THE DAW STRUCTURE FOR THE NBS/LOS ALAMOS RACETRACK MICROTRON*

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Summary

The results of a testing program on the disk-and-washer (DAW) structure with tee supports are presented. These results have led to the design of a 2.4-m DAW linac for use as the preaccelerator section of the National Bureau of Standards (NBS)/Los Alamos racetrack microtron (RTM).[1,2] This structure uses two tee supports for each pair of washers, instead of four, and the structure has a larger diameter than earlier test structures. Two properties of this structure, which make it appear to be ideal for the RTM application, are a high shunt impedance and a high cell-to-cell coupling factor.[3-7] This coupling factor eases construction tolerances and reduces sensitivity to thermal effects from the high rf heating load that will be imposed upon it. The structure is designed to operate at a 100% duty factor with a 1.5-MV/m accelerating gradient at 2380 MHz. This load would detune most accelerating structures. The tuning procedures, the transverse modes, and their effect on the structures design also are presented.

Introduction

The DAW linac structure is being developed at the Los Alamos National Laboratory for the NBS/Los Alamos RTM. This structure would be useful for a number of electron and proton accelerators because it offers efficient acceleration of particles with velocities greater than half the velocity of light. The structure is a standing-wave linac with an extremely stable field distribution because the operating mode has the stability of a π/2 mode with large cell-to-cell coupling. Other advantages include good vacuum conductance, an all-coaxial structure, high effective shunt impedance, and a high quality factor.

The geometry of the three test cavities and the preaccelerator section has been determined in an iterative procedure with the aid of the rf cavity calculational program SUPERFISH and the results of the frequency measurements and beadpulls on the test cavities.

The tee-shaped washer supports have been selected for their fore/aft symmetry and their small perturbation to the accelerating mode. The washers are supported in pairs from a number of tee-shaped supports. The axis of the supports lie along an equipotential of the accelerating mode as calculated by SUPERFISH.

Test Results

Three cavity designs were tested during the last year. The first two designs had quality factors (Q) considerably lower than anticipated. The third design had a measured Q of 29 000 for a six-cell, ß = 1 cavity, indicating an effective shunt impedance of 90 MΩ/m for a long structure. Although this is less than the 100 MΩ/m we had hoped for, it is certainly adequate for our needs. These results have led to a final design for the 2.4-m long preaccelerator structure, which is now under construction and should be ready for low power tests in December 1981 and full power tests by February 1982.

The dimensions of the three test cavities and the preaccelerator are defined by the half-cell geometry shown in Fig. 1 and tabulated in Table I. A summary of test results are shown in Table II. Changes in the DAW design from the original conception include the use of two (instead of four) tee supports for each pair of washers, and an increased diameter of the structure. These changes were made to increase the structure's shunt impedance. Even though the tees are placed on an equipotential line, they are in a region of high magnetic field and therefore dissipate rf power as a result of surface currents. The rf power loss caused by these stems is cut in half by reducing the number of these stems from four to two. In addition, the perturbation of the accelerating-mode frequency is cut in half. The use of four stems raised the accelerating mode by about 50 MHz. When

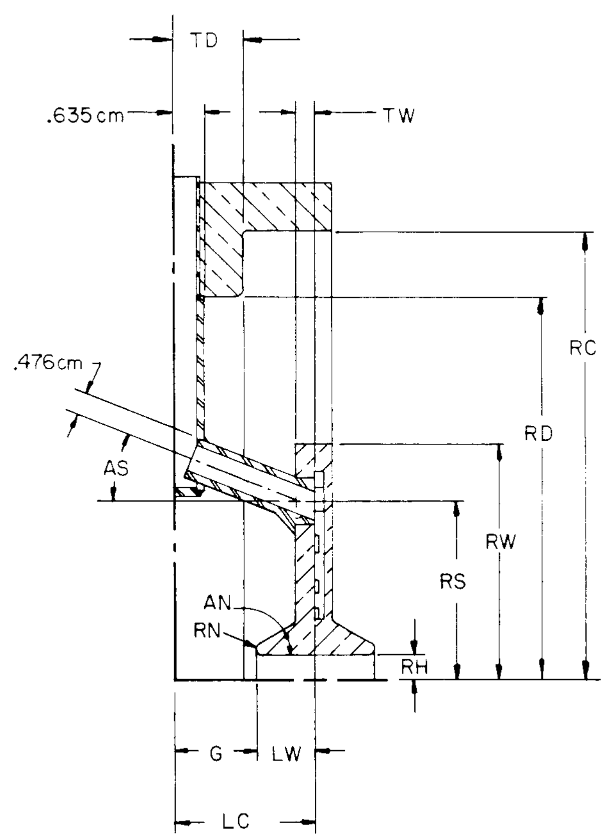

Fig. 1. Half cell dimensions for disk-and-washer structure.

*Work supported by the US Department of Energy.

Table I

HALF-CELL DIMENSIONS (IN CM) OF THE THREE TEST CAVITIES AND THE PREACCELERATOR STRUCTURE

	Test Cavity Number 1	2	3	Preaccelerator Section
LC=	3.149	3.149	3.149	3.149
RC=	8.225	8.651	9.914	9.729
TD=	1.503	1.503	1.503	1.503
RD=	6.944	6.944	8.446	8.446
G=	1.833	1.833	1.833	1.833
LW=	1.316	1.316	1.316	1.316
RW=	5.058	5.278	5.159	5.130
TW=	0.400	0.400	0.400	0.400
AN=	30°	30°	30°	30°
RN=	0.140	0.140	0.140	0.140
RH=	0.625	0.625	0.500	0.500
RS=	3.810	3.810	3.896	3.865
AS=	23°	23°	23°	23°
Number of stems per washer pair	4	4	2	2

two stems are used, this perturbation is only 25 MHz, and the perturbation of the coupling-mode frequency is decreased by more than a factor of 2. The increased diameter of Test Cavity 3 probably caused part of the decrease in this perturbation. Increasing the diameter of the structure lowers the rf losses on the outer wall, which raises the shunt impedance. Finally, the diameter of the bore hole was reduced to further increase the shunt impedance. Beam-transport calculations of the RTM indicated that the smaller bore hole would be satisfactory.

Figure 2 shows the Brillouin diagram of the accelerating mode, as well as some other modes that the DAW Test Cavity 3 supports below 2700 MHz. Above 3000 MHz, there is a very large number of modes possible. Of special concern is the set of TM11 modes just below the accelerating frequency. The frequencies of these modes are lowered by increasing RC and RD. These TM11 modes are of most concern because they are the most likely to cause beam blowup. The TE11 modes do not interact strongly enough with the beam to be of concern for beam blowup. The "acc. stem" modes are modes that exist only because conducting stems are used to support the washers. The stop bands in some of the mode spectrums at a phase shift of $\pi/2$ per

Table II

SUMMARY OF TEST RESULTS

	Test Cavity Number 1	2	3	Preaccelerator Section
Acc-mode freq. (Mhz)				
SUPERFISH	2382	2331	2346	2352
Experiment	2420	2387	2371	(2377) predicted
Difference	38	56	25	
Coupling-mode freq. (Mhz)				
SUPERFISH	2380	2200	2228	2308
Experiment	2590	2469	2320	(2380) predicted
Difference	210	269	92	
Ratio of electric field in cell with stems to cell without stems	0.85	0.82	1.06	(1.0) predicted
Q (6-cell)experiment	20 000	20 000	29 000	
Q (6-cell)SUPERFISH	32 400	32 400	39 800	
ZT^2 for long structure				
SUPERFISH (MΩ/m)	104	104	122	
Experiment (MΩ/m)	64	64	89	

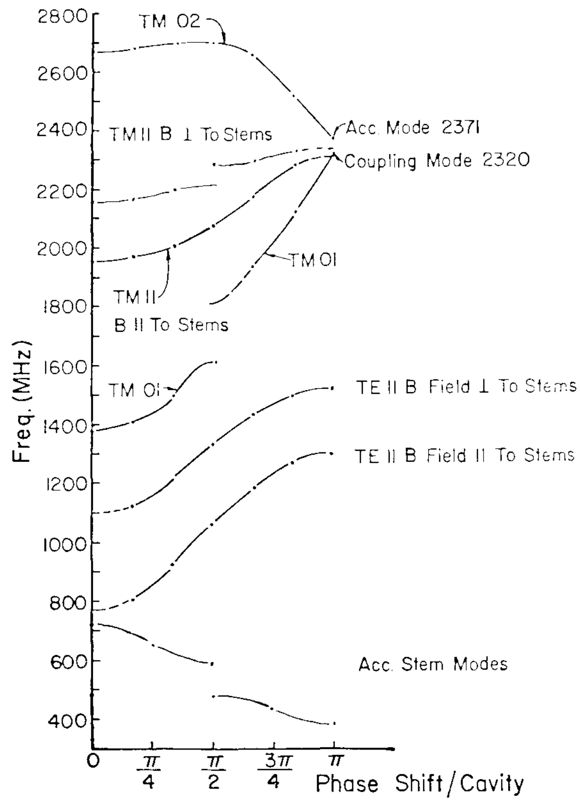

Fig. 2. Brillouin diagrams of some modes in the DAW Test Cavity 3.

cavity are due to the biperiodic distribution of the tee supports.

The accelerating mode and the coupling mode occur at the confluence of the TM01 and TM02 modes. The geometry of the DAW structure is designed so that these two mode spectrums join at this point. Because the supports perturb the frequency of the accelerating mode and the coupling mode, minor changes must be made in the geometry to obtain the desired accelerating frequency and to retain a closed stop band, with its implied stability and uniform distribution of accelerating fields. Figure 3 shows a section of DAW structure with locations where material must be added or removed for tuning. Because the stems increase the accelerating-mode frequency, the washer radius initially must be made larger so that the accelerating frequency is lower than that desired. Material then can be removed to tune the structure to the right frequency.

The accelerating frequency rises 20 MHz for each millimeter of material removed from the washer radius. The coupling-mode frequency is lowered 43 MHz when the radius RC is increased by 1 mm. Table II shows the predicted frequencies of the accelerating and coupling mode of the preaccelerator section. The dimensions are given in Table I. A small amount of material has been left on the washer radius for final tuning of the structure to 2380 MHz.

In addition to perturbing the frequency of the accelerating and coupling modes, the stems can

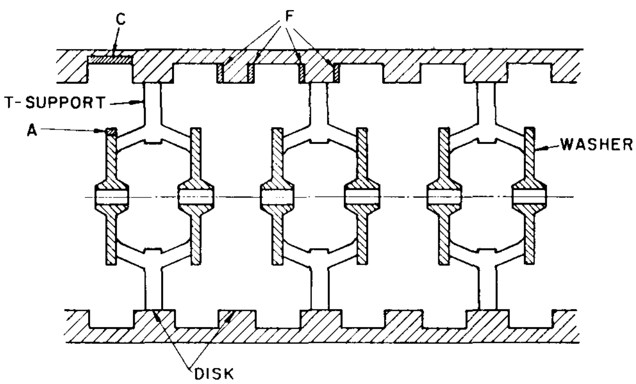

Fig. 3. A cross section of the DAW structure showing locations where material can be removed to tune the structure.
C. Decrease coupling-mode frequency.
A. Increase accelerating-mode frequency.
F. Decrease accelerating field in cavity where disk has been made thinner.

create a biperiodic distribution of the accelerating field. Figure 3 shows where material can be removed to compensate for this effect. The value chosen for RS also affects this biperiodic distribution. By using a different value of RS in Test Cavity 3 than that used in Test Cavities 1 and 2, the electric-field ratio in the cells with stems to the cells without stems changed from <1 to >1. The value of RS for the preaccelerator section has been chosen to give the same accelerating field in all cells.

Preaccelerator Design

The preaccelerator is illustrated in Fig. 4. The structure is 2.4 m long and is bolted together with stainless steel flanges at three places. It

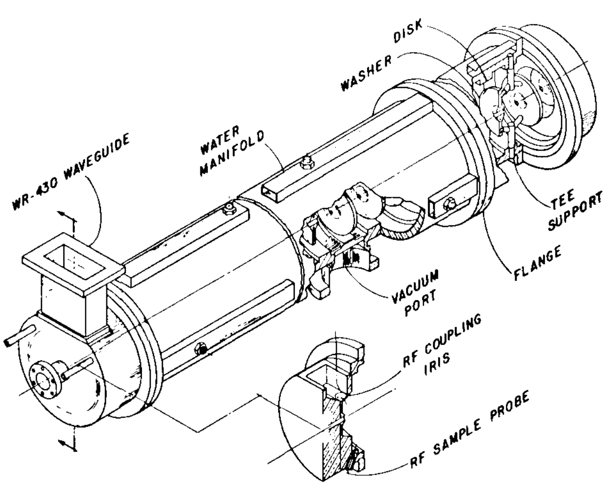

Fig. 4. Preaccelerator structure showing the waveguide coupling, the vacuum port, and the water-cooling channels.

consists of two ends and two sections, each slightly longer than 1.1 m. One end piece has an rf coupling iris to the WR-430 waveguide. Only one vacuum port is required, because the structure is so open that vacuum conductance is no problem for a structure of this length. Longer sections will require more vacuum ports.

Acknowledgment

The authors would like to thank F. J. Humphry, P. L. Roybal, and L. C. Wilkerson for their work on the DAW test cavities.

References

1. S. Penner, P. H. Debenham, D. C. Green, E. R. Lindstrom, D. L. Mohr, M. A. D. Wilson, L. M Young, T. J. Boyd, E. A. Knapp, J. M. Potter, D. A. Swenson, and P. J. Tallerico, "NBS-LASL Racetrack Microtron," Proc. 11th Int. Conf. on High-Energy Accelerators, CERN, Geneva, July 7-11, 1980, Experimentia: Supplement 40, p. 110 (1981).

2. S. Penner, R. I. Cutler, P. H. Debenham, E. R. Lindstrom, D. L. Mohr, M. A. D. Wilson, N. R. Yoder, L. M. Young, T. J. Boyd, E. A. Knapp, E. R. Martin, J. M. Potter, C. M. Schneider, D. A. Swenson, and P. J. Tallerico, "The NBS-LASL CW Microtron," Proc. 6th Conf. on Applications of Accelerators in Research and Industry, Denton, Texas, November 3-5, 1980, IEEE Trans. Nucl. Sci. 28, p. 1526 (1981).

3. S. O. Schriber, "Room-Temperature Cavities for High-Beta Accelerating Structure," Proc. Conf. on Future Possibilities for Electron Accelerators, Charlottesville, Virginia, January 8-10, 1979 (University of Virginia, Charlottesville, Virginia, 1979), Paper L.

4. S. O. Schriber, "High-Beta Linac Structure," Proc. 10th Linear Accelerator Conf., Montauk, New York, September 10-14, 1979, Brookhaven National Laboratory report BNL-51134, p. 164 (1980).

5. S. O. Schriber, and J. M. Potter, "Limitations of the Disk-and-Washer Structure," Proc. 10th Linac Conf., Montauk, New York, September 10-14, 1979, Brookhaven National Laboratory report BNL-51134, p. 176 (1980).

6. J. M. Potter, S. O. Schriber and F. J. Humphry, "Experimental and Calculated rf Properties of the Disk-and-Washer Structure," Proc. 1979 Particle Accelerator Conf., San Francisco, California, March 12-14, 1979, IEEE Trans. Nucl. Sci. 26, p. 3763 (1979).

7. S. O. Schriber, "Accelerator-Structure Development for Room-Temperature Linacs," Proc. 1981 Particle Accelerator Conf., Washington, DC, March 11-13, 1981, IEEE Trans. Nucl. Sci. 28, p. 3440 (1981).

Discussion

The accelerating mode has a shunt impedance of about 90 MΩ/m. The TM_{11} mode is close to the accelerating mode, but it can be lowered by tuning. The structure is very strongly coupled from cell to cell, like 50%, so the drive can be coupled in anywhere and the field level will be the same in every cell. We do the tuning before the final braze. Some fine tuning could be done afterwards; the water temperature can also be used to adjust the resonant frequency about 40 kHz per degree centigrade.