DAMPED ACCELERATOR STRUCTURES FOR FUTURE LINEAR $e^{\pm}$ COLLIDERS*

H. DERUYTER, H. A. HOAG, A. V. LISIN, G. A. LOEW, R. B. PALMER,
J. M. PATERSON, C. E. RAGO AND J. W. WANG
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94309

1. Introduction

This paper describes preliminary work on accelerator structures for future TeV linear colliders which use trains of $e^{\pm}$ bunches to reach the required luminosity. These bunch trains, if not perfectly aligned with respect to the accelerator axis, induce transverse wake field modes into the structure. Unless they are sufficiently damped, these modes cause cumulative beam deflections and emittance growth. The envisaged structures, originally proposed by R. B. Palmer,[1] are disk-loaded waveguides in which the disks are slotted radially into quadrants. Wake field energy is coupled via the slots and double-ridged waveguides into a lossy region which is external to the accelerator structure. The requirement is that the Q of the HEM_{11} mode be reduced to a value of less than 30. The work done so far includes MAFIA code computations and low power RF measurements to study the fields. A four-cavity $2\pi/3$ mode standing-wave structure has been built to find whether the slots lower the electric breakdown thresholds below those reached with conventional disk-loaded structures.[2]

We set out to assess the microwave properties of the structure and the problems which might be encountered in fabricating it.

2. Description of Proposed Structure

A three-dimensional view of the originally proposed structure is shown in Fig. 1. The cross-section of a variant of the structure (using ridged waveguide outer channels) is given in Fig. 2.

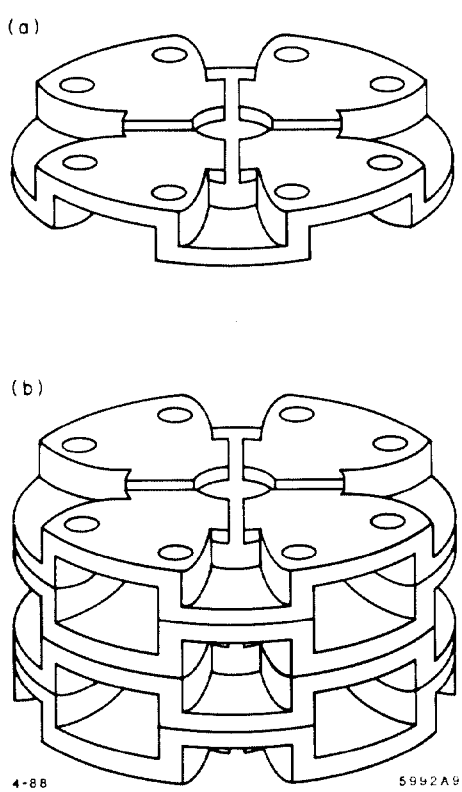

Fig. 1. Accelerator structure with HEM_{11}-mode damping.

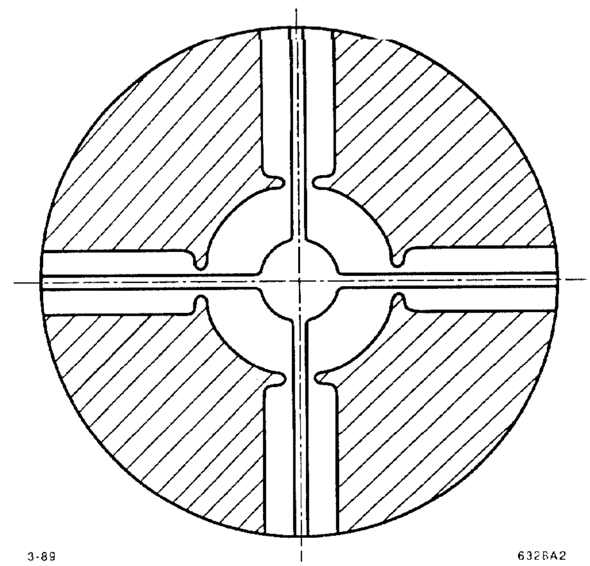

Fig 2. Cross-section of modified structure.

It can be seen that the disk, or iris, of the conventional structure is divided into four quadrants by four orthogonal radial slots. The slots continue radially past the outer wall of the cavity, transforming into double-ridged waveguides. When originally conceived, these waveguides had their dominant-mode cut-off above the frequency of the fundamental accelerating mode of the structure, but below the frequencies of the transverse and higher longitudinal wake field modes. Power in these higher frequency modes was to propagate along the slots into the ridged waveguides, and be absorbed in an outside lossy region.

Four radial slots in each disk are thought to be necessary to assure coupling to all arbitrary polarizations of the wake field modes which can be excited by the beam. Additionally, the slot pattern in successive disks is rotated by 45° to further improve the coupling and also to prevent the ridged waveguides from cutting into each other (this may or may not happen, depending on the dimensions chosen).

