TUNING OF THE 4-ROD RFQ FOR MSU*

J. Schmidt, J. Maus, N. Mueller, A. Schempp, IAP, Univ. Frankfurt, Germany
O. Kester, NSCL, Michigan State University, East Lansing, MI, USA
J. Haeuser, Kress GmbH, Biebergemuend-Wirtheim, Germany

Abstract

A new reaccelerator facility ReA3 is currently under construction for National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU). As part of that project a new 3.5 m long 4-rod Radio Frequency Quadrupole (RFQ) has been build. This RFQ accelerates ions with a Q/A ratio of 0.2 up to 0.5 from an input energy of 12 keV/u to the final energy of 600 keV/u. We have designed the 80.5 MHz-RFQ with a square cavity cross section. It was build and tuned in Frankfurt and has been delivered to MSU. The design and the tuning process of the ReA3-RFQ will be discribed in this paper.

INTRODUCTION

The RFQ discribed in this paper is part of the new reaccelerator facility ReA3 of NSCL at Michigan State University. Experiments with reaccelerated beams are of high interest for example in astrophysics. Highly charged rare isotops can be produced with energies from 0.3 MeV/u up to 3 MeV/u for ions with Q/A=0.25 in a very high quality to be used for nuclear science experiments.

The setup of the ReA3 reaccelerator facility is shown in Fig. 1. The stopping process of the rare isotopes is based on a gas stopping installation. The charge of these isotopes is then increased in an EBIT, from where the beam is send to the reaccelerator with the room temperature RFQ and a superconducting linac.

RFQ

The RFQ for the ReA3 facility at MSU accepts ions from the EBIT with an energy of 12 keV/u. The operation frequency is 80.5 MHz with an intervane voltage of 86.2 kV for Q/A = 0.2 . It has a square cross section and is designed for cw duty cycle. The main parameters of the ReA3-RFQ are summerized in Table 1.

The RFQ-cavity has a square cross section and is made out of a 50 mm thick wall, with an inner edge length of 390 mm. The resonant insert of solid stems and vane shaped electrodes are water cooled. Instead of a base plate the RFQ has cooled tuning plates in each cell, which allow a flexible voltage adaption.

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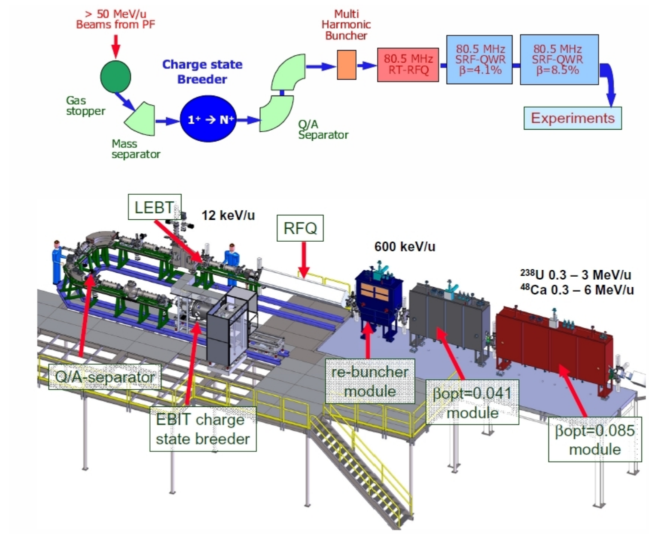

Figure 1: Overview of the Reaccelerator Facility Setup of the ReA3 at MSU [1].

In the new square layout the stems are inserted from the outside. The cooling tubes lie at the side of the stems and are also connected outside the tank. As one can see in Fig. 2 the shape of the cavity has only little influence on the fields of a 4-rod RFQ structure, because it is concentrated around the stems. So there are very low currents on the cavity walls. Because of that reason the tank is not copper plaited anymore. Due to the good thermal conductivity of aluminium the tank is made of this material. This design helps to decrease the number of water to vacuum brazes.

