RF SETUP OF THE MedAustron RFQ*

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Abstract

A Radio Frequency Quadrupole (RFQ) was built for the injector of the cancer treatment facility MedAuston in Austria [1]. For the RF design simulations were performed using CST Microwave Studio® and the structure was manufactured by Firma Kress in Biebergemuend, Germany. The simulations and the RF setup of the delivered RFQ are presented in this paper.

INTRODUCTION

The 216.8 MHz MedAustron RFQ was designed to accelerate protons and carbon ions from 8 keV to 400 keV [2] on an electrode length of 1.25 m. It is a state of the art 4-Rod RFQ with quite slim electrodes and newly developed connections of the stems to the electrodes. Usually clamps were used to fix the electrodes to the stems (see Fig. 2). The accuracy of the machining allows us to remove the clamps. Simulations have shown that these new connections are causing less capacitance and hence less disturbing electric field than the clamps.
Fig. 1 shows the RFQ during its preparation at the Institute of Applied Physics (IAP) in Frankfurt am Main. More details about the RFQ basic design parameter can be found in Table 1.

Table 1: Design Parameters of the MedAustron RFQ

Parameter	Value	
Frequency	216.612	MHz
Input Energy	8	keV
Output Energy	400	keV
Beam Current (max)	4	mA
Aperture (min)	2	mm
Modulation Factor (max)	2	
Electrode Length	1250	mm
Intervane Voltage	70	kV
RF Cells	15	
Beam Height in Tank	19.5	mm
Stem Thickness	20	mm
Stem Distance	68	mm
Tank Length	1233	mm
Wall Thickness	40	mm

SIMULATIONS

Simulations have been performed using CST Microwave Studio® for the RF design. During this process two different shapes of the backside of the electrodes have been investigated. One is a broad and the other one a more narrow socket of the electrodes backside. A top view of the two different shapes is shown in Fig. 2.

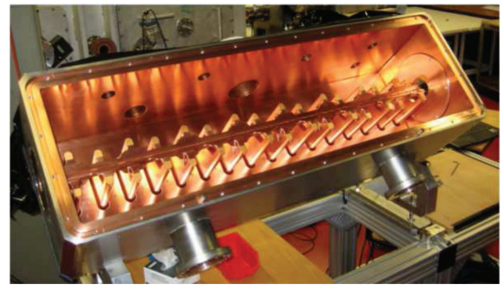

Figure 1: RFQ during preparation at IAP.

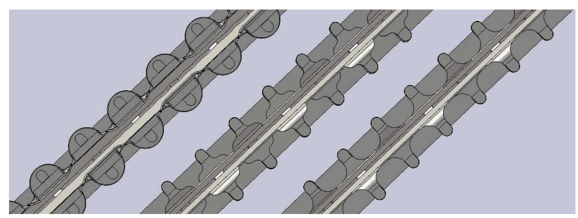

Figure 2: Former clamps (left), new broad (middle) and narrow (right) sockets.

Both shapes are rising the resonance frequency due to less capacitance compared to the old design with clamps. The broad shape increases frequency about one MHz more than the slim one, it shows less inductance and provides a fast and homogenous charge distribution on the electrode tips. Further informations about the RF characteristics of the connections of the electrodes can be found in [3].

MEASUREMENTS AND TUNING

Geometric Measurements

The accuracy of the machining and assembling of the single parts have been checked with a 3-D measurement device. The angle and the distance of the stems, the angle of the electrodes to each other and the position of the beam axis relatively to the reference surfaces have been measured. The measurements have met our expectations. Also no significant longitudinal electrode shift could be measured. Fig. 3 shows the measurement of the angle of the electrodes to each other and the longitudinal shift of the electrodes.

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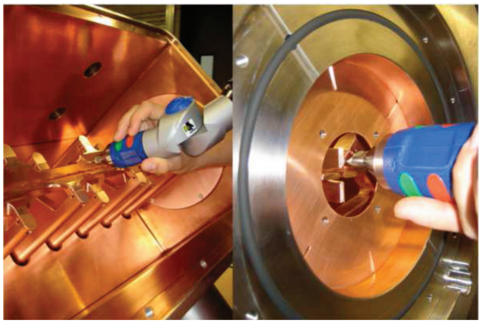

Figure 3: Measurements of the angle and the longitudinal shift of the electrodes using a 3-D measurement device.

RF SETUP

The frequency and flatness tuning have been executed in one procedure. First without the piston tuner to analyse the RF behavior of the RFQ. Later the final tuning was made with the inserted piston tuner on its zero position.

After investigation of the single influence of the tuning blocks, the piston tuner and the input power coupler on frequency and flatness, all the parts together have been adjusted and tuned. The tuning blocks have been fixed with silver screws on individual distance parts made of copper. The whole procedure is very similar to the tuning of the FNAL RFQ described in [4].

Flatness

For operation a homogenous longitudinal voltage distribution (flatness) of the electrodes is required according to the beam dynamics design. By changing the height of the tuning blocks the frequency of the RFQ and the local eigenfrequency of a single cell can be adjusted. Hence an uneven voltage distribution, caused by the modulation of the electrodes or inaccuracies by manufacturing of the RFQ, can be adjusted. The typical banana shaped flatness of the untuned MedAustron RFQ is shown in Fig. 4. It has an unflatness of about ±10 %.

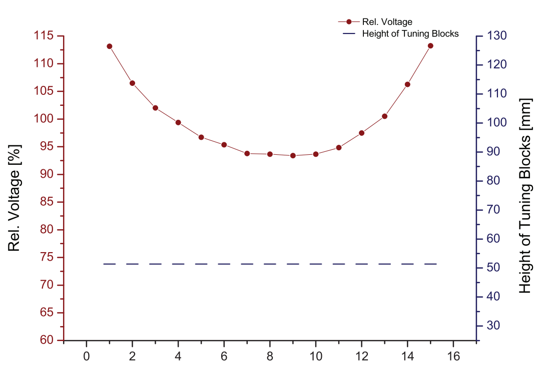

Figure 4: Untuned flatness with equal heights of the tuning blocks.

