Q VALUE OF DAW LINAC WITH BIPERIODIC T STEM

Y.Iwashita, S.Abe, H.Takekoshi
Institute for Chemical Research, Kyoto University
Awataguchi Torii-cho, Sakyo, Kyoto, JAPAN 606

SUMMARY

Two sets of large radius DAW test cavity with biperiodic 4-T stem was studied for the T-stem effect to Q-value degradation and coupling mode frequency. Two shapes of T stem were tested. The frequency was 1300MHz and 2380MHz, and β=1.0. The overlapping problem connecting with the large radius for high shunt impedance was solved by the biperiodic 4-T stem geometry. The cavity radius was 0.767λ and 0.786λ. The Q value degradation introduced by the stem was evaluated by comparing with the non-stem geometry which was achieved by nylon string hanging. The coupling and accelerating mode frequency compensation method was also investigated to cancel the biperiodic perturbation to electric field distribution along the axis.

INTRODUCTION

The disk-and-washer(DAW) structure has outstanding features of high efficiency, high stability, and good vacuum conductance. The high efficiency is desirable for converting rf power into beam power. The high stability is resulted by the high coupling constant, and reduces structure sensitivity to tuning and assembly errors, beam loading effects and transients. The high coupling constant and the good vacuum conductivity come from the very open structure.[1]

Because of higher order passbands (in particular the TM11-like passband) overlapping the region of the operating-mode frequency, DAW structures have not been accepted for many projects, in contrast to an early enthusiasm based on structure attributes. There are solutions to the mode overlapping situation.[2-5] One of them is biperiodic 4-T stem configuration.[2] The advantages of this configuration is availability of large cavity radius connecting to high efficiency and coupling constant without mode overlapping. Another advantage is the least perturbation of the stem to the accelerating mode. To the coupling mode, however, the perturbation of the stem is not small and the frequency is pushed up about 5% of the designed value in our case. To close the stopband and make the confluence, the coupling frequency should be compensated to its designed value. Also the Q value is important factor for fabrication. In this paper, Q-value degradation introduced by the stem , and the coupling frequency compensation are reported.

TEST CAVITY

Two sets of β=1 aluminum alloy (5052) DAW test cavities were used for measurements of the Q value and coupling frequency. Fig. 1 shows the structure assembly for accelerating mode(right) and coupling mode(left) termination. The geometry is given in table 1. The number of cells was restricted by the number of parts available. One of two has frequency of 2380MHz and cavity radius (Rc) of 0.767λ. Another has that of 1300MHz and Rc of 0.786λ which is 2.5% larger than former one. All of the washer support geometry were the biperiodic T, where pairs of washers are supported by Ts. The shape of T stem for 2380MHz model was just like "Y" shape rather than "T", and that for 1300MHz model was not only "Y" but also "T", which is complete electric field perpendicular shape (fig.2). There was little difference in shape between "Y" stem for 2380MHz cavity and that for 1300MHz cavity. For comparison,

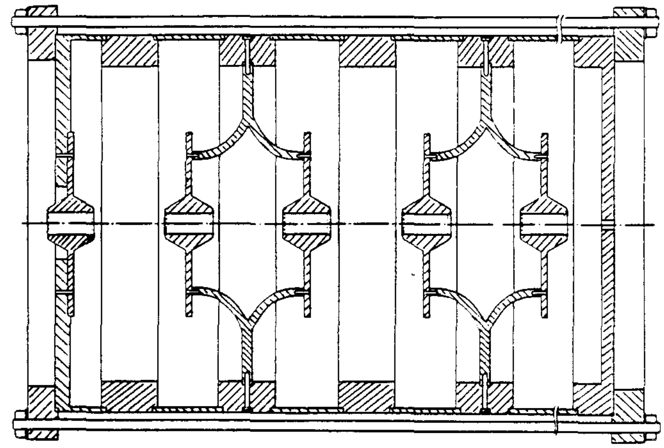

Fig.1 Structure assembly for accelerating (right) and coupling (left) mode termination with "T" stems for 1300MHz cavity.

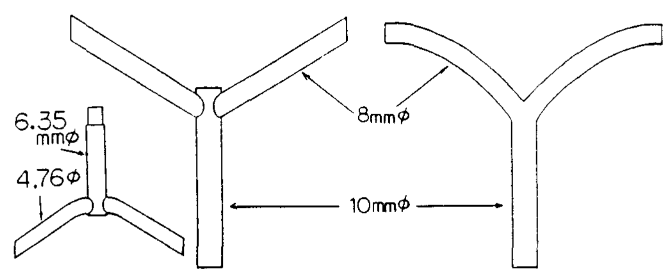

Fig.2 "Y" stem of 2380MHz cavity(most left), "Y" stem of 1300MHz cavity(middle),and "T" stem of 1300MHz cavity(right).

Table 1
DAW TEST CAVITY PARAMETERS

Frequency	(MHz)	2380	1300
Wavelength	(cm)	12.596	23.077
Half cell length	(cm)	3.149	5.765
Cavity radius	(cm)	9.667	18.14
Disk radius	(cm)	8.582	16.2(15.2)
Half disk thickness	(cm)	1.503	2.752
Washer radius	(cm)	4.947	9.024
Half washer thickness	(cm)	0.222	0.324
Nose angle	(deg)	30	30
Nose radius	(cm)	0.14	0.25
Bore radius	(cm)	0.616	1.128
Half gap length	(cm)	1.832	3.26(3.16)
Rc/λ		0.767	0.786
ZT^2	(MΩ/m)	121	91

non-support geometry were also measured which was achieved by nylon string hanging of the washers.

The 2380MHz cavity was not coupling mode frequency compensated, and had about 100MHz higher coupling mode frequency. The accelerating mode was also slightly higher than the designed one (about 0.5%). The 1300MHz model was designed to have compensated frequency of both coupling and accelerating mode as following. The disk radius Rd was reduced to push back the coupling frequency down, and the gap length was slightly reduced to push back the accelerating frequency. In early stage, both compensations was biperiodically performed at the cell with stem, because of the localized compensation and its simplicity. It was found that the alternate coupling strength between cells made the electric field distribution unbalance. Recently the compensation was modified to be uniform, and the accelerating frequency will be compensated by increase of washer radius, keeping the original gap length.

Q VALUE

Q value was measured with various number of cells for the elimination of the endplate losses. The reciprocal of unloaded Q value of n-cell cavity Qn is given as follows;

$$\frac{1}{Qn} = \frac{P_n}{\omega\, Wn},$$

where Pn, ω, and Wn are the power loss on the cavity wall, the angular frequency, and the stored energy in the cavity, respectively. Pn is sum of the power loss on the endplates Pe and the power loss in one cell without endplate Pc multiplied by the cell number n. Then we get;

$$\frac{1}{Qn} = \frac{Pe + n\, Pc}{\omega\, n\, Wc}$$

$$= \frac{Pe}{n\, \omega\, Wc} + \frac{Pc}{\omega\, Wc}$$

$$= \frac{1}{n}\,\frac{1}{Qe} + \frac{1}{Qc},$$

where Qe and Qc are the Q values of the endplates and that of a cell without endplate respectively. Qc is equal to the Q value of an infinitely long structure Q_∞. For a cavity with stems, Pc and Wc are averages between cells with stem and a cell with non-stem, if the stem perturbation is small. Wn is the stored energy in one cell multiplied by the number of cell n. Figs. 3-5 shows the reciprocal of Q value as a function of the reciprocal of the number of cells. Q_∞ is given at the y intercept.

2