Field Study of Radio Frequency Quadrupole Cavity End-Region

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The Radio Frequency Quadrupole (RFQ) has been widely utilized for low energy particle focusing, bunching, and acceleration in ion accelerators (I.M. Kapchinskiy and V.A. Tepliakov, Prib. Tekh. Eksp. 2, 19-22, 1970). The fundamental quadrupole TE110 mode (TE210 for circular cross-section) is the operation mode of RFQ since it generates a strong electric focusing field due to capacitive loading of RFQ vanes, which is equivalent to the ridges of a ridge waveguide. To provide a uniform electric field along the entire structure, the RFQ end-region should not have the perfect electric conductor (PEC) boundary which forces the electric field magnitude at the boundary to drop to zero. To resolve this problem, mechanical cut-backs are applied at all RFQ vane ends to create virtual open circuit in view of electric field while introducing a path for magnetic flux circulation with high efficiency (M.J. Browman, G. Spalek and T.C. Barts, Linac conference, 1988). Most operational RFQs utilize the cut-back method on all four RFQ vane ends (4C). A drawback of this scheme is, however, the inter-cell coupling of RFQ cavity mostly depends on magnetic field coupling, rather than electric field which is much sensitive to structure errors.

Alternatively, to enhance the electric field coupling, two other schemes have been developed by applying the cut-backs on only two RFQ vanes as proposed by some researchers (R.M. Hutcheon, L.D. Hansborough, K.J. Hohban, and S.O. Schriber, IEEE Transactions on Nuclear Science, 1983). These two vane cut-back (2C) methods have different field characteristics from that of 4C method, and may affect beam quality if it is not well understood. Therefore, detailed EM field studies on RFQ end-region in 4C and 2C RFQs have been performed in this study and will be presented. For the structures, electromagnetic (EM) computations were performed- using the 3D EM simulation tool CST Microwave Studio. Field data is analyzed in view of field-particle interaction. An optimization study of the 2C RFQ design will be also presented and discussed.