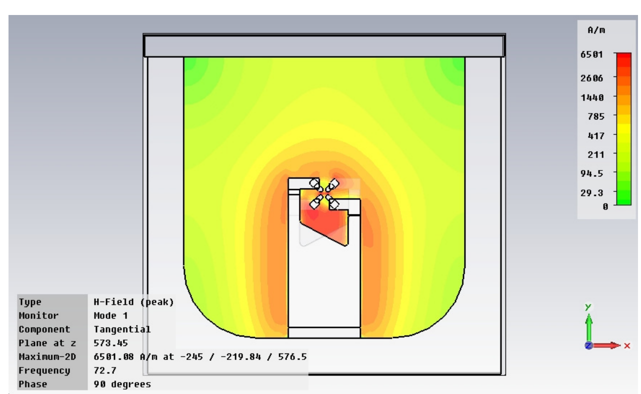

Figure 2: Magnetic field in the cross section of the ReA3 cavity.

Table 1: Characteristics of the ReA3-RFQ

Parameter	ReA3-RFQ value
resonance frequency	80.5 MHz
injection energy	12 keV/u (β=0.005)
final energy	600 keV/u
Q/A	from 0.2 to 0.5
max. A/Q	5
duty cycle	cw
acceptance	0.6 mm mrad (norm.)
modulation factor	1.15 to 2.6
intervane voltage	86.2 kV (Q/A = 0.2)
transmission MHB and RFQ	82 %
mid-cell aperture	7.3 mm
tank length	3.5 m
max. rf power	160 kW

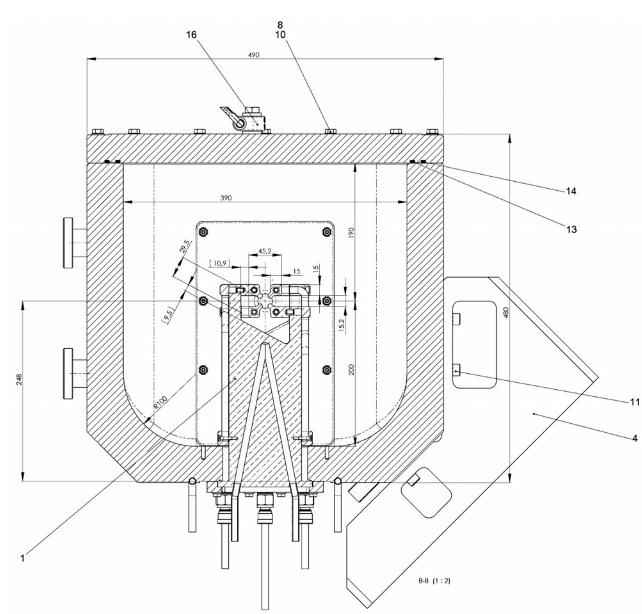

Figure 3: Scheme of the ReA3-RFQ with a square cross section and a sight of a stem and its cooling system.

RF Tuning

The 4-rod-RFQ consists of a chain of λ/4-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 as shown in Fig. 4, at which the electrodes are the capacity and the stems the inductivity respective the short line.

A constant voltage on the electrodes of the RFQ is required for correct operation according to the beam dynamics design. First measurements in the structure with a length of 3.5 meters have shown a resonance frequency of 78.5 MHz. At this frequency the difference between minimum and maximum of the longitudinal voltage distribution was about 6 %, which was already a quite good value.

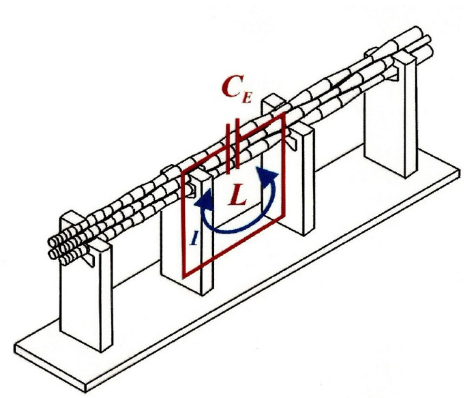

Figure 4: Basic cell of the 4-rod RFQ structure.

To balance this unflatness, tuning plates are readjusted between the stems. They change the local eigenfrequency of about 10 kHz per mm and are able to correct the voltage differences, which is measured with a network analyzer. So tuning plates in each cell are positioned at an individual height. As results of the tuning the difference in the quadrupole voltage along the electrodes is less than $\pm$ 1 %.

