STATUS OF THE HMI-RFQ-INJECTOR

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Abstract

The new injector of the ISL (Ionen-Strahl-Labor, Berlin) consists of an RFQ-section and an ECR-source. The RFQ-section consists of two closely coupled VE-(Variable Energy) RFQs. They are designed for direct injection into the cyclotron, with a small energy spread and a duty factor of 100 %. The status of the project will be discussed.

1 INTRODUCTION

The scientific program at the ISL, the former VICKSI- (Van de Graff Isochron Cyclotron Kombination für Schwere Ionen) facility has changed from nuclear physics to solid state physics [1]. The VICKSI-facility consists of two external injection beamlines, a Van-de-Graff and a Tandem injector with a separated sector cyclotron as postaccelerator. To meet the demands of the solid state physics users the Tandem injector will be replaced by a combination of an ECR-source mounted on a 200 kV platform and a two stage VE-RFQ. The ECR-RFQ-combination will accelerate the ions to energies between 0.09 and 0.36 MeV/n to cover the range of final energies out of the cyclotron between 1.5 and 6 MeV/n.

2 RFQ-PARAMETERS

To stretch the energy range of the injector the RFQ is split into two RFQ stages, mounted in one vacuum-tank. Each stage with a length of 1.5 m consists of a ten stem 4-Rod-RFQ-structure. With a power consumption of 20 kW per stage an electrode voltage of 45 kV at 85 MHz for q/a=0.125 and 35 kV at 120 MHz for a q/a=0.15 will be possible.

The RFQs will be driven in two different modes of operation. In the high energy mode both RFQs accelerate, the output energy of the cyclotron is between E_{out}=3 MeV/n and E_{out}=6 MeV/n with a harmonic number of 5 for the cyclotron. In the low energy mode the second RFQ has a detuned phase and works as a quadrupole transport channel. The energy range of the cyclotron in this mode is between E_{out}=1.5 MeV/n and E_{out}=3 MeV/n. The cyclotron works on the harmonic number 7. In both modes the frequency of the RFQ is tuned to the eighth harmonic of the cyclotron frequency.

A schematic view of the structure with the movable tuning plate to vary the frequency is given in figure 1, the main parameters of the RFQ and the cyclotron are given in table 1.

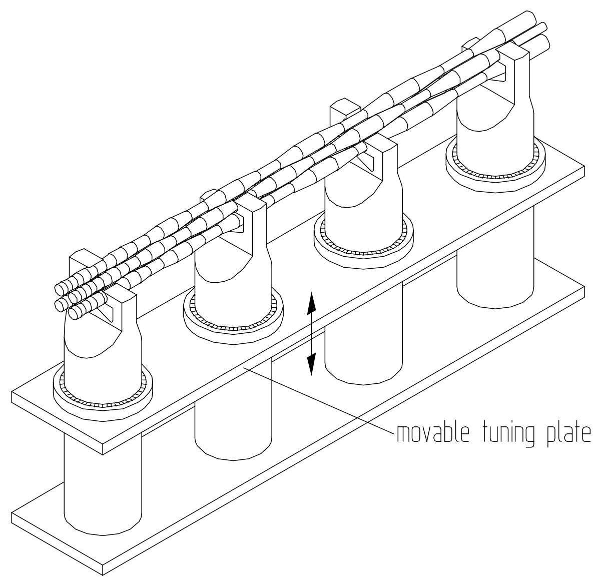

Figure 1: Scheme of the VE-RFQ.

RFQ:	low energy mode	high energy mode
Ein [keV/n]	15 / 30	
E_{out} RFQ1 [keV/n]	90 / 180	
E_{out} RFQ2 [keV/n]	90 / 180	180 / 360
energy gain factor RFQ1	6	
energy gain factor RFQ2	1	2
charge-to-mass-ratio	1/5 - 1/8	
frequency [MHz]	85 - 120	
electrode voltage [kV]	45	
length / diameter [m]	3 / 0.5	
Cyclotron:		
injection radius [m]	0.43	
extraction radius [m]	1.8	
frequency [MHz]	10 - 20	
max. dee-voltage [kV]	140 (peak)	
energy gain factor	16.8 - 18.6	

Table 1: Main parameters of the RFQ and the cyclotron

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The RFQ output emittance depends largely on the input conditions. For matched input beams with an energy spread $\Delta E/E < 1.5\,\%$, a normalized emittance $\varepsilon_n < 0.5\,\pi$ mm mrad and a bunch length $\Delta t < 1$ ns a transmission of 100 % is expected. To reach this beam quality it is necessary to have a buncher-chopper system between the ECR and the RFQs.

The ECR-source is mounted on the 200 kV platform formerly used for the Tandem. The vertical beam is bent 90°, passes through the buncher-chopper system and will be injected into the RFQs. The final matching into RFQ1 will be done by a triplet lens. The beam from RFQ2 is transported through the injection beamline of the cyclotron, to which a rebuncher has been added to obtain a proper time focus for the entrance of the cyclotron.

3 RF-PROPERTIES

The important rf-properties like Q-value, shuntimpedance, flatness and the relation between the movable tuning plate and the frequency as seen in figure 1 were calculated with the code MAFIA Ver. 3.2 [2] at the beginning of the project [3]. They are compared with the first low level measurements made in February 1997.

The main point of interest is the relation between the tuning plate position and the frequency as well as the dependence of the shuntimpedance and the Q-value on the frequency, as shown in figures 2, 3 and 4. The dots represent the measured values.

