Comparison of 4-Rod- and IH-RFQ accelerators at 101 MHz

T. Sieber, O. Kester, and D. Habs

The first accelerator modules of the REX-ISOLDE Experiment at CERN [1] and of the planned Munich Accelerator for Fission Fragments (MAFF) [2] are Radio Frequency Quadrupole (RFQ) structures. The RFQ at REX is of the so called 4-rod type. It is a transmission line resonator, consisting of equidistant stems, which alternately carry two of the four quadrupole electrodes. The REX-ISOLDE RFQ was designed built up and tested at Munich [3] and has been integrated in the REX-ISOLDE beamline in 2000. Figure 1 shows a schematic of the 4-Rod RFQ. Positive characteristics of this RFQ-type are good tuning possibilities (due to the modular setup) as well as a cost efficient and variable design, because the vacuum tank does not affect the resonator behavior.

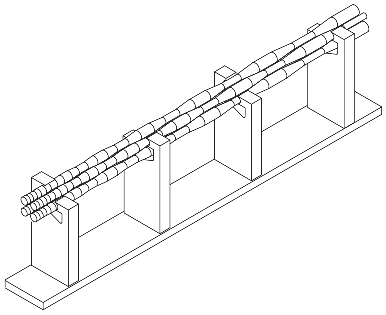

Fig. 1: Schematic of the 4-rod RFQ.

For the MAFF project a new RFQ type - the IH-RFQ - was proposed and has been investigated by simulation calculations with the MAFIA code. The IH-RFQ consists of a cavity excited in the TE_{111}-Mode, in which two opposite girders are mounted. These girders carry equidistant interdigital holders on which the quadrupole electrodes are fixed (see Fig. 2). At the moment, the only existing IH-RFQ is the GSI high current injector RFQ, which operates at a frequency of 36 MHz. This machine has shown advantages concerning the rf-power consumption, the cooling and the field distribution in the quadrupole. These advantages we want to transfer to 100 MHz.

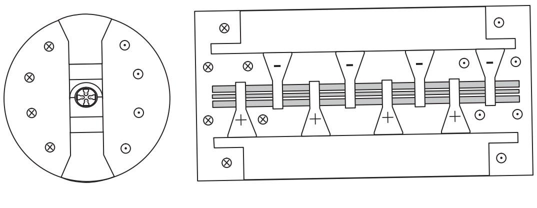

Fig. 2: Schematic of the IH-RFQ with magnetic field.

Since the MAFF-RFQ will operate at the same frequency as the REX-RFQ, and the particle dynamics (the electrode-geometry) of the two accelerators is very similar, a direct comparison of the two RFQ types is possible. Herefore the MAFIA values for quality factor (ratio of stored energy and dissipated power) and R_p-value (efficiency of transforming rf-power in accelerating voltage) of the completely assembled and experimentally tested REX-RFQ were compared with the values of the theoretically optimized MAFF IH-RFQ model. For the optimization of the IH-RFQ the resonant frequency was kept constant by variation of the tank diameter. Varying step by step the whole geometry, the most rf- and cooling efficient model turned out to be a resonator with a diameter of 30 cm, a holder distance of 7 cm and a holder thickness of 1 cm. The following table shows the MAFIA values for both accelerators. It gives also the fraction of the total rf-power, which is dissipated on the quadrupole electrodes. Here the cooling is most critical.

	REX-RFQ	IH-RFQ
frequency [MHz]	99.2	99.9
R_p [$k\Omega m$]	259	255
Q	7.3	11.9
electr. Losses [%]	26.7	8.7
no. of holders	18	37

Table 1: Some characteristic resonator parameters calculated with MAFIA for the 4-rod- and the IH-RFQ.

One can see a significant difference in quality factor while the R_p-values of the two different structures are nearly identical. This is caused by the expected lower power dissipation in the IH-RFQ (increased Q) in connection with the increasing capacitive load due to the short girder distances (decreased R_p). The question arises how reliable the calculated Rp-values are. A comparison of the measured (150 $k\Omega m$) and calculated (259 $k\Omega m$) R_p- value of the REX-RFQ shows that the theory lies about a factor 1.7 too high. This is the result of several idealizations which are done in the MAFIA calculations [4]. The IH-RFQ will have - because of the different form of appearance - a correction factor, which differs from the one of the 4-rod RFQ. To calculate this factor, an analytical approach by U. Ratzinger was used [5], including fit values which were derived from measurements at the 36 MHz high current IH-RFQ at GSI. ¿From this an R_p value of 198 $k\Omega m$ was calculated for the 101 MHz MAFF IH-RFQ! It is a strong indication for an indeed higher R_p-value of that structure (compared to the 4-rod RFQ), that the ratio of the MAFIA value for R_p and the analytically calculated value (including experimental data) is nearly the same as at the 36 MHz GSI machine. Here the measured and analytically calculated value is 620 $k\Omega m$ respectively 840 $k\Omega m$ in MAFIA.

References

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