Improvement of Bridge Coupler for Disk-and-Washer Structure

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Abstract

A high power model of the DAW cavity for electron acceleration is under fabrication. In this model, two separate accelerating tubes are connected by a coaxial bridge coupler. The accelerating mode frequency(f_a) and the coupling mode frequency(f_c) of the bridge coupler were calculated by SUPERFISH and MAFIA and tuned to the operating frequency (2857MHz). We adopt a choke termination at the supports of the bridge coupler. It is effective for adjusting both frequencies. Based on these results, the final dimensions were fixed by cold model measurement. This modification brings much higher RF coupling between cavities with the bridge coupler, so that the electric field distribution becomes uniform and the tilt sensitivity is improved.

1 Introduction

The DAW(disk-and-washer) linac structure has high shunt impedance, good vacuum properties, and high stability. These advantages are suitable for a high beta accelerator. The mode overlapping problem that was found in early studies have been overcome by adopting the biperiodic structure.[1]

A high power model of the biperiodic L-support DAW(see Fig.1) for an electron acceleration is under fabrication and test. The operating frequency is designed at 2857MHz which is the same as the disc-loaded waveguide accelerating tubes used in our laboratory. The injection energy for the acceleration test is intended to be about 60MeV. In this model, two separate 1.2m long accelerating tubes are connected by a coaxial bridge coupler which has an RF coupler, a vacuum port, and three frequency tuners on its outer wall. Figure 2 shows the conceptual design of the bridge coupler. A spool is fixed by four supports. It replaces the two washers so that one accelerating gap is filled with the spool.

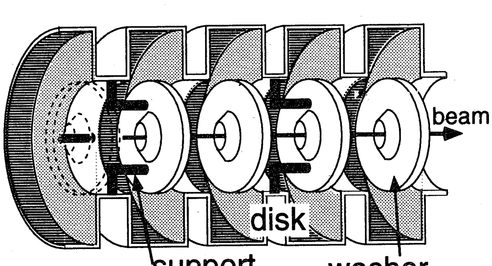

Fig. 1 DAW with biperiodic L-support

2 Accelerating Mode and Coupling Mode

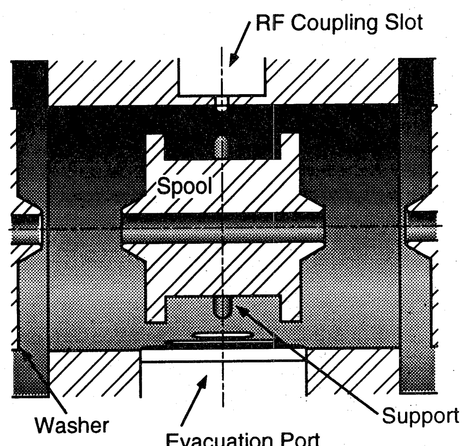

Fig. 2 Conceptual design of the bridge coupler

Two RF mode frequency, accelerating mode and coupling mode, must be adjusted to the operating frequency in the DAW structure.

The accelerating mode generates the strong electric field at the accelerating gaps (see Fig.3). The frequency of the high power RF supplied from a klystron is 2857MHz which is as same as the disc-load linac. So, the frequency of the accelerating mode must be adjusted to the operating frequency (2857MHz) exactly.

On the other hand, the coupling mode produces coupling between accelerating cavities (see Fig.4). This mode redistributes stored energy and recover the flatness of the accelerating field when the field flatness is disturbed.

Although there are the two modes at the same frequency, only the accelerating mode is excited because of the boundary condition at the end plate of the linac. Only when the field flatness is disturbed, the coupling mode is excited. It is not necessary to adjust the coupling mode frequency to the accelerating mode one strictly, because the DAW has a very high RF coupling between the cavities. But, if the coupling mode frequency is located far from the accelerating mode one, this frequency difference breaks flatness or stability of the accelerating field. So, it is desirable to keep the coupling mode frequency close to the accelerating mode one.

