THE NEW 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. HF-Simulations with CST Microwave Studio and measurements were done. The RF-Tests with continues power of 20 kW/m were finished successfully. Simulations of thermal effects with ALGOR are 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 bunches 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].

To be compatible with 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 parameters 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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Using a rectangular tank geometry has the advantages: It can be produced easier and even more economic. The RFQ structure is mounted directly on the tank bottom without the massive ground plate, which is needed inside a cylindric tank. It gives a good access for adjustment, tuning and maintenance

CONSTRUCTION

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

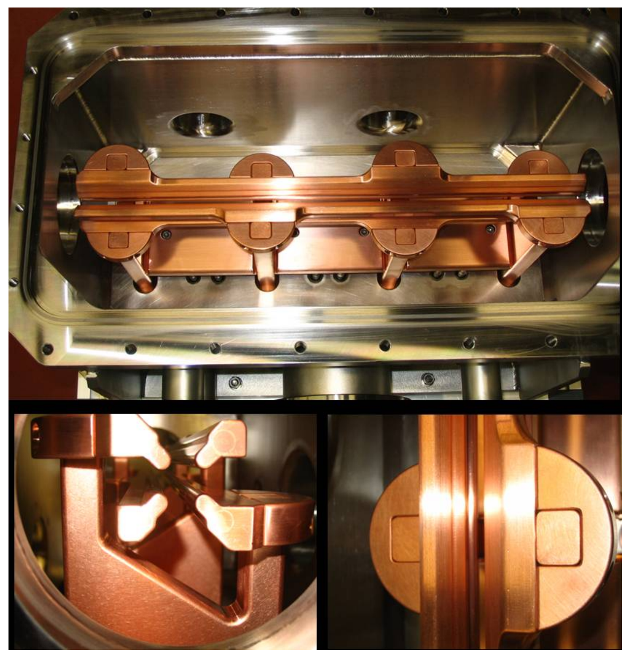

Figure 1: The new cw RFQ prototype.

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. A matrix algorithm gives exact results for every infinite cube [3]

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.

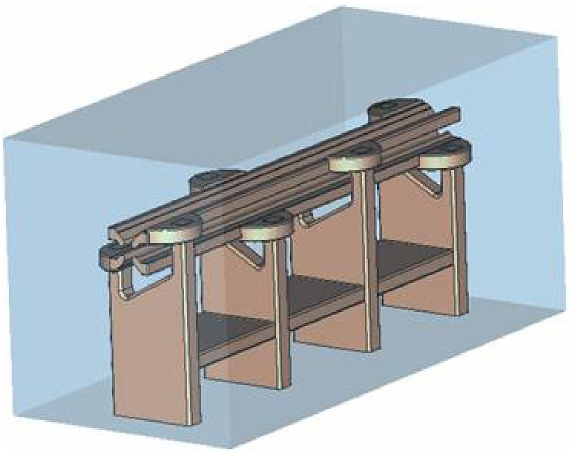

Figure 2: The new prototype in CST.

Table 2: Overview of the Resonator Parameters

Resonator parameter	Simulated value	Measured Value
Qualityfactor	Q=4700	Q=3200
Shunt impedance	Rp=127 kOhm	139 kOhm ± 20%
Frequency range	105-154 MHz (Fig. 3)	

Figure 3 shows the wide frequency range between minimum height and maximum height of the tuningplates.

