HIGHER MODES IN THE COUPLING CELLS OF COAXIAL AND ANNULAR-RING COUPLED LINAC STRUCTURES

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Summary

Dipole- and quadrupole-like modes in the coupling cells of coaxial and annular-ring coupled structures have been examined up to a frequency of 4 GHz. The quadrupole mode frequencies appear to lie high enough above the frequency of the accelerating mode to make coupling between the two unlikely. In the annular-ring case, however, a dipole mode was found very near the accelerating mode frequency. Evidence is presented which suggests that some power may couple between these two modes in a real cavity.

Introduction

As part of the room temperature cw electron microtron development project at the University of Illinois, a detailed evaluation of the coaxial coupled linac structure[1] is in progress. This structure has potential advantages over both the on-axis coupled and side coupled designs. As compared to the on-axis structure, it has considerably better mechanical stability and should show a much reduced sensitivity to beam-blowup mode excitation. As compared to the side coupled structure, the coaxial structure has greater cell to cell coupling and can be much more easily fabricated. All three of these designs have similar shunt impedances.

Recent work by the accelerator group at LANL on the annular-ring coupled structure has shown the presence of substantial degradation in both Q and shunt impedance relative to what is expected on theoretical grounds.[2] These effects have been attributed to the excitation of higher order quadrupole-like modes in the coupling cells at frequencies that lie near the frequency of the $\pi/2$ accelerating mode. Because the annular-ring and coaxial coupled designs are rather similar as can be seen from the profiles shown in Figure 1, we were motivated to examine the mode spectra of coupling cells in the coaxial structure.

Procedure and Results

Tests were made on an aluminum section consisting of a coaxial coupling cell between two median-plane terminated accelerating cells. Magnetic probes were placed around the coupling cell at azimuthal angles of 0°, 45°, and 90° (see insert in Figure 2). This probe placement allowed the unambiguous identification of m=0 (coupling or zero), m=1 (dipole), and m=2 (quadrupole) modes. Measurements were made at frequencies up to 4 GHz and for two symmetrically placed coupling slots with lengths of 0° (no slots), 45°, and 90°. The results are shown in Figure 2. Also shown in Figure 2 are triangular points at 0° (no slots) and 180° (continuous open slot) that correspond to the calculated frequencies for the TM_{010}, TM_{110}, and TM_{210} modes in an ideal cell with the geometry of the test cavity.[3,4] It can be seen that both the dipole and quadrupole modes split into two branches,

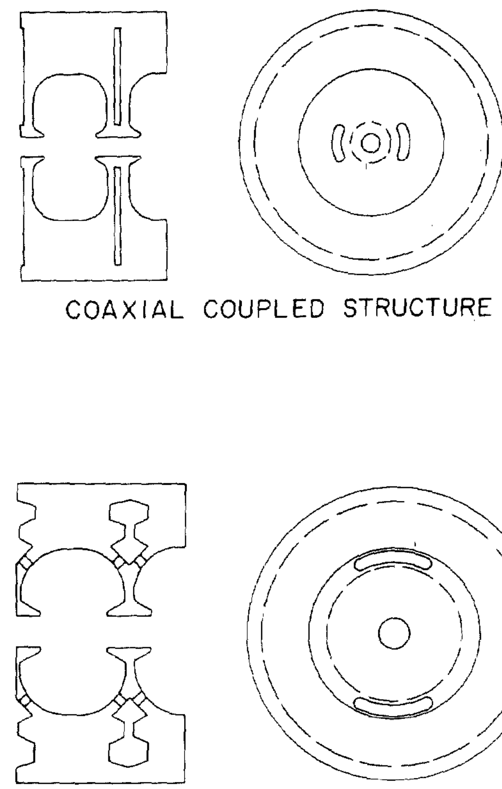

Figure 1. Profiles of the coaxial coupled and the annular-ring coupled linac structures.

as the slots are opened, due to two possible orientations of the mode symmetries with respect to the slots. There is also an effect that depends on the relative orientation of slots on opposite faces of the coupling cavity (cell to cell orientation). This dependence is most pronounced in the case of the dipole mode. The most important observation, however, is that both branches of the quadrupole mode remain at about 1 GHz above the frequency of the coupling mode. In all of these measurements, total resonant band widths were approximately 2 MHz (-3db), 25 MHz (-20db), and 700 MHz (-30db) about the respective resonant frequencies. Consequently, it seems unlikely that power at the coupling mode frequency would be able to excite a quadrupole mode significantly. The dipole mode is closer in frequency to the coupling mode, although it too remains several hundred MHz above. Also, at least to first order, an m=0 mode should not be able to couple to an m=1 mode through two symmetrically placed slots. We conclude that a destructive coupling of power to higher order modes in the coupling cells of the coaxial structure is very unlikely.

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For the purpose of comparison, we next fabricated a standard LANL annular-ring coupling cell section with magnetic probes at azimuthal angles of 0°, 45°, 90°, 180°, and 270° (see insert Figure 3). Again measurements were made at frequencies up to 4 GHz, this time for coupling slot lengths of 0° (no slots), 30°, 60°, and 90°. The results are shown in Figure 3. The mode structure is very similar to what we observed in the coaxial case except that here the mode frequencies are somewhat more compressed and a second dipole is seen to come in above the quadrupole. Even so, the quadrupole modes are still 500-700 MHz higher than the coupling mode frequency and as before it seems unlikely that power could be coupled into them. One of the dipole branches, however, actually crosses the coupling mode. As was indicated above, significant excitation of a dipole mode by a coupling mode through symetrically placed slots seems improbable. However, it is possible that if there are in fact small asymmetries in the slots some power could be coupled between these modes. This is especially true if the frequencies of the coupling mode and the dipole mode are very nearly the same, as we found to be the case here.

