Status of the RFQ-Accelerators for the Heidelberg High Current Injector

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Abstract

Two 4-rod type RFQ-accelerators for the Heidelberg high current injector are under construction. The RFQs accept ions with an energy of 4 keV/u and a maximum mass to charge ratio of 9:1. The ion beam is bunched and accelerated up to 0.5 MeV/u. The two resonators operate at a frequency of 108.48 MHz. The design duty cycle is 25% at the maximum power consumption of 80 kW per resonator. New vane-like electrodes have been constructed to provide mechanical stability and good cooling efficiency. To study the properties of the RFQ resonators with the new electrodes a prototype resonator with a length of 1 meter was built. Low-level measurements are compared with 3-D numerical field calculations and power and beam tests of the prototype resonator are described and discussed.

Figure 1: *The prototype RFQ-resonator structure*

1 INTRODUCTION

The first accelerator section of the high current injector [1, 2] consists of two 4-rod-RFQ-resonators [3, 4] each with a length of 3 m. Since operation at a duty cycle of 25% is needed, sufficient cooling of all inner parts of the resonators is an important design criterion. Vane-like shaped electrodes combine easy manufacture on a milling machine and good cooling properties if a cooling channel of satisfactory diameter is used. Nevertheless, the transverse cross-section of the electrodes has to be small to minimize the inter-electrode capacity.

Different electrodes have been manufactured and tested in an 1 m long prototype-resonator to determine the properties of a 4-rod-RFQ with vane-shaped electrodes. Also calculations with the MAFIA-code [5] have been carried out for comparision with the low-level measurements.

2 THE 4-ROD-RFQ PROTOTYPE-RESONATOR

A prototype resonator with a shortened length has been designed and mounted into one of the two RFQ vacuum chambers (Fig. 1). The resonator consists of electrodes with a length of 95 cm supported by six stems in linear arrangement.

The distance between the supports has to be reduced at the ends of a 4-rod-resonator to reach a proper voltage distribution along the electrodes. As one of the vacuum chambers of the final RFQ-resonatos has been used this only could be realized at the entrance of the prototype resonator.

The asymmetric profiles for the electrodes have at first been manufactured from a quadratic copper hollow profile soldered together with a rectangular profile of a copper-chromium alloy (prototype I). The experience with these electrodes leads to a new construction with much better cooling and mechanical rigidity (prototype II). With a specially designed hollow profile from a copper-tin alloy the electrodes have mechanical stability as well as good cooling properties.

The 3 m long electrodes scheduled for the first resonator have also been machined since the mechanical tolerance of ($\pm$0.01 mm) for the modulation function could be achieved easily due to the absence of segmentation.

3 LOW-LEVEL MEASUREMENTS

Measurements were done with the pertubation method and compared with MAFIA calculations. Fig. 2 shows the prototype geometry as modelled by MAFIA, Fig. 3 displays the transverse cross-section through a support.

It must be taken into consideration that due to the limited number of mesh points the transverse cross-section of the vacuum-chamber has to be reduced in the simu-