It was first thought that lossy ceramic loads could be placed at the outer ends of the ridged guides to absorb the RF power. However, present thinking is that any arcing across the disk quadrants (which must be expected to occur, albeit very occasionally) will cause frequency multiplication of some of the fundamental RF power which will then reach the loads and destroy them. It is now intended to couple the power into the annular chamber between the structure and the outer coaxial envelope. The walls of this region, which acts as the vacuum pumping manifold for the whole structure, will be coated with lossy material, such as *Kanthal*.

3. Design, Construction and Materials

At the outset, it is recognized that even a conventional disk-loaded waveguide is difficult to build with appropriate tolerances in the presently contemplated frequency range, namely four or six times the SLAC frequency (11.424 or 17.136 GHz). The structure considered here also poses additional problems. To get a first

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assessment, the Mechanical Fabrication Group at SLAC was asked to build a few cells, using existing machine shop tools and techniques. It is no surprise that the largest problems are associated with the disk quadrants: the profile and surface finish of the slot and beam iris edges, and the location of the quadrants in the finished assembly.

To date, no creditable methods of coining or electroforming the structure have been proposed. It appears likely that brazing self-jigging parts shows the best promise. Precision stainless-steel tubes provide water cooling and alignment. It is thought that the quadrants will be made on a very high-quality numerically-controlled milling machine.

Calculations made at CERN[3] predict that damage to the cavity inner metal surfaces due to fatigue from thermal cycling is likely to be a problem if OFE copper is used. However, Dispersion-Hardened (DH) coppers have significantly higher yield strengths (even after brazing) than work-hardened OFE copper, and yet they retain the same thermal and electrical (RF) conductivities. Samples of one DH copper (*GlidCop*) are being prepared for test.

4. Low Power Experiments and MAFIA Calculations

The purpose of the first experiments was to find how the presence of quadrant slots in the disks affects the fundamental and higher-order mode frequencies, field patterns and RF voltage breakdown limits. A three-cavity stack (two full cavities and two half-cavities) was made utilizing slotted disks. The end plates had small holes for exciting and pick-up probes, and for bead pulling. The slots and probes could be aligned in any desired manner. Voltage transmission coefficient (S_{21}) plots were taken with a network analyzer.

In the first experiment, the cavity diameter (2b) was 8.71 cm, and the beam aperture diameter (2a) was 4.2 cm. The disks were slotted all the way back from the iris to the cavity wall. No problem was found when the probes were on the axis of the structure: only the fundamental modes (0, $\pi/3$, $2\pi/3$ and π) were excited. However, when the probes were off-axis, slot modes were excited, as shown in Fig. 3. One of these modes ($f = 2961$ MHz) was very close to the $2\pi/3$ fundamental, which was resonant at 2963 MHz with the above structure dimensions.

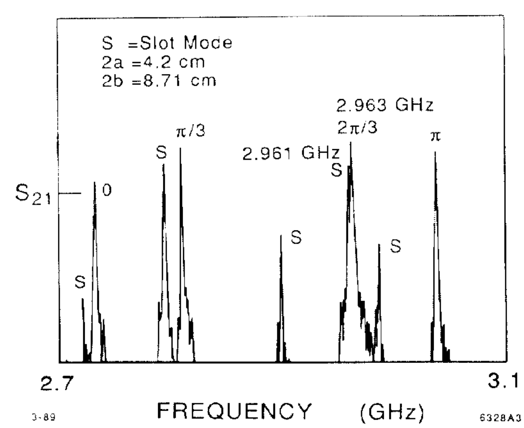

Fig. 3. S_{21} Plot: Large beam aperture, slots aligned.

To lower the frequency of the slot mode competing with the $2\pi/3$ mode, the slot length was increased by reducing 2a to 3.6 cm. Then 2b was adjusted to put the $2\pi/3$ mode frequency close to 2856 MHz. A new stack incorporating these dimensions was made.

Dispersion curves were also generated by using the MAFIA code to understand this problem more thoroughly. Figure 4 gives the $\omega - \beta$ diagrams derived from these calculations for the case where the slots in the disks are all aligned. The calculations also indicate that some slot modes are heavily affected by the relative orientations of slots in successive disks, and this is confirmed by stack measurements (see Figs. 5 and 6). In the final configuration (Fig. 6), slots in successive disks are rotated by 45°, and all modes are well separated. As this paper is being prepared, a different computation by N. Kroll[4] confirms that the combination of the slots and ridged waveguides indeed can support the slot mode which appears at a frequency below the accelerating mode. In order to damp this mode, the cutoff of the rectangular waveguide would have to be modified to be below the accelerating frequency. If one were to do this, the Q of the accelerating mode need not be significantly affected since its polarization is orthogonal to that transmitted by the guide. However, at this point it is not clear whether this slot mode needs to be damped because its transverse deflecting impedance may be very low.

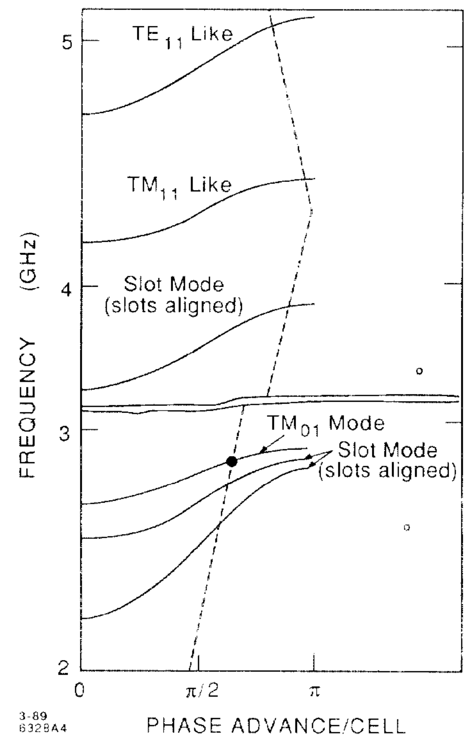

Fig. 4. MAFIA-generated dispersion curves.

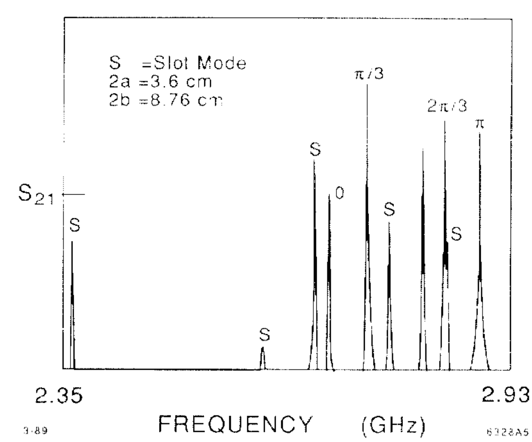

Fig. 5. S_{21} Plot: Small beam aperture, slots aligned.

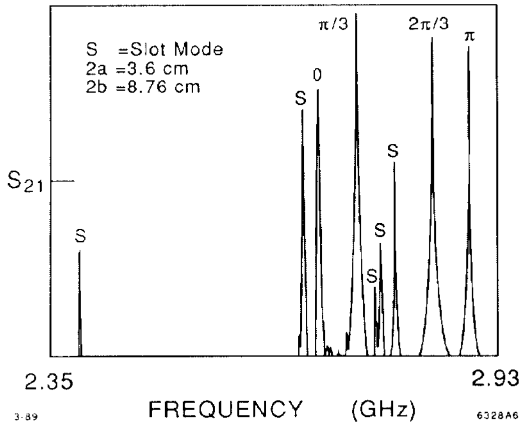

Fig. 6. S_{21} Plot: Small beam aperture, slots at 45°.

5. Four-Cavity Assembly for High-Power Test

The test structure shown schematically in the lower part of Fig. 7 has been fabricated. Many difficulties have been experienced in tuning the $2\pi/3$ mode to 2856 MHz in this standing-wave section. Annular plugs had to be inserted into the "beam tubes" at each end, and the coupling iris size had to be determined experimentally to bring the input match to 1.08:1. When these adjustments were made correctly, the axial field profile shown in the upper part of the figure was obtained. With this configuration, the relationship between the peak field in the middle cavity and the input RF power to the structure is known, permitting the fields at breakdown to be deduced. As this paper is being prepared, the high power tests are being set up.

Acknowledgements

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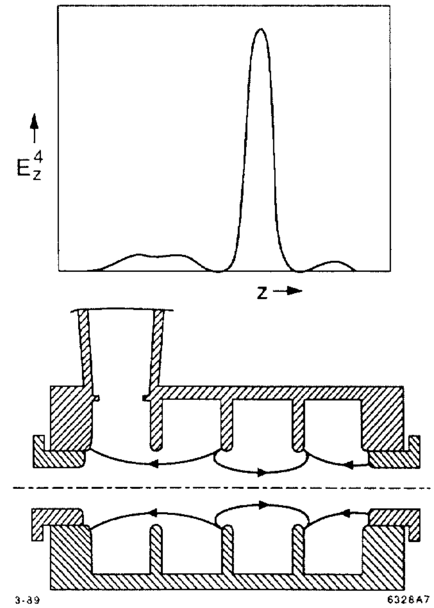

Fig. 7. Cross-section of high-power test structure, with axial field profile.

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4. N. Kroll, private communication.