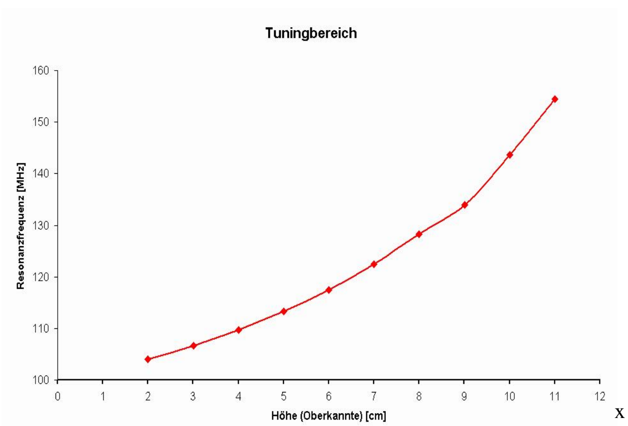

Figure 3: Frequency range. (x-axis: Tuningplate height)

The simulation of the flatness curve is shown in Fig. 4 with a variation of ca. 1.2 % of the normalized voltage along the beam axis. The measurement shows a variation of ca. 1.5%. This is a typical distribution for a symmetric RFQ structure with unmodulated electrodes.

Measured and simulated values for the frequency range are nearly equal. Both flatness curves (Fig. 4) are similar. For the determination of the Q value CST uses a one piece massive model made out of perfect conducting copper. But the real prototype is an assembly made out of separate parts. A lower measured Q value of 20 – 30 % is typical.

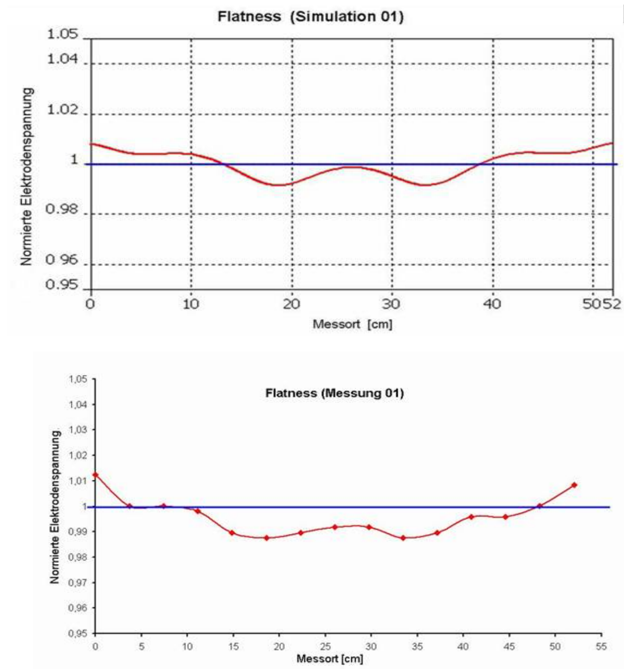

Figure 4: The flatness curve.

RF -TESTS

RF-tests are relevant to check the temperature distribution and the capability of the structure at cw-operation. Figure 5 shows the experimental setup.

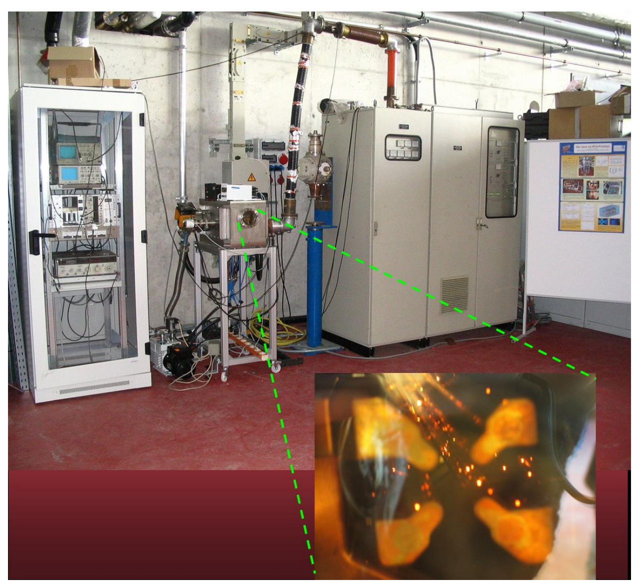

Figure 5: Experimental setup for RF-tests with a detail.