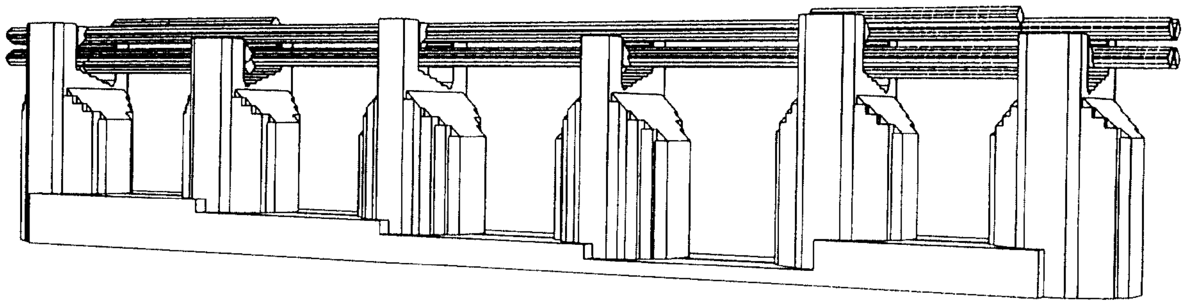

Figure 2: *MAFIA plot of the inner part of the prototype 4-rod resonator*

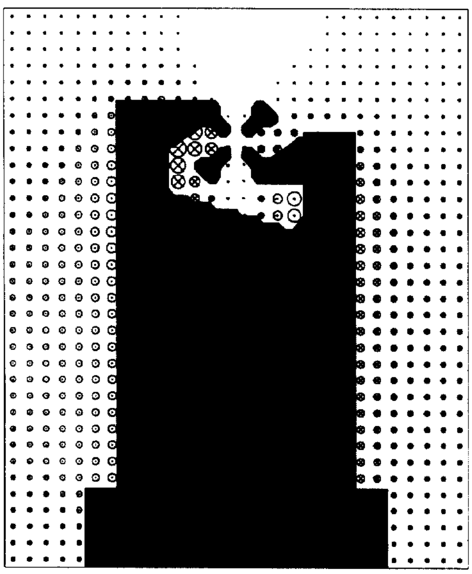

Figure 3: *MAFIA plot $\vec{B}$-field (transverse cross section)*

lation. Therefore the calculated frequencies are approximately higher (5%) than the measured ones (Tab. 1).

Table 1: *Measured and calculated properties of the prototype resonators (with tuning plates)*

	f [MHz]	Q-value [10^3]	R_S [kΩm]
MAFIA	110.7	6.5	250
measurement	105.1	3.1	115

Due to the non-ideal contacts of the different parts of the resonator the measured Q-value and shuntimpedance $R_S = U_0^2 l_e / N$ (U_0: interelectrode voltage, N: rf-power, l_e: electrode length) are lower compared to the calculated ones. In Fig. 4 the voltage distribution along the electrodes of the prototype II is shown. Due to the asymmetric arrangement of the supports the distribution is skewed.

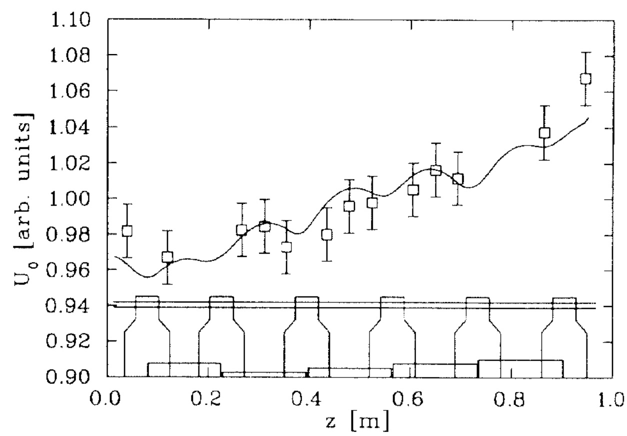

Figure 4: *Inter-electrode voltage distribution. line: MAFIA-calculation*

4 POWER TESTS

Power tests have been carried out with the different electrodes. Stable operation was limited with respect to the rf-power in cw-mode to 2 kW when the electrodes of the prototype I were used. Evaluations of the MAFIA-calculations show that a significant part of the power is dissipated at the uncooled 'long end' at each electrode. Therefore the long ends of the new electrodes (prototype II) were provided with a supplementary cooling tube as shown in Fig 2 & 5. This cooling tube is soldered to the electrode and stabilizes this long end also mechanically.

Power tests of up to 15 kW in cw mode and 50 kW in pulsed mode (1:4) with this electrodes could be carried out during several weeks. Scaled to the 3 m resonators, the design rf-power load of 80 kW (1:4) was reached without problems. Ponderomotoric oscillations could not be observed in pulsed mode.

