

THE NEW GSI HLI-RFQ FOR CW-OPERATION

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Abstract

A new CW-RFQ has been built for the upgrade of the HLI (High Charge State Injector) of GSI for operating with a 28GHz-ECR-Ion source and simultaneous increase of the beam duty cycle from 25 % now to 100 %. The new HLI 4-rod RFQ will accelerate charged ions from 4 keV/u to 300 keV/u for the injection into the IH-structure. High beam transmission, a small energy spread and small transverse emittance growth and good input matching are design goals. Properties of this CW-RFQ, status of project and first measurements will be presented.

INTRODUCTION

The upgrade of the HLI for operating with a 28GHz ECR-Ion source and simultaneous increase of the beam duty cycle from 25 % now to cw-operation in future. This New RFQ will replace the old one working since 1991. [1]. The new HLI 4-rod RFQ will accelerate charged ions from 4 keV/u to 300 keV/u for injection into the subsequent rebuncher cavity and IH-structure. High beam transmission, a small energy spread and small transverse emittance growth are required, has been demonstrated in design calculations. In particular the beam input convergence is to be kept as small as possible to provide for a smooth input matching. It is intended to use the HLI in future as an injector for a proposed cw linac dedicated to UNILAC experiments especially like SHIP [2]. Fig. 1 shows a layout of the actual HLI injector structure at the GSI.

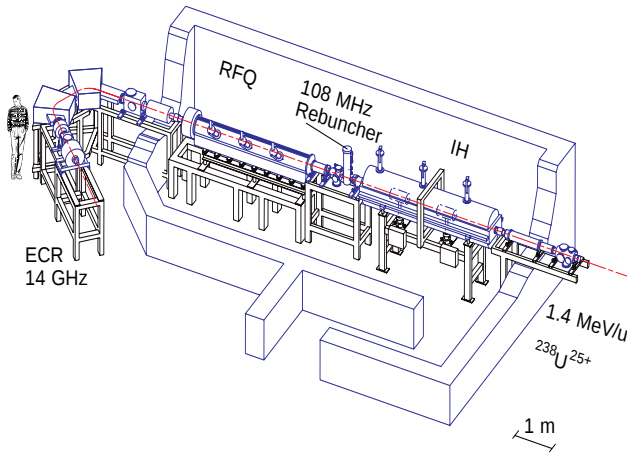


Figure 1: Layout of the HLI Structure at GSI.

Our design is based on our methode of adiabatically varied electrode parameters in contrast to the shaper matcher, accelerator structure used normally, which allows small emittance growth, a high accelerated current and low parameter sensitivity. This choise of a modest electrode volage and the short RFQ length are favour of the rf- and mechanical design, the total power consumption and the cost of such a system [3].

RFQ

The RFQ for the HLI at GSI accepts charged ions from the ECR ion source with energy of 4 keV/u and ion currents of up tp 5 mA. The operation frequency will be 108.48 MHz.

Beam Dynamics

The beam dynamics design does an adiabatic variation of the RFQ parameters to shape, bunch and accelerate the beam [4]. We optimized the design to get a rather short structure with $L_{RFQ} = 2m$

Table 1: RFQ Beam Dynamics Design Parameters

Operation frequency	108.48 MHz
Injection energy	2,5/4 keV/u
Operation energy	0.3 MeV/u
Mass to charge ratio for cw-operation	6
Transverse acceptance	200 mm mrad
Maximum input beam current	5 mA
Output transverse emittances (n,rms)	0.1 mm mrad
Output energy spread	± 3 keV/u
Output phase spread	± 20 degrees
Electrode length	1.99 m
Cell number	153
Intervane voltage	55 kV

Results of particle dynamics simulations show the RFQ output transmission and emittances for different beam input emittances and currents. These show low emittance growth and very high transmission also for $I = 5mA$.

The extraction energy for both sources will be raised from 2.5 keV/u now to 4.0 keV/u. This value states a compromise between optimal ion extraction for the MS-ECRIS and the limits of the present CAPRICE ECR [5].

Table 2: RFQ Beam Emittances

$\epsilon_{out \ r}^{n., rms}$ [π mm-mrad] (90/100%), 0mA	0.07 / 0.102
$\epsilon_{out \ z}^{rms}$ [π keV-deg] (90/100%), 0mA	73 / 97
$\epsilon_{out \ r}^{n., rms}$ [π mm-mrad] (90/100%), 5mA	0.07 / 0.103
$\epsilon_{out \ z}^{rms}$ [π MeV-deg] (90/100%), 5mA	47.5 / 58

Beam dynamics simulations have been done with Parmteqm Vers.3.07. This allows applying a Crandall-Output cell with low divergence of the beam. The final design has good emittances in both axial and radial direction, a very high transmission.

