POWER TESTS OF THE 325 MHz 4-ROD RFQ PROTOTYPE*

B. Koubek, H. Podlech, A. Schempp, J. Schmidt
IAP, Goethe University, Frankfurt, Germany

Abstract

For the FAIR project of GSI as part of the proton linac a 325 MHz RFQ with an output energy of 3 MeV is planned. Simulations that have lead to a prototype of a 4-Rod Radio Frequency Quadrupole (RFQ) have been done. The RF parameters have been verified with the prototype. Power tests of this 6 stem copper RFQ should now verify parameters like shunt impedance, electrode voltage and give answers of how much power the structure can sustain.

PROTOTYPE

Overview

Based on simulations using CST Microwave Studio® a prototype was built by our in-house workshop. The 6 stem 4-Rod RFQ prototype is made of copper with a water-cooled ground plate (see Fig. 1). The geometric parameters are listed in Table 1. After tuning of the RFQ also the resonant values have been measured and compared to the simulations (see paper [1]). The results concerning the tuning range and dipole field are summarized in Table 2.

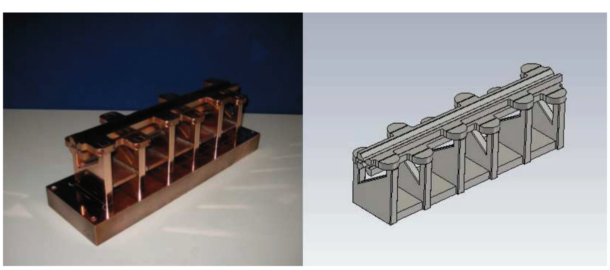

Figure 1: Prototype and Simulation Model.

Table 1: 325 MHz RFQ Geometric Parameter

Parameter	Prototype
Beam Line Position [mm]	65
Stem Width [mm]	63
Stem Distance [mm]	50
Mean Aperture [mm]	2.9
Electrode Tip Radius [mm]	2.5
Clamp Height [mm]	8
Clamp Broadness [mm]	26
Width of Stem Arm [mm]	10

* Work supported by BMBF

Table 2: RF Measurement Results

Parameter	Prototype
Frequency	
Tuning Range	
Tuning Plate min [MHz]	283.8
Tuning Plate max [MHz]	335.3
Tuning Plate Shift [mm]	20.2
Frequency Shift [MHz]	51.5
Dipole	
U/L TPh min	1.00
U/L TPh max	1.03

Measurements gave a quality factor of 2800 and a shunt impedance of 46.8 kΩ. With the RFQs length of 285 mm the R_{pL} value is 13.2 kΩm. This sounds initially quite low but as one can see in Fig. 2 the shunt impedance of different RFQ resonator types is strongly depending on its frequency. By approximation the shunt impedance is about $R_p \propto f^{(-3/2)}$ [2].

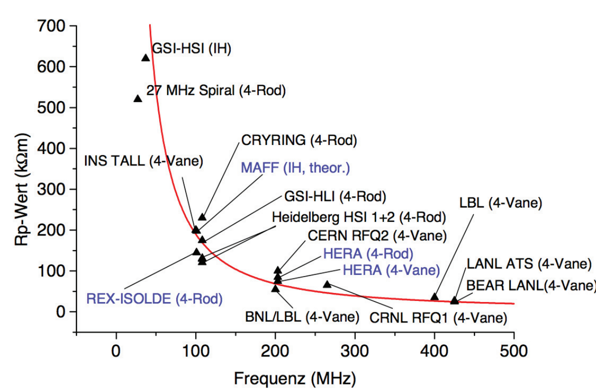

Figure 2: Shunt impedance and frequency correlation of different RFQ resonator types [2].

In addition on this short structure the electrode overlap is relatively high and causes comparatively much capacitance. On a length of about 3.2 m this capacitance would be compensated and increases the shunt impedance. Furthermore one would have expected a higher quality factor, but due to the production in house the copper surface is not very clean. It‘s quite scratchy and the connections of the single parts are not that good than they are at a RFQ which was made by a specialized manufacturer.

Figure 3: Prototype in cavity tank and its 1⁵/₈ inch coaxial transmission line.

