DIPOLE COMPENSATION OF THE 176 MHz MYRRHA RFQ

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Abstract

The MYRRHA (Multi-purpose hYbrid Research Reactor for High-tech Applications) Project is planned as an accelerator driven system (ADS) for the transmutation of long-living radioactive waste [1]. For this project a cw 4-Rod-RFQ with 176 MHz and a total length of about 4 m is required [2]. It is supposed to accelerate protons from 30 keV up to 1.5 MeV [3]. One of the main tasks during the development of the RFQ is the very high reliability of the accelerator to limit the thermal stress inside the reactor. Another challenge was to compensate the dipole component of the MYRRHA-RFQ which is due to the design principle of 4-Rod-RFQs. This dipole component is responsible for shifting the ideal beam axis from the geometrical center of the quadrupol downwards. Design studies with CST MICROWAVE STUDIO [4] have shown that the dipole component can be almost completely compensated by widening the stems alternately so that the current paths of the lower electrodes are increased.

INTRODUCTION

The center of an ideal quadrupole is field-free. The accelerating fields inside an RFQ result of the modulation on the quadrupole electrodes. Nevertheless should the field distribution inside an RFQ be as symmetrical as possible because the simulation programs assume symmetrical fields.

The dipole component is the result of an asymmetrical quadrupole in which the field free region and therefore the position of the ideal beam axis is shiftet (see Fig. 1).

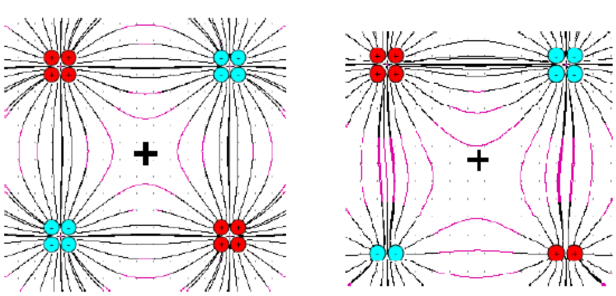

Figure 1: Comparison of an ideal (left side) and a non ideal quadrupole (right side). The cross marks the geometrical center.

The voltage between the electrodes of a 4-Rod-RFQ depends on the lengths of the current paths. Therefore, the lower voltage between the lower electrodes is inferior to the voltage between the upper electrodes. Within RFQ accelerators this is an exclusive problem of the 4-rod-RFQ. IH- and 4-Vane-RFQ are typically not affected by this problem because of their symmetrical geometrical design.

DIPOLE COMPENSATION BY STEM CUTTING

The most common method for the compensation of the dipole component is the stem cutting. This involves the variation of the angle of the cut between the mountings for the upper and the lower electrode of one stem [5]. The disadvantage of this method is that the sharpness of the angle is limited. Once the angle gets smaller the range of the tuning plates decreases. Also the design of the cooling channels inside the stems are more complicated with a larger stem cut.

DIPOLE COMPENSATION BY WIDENING THE STEMS

Another way to expand the current paths for the lower electrode is to shift the stems alternately perpendicular to the beam direction (see Fig. 2).

Figure 2: Comparison of the original MYRRHA-RFQ model (right side) and the new model with widened stems (left side).

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Table 1: The results of the simulations have been calculated with different methods (A to F). The best result for compensating the dipole is achieved with an offset of 18 mm (in grey).

offset	$\langle\frac{U_u - U_d}{U_u}\rangle$	$\langle\frac{\lvert U_u - U_d\rvert}{U_u}\rangle$	$\langle\frac{U_u - U_d}{\left(\frac{U_u + U_d}{2}\right)}\rangle$	$\langle\frac{\lvert U_u - U_d\rvert}{\left(\frac{U_u + U_d}{2}\right)}\rangle$	$\langle\frac{\int \vec{e}_u - \int \vec{e}_d}{\left(\frac{\int \vec{e}_u + \int \vec{e}_d}{2}\right)}\rangle$	$\langle\frac{\int \vec{e}_u - \int \vec{e}_d}{\int \vec{e}_u}\rangle$
in mm	in % (A)	in % (B)	in % (C)	in % (D)	in % (E)	in % (F)
0	24.8	24.8	28.3	28.3	27.7	24.3
4	20.7	20.7	23.2	23.2	22.3	20.1
8	15.6	15.6	16.9	16.9	16.1	14.9
12	9.7	9.7	10.2	10.2	9.7	9.2
16	3.1	3.4	3.2	3.5	2.6	2.5
18	-0.4	1.8	-0.4	1.8	-0.9	-0.9
20	-4.2	4.4	-4.1	4.3	-5.2	-5.3
24	-13	13	-12.2	12.2	-12.7	-13.5

Simulations exploring this method have been performed and have shown a decrease of the dipole component but also an occurring problem with the tuning plates.