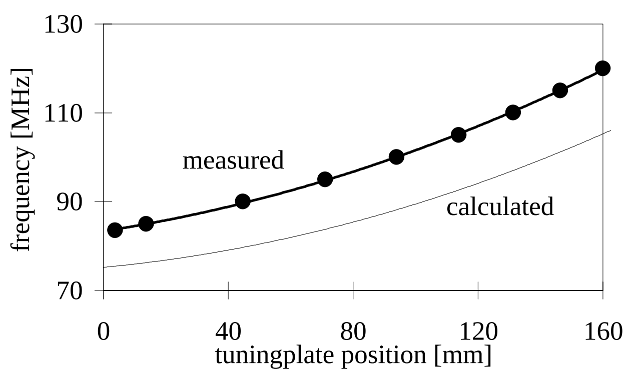

Figure 2: Relation between the position of the tuning plate and the frequency.

There is a good agreement of measurement and calculation in the way how the frequency varies by moving the tuning plate. As seen in several calculations before made with MAFIA the measured frequency is generally above the calculated one. The modulation of the RFQ-electrodes for the electrodynamical calculation is approximated by 4 unmodulated rods, which have the same capacity as a two-dimensional cut of four modulated rods with the average aperture. This approximation might be a reason for the offset.

Figure 3 shows the relation between the frequency and the Q-value, figure 4 shows the relation between the frequency and the shuntimpedance.

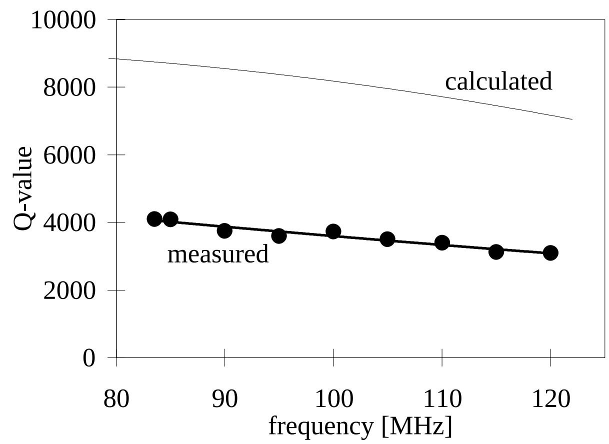

Figure 3: Relation between the frequency and the Q-value.

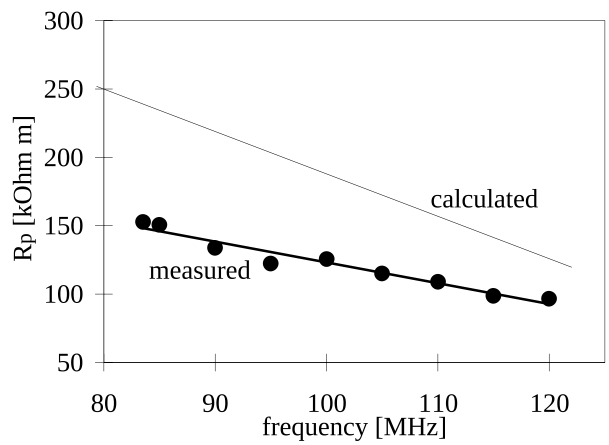

Figure 4: Relation between the frequency and the shuntimpedance.

There is a factor of 2 between the calculations and the measurements for the Q-value. This is a known effect of MAFIA and has been observed with other RFQ-resonators as well [4]. There are different reasons for the more optimistic results for complex structures. On the one hand a simplification for the electrodes is made, as explained above. On the other hand the transition resistance between the RFQ parts are totally neglected.

These effects are not intrinsic for MAFIA; due to the immanent computer limits, a limited matrix size of the resonator geometry has to be used. With a finer grid the results should fit better. Anyway, the code MAFIA is very helpful for structure optimization [5].

Another point of interest is the electrode voltage along the RFQ (flatness). Calculations have shown that the flatness is a function of the frequency. The value of 3 % at the highest frequency is noncritical and improves at lower frequencies, as shown in figure 5.

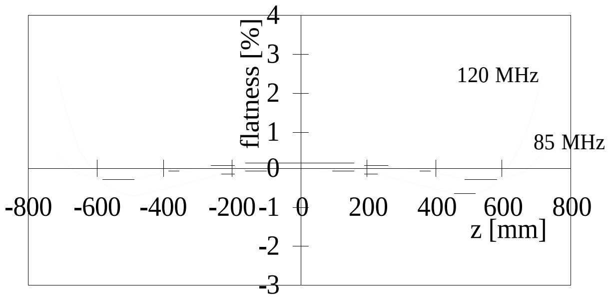

Figure 5: Calculated flatness .

4 STATUS AND SCHEDULE

The alignment of the electrodes of the two RFQ-stages is finished. The maximum misalignment in relation to the theoretical beamline is 70µm. The alignment was measured with an optomechanical system, having the electrodes readily assembled for operation, and not on a bench before mounting. Figure 6 shows a picture of the electrodes mounted in the chamber.

Figure 6: Electrodes mounted in the chamber.

First high power rf-tests started in March 1997, with 24 hours of operation with an preamplifier (rf-power 200 W). With full cooling operation and an adjusted transmitter controlling device the applied rf-power could instantaneously be increased to 20 kW in cw-mode in thermal equilibrium. No further frequency tuning of the resonator structure with the slow tuner was necessary. No ponderomotive effects were detected.

These tests confirmed the ability of the RFQ to work under the design conditions. The only cooling problems were caused by the slow tuner and the coupling loop. An improved tuner and a slightly modified cooling have been set-up in the meantime.

Testing of the second rf-transmitter with the 50 Ohm dummy load, the final tuning of the transmitter controlling device as well as the completion of the main computer control are the next steps to be undertaken at NTG in Gelnhausen.

REFERENCES

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