SET UP

Low Power Conditioning

For the low power conditioning a 500 W amplifier was provided which was used mainly in cw mode. As transmission line N-type coaxial cabels are applied. Along the transmission line a circulator with a 2 kW load was mounted to protect the amplifier. A bidirectional coupler as well as a pickup probe on the cavity are used together with power meters to observe the input power by measuring the forwarded, the reflected and the transmitted power. A schematic setup is displayed in figure 4. On one side of the cavity a glass window was flange mounted to observe discharges.

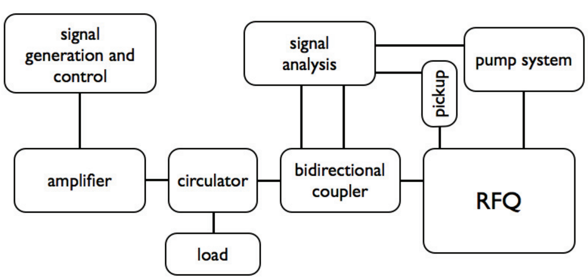

Figure 4: Schematic experimental setup.

High Power Tests

For high power tests a 325 MHz 40 kW amplifier made by DB Elettronica in Italy is provided with a duty cycle of 1 % and a pulse length of 2 ms at 5 Hz. For the RF power transport 1⁵/₈ inch coaxial transmission lines are used. The load was replaced by a 10 kW water cooled load. Power meters, NWA, spectrum analyzer provided for controlling and observing the tests. The power supply and measurement devices are shown in Fig. 5

Figure 5: Power supply and measurement devices.

LOW POWER TESTS

By carrying out vacuum tests of the cavity a pressure of $3.6 \cdot 10^{-7}$ mbar was achieved, before we started low power conditioning.
At the beginning the RFQ did not accept power very well. Almost all the forwarded power was reflected and multipacting could be observed at very low power levels. In Fig. 6 one can see this behavior on the uncalibrated pickup signal at the cavity over approximately 1.5 hours. Then a forwarded power of 2 W was provided overnight.

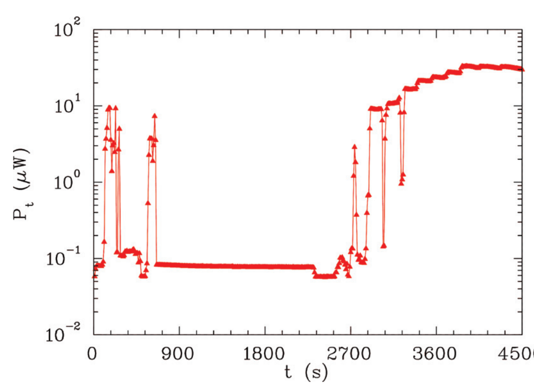

Figure 6: Uncalibrated pickup signal day one.

On the next day a cw power of 50 W was accepted, later it was rising up to 350 W (see Fig. **??**) but still with glowing discharges going along with unstable pressure in the cavity.

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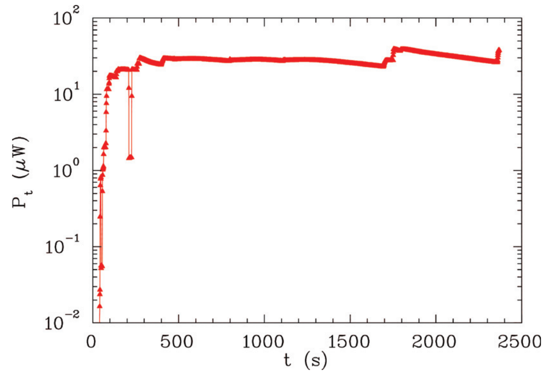

Figure 7: Uncalibrated pickup signal day two.

Due to the warming of the structure during low power conditioning the frequency had to be adjusted manually because the cavity was not equipped with a piston tuner. Also the water cooling wasn‘t mounted at that time. This explains the quite unstable input power curve during low power conditioning in Fig. 7.

After another day it was getting much better and the RFQ accepted up to 450 W cw power, still sometimes with glowing spots (see picture 8) but with quite stable pressure.

