A CW RFQ PROTOTYPE*

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Abstract

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

INTRODUCION

As a first section behind the ion source the RFQ bunches the low energy DC-beam adiabaticly, keeps it focused and accelerates the bunchs to be accepted at the following DTL-structures.

The 4-rod design was developed at the IAP as a flexible, stable, efficient and economic RFQ-version [1].

For high power LINAC structures for projects like FRANZ (IAP), FAIR (GSI) and FRIB (MSU) a new RFQ prototype to study primarily thermal effects was built.

SPECIFICATION

Table 1 shows the general layout of the new RFQ model with its parameters based on the 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. The traditional circular tank cross section was changed to a rectangular shape.

Table 1: General Layout of the New Prototype

Specification	Technical data
Realisation	4-stems model assembled copper parts, the electrodes have no modulation
Lengh	520 mm
Distance stem to stem	146 mm
Distance bottom to beam axis	182 mm
Aperture	7 mm
Tuningplate varribility	20-110 mm
Vacuum tank dimension	550x262x254 mm^3

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CONSTRUCTION

Figure 1 shows pictures of the RFQ. It articulates explicit the compactness of the assembled copper parts for an effective thermal conduction.

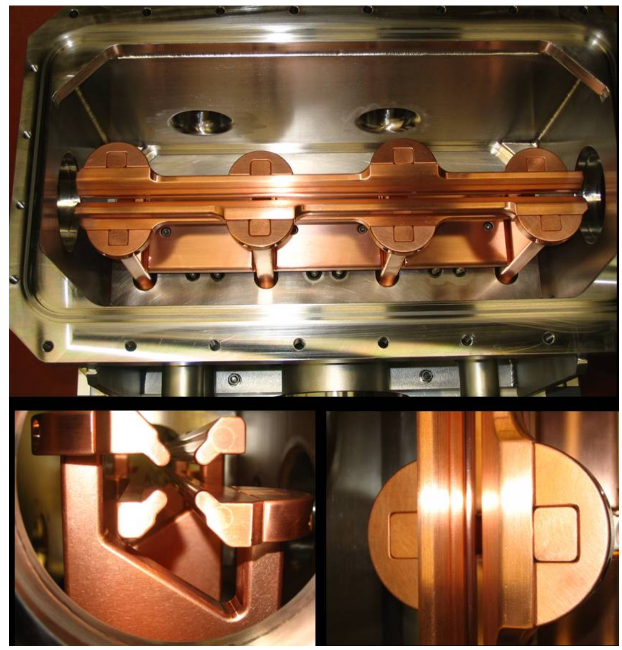

Figure 1: The new cw RFQ prototype.

SIMULATIONS AND MEASUREMENTS

CST Microwave Studio is a program to simulate HF-resonator structures. After a virtually construction in a 3d-graphic, it solves the Maxwell equations by using a dual grid with a defined number of mesh cells [3].

The simulations were done with 1 million mesh cells. Table 2 gives an overview of the simulated and measured results.

Table 2: Overview of the Resonator Parameters

Resonator parameter	Simulated value	Measured Value
Quality factor	Q=4700	Q=3200
Shunt impedance	Rp=179 kOhm	140 kOhm ± 20%
Frequency range	104-154 MHz	
Flatness	±1,2%	±1,5%

The simulated values correspond to the measured ones. A wide frequency range is a feature of the new RFQ prototype, which arranges its capabilities very flexible. This is possible by changing the height of the tuning plates. CST interprets the whole structure as made in one piece and calculates a 20-30% better Q-factor and Rp-value as measured. With unmodulated electrodes the variation of the flatness constitutes ±1.5% (simulated ±1.2%). The measured performance is very close–by 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 2: The thermal distribution on the stainless steel tank surface is shown on the infrared image.. It corresponds with the MWS simulated surface currents above.

