

## A CW RFQ PROTOTYPE\*

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### Abstract

A short RFQ prototype was built for tests of high power RFQ structures. We will study thermal effects and determine critical points of the design. High frequency simulations with CST Microwave Studio, and measurements, were done. The RF-tests with continuous power of 20 kW/m and simulations of thermal effects with ALGOR were finished successfully. The focus now is on optimization of some details of the facility. First results and the status of the project will be presented.

### INTRODUCTION

As a first section behind the ion source, the RFQ bunches the low energy DC beam adiabatically, keeps it focused, and accelerates the bunches to be accepted at the following drift tube linac (DTL) structures. The 4-rod design was developed at the IAP as a flexible, stable, efficient and economic RFQ version [1]. To be compatible with high power linac structures for projects like FRANZ (IAP), FAIR (GSI) and FRIB (MSU), a new RFQ prototype was built primarily to study thermal effects.

### SPECIFICATION

Table 1 shows the general layout parameters of the new RFQ model; its parameters are based on experience with the SARAF RFQ [2].

An extended frequency tuning range is provided by water-cooled tuning plates. Stems and electrodes are cooled separately. The connecting parts between electrodes and stems are more massively designed to give better thermal properties there. Instead of the traditional circular tank cross section the cheaper, easier to produce rectangular cross section was chosen.

### CONSTRUCTION

Figure 1 shows an overview and some details of the new model. Note the compactness of the assembled copper parts for effective thermal conduction.

### SIMULATIONS AND MEASUREMENTS

CST Microwave Studio is a program to simulate HF resonator structures. After virtual construction in a 3d graphic, it solves the Maxwell equations by using a dual grid with a defined number of mesh cells. A matrix algorithm gives exact results for every infinite cube. [3]

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Table 1: General Layout of the New Prototype

Specification	Technical data
Realisation	4-stems model of assembled copper parts; no electrode modulation
Length	520 mm
Distance, stem to stem	146 mm
Distance, bottom to beam axis	182 mm
Aperture	7 mm
Tuning plate variability	20–110 mm
Vacuum tank dimension	550×262×254 mm <sup>3</sup>

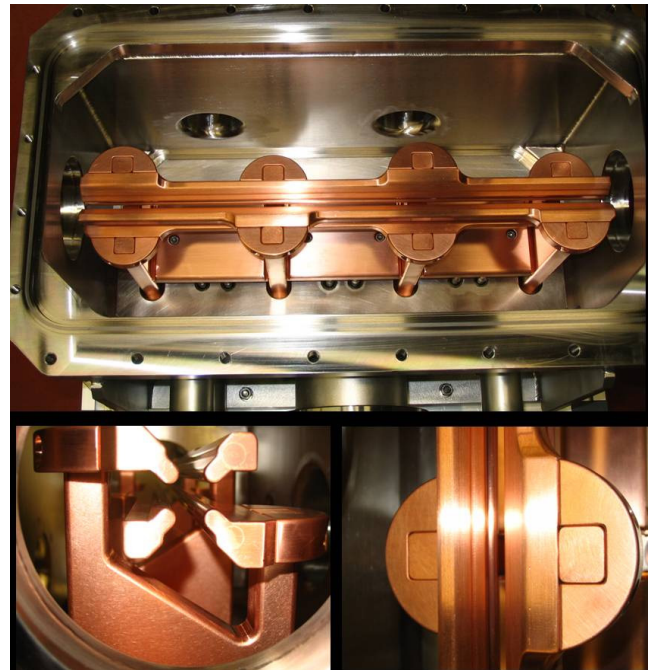


Figure 1: The new cw RFQ prototype.

The following simulations were made with 1 million mesh cells. Figure 2 shows a diagonal view of the computer model inside the tank. Table 2 gives an overview of the simulated and measured results.

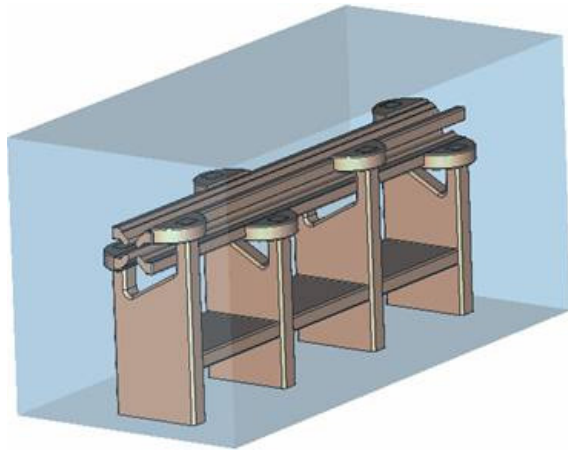


Figure 2: The new prototype in CST.

