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3D-MODELING FOR THE LANL-APT RFQ

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Introduction

An 8-meter-long four-vane Radio Frequency Quadrupole (RFQ) has been proposed by Los Alamos National Laboratory (LANL) for use in high-current proton accelerators [1]. This RFQ is made up of four 2-meter-long segments that are coupled. Disregarding the vane modulations, most of the structure can be modeled in 2D. However, the end regions and the segment joints need a full 3D treatment. Even using the four-fold symmetry of the structure, it is too complex to be modeled in one step. Here, the strategies for a piece-wise treatment of the RFQ and the results of this modeling are represented. Depending on the beam-dynamics requirements, the geometry has to yield either a flat or a significantly ramped on-axis field at different locations along its length. The discrete model simultaneously takes into account vane modifications for radial matching, vane undercuts to adjust the field flatness, tuning devices and the positioning of vacuum slots. The simulations have been done with the electromagnetic simulator MAFIA, Rel 3.2 [2]. Many of the modeled features of this RFQ have also been demonstrated in a laboratory cold model[3].

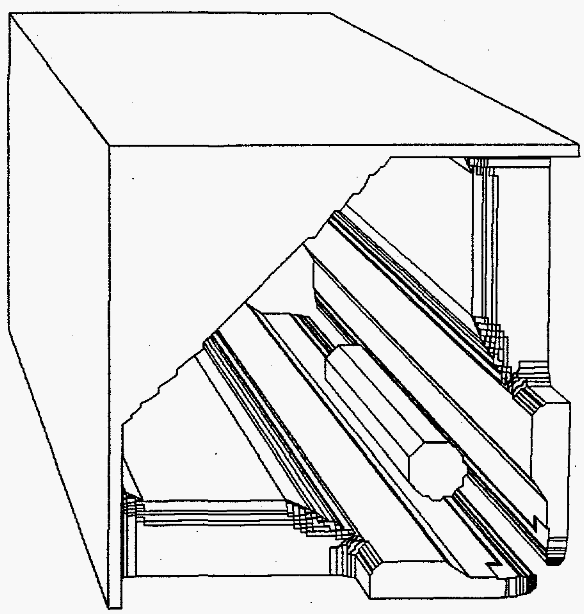

Figure 1: Discrete model of the low-energy end of the LANL RFQ. This quarter structure that includes vane modifications for radial matching, an rectangular undercut for a flat on-axis field and tuning rods fixed to the (non-visible) end-plate is a typical example of the partial problems to be solved. The length of the modeled piece is 0.5 meters. The description of this model needs approximately 700,000 mesh cells in a strongly inhomogeneous Cartesian mesh.

General Strategies

The complexity of the full 8-meter-long structure requires modeling smaller pieces. Inside the structure, the smallest sections that can be modeled are defined by the axial locations, where the mode of interest has a translational invariant field pattern. Approximately 0.5 meters from the ends and from the segment joints the fields are sufficiently homogeneous to be described by a calculation-volume boundary with the appropriate boundary conditions. Thus in all symmetric cases, a model from the symmetry plane up to a distance 0.5 meters away yields an adequate description for a local design. This also applies for the ends that only need to be modeled from the limiting end-plate until 0.5 meters into the structure. All segment joints with required flat on-axis field amplitudes require a symmetric geometry before and after the joint. Here, finding a vane undercut for a flat field in one half is sufficient.

Calculations for several cross-sections at different locations of the RFQ show that a change in undercut length (depth) by 1/16 inch corresponds to a change in field flatness by 2 %. Flat field undercuts require only 2 simulations with the use of this relation. Slight variations of the field flatness can easily be adjusted by tuners added along the quadrant walls of the RFQ.

Also for the non-symmetric case, when a ramp in field amplitude by almost 20 % per meter is required for the beam-dynamics, a figure of merit allows deducting the geometry variation for a ramp from the flat-field geometry. These strategies help to treat the 3D effects in the RFQ with a reasonable amount of effort. A description of undercut sizes and tuner volumes along the structure has been derived. These results are being used in the design of the actual full power, full current RFQ under construction at Los Alamos.

Test of the Predictions from the MAFIA Model

Before the design effort was started, results predicted by the MAFIA models were tested on a cold model. Field levels in the area of the undercuts predicted by the numerical model have been found to be in good agreement with measurements. Also, the required field ramp across a segment joint has been demonstrated in the laboratory. The non-symmetric undercuts before and after the joint, for an even more complex undercut cross-section, have been determined by numerical simulations. The predicted ramp of the on-axis field has also been reasonably well reproduced in experiments.

References

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[3] L. Young, "An 8-Meter-Long Coupled Cavity RFQ Linac," Proceedings of the 1994 International Linac Conference, Aug 21-26, 1994, Tsukuba, Japan