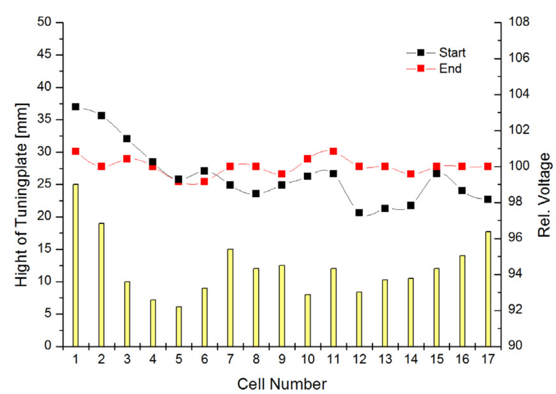

Figure 5: Relative longitudinal voltage distribution before (black) and after (red) the tuning. The bars show the positions of the tuning plates.

The voltage distribution and the positions of the tuning plates are shown in Fig. 5. The relative voltage distributions were measured with an pertubation capacitor placed on the electrodes.

This method was also used to calculate the shunt impedance R_{pL} given by the frequency shift Δf, the quality factor Q_0, a pertubation capacity ΔC and the resonance frequency f_0:

$$R_{pL} = \frac{2\Delta f Q_0}{\pi \Delta C f_0^2} \cdot l \quad (1)$$

Based on the avarage frequency shift of 119 kHz, a resonance frequency of 80.4 MHz and an avarage Q_0 of 4200, the shunt impedance is 200 kΩm.

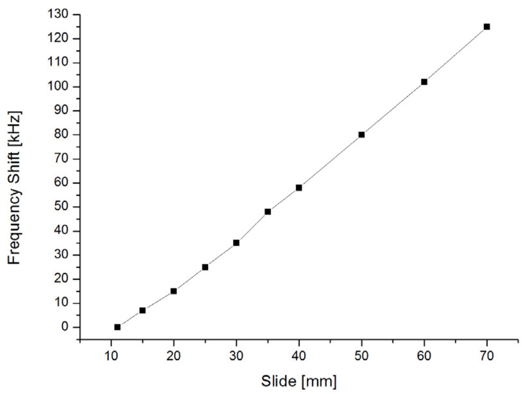

Figure 6: Frequency range of the tuners.

For the precise adjustment of the resonance frequency, two inductive piston tuners are used. They increase the resonance frequency up to 0.3 MHz. Fig. 6 shows, that the dependancy of the resonance shift on the postition of the tuners is almost linear. In their minimum positions the RFQ has a final resonance frequency of 80.4 MHz. The RFQ has a water cooled coupling loop. By adjusting the power coupler loop inside the cavity a reflection coefficient of -35 dB has been reached.
Two coupling probes are installed to control the output signals. They have transmission coefficients of -55 dB and -49 dB.

STATUS

The rf tuning was finished by the end of 2009. In the beginning of January, 2010 the ReA3-RFQ has been send to MSU and the fist performance tests are planend in May 2010.

Table 2: Final Parameters after RF-settings

Parameter	**ReA3-RFQ value**
resonance frequency	80.4 MHz
quality factor Q_0	4200
Tuner plunger shift (total)	300 kHz
voltage distr.	$< \pm 1\%$
shunt impedance	200 kΩm
reflexion power coupler	- 35 dB
transmission pick up 1	-55 dB
transmission pick up 2	-49 dB

The resonance frequency of 80.5 MHz and a variation in the longitudial voltage distribution of under ± 1 % were reached after tuning and the tuner plunger range of 300 kHz is satisfactorily. A quality factor Q_0 of 4200 and a final shunt impedance of 200 kΩm were measured. The power coupler has a reflection coefficient of S_{11} = - 35 dB and the pick ups are calibrated. Table 2 summarizes the final values of the rf adjustment.

REFERENCES

[1] O. Kester et. al., "The MSU/NSCL Re-Accelerator ReA3", SRF 2009, Berlin, Germany.

[2] A. Schempp, "Overview of Recent RFQ Projects", LINAC 2008, Victoria, BC, Canada.

[3] P. Fischer and A. Schempp, "Tuning of a 4-rod CW-Mode RFQ Accelerator", EPAC 2006, Edinburgh, Scotland.

[4] P. Fischer and A. Schempp, "Tuning CW 4-rod RFQ", LINAC 2006, Knoxville, Tennessee, USA.