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Biperiodic L-Support DAW for Electron Acceleration

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The disk-and-washer (DAW) linac structure with the biperiodic L-washer-support geometries is studied. For electron acceleration, the DAW is the one of good geometries, with smaller filling time, and fewer unwanted passbands.

KEY WORDS: DAW/ Biperiodic L-support/ Electron accelerator/ Cold model

1. INTRODUCTION

An electron linac and a storage ring (KSR)[1] are being assembled at the Accelerator Laboratry, Institute for Chemical Research, Kyoto University. For the first stage, the disc-loaded waveguides are installed as the accelerating tube. Because of the limited size of the building, the available space for the linac is only for three of 3-m accelerator tubes. The available RF power from a klystron is up to 20 MW for each accelerator tube, and the accelerated electron energy is expected to be 100 MeV at 100 mA. It is desirable to increase the injection energy of the storage ring, because of the shorter damping time in the storage ring. A new accelerating tube with higher shunt impedance is required to achieve the higher accelerating gradient with the same input RF power.

The DAW structure has outstanding features in high stability, good vacuum properties, high shunt impedance, and ease of fabrication[2,3]. It was found that the mode overlapping problem can be overcome by the biperiodic support configuration with the carefull choice of the tank diameter (See Fig. 1). There are varity of options for DAW linac structure with such biperiodic washer support. For example, in a large tank-diameter configuration, the operating frequency drops between the two split TM_{11} (-like) mode passband, and the shunt impedance is higher. When the tank diameter is small, both TM_{11} mode passbands are above the operating frequency, and the mode density is smaller. The basic configuration described here is the extension of the PIGMI[4] geometries, except for the thicker washers and the 20% reduced tank diameter. This geometry has the smaller number of the unwanted modes and the shorter filling time compared with the large diameter 4-T support DAW. The washer thickness is increased for the cooling water channels machined in the washers. Because the L-support configuration has only two supports on the washer, there are only one inlet and one outlet for the waster. It may simplify the fabrication problem compared with the 4-T support geometry, which has two inlets and two outlets on the washer.

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2. MAFIA AND SUPERFISH CALCULATION

Some L-support configurations cannot be measured in real cavities because of the termination problem. Because the cavity should be surrounded by the metal surfaces, only the mirror symmetry imposed by a metal surface is available in a real cavity. MAFIA[5] can analyze even some of such problems using only electric and magnetic symmetries. Figure 1 shows one example of the meshes in such calculations. This geometry corresponds to a quad-periodic structure. The rest of the problems that cannot be expressed with such reflection symmetries are the periodic boundary problem, which cannot be analyzed by MAFIA of the old release. The biperiodic structure, which mostly concerns here, requires such periodic boundary handling capability in the analysis.

The quad-periodic L support DAW geometry is analyzed by MAFIA using such reflection symmetries. The notations of the DAW dimensions are shown in Fig. 2. Two-cell geometry should be included in the calculations because the structure has quad-periodicity. The corner of the L-support is rounded considering the manufacturing, because the support will be made of a bent pipe. Firstly, the starting dimensions are determined by SUPERFISH calculations so that the accelerating frequency and coupling frequency are equal to the operating frequency. The starting dimensions and the calculated results are listed in Table 1. The same geometry without the L-support is calculated by MAFIA, but the nose shape and minor corrections are made to give the right frequencies. Because the L-supports push up the coupling mode frequency, the washer radius and the disk radius are re-adjusted after the L-supports are included. The connection radius of the L-support on the washer is the "zero-electric field" point (Rt=32.5 mm)