The flatness tuning is an iterative process to get an equal voltage distribution along the electrodes [5]. Each RF-cell is detuned using a perturbation capacitor (see Fig. 5). From the detuned RF-cell one can calculate the longitudinal voltage distribution of the electrodes. After this a next guess of the tuning block distribution can be made to improve the flatness.

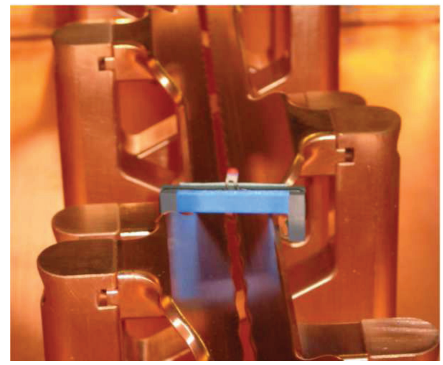

Figure 5: Pertubation capacitor used to detune each cell of the RFQ.

Piston Tuner

The frequency of the RFQ can change under operation due to several reasons. To correct the frequency a piston tuner is used. It has an influence on the resonance frequency by suppressing the magnetic field [6], but it is changing the flatness as well. If the flatness is not adjusted with an inserted tuner it may decrease of about ± 0.8 %. The piston tuner is placed in the middle of the cavity, its influence on the frequency is shown in Fig. 6.

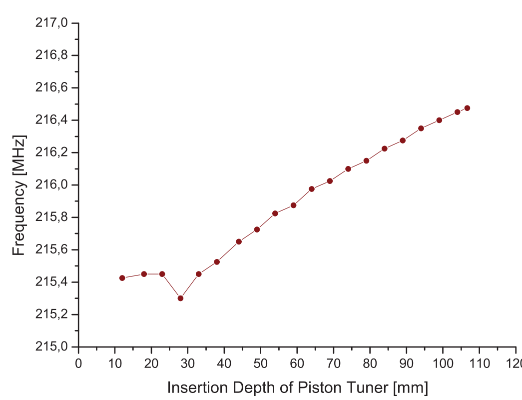

Figure 6: Frequency shift due to the piston tuner.

One can see that the insertion depth of the piston tuner has an almost linear influence on the resonance frequency of the RFQ. Before it enters the RF-cell between the stems it has only weak influence on the frequency. Then there is a small region where it disturbs the resonance of the structure. This means one has to regard a minimum insertion depth of the piston tuner. When it enters the RF-cell between the stems it rises the frequency with its depth with an approximately linear behavior.

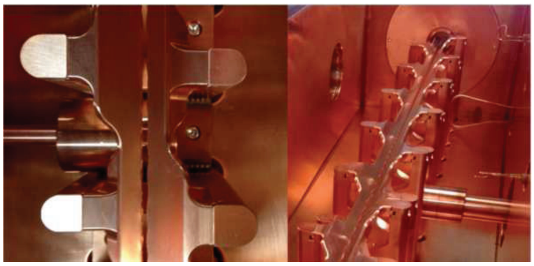

Figure 7: Top and side view of the piston tuner.

RESULTS

After the tuning process the resonance frequency was adjusted to 216.6 MHz with a deviation of the longitudinal voltage distribution of ± 1.7 %. This flatness with its distribution of the tuning blocks is shown in Fig. 8.

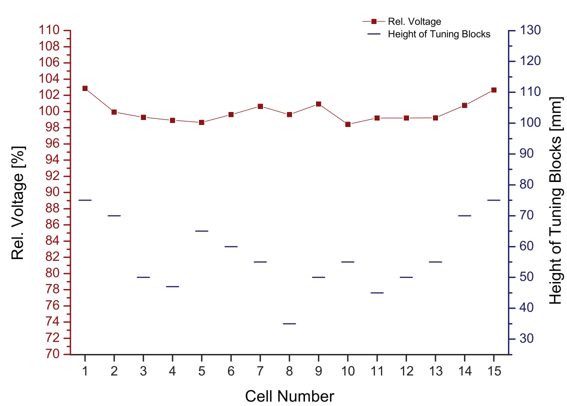

Figure 8: Final flatness and distribution of the tuning blocks.

Finally the piston tuner has been set to be able to adjust the frequency from minimum of 216.4 MHz to maximum 216.9 MHz. This values might rise about 0.1 MHz under vacuum. The overall shift of the piston tuner is about 0.5 MHz. The power coupler has a reflection of -27 dB.
The shuntipedance measured with an perturbation capacitor was 92 kΩm. The RF parameter of the MedAustron RFQ are summerized in Table 2. Overall the tuning process took several weeks and has led to quite satisfactoring results.

Table 2: RF Parameters of the MedAustron RFQ

Parameter	Value	
Frequency	216.612	MHz
Quality Factor Q_0	3600	
Voltage Distribution	± 1.7	%
Shunt Impedance	92.57	kΩm
Reflection Power Coupler	-27	dB
Transmission Pickup 1	-40	dB
Transmission Pickup 2	-39	dB
Transmission Pickup 3	20	dB

OUTLOOK

The MedAustron RFQ has been delivered at the end of July 2012. The ion source, the low energy beam transfer line and the RFQ will be commissioned at the Injector Test Stand (ITS) at CERN [7]. The test stand provides the possibility to prepare the LEBT independently from civil engineering in Austria. As soon as the building is ready the LEBT can move to Wiener Neusadt for commissioning and start of operation [8].

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