The beam dynamics design is very flexible, it allows rather large variations of the input beam parameters and has good output beam quality.

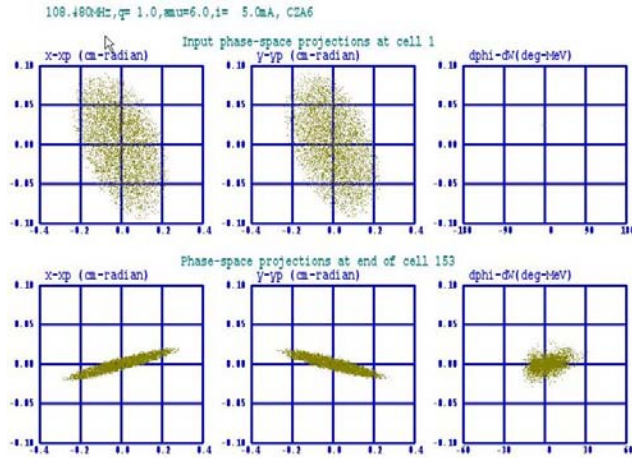


Figure 2: RFQ emittances for I = 5 mA.

4-Rod-RFQ-Structure

The 4-Rod-RFQ consists of a chain of $\lambda/2$ resonators which are operated in π -0-mode, to have opposite voltage on the adjacent electrodes and constant voltage along the RFQ. It is possible to describe the basic cell of the 4-Rod-RFQ as a capacitively loaded line, at which the electrodes are the capacity and the stems the inductivity resp. the short line.

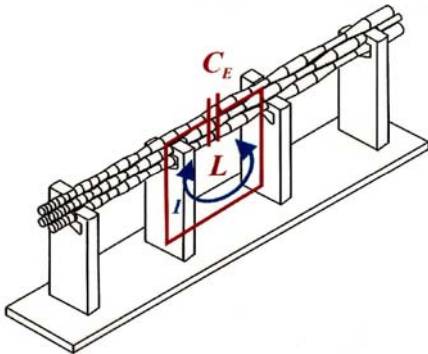


Figure 3: Basic cell of the 4-Rod RFQ structure

Table 3: 4 Rod Structure Parameters

4-Rod-RFQ	108,48 MHz
Tank diameter	350 mm
Tank length	2000 mm
Beam axis height	175 mm
Stem number	14
Stem distance / thickness	146 mm / 10mm
Aperture	5.2-2.96 mm
Modulation factor	1-1.99

Based on MWS-simulations and experimental results of similar low duty factor RFQs the structure power for the new HLI-RFQ is $P_S = 45$ kW. Two inductive tuners will perturb the field in the plane between the stems. The 3-1/8" power line will be fed in by a central coupling loop.

The RFQ-cavity is made out of a 5 cm thick wall tube, copper plated, with inner diameter of 350 mm. The resonant structure has a cooled base plate, the stems, sloped-electrodes and tuning-plates are also cooled.

The mechanical design is very stiff, avoids most welding for stress free, precise basic structure and by the use of the top lid allows rather easy installation, alignment, inspection and maintenance. At first a set of electrodes will be installed for a $T_i = 2.5$ keV/u using the existing ECR Ion-source because of problems with the new 28 GHz-ECR-source.

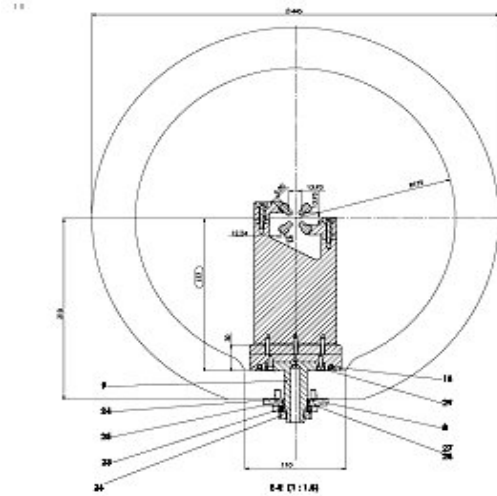


Figure 4: HLI-RFQ Cross section.