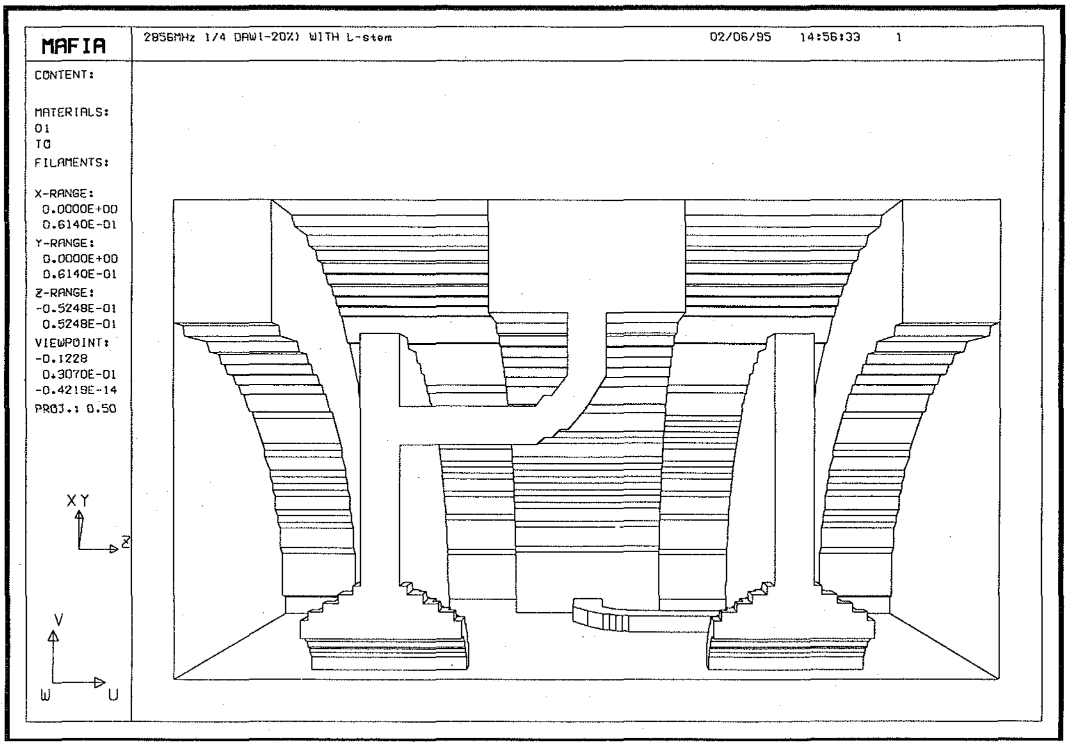

Fig. 1. An example of MAFIA mesh.

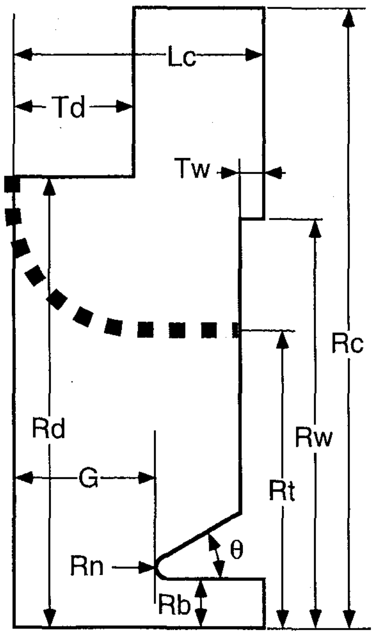

Fig. 2. The notations of the DAW dimensions.

on the washer calculated by SUPERFISH. Because of the biperiodicity in the support existence along the structure, the uniformity of the electric field distribution is broken. In order to recover the uniformity, the disk radius is modified biperiodically. The modified dimensions are listed in Table 2. Figure 3 shows the SUPERFISH flux plots of the resulted DAW geometry. The calculated values are listed in Table 3.

Calculating with different boundary conditions in MAFIA, the dispersion curves are obtained. The calculated dispersion curves are shown in Fig. 4. Because the TM_{11} and TE_{31} modes are largely perturbed and mixed together, the mode identifications are difficult for these modes. The broken line in Fig. 4 shows the line where the phase velocity v_p matches the speed of light. The lower dipole mode passband (TE_{11}) crosses this line around its $\pi/2$ modes. This effect on the beam break up should be investigated further.

The calculated shunt impedance by MAFIA is 92% of that by SUPERFISH. The real shunt impedance should depend on the surface finish of the fabrication process. Because the DAW linac will be operated in the standing wave mode, the filling time should be small as the replacement of the disc-loaded waveguide. The filling time of the proposed geometry is calculated as $\tau = Q/\omega = 1.3\,\mu S$. Because the RF pulse width of the present system is less than 2 μs, it may have to be elongated for the DAW operation.

The full accelerating mode termination is designed by SUPERISH. Figure 5 shows the flux plot in the accelerating mode termination. Because of the simplicity and the power loss consideration, just a conical shape is applied to the wall between the last disk part and the last end vertical wall. The small vertical wall is put on the disk side, for a reference surface in a tuning process of the cold model test descried later.

According to the SUPERFISH calculation, two thirds of the cavity power is dissipated on the washer. Because the maximum output power of the present klystron is 20 MW, and the duty

Table 1. Starting dimensions of DAW cavity.