On .the left side is the circuit controlling unit followed by the prototype, which is connected with the HF-Power Amplifier on the right. The detail picture shows some lightning points on the surface of the tank window with an x-ray output of 50 µSv/h at 5 kW cw power. It was changed into a steel cover plate.

A similarity between simulated currents on the tank surface and measured temperature by using a infrared camera is shown in Fig. 6.

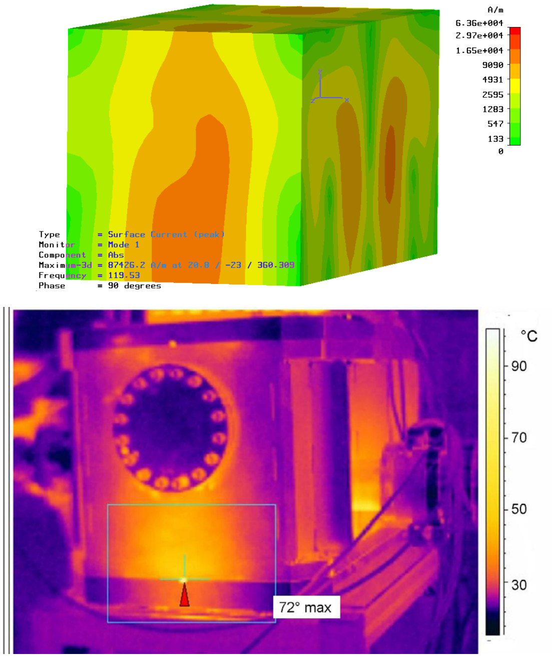

Figure 6: Similarity: Surface currents and temperature.

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 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 (Fig. 7). The temperature goes down to 35 °C maximum after switching on the cooling (Fig. 8).

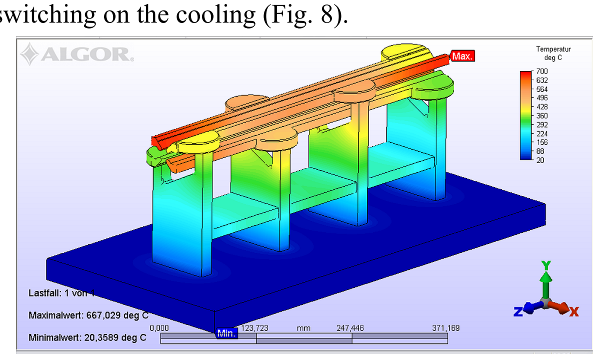

Figure 7: Without cooling.

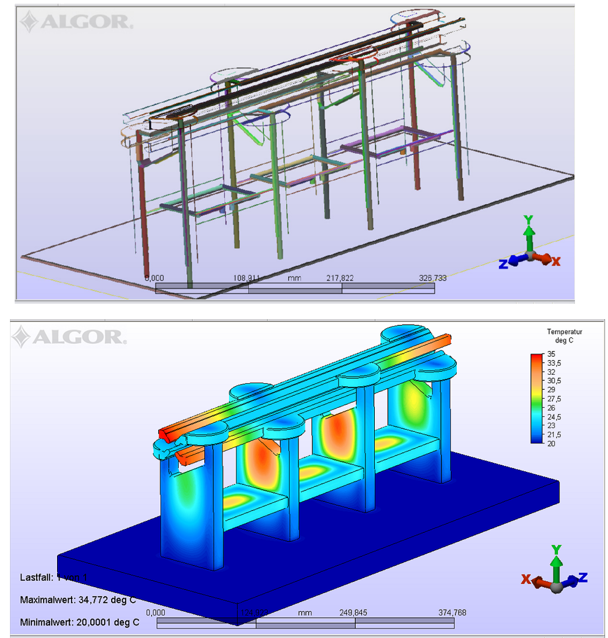

Figure 8: With cooling.

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 after getting over the multipacting barriers. 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.

Next steps will be an optimizing of some mechanical details of the cw Prototype.

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.