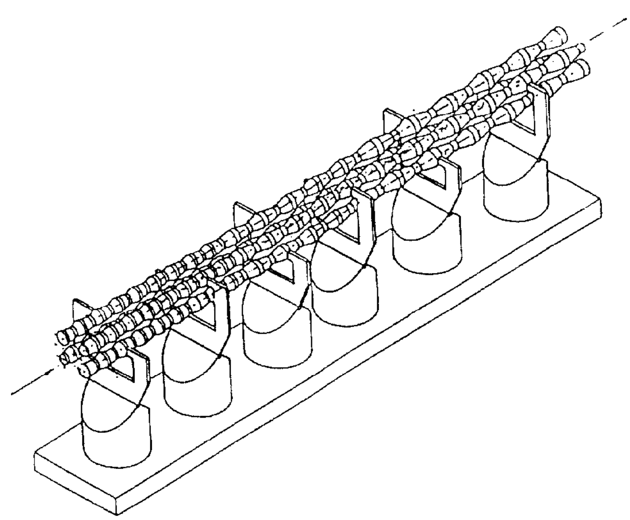

Fig. 2 Scheme of the 4-Rod RFQ structure

[×]Work supp. by BMFT under contract FKLA

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The RFQ structure should be as short as possible to save rf power and costs proportionally. When the structure frequency and electrode voltage have been chosen to give good focusing properties, the length L_S has to be optimized with respect e.g. to the beam emittance, the power consumption and the transmission, which is the ratio of d.c. input beam versus output beam.

Fig. 3 shows the final design parameters a,m, and L_i along the RFQ structure. Table I summarizes characteristic parameters. The slow increase of the ion energy T as function of the RFQ cell number N is demonstrating the fact that a significant part of the RFQ structure is required for bunching.

Results of PARMTEQ calculations [13] show a normalized radial acceptance of 1π mm mrad, for a transverse input emittance of 0.8πmm mrad the transmission is 90%. For a matched beam (α_{xy}=0.7, β_{xy}=1.6cm/rad)and the design emittance of 0.5 π mm mrad the transmission is 99% at an emittance increase of only 10% for the full beam. Figs. 4 and 5 show the corresponding output emittances at the end of the electrodes and the phase and relative energy spectra. As can be seen from fig. 6a a few particles (about 5%) are transfered into neighboring buckets during the first stage of bunch formation. The longitudinal emittance is 10°keV/u (100%r.m.s.)

The transverse beam behaviour is plotted in fig.6 for the full beam. All calculations were done for an injected dc beam without energy spread and a transverse waterbag distribution. Fig. 7 shows results of calculations for a mismatched input beam (1mm radial displacement). While the transmission is reduced (99 to 72%) the radial output emittance is nearly constant (from ε_N=0.55 to ε_N=0.74 πmm×mrad)

Fig. 7 shows the low energy end of the cavity, which incorporates also beam diagnostic devices and indicates the coffin like design with a wide top flange along the RFQ which facilitates installation, alignment and maintenance. The RFQ has been manufactured, assembled, aligned and tuned to the operating frequency of 108.5 MHz.

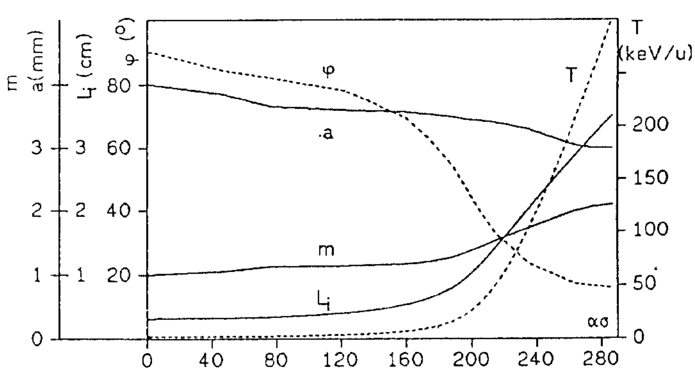

Fig. 3 Main RFQ parameters vs. cell number

The field flatness is within 5% as shown by fig.8, the Q value is Q=4150 and the impedance is R=200kΩm which means that a rf-power of 100kW is required for the design field amplitude. Fig. 9 shows views of the HLI-RFQ.

The HLI-RFQ is undergoing rf-tests now and first beam tests are planned for the week after a shut-down period in May.