To obtain an indication of the amount of slot-coupled power in the annular cavity, a quasi-nonresonant waveguide coupler excited with a coaxial electric probe was connected to the slot side of the test section, and relative power levels were measured inside the coupling cell as a function of frequency. With symmetric 90° slots we observed that, at the respective resonant frequencies, the lower 1-4 dipole could be excited to about 50% of the power level of the 1-quadrupole. We estimate that at least 2% of the power in the accelerating mode could be coupled into the dipole mode if the frequencies of the two were coincident. In this example, the coupling slots were as symmetric as the machining process allowed. Slightly greater asymmetry in the slots could permit even more power to couple into the dipole mode.

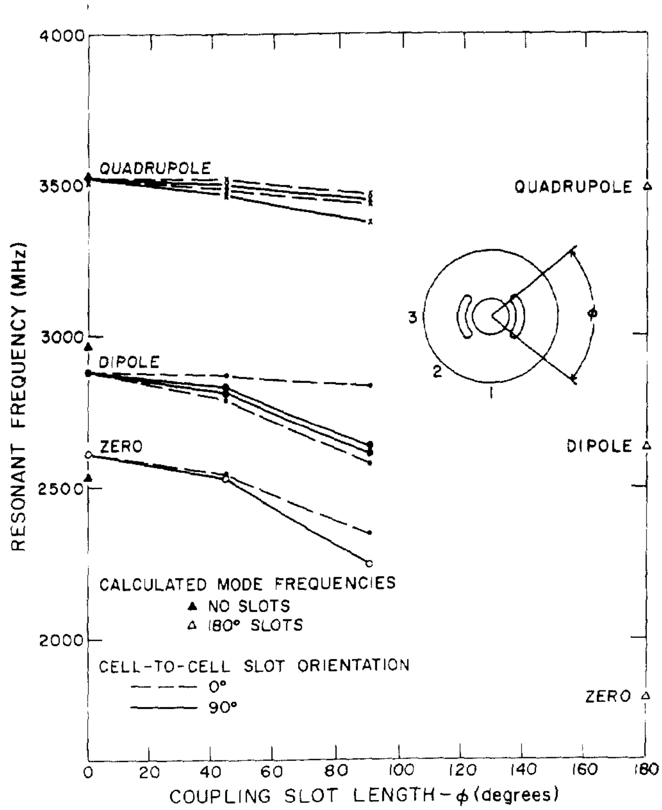

Figure 2. Frequency spectrum of the coaxial coupling cell for coupling slot openings between 0° and 90°. Triangular points at 0° and 180° come from a calculation of the lowest modes in an ideal cavity.

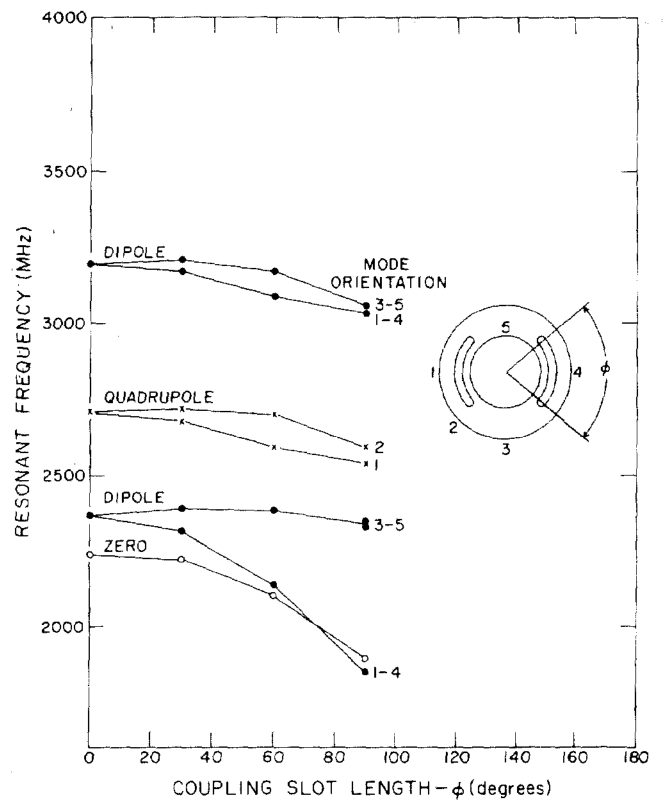

Figure 3. Frequency spectrum of the annular-ring coupling cell for coupling slot openings between 0° and 90°. Note that the zero (coupling) mode and the 1-4 dipole mode lie in close proximity for slots between about 60° and 90°.

Conclusion

It seems unlikely that significant amounts of power can be coupled from the accelerating mode into higher order modes in the coupling cells of the coaxial structure. Our partial investigation of the LANL annular-ring coupling cell design suggests that the difficulty with it may not be due to the relatively high lying quadrupole modes, but rather to a dipole mode that nearly coincides in frequency with the coupling mode.

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