Table 2: Overview of the Resonator Parameters

Resonator parameter	Simulated value	Measured Value
Qualityfactor	Q=4700	Q=3200
Shunt impedance	$R_p=179 \text{ k}\Omega$	$140 \text{ k}\Omega \pm 20\%$
Frequency range	104-154 MHz	
Flatness	$\pm 1.2\%$	$\pm 1.5\%$

The simulated values correspond to the measured ones. A wide frequency range, achieved by changing the height of the tuning plates, is a feature of the new RFQ prototype, making its capabilities very flexible. CST interprets the whole structure as being made in one piece, and calculates a Q and a shunt impedance  $R_p$  20–30% than the measured values. With unmodulated electrodes the variation of the flatness is  $\pm 1.5\%$  (simulated  $\pm 1.2\%$ ). The measured performance is very close to the simulation.

### RF TESTS

RF tests are relevant to check out the temperature distribution and the capability of the structure at cw-operation. The tests with a continues power of 20 kW/m were done successfully after getting over the multipacting barriers. Figure 3: The thermal distribution on the stainless steel tank surface is shown on the infrared image.. It corresponds with the MWS simulated surface currents above.

Using a stainless steel tank makes it possible to achieve a thermal distribution on the tank surface while stationary operation, because the electrical and thermal conductivity are in each case seven times less than using copper.

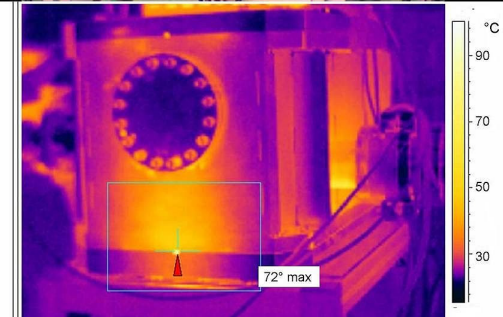
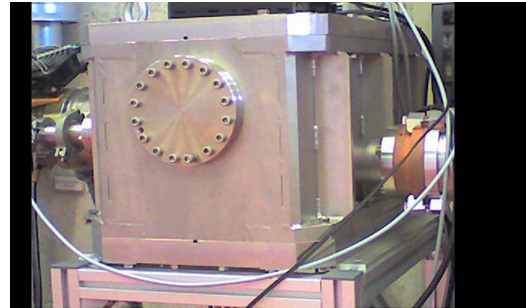
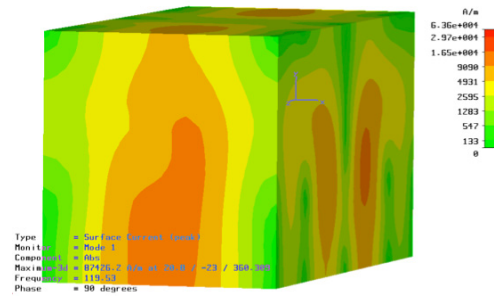


Figure 3: Similarity of surface currents and temperature.

### SIMULATIONS WITH ALGOR

With the software *ALGOR* it is possible to simulate a steady state temperature distribution by allocating the surfaces of the structure with, for example, heat flux or convection cooling [4]. It is possible to “look inside” and to gate out surfaces.

Without cooling the only way for the heat (from a 10 kW heat flux) to escape is over the ground plate of the vacuum tank, with a maximum temperature of nearly 700° C. The temperature goes down to 35° C maximum after switching on the cooling (Figure 4).

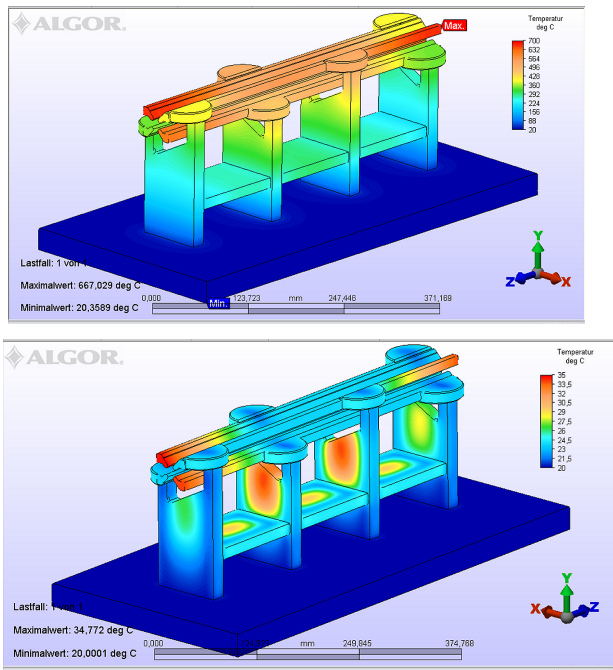


Figure 4: Without (upper image) and with cooling.

**OPTIMIZATION: THE DIPOLE RATIO**

A 4-rod RFQ is a  $\lambda/4$ -resonator structure. The stem height is responsible mostly for the inductance, and the geometry of the electrodes for the capacitance, of the LC resonator. The voltage increases linearly from the bottom up to the beam axis. The difference  $\Delta h$  between the height of the lower and upper electrodes causes a dipole ratio (Figure 5).

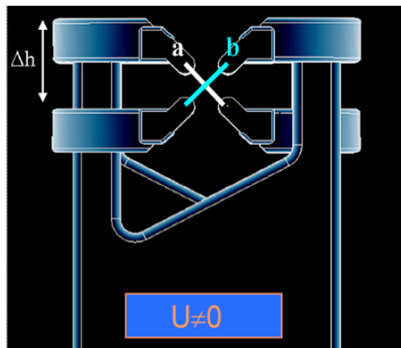


Figure 5: Two crossbred dipoles.

The integral of the E field along tracks *a* and *b* is shown in Figure 6 along the beam axis. Both curves (a+b) of the dipole ratio add up to 12% of the total accelerating voltage.

The dipole ratio increases with the height of the tuning plates. For flatness and frequency adaption the tuning plates should be lifted not too close to the beam axis.

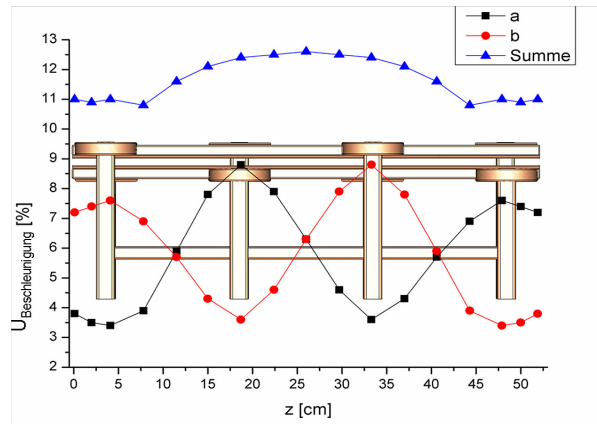


Figure 6: The dipole ratio in detail.

To reduce the dipole ratio, the stems have a diagonal cut out with a defined angle (Figure 7). This modification becomes more effective for RFQ structures with a higher resonator frequency.

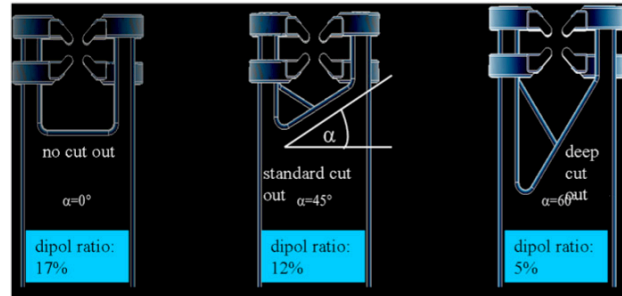


Figure 7: Optimization of the dipole ratio.

**CONCLUSION AND OUTLOOK**

The new RFQ prototype is a 4-rod RFQ LINAC structure especially for high duty cycle and cw operation. The simulations and measurements were a reasonable basis for the RF tests with a continuous power of 20 kW/m. The tests were done successfully. Simulations with ALGOR gave a realistic image of the temperature distribution of the surface of the RFQ structure with and without using the cooling system. The optimizing of some critical points of the 4-rod RFQ design was done by simulation with MWS.

Next steps will be the realisation of the optimized design in further RFQ structures.

**REFERENCES**

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