OPTIMIZATION OF A CW RFQ PROTOTYPE*

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Abstract

A short RFQ prototype was built for RF-tests of high power RFQ structures. We studied thermal effects to 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 RF-design is on focus now. 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].

For high power LINAC structures a new RFQ prototype to study primarily thermal effects was built.

SPECIFICATION

Table 1 shows the general layout of the RFQ structure 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 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.

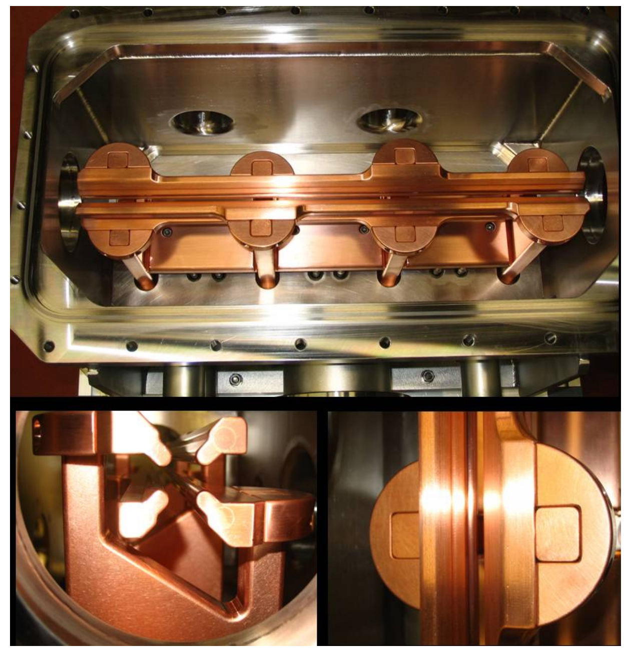

Figure 1: The cw RFQ Prototype.

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. Figure 2 shows the computer model, the currants (ABS) and the E-field (ABS) between the electrodes. Table 2 gives an overview of the simulated and measured results.

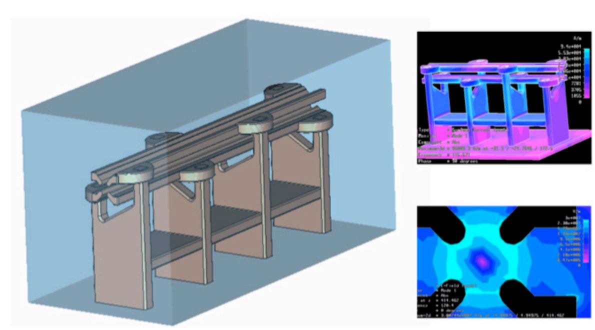

Figure 2: CST MWS computer graphics.

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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%

A wide frequency range is a feature of the 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 shunt impedance 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.

OPTIMIZATION (A): THE TANK GEOMETRY

There are different aspects to make a decision about the design of the tank geometry. In figure 3 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 to the boundary conditions for the fields. So the shunt impedance is ca. 15% better than using the more economic and easier 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-mailbox-design" c) would combine the advantages of a) and b).

The CST simulations have been experimental verified by a Bachelor student work. A small transportable RFQ model has been put inside different cross sections.

The results of the experiment are even more pregnant than the simulated ones.

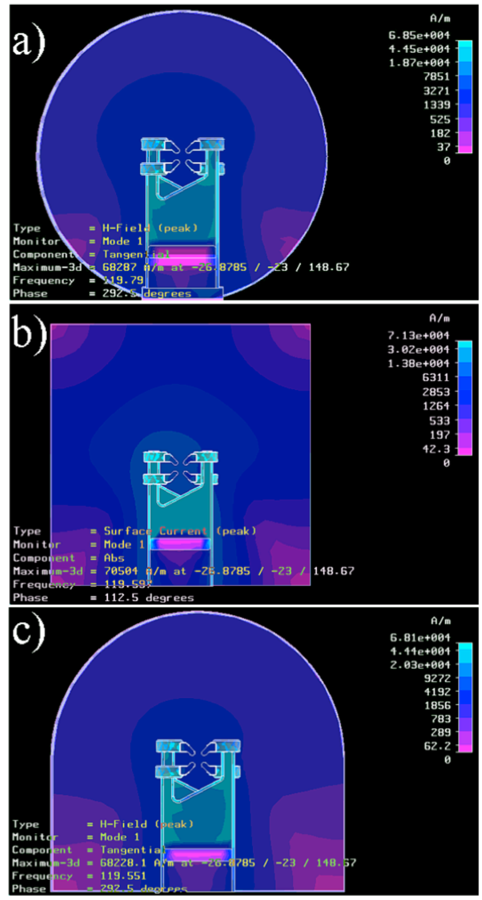

Figure 3: The magnetic field (ABS) inside the tank.

OPTIMIZATION (B): CAPACITY BETWEEN STEMS AND ELECTRODES

The perturbing capacity between the stems and the electrodes $C_{stütz}$ can be reduced to the half by rounding down the internal sides of the stems (figure 4). That reduces the probability of sparking and enhances the shunt impedance up to 5%. By increasing the thickness of the stems that detail gets more important.