5 BEAM TESTS

Acceleration tests have been carried out with H_2^+-ions. Fig. 6 shows the arrangement and the trajectory calculations of ion-source and electrostatic lens in front of the

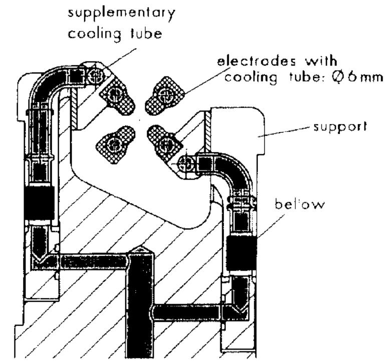

Figure 5: *Transverse cross section through the supports with the water supply of the electrodes*

RFQ-prototype as performed by the SIMION-code [6].

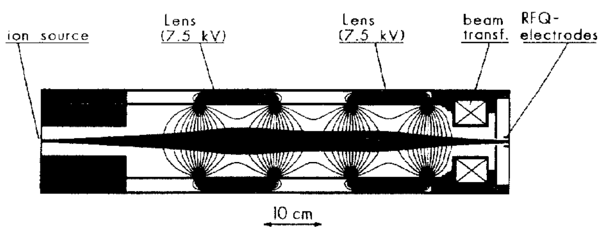

Figure 6: *Potential distribution and beam optics up to the RFQ-prototype*

To accelerate H_2^+-ions, the modulation function has been designed with the PARMTEQ-code [7] as shown in Fig. 7.

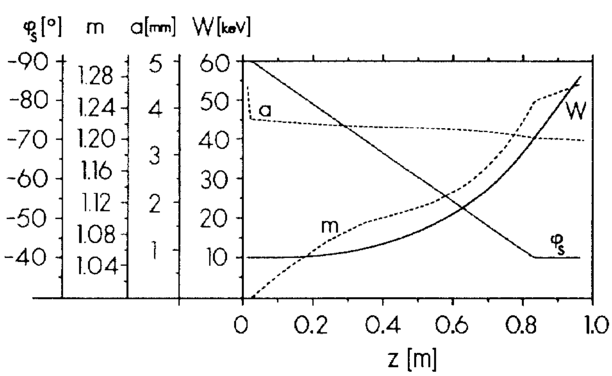

Figure 7: *Characteristic parameters of the prototype resonator. a: aperture, m: modulation, W: energy, φ_s: synchronous phase*

Beam diagnostic in front of the RFQ could be done with an inductice beam transformer [8] whereas the accelerated bunches were measured via a fast faraday-cup. The measured time structure was compared with the calculated time structure at different rf-power levels. Fig. 8 shows the measured time structure a rf-power level of 10 kW. The shuntimpedance of $R_S = 115$ kΩm determined by the pertubation method was confirmed by the beam test.

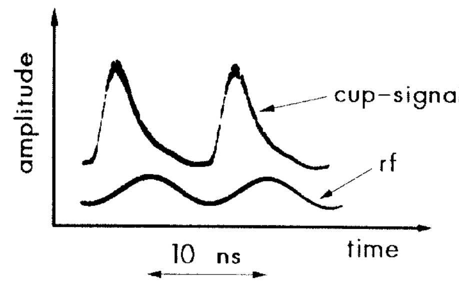

Figure 8: *Cup-signal and rf-signal of the resonator*

6 CONCLUSIONS

The experiments and results achieved by building and evaluating the RFQ-prototype have provided the needed knowlegde and technical details to proceed the final design of the RFQ-resonators. The test and calculations also yielded valuable information of the frequency dependance of the rod and stem geometry, the tuning method and design of the rf-coupling loop. The assembly, rf-tuning and measurements of the first RFQ-resonator will be finished at the end of this year.

7 ACKNOWLEDGEMENT

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