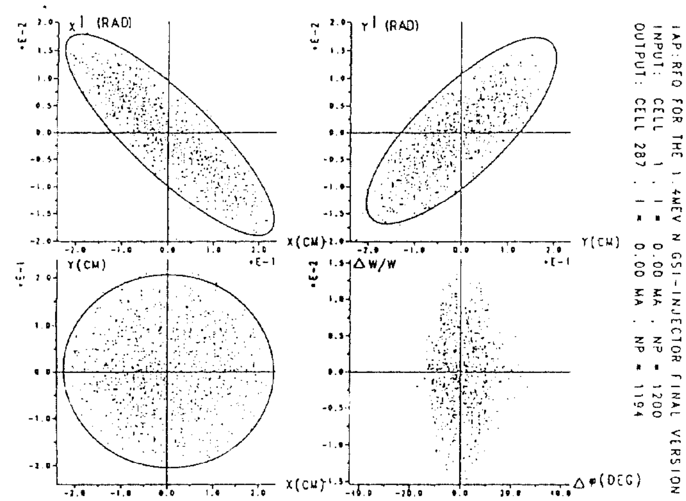

Fig. 4 Output emittances of the HLI-RFQ

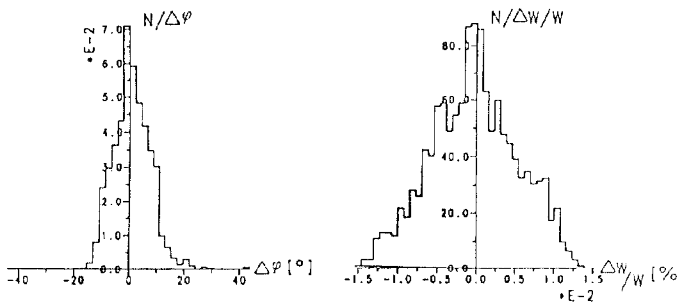

Fig. 5 Phase and energy spectra behind the RFQ

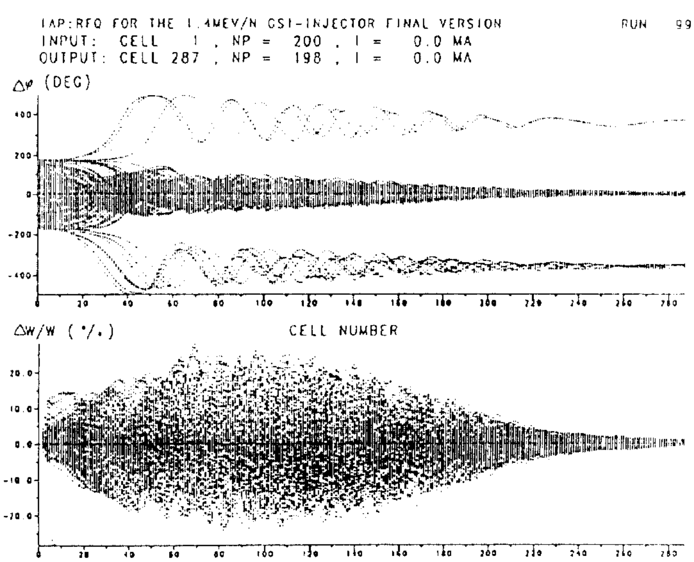

Fig. 6 Longitudinal beam behaviour along the RFQ

III. ACKNOWLEDGEMENTS

We thank those who helped and those which are patiently waiting for the completion and hope they will still be patient until everything is perfect.

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Table I. Parameters of the HLI-RFQ

Injection/final energy	2.5 / 300 keV/u
Charge to mass ratio	28/238 - 1
Frequency, electrode voltage	108.5 MHz /80kV
Duty cycle - rep. rate	25-50%, 50-100 Hz
Aperture/modulation	3.0 mm / 1 - 2.1
Tank diameter, length	35 cm / 3.0m
Radial acceptance (norm.)	1.0 πmm mrad
Input/output emittance	0.5/0.55 πmm mrad
Longitudinal emittance r.m.s. (100%)	10° keV/u