Rc/λ	0.585	—
β	1.0	—
Frequency	2.856	GHz
L=$\beta\lambda/4$	2.624	cm
Rc (cavity radius)	6.140	cm
Rd (disk radius)	4.96	cm
Td (half disk thickness)	1.253	cm
Rw (washer radius)	4.2	cm
Tw (half washer thickness)	0.25	cm
θ (nose angle)	30	degree
Rn (nose radius)	0.12	cm
Rb (bore radius)	0.513	cm
G (gap)	1.484	cm
Zp^2 (SF)	109	MΩ/m
facc (SF)	2,860	MHz
Qacc (SF)	2,8200	—
fcpl (SF)	2,856	MHz
Qcpl (SF)	14,200	—
ZT^2 (MAFIA w/o support)	112	MΩ/m
facc (MAFIA w/o support)	2,873	MHz
Qacc (MAFIA w/o support)	29,400	—
fcpl (MAFIA w/o support)	2,851	MHz
Qcpl (MAFIA w/o support)	15,200	—
ZT^2 (MAFIA with support)	100	MΩ/m
facc (MAFIA with support)	2,894	MHz
Qacc (MAFIA with support)	26,100	—
fcpl (MAFIA with support)	3,014	MHz
Qcpl (MAFIA with support)	14,200	—

Table 2. The modified cavity dimensions.

Rdn (non-support disk radius)	4.75	cm
Rde (support disk)	4.50	cm
Rw (washer radius)	4.4	cm

Table 3. DAW cavity geometries.

	(MAFIA w/o support)	(MAFIA with support)	SUPERFISH	Unit
ZT^2	95	103	103	MΩ/m
facc	2,860	2,839	2,824	MHz
Qacc	23,400	25,700	25,100	—
fcpl	2,852	2,666	2,674	MHz
Qcpl	12,000	12,900	12,300	—

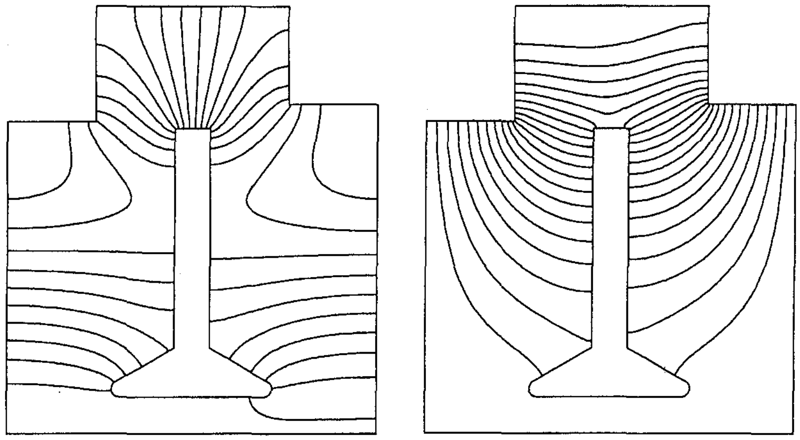

Fig. 3. SUPERFISH flux plots of the modified DAW.

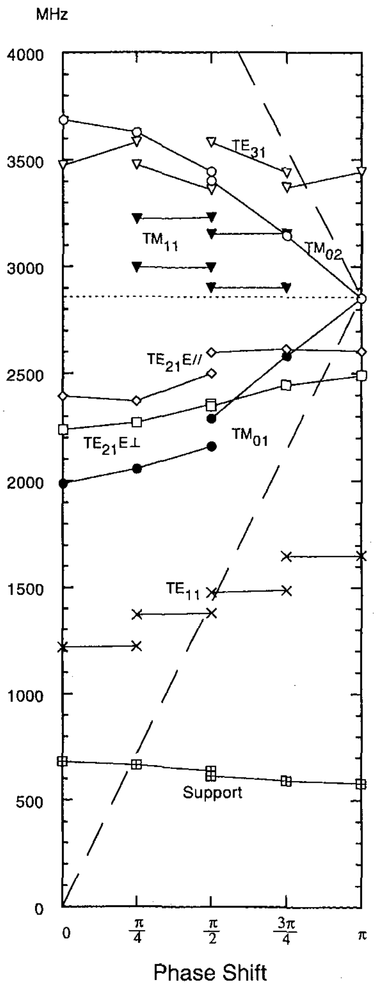

Fig. 4. Calculated dispersion curves.