If the stems are just shifted and not widened, the widths of the tuning plates is getting smaller. This may lead to an increased current flow on the surface and higher cooling requirements.

The new dipole compensation consists of the alternate widening of the stems (offset). Therefore the widths of the tuning plate and the distances between the neighbouring electrodes and the stems could stay the same.

SIMULATIONS

A series of simulations has been made to determine the size of the needed offset.

For the measurement of the dipole component within the simulations different methods were used.

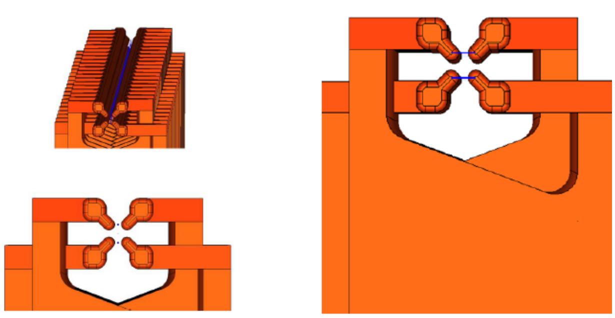

Figure 3: The left side shows the position of the curves over which the integrals were calculated (method E and F). On the right side is seen which voltages have been compared for the methods A to D.

Comparison of the Voltages

In an ideal quadrupole the voltage between neighbouring electrodes should be identical.

The first method is based on the comparison of the voltages between the upper electrodes and between the lower electrodes (see Fig. 3, right side).

This comparison has been made on 160 evenly distributed points along the electrodes and the results have been averaged (Method A to D).

For the evaluation 4 different types of calculation were used. This comprises whether the amount of the different voltages is used (method B and D) or not (method A and C) and whether the upper voltage (method A and B) or the average between the upper and lower voltage (method C and D) is used as denominator (see Fig. 4).

Comparison of the Integrals

For the second method the integrals over the electric fields were compared. In an ideal quadrupole these integrals should be the same.

For this measurement two curves were located between the upper and the lower electrodes alongside the beam axis over which the integral was calculated (shown in Fig. 3 right side). In method E the average between the two integrals is used as denominator while in method F the upper integral is used (see Fig. 4).

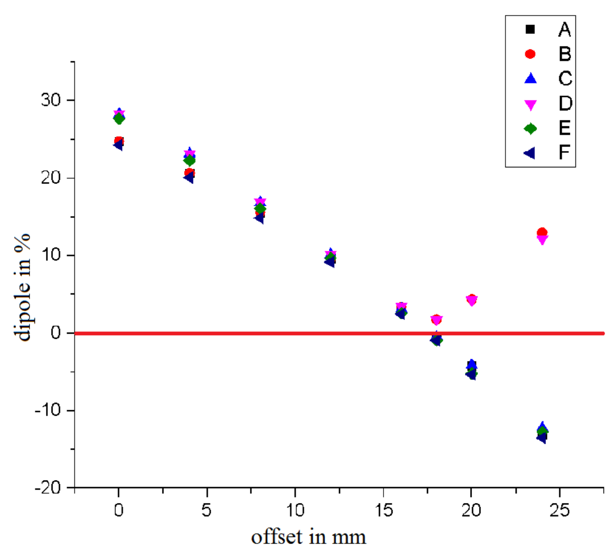

Figure 4: Comparison of the different simulations with different offsets.

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RESULTS

The simulations with different offsets have shown a significant decrease of the dipole component from more than 20 % to less than 2 %. The best results have been made with an offset of 18 mm. With an even bigger offset the dipole component would be overcompensated (see Fig. 4). This means that the there would be a higher voltage on the lower electrodes than on the upper electrodes and that the ideal beam axis would shift upwards.
Also the widening of the stems have shown only minor impacts on the frequency so that the range of the tuning plates is still sufficient.

CONCLUSION

For the MYRRHA project a 4-rod-RFQ with a total length of about 4 m has been examined with regards to the dipole compensation.

The best results could be achieved through alternately widening the stems with an offset of 18 mm. Different methods of calculating the dipole component have shown that the dipole component with this compensation is reduced to less than 2%.

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