3 Tuning of the Accelerating Mode Frequency

Firstly, we estimate the effect of the supports on the frequency. The dimensions of the spool are determined by the SUPERFISH calculation so that the accelerating mode frequency(f_a) matches to about 2857 MHz. Then, the frequency is re-calculated for both cases—

with supports and without supports—by MAFIA. The cross-section of the support is treated as square in the MAFIA calculation because of its mesh characteristics. By comparing the results of both cases, the support effect on the frequency is estimated as about 10MHz increase for the accelerating mode. The correction of the dimension is calculated by SUPERFISH so as to compensate the support effect. And then, the frequency is re-calculated including the supports by MAFIA. These steps are repeated until the frequency converges to the designed value. The final results are shown in Table 1. The electric field plot obtained by SUPERFISH is shown in Fig.3,4.

Table 1
The results of the accelerating mode frequency(f_a) calculation.

	f_a [MHz]
SUPERFISH	2847.24
MAFIA(without support)	2847.31
MAFIA(with support)	2855.65

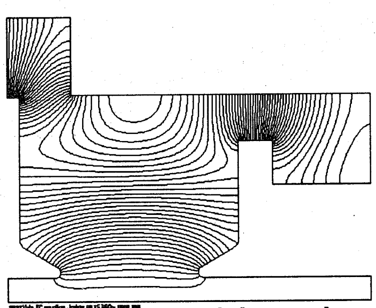

Fig. 3 The electric field of the accelerating mode.

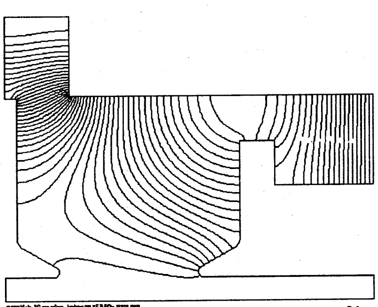

Fig. 4 The electric field of the coupling mode.

4 Tuning of the Coupling Mode Frequency

As the electric fields(Fig.3,4) show, the support is perpendicular to the electric field of the accelerating mode, while it is parallel to that of the coupling mode. In order to recover the support effect on coupling frequency, we adopt the $\frac{\lambda}{4}$ coaxial choke termination to

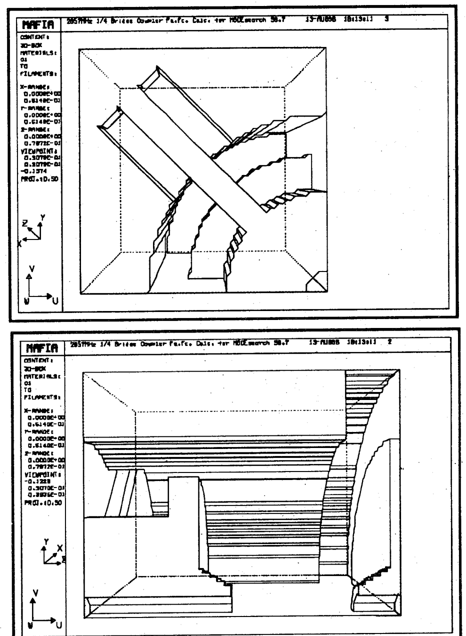

Fig. 5 The MAFIA mesh of the bridge coupler with the support.

make an RF insulation between the outer wall and the support. Fig.5 shows the mesh for the MAFIA calculation. The accelerating mode frequency(f_a) and the coupling mode frequency(f_c) are calculated by MAFIA changing the length of the coaxial area. The cross section of the outer conductor is treated as square again. The results are listed in Table 2. It decreases the coupling mode frequency drastically, while the accelerating mode frequency is not changed much.

Table 2
The results of the MAFIA calculation. f_a is calculated for 0mm and 24.8mm only.

coaxial length [mm]	f_a [MHz]	f_c [MHz]
0	2855.65	3242.86
23.5	-	2917.31
24.8	2852.12	2855.14
25.5	-	2824.67

5 Cold model measurement

Because approximation errors cannot be avoided in the calculations, the final dimensions should be determined by cold model measurement. The cold model of the bridge coupler with choke termination supports was fabricated. Then it was connected with the cold model of regular cells. The frequencies of the two modes and the electric field distribution were measured.

5.1 Electric field distribution

It is expected that the high RF coupling gives more flat distribution of the electric field. And it reduces the effect from the fabrication error too. Two types of cold model are measured. One has the choke termination, and the other does not. Fig.6 and Fig.7 show the results. The bridge coupler is installed at the center(cell number 0) of the accelerating tube. Two figures shows that the improvement of the coupling mode frequency brings the high RF coupling constant and high stability of the electric field.