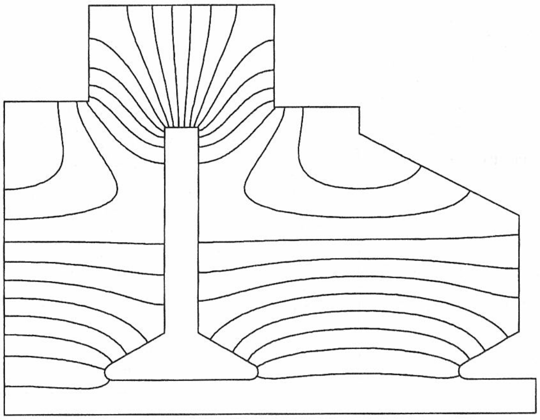

Fig. 5. The flux plot of the full accelerating mode termination.

factor is about 10^{-4}, the power dissipated on a washer is less than 30 W for 48 cell cavity. In order to remove the heat from the washer, enough cooling water should flow through the supports. The rest of the power is dissipated on the inner surface of the tank wall that includes the disk part. The cooling of the tank wall should be easy compared with that of washers.

3. COLD MODEL

Because the calculations do not simulate the real full cavity, only the calculations are not sufficient for determining the DAW structure, and then a cold model of aluminum alloy (5052) is fabricated (See Photo 1). The main parts of the cold model are twelve washers, thirteen disks, twelve wall rings, two half-cell-accelerating-mode-terminations, two full-cell-accelerating-mode-terminations, two coupling-mode-terminations, and many L-supports with different length. In order to investigate the effect of the connection radius of the L-support on the washer, five types of L-supports with different length are prepared; namely Rt=25.3, 27.3, 29.3, 32.3, and 34.3 mm.

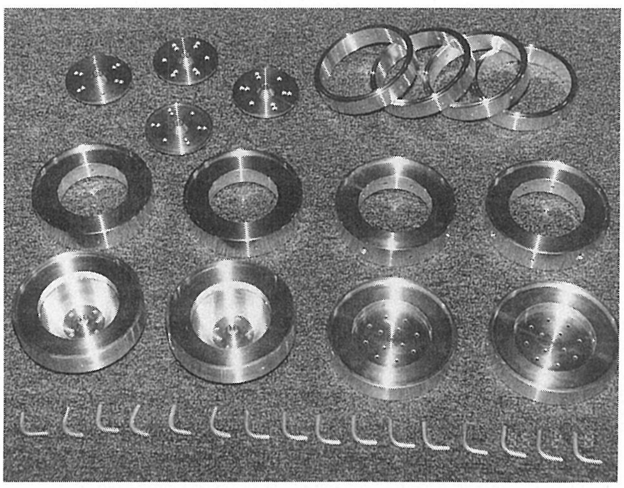

Photo. Some parts for the cold model.

Stacking these parts, the DAW cavity can be assembled with several configurations. There are three requirements to be satisfied for the final dimension ; two of them are to tune the frequencies of the accelerating mode and the coupling mode on the operating frequency, and another one is to make the uniform field distribution on the axis, which is broken by the bi-periodicity. For such conditions, the two disk radii (R_{dn}, and R_{ds}) and the washer radius (Rw) are adjusted by removing material from the surfaces using a lathe. The cold model parts have the margin for such purpose.

The field distributions are measured by the bead perturbation method. Figure 6 shows a result from the measurements. Because the frequency shift is proportional to the energy density, the electric field is proportional to the square root of the frequency shift. The frequency shift is measured by the Phase Locked Loop configuration (See Fig. 7).

The coupling frequency measurement is not straight forward, because the coupling mode

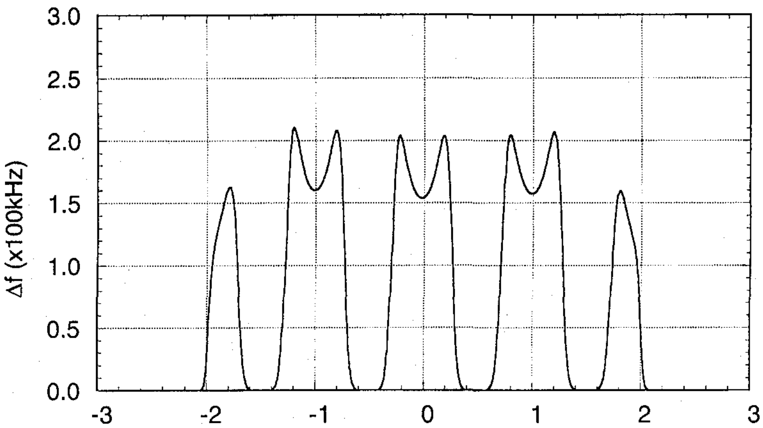

Fig. 6. The field distrbution measured by the bead perturbation method.