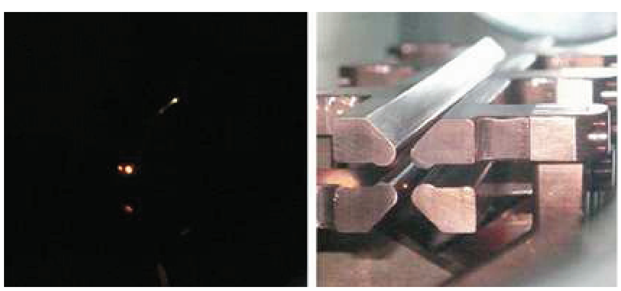

Figure 8: Glowing spots on the RFQ structure during low power conditioning.

At 350 W some thermic pictures were taken. One can see the temperature of the cavity and the circulator with the water cooled load in figure 9. Due to the low warming of the structure we did not use the water-cooling on the RFQs ground plate during low power conditioning.

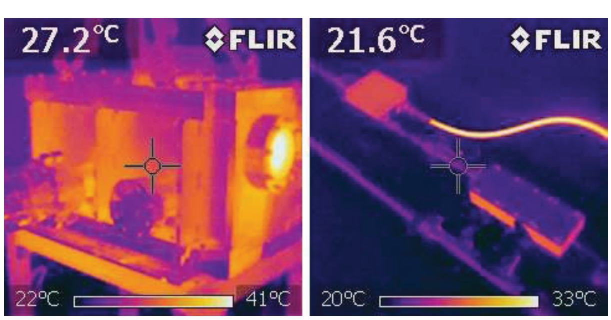

Figure 9: Thermal image of the RFQ cavity and the transmission line, the circulator and the water cooled load.

By switching from cw into pulse mode Fig. 10 was taken on the oscilloscope. It shows stable pulses at an input power of 360 W. From top to bottom it is shown the forwarded, the transmitted and the reflected power.

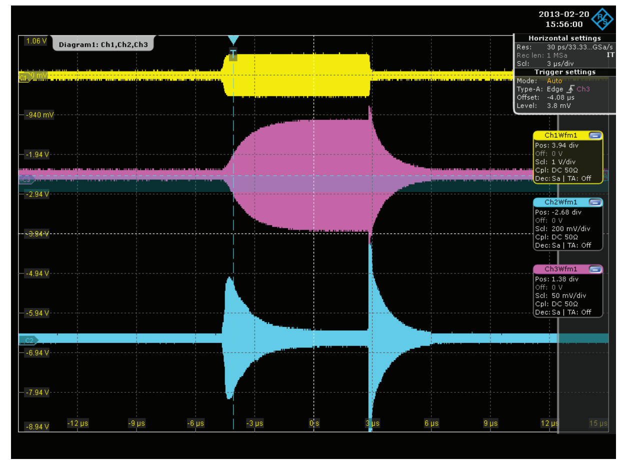

Figure 10: Pulse signals of forwarded, transmitted and reflected power (from top to bottom) at 360 W.

OUTLOOK

The low power conditioning up to 450 W was successfully completed. Now the 40 kW amplifier is installed and the N-type coaxial cabels are replaced through 1 5/8 inch coaxial transmission lines. Also the 2 kW load was replaced through a 10 kW water cooled load. After some problems on the transmission line we started the power tests but still have some minor problems with the amplifier to go on higher power levels. When these challenges are solved we are looking forward to perform the high power tests. It is planned to check how much power the cavity can sustain. The electrode voltage depending on the input power will be measured by using gamma spectroscopy. Beyond that the gamma spectroscopy will enable us to verify the shunt impedance as well.

REFERENCES

[1] B. Koubek, J. Schmidt, A. Schempp, L. Groening, “STATUS OF THE 325 MHz 4-ROD RFQ”, IPAC’12, New Orleans, USA

[2] T. Sieber, “Entwicklung von 4-Rod- und IH- Radio-Frequenz-Quadrupol (RFQ)-Beschleunigern für radioaktive Ionenstrahlen bei REX-ISOLDE und MAFF”, PhD Thesis, 2001, München, Germany

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