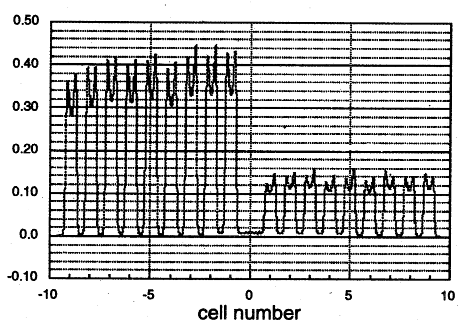

Fig. 6 Field distribution of no choke termination (fa=2857[MHz],fc=3029[MHz])

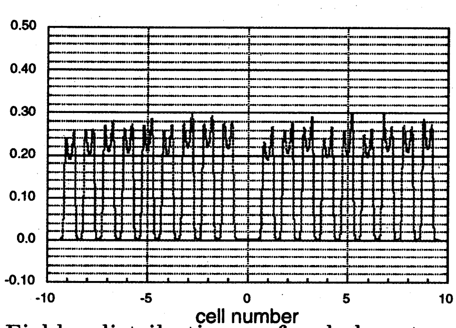

Fig. 7 Field distribution of choke termination (fa=2854[MHz],fc=2857[MHz])

5.2 Tilt sensitivity

Tilt sensitivity (TS) is an index of the field stability. The effect from fabrication errors is estimated.

The field stability was investigated as follows : Two field distributions with different detuning of the end cells are carried out :

1. The accelerating mode frequency is lowered by sticking perturbation rods into both the end cells.
2. One rod is pushed in more to lower the frequency by Δf.
3. The other rod is pulled out to restore the frequency.
4. Measure the field distribution by the bead-pull method.
5. Measure the distribution with perturbation in opposite direction, which tends to tilt the field opposite direction.

TS is defined as follows:

$$TS = \frac{E_n^+ - E_n^-}{(E_n^+ + E_n^-)\Delta f} \times 100\ [\%/\text{MHz}]$$

where E_n^+ and E_n^- are the on-axis electric field of the cell-n in the first and second measurement. Fig.8,9 shows TS measurements.

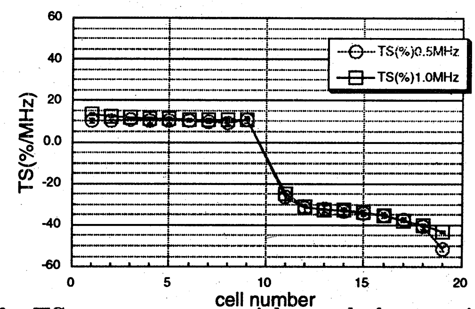

Fig. 8 TS measurement without choke termination

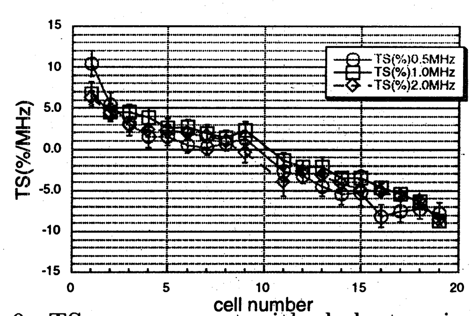

Fig. 9 TS measurement with choke termination

6 Conclusion

The cold model with the choke termination was fabricated and measured. The frequencies of accelerating and coupling modes were tuned to the operating frequency. This improvement brings the high RF coupling which leads to the flat field distribution and the low tilt sensitivity.

In a high power model, a vacuum, cooling and RF contact must be considered. The design of high power model is proceeded on the basis of these results.

Acknowledgment

The version of the MAFIA used here is release 2.04. The version of SUPERFISH is Release 4.12. Computation time of MAFIA was provided by the Supercomputer Laboratory, Institute for Chemical Research, Kyoto University.

References

[1] Y. Iwashita, "Disk-and-washer structure with biperiodic support", Nuclear Instruments and Method in Physics Research A348, pp. 15-33 (1994)