Mechanical Alignment and Tuning

The first step for the mechanical alignment is to mount the stems onto the base plate and insert this set-up into the cavity. For alignment in the tank, measurements of the distance between the backsides of the electrode bridge heads and the minima of the aperture are needed. This is done with a Tesla meter in vertical and horizontal plane. Afterwards the electrodes are attached on the stems in the

tank. To align them silver plated shims with a size of 4mm up to 6mm are fixed between the electrodes and the stems. They can easily be changed and machined in order to get the proper vertical position. To align the electrodes horizontal we can change their position by shifting them horizontally. The top flange of the tank serves as reference for these measurements. Our measurement equipment for the alignment in the tank is the FARO Gage plus meter with which we can quantify distances of planes easily. The results of measurement show, that the positions can be achieved better than $\pm 0,03\text{mm}$.

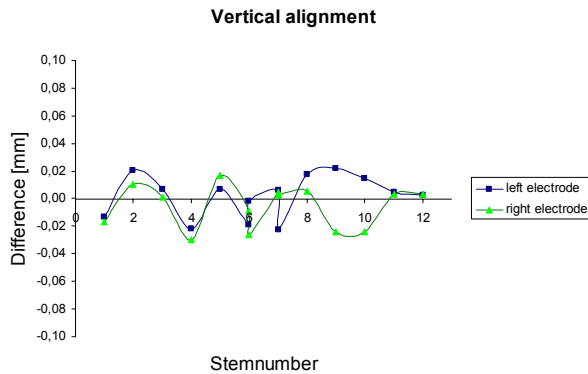


Figure 5: Alignment results of the electrodes.

A constant voltage on the electrodes of the RFQ is required for correct operation according to the beam dynamics design. For electrodes with no modulation and constant capacity a Microwave-Studio (MWS CST) simulation of the whole structure shows a parabolic field variation along the RFQ.

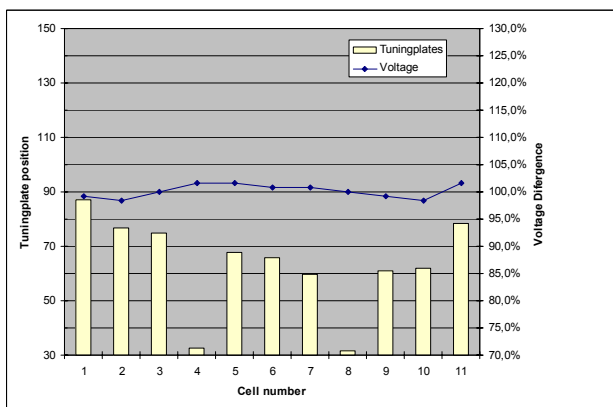


Figure 6: Electrode voltage distribution after tuning.

The tuning-plates change the local eigenfrequency and also the resonator frequency. So a combination of tuning plates position has to be found to match flatness and frequency. For the compensation of thermal effects and precise adjustment of the resonance frequency, two inductive piston tuners will be used.



Figure 7: Tuning plates with different positions between the stems.

First Measurements

Different measurements were carried out up to now. The first measuring results are to be seen in figure 6. Here the results of the ray introduction are to be seen for the transmission, the ion energy and the emittance whit different ions. All together the first tests of the HLI-RFQ were very promising. The tests shows that the works carried out during the construction phase, like alignment and HF coupling of the resonance structure were mastered successfully. The conditioning and the good transmission show that the HLI-RFQ will work. After these first tests it was begun with the heavy ion beam tests. For this 48 calcium $^{10+}$ whit a pulse achievement of 50 kW was used. The HF-pulse duration amounted to 6 ms whit a frequency of 50 Hz. The resonator voltage lay on 4.67 volts, and the measured transmission was about 70%. Since June nitrogen is tested, whit pulsed achievement of 90 kW.

STATUS

The resonant structure was inserted into the cavity. After the alignment, tuning and vacuum test the cavity has arrived in GSI Darmstadt. First measurements and beam tests have done.

REFERENCES

- [1] J. Friedrich et al., Performance of the GSI HLI-RFQ, EPAC 1992, Berlin, Germany (1992)
- [2] W. Barth et al., Performance for the Heavy Element Research at GSI-SHIP, Epac2006, Edinburgh, UK (2006)
- [3] P. Gerhard et al., Status of the UNILAC-upgrade programme for the heavy element research at GSI-SHIP, EPAC08, Genoa, Italy (2008)
- [4] A. Schempp, Design of Compact RFQs, Proc. of the 1996 LINAC Conf., Geneve (1996)
- [5] L. Dahl, UNILAC upgrades for coulomb barrier energy experiments, LINAC10, Tsukuba (2010)