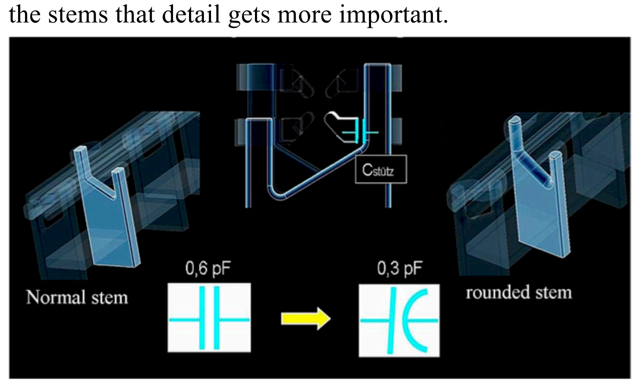

Figure 4: The capacity between stems and electrodes.

OPTIMIZATION (C): 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 (Fig. 5). The positive effect of the modification to the RF-parameters is shown in Table 3.

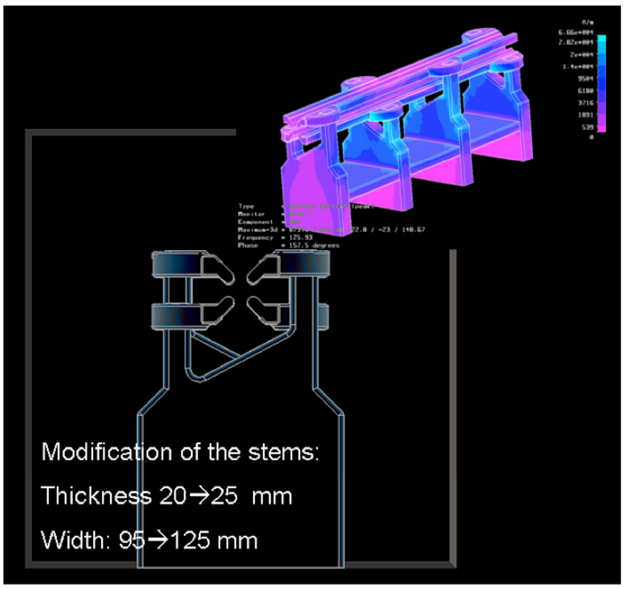

Figure 5: Modification of the stems.

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

REALIZATION OF THE STUDY

Some results of the study could be realized directly with the creation of a new cw RFQ prototype for the high intensity projects FRANZ (IAP) and MAX (Belgium): Rounding down the internal sides of the stems and increasing the thickness of the stems from 2 cm to 2.5 cm. The rectangular tank has rounded down edges and copper applications (Fig. 6).

Figure 7 shows the computer model of the FRANZ RFQ with a plastic stem which allows to see the water cooling channels [4].

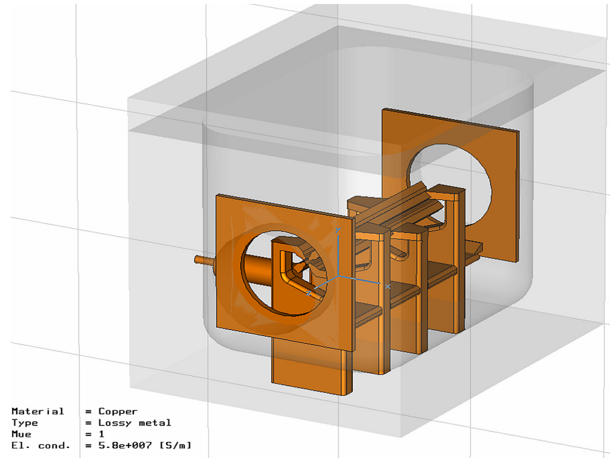

Figure 6: A new cw RFQ Prototype (175 MHz).

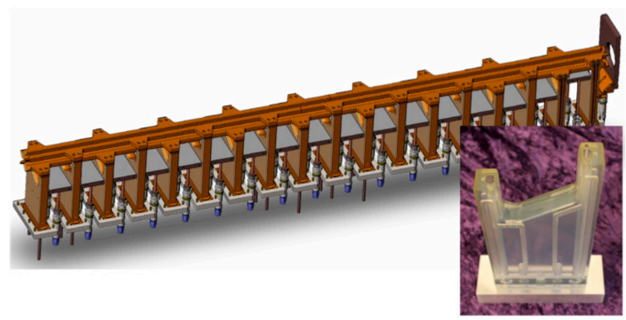

Figure 7: Computer model of the FRANZ RFQ and stem.

CONCLUSION AND OUTLOOK

The 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 continues power of 20 kW/m. All tests were done successfully. The optimization of some critical points of the 4-rod RFQ design was done by simulation with CST MWS and has been experimental verified. Some results could be used directly for the development of RFQ structures for the high intensity projects FRANZ and MAX.

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