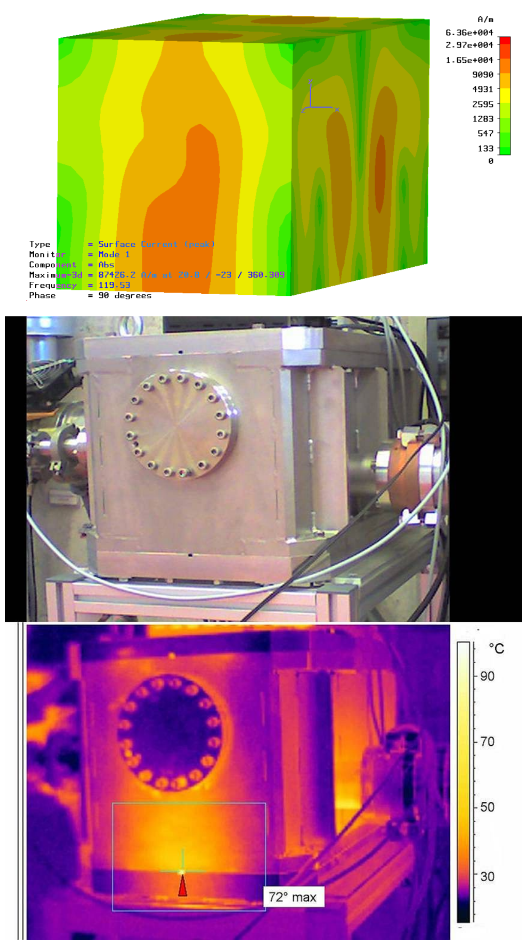

Figure 2: Similarity: Surface currents and temperature.

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.

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 cooling convection [4]. To look inside it is possible to gate out surfaces.

Without cooling the only way for the heat (10 kW heat flux) 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 3).

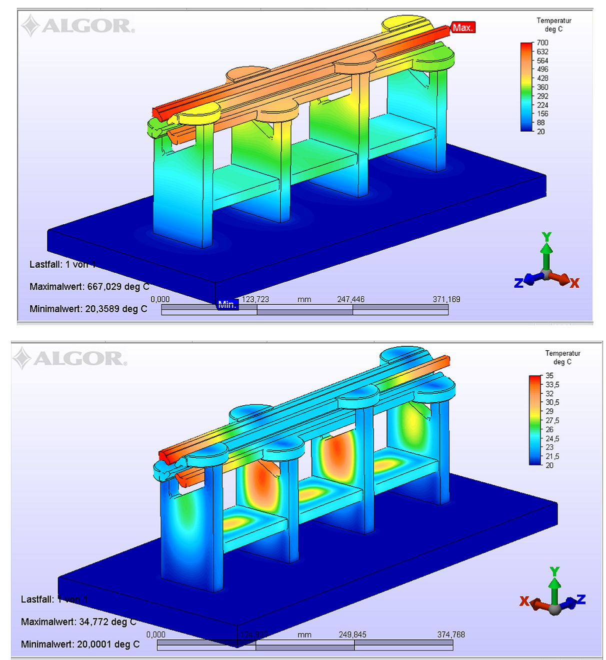

Figure 3: Without and with cooling.

OPTIMIZATION: THE STEMS

A 4-rod RFQ is a λ/4-resonator structure. The height of the stems is responsible mostly for the inductivity and the geometry of electrodes represents the capacity of the LC resonator. The currants are located mostly at the stems and along the tuning plates. To connect the stems with the flexible tuning plates is not trivial due to the high currants there (more than 100 A/cm at cw operation). A more massive design of the stems provides an augmented surface for the currents and enhances the cooling (figure 4). The positive effect for the RF-parameters is shown in table 3.