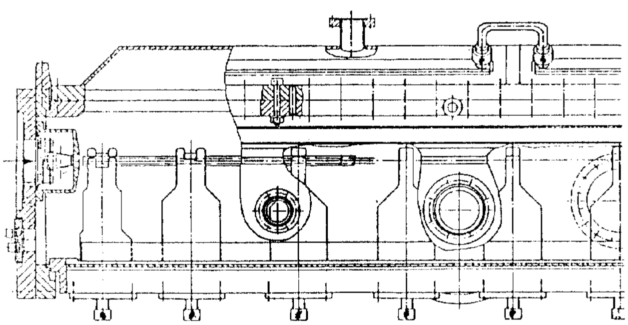

Fig. 7 Low energy end of the HLI-RFQ

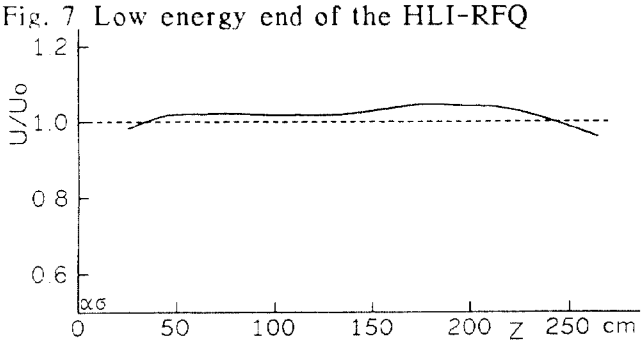

Fig. 8 Voltage distribution along the RFQ

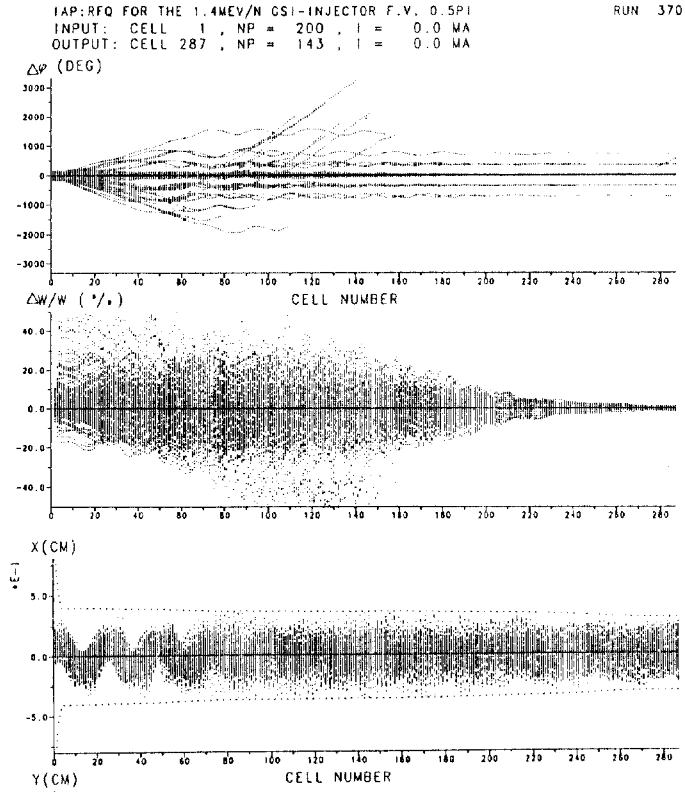

Fig. 7 Beam behaviour for a mismatched beam

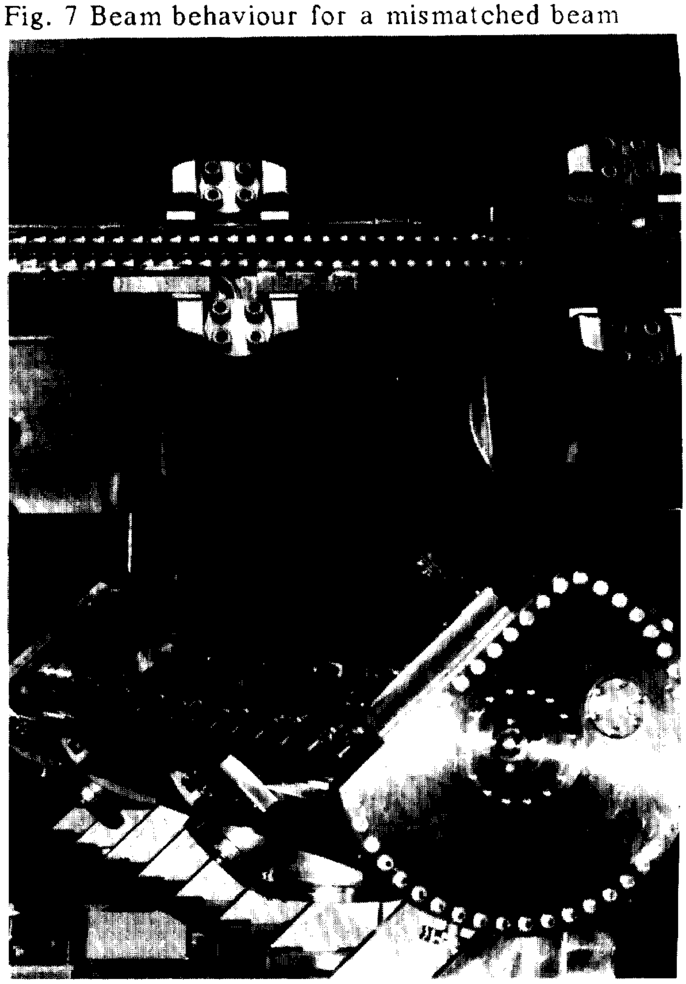

Fig. 9 Views of the HLI RFQ