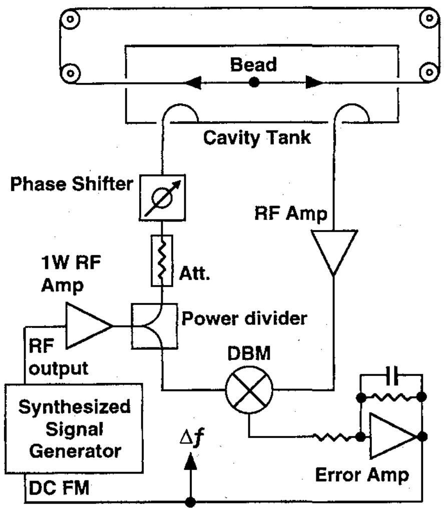

Fig. 7. The full accelerating mode termination.

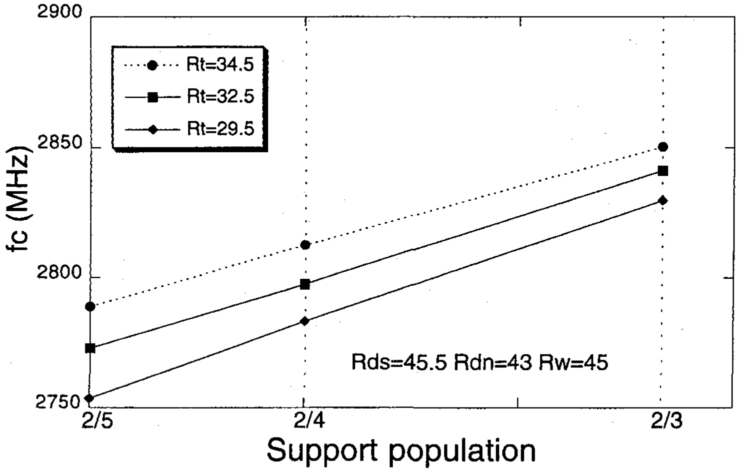

Fig. 8. Coupling frequency as a function of the support population.

(TM01π) itself does not appear in the real finite length accelerating cavity with the accelerating mode terminations. The support-disk population in the infinitesimally long cavity should be 50%, where the number of disks with supports is the same as that without support. Figure 8 shows the coupling mode frequency measured as a function of the population changing the support connection radius Rt. In the figure, "2/4" means that there are two support-disks in the four cell cavity. Because the coupling frequency is almost proportional to the support population, only the measurement of the 2/4 configuration may be sufficient to determine the coupling mode frequency.

4. CONCLUSION

The DAW structure with L support seems to be a good candidate of the linac structure for the electron acceleration. Assuming 80% as the Q degradation in fabrication process, two of 1.3-m long accelerator cavities with 24-washers each will have the shunt impedance of about 200 MΩ/m$\times$2.6 m$\times$80%). The DAW cavity will produce more than 60 MV at the input power of 20 MW, hence the ordinary 3m-long disc-loaded waveguide produces 45 MV. Two of 1.3-m long accelerator cavities are coupled together with a coaxial bridge coupler, where an RF feed slot and an evacuation port are located. Frequency tuners are also installed in the bridge coupler. In the inner-conductor of the bridge coupler, a current monitor may be installed. A cold model with 12-washers made of Aluminum is fabricated for the confirmation of the calculation and the determination of the detailed dimensions. The tuning process using these measurement techniques is now underway.

5. ACKNOWLEDGMENT

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Research, Kyoto University.

6. REFERENCES

(1) A. Noda et. al., "Design of an Electron Storage Ring for Synchrotron Radiation", Proc. of the 4th European Particle Accelerator Conference, in print.
(2) R.K. Cooper, Y. Iwashita, J.M. Potter, S.O. Schriber, D.A. Swenson, J.M. Watson, L.C. Wikerson and L.M. Yogung, "Radio-Frequency Structure Development for the Los Alamos/NBS Racetrack Microtron" Los Alamos National Laboratory document LAUR-83-95 (Jan. 1983).
(3) Y. Iwashita, "Disk-and-Washer structure with biperiodic support", *Nucl. Instrum. and Meth. in Phys. Res.*, **A348**, 15–33 (1994).
(4) L.D. Hansbrough, Compiler, "PIGMI : A Design Report for a Pion Generator for Medical Irradiation", *LANL report* LA-8880 (1980).
(5) "MAFIA USER GUIDE", The Mafia Collaboration, DESY, LANL, KFA, March 16, 1988.