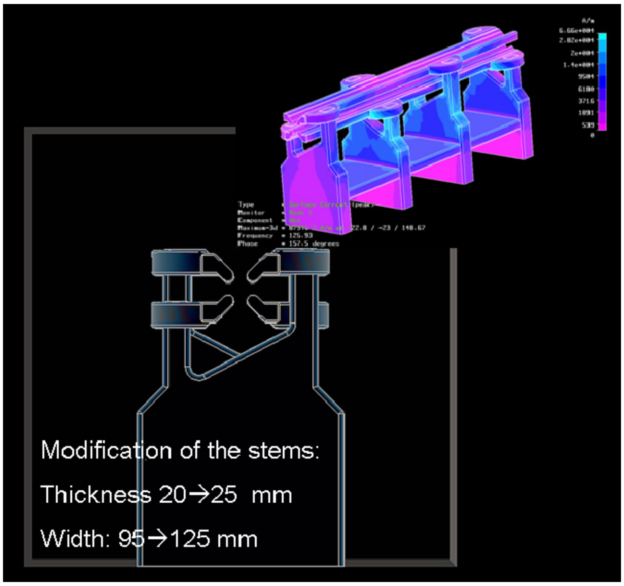

Figure 4: Modification of the stems.

Table 3: The Positive Effect of the Modification

Resonator parameter	Real Prototype	Modified Prototype
Quality factor	Q=4690	Q=5010
Shunt impedance	Rp=179 kOhm	183 kOhm
Frequency	119,9 MHz	125,9 MHz

OPTIMIZATION: THE TANK GEOMETRY

There are different aspects to make a decision about the design of the tank geometry. In figure 5 the distribution of the B-field (ABS) is shown inside different cross sections. The cylinder a) causes higher producing costs and maintenance of the RFQ is difficult but it is conform with the boundary conditions for the fields. So the shunt impedance is ca. 15% better than using the more economic and easyer to handle rectangular shape b). In a cuboid a part of the HF-power is needed to keep the E-field normal to the B-field especially inside the corners. The "American-postbox-design" c) would combine the advantages of a) and b).

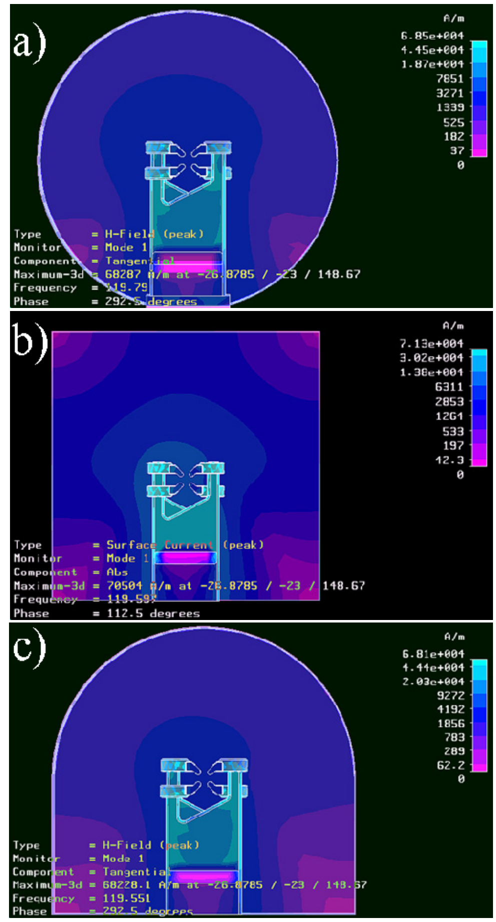

Figure 5: The magnetic field (ABS) inside the tank.

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 continues 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

[1] A. Schempp, „*Beiträge zur Entwicklung des Radiofrequenz-Quadrupol*" (RFQ)-Beschleuniger, Habilitationsschrift, IAP, Frankfurt am Main, 1990.

[2] P. Fischer, "*Ein Hochleistungs-RFQ-Beschleuniger für Deuteronen*", Dissertation , IAP, Frankfurt am Main, 2007

[3] Manual of CST Microwave Studio

[4] Manual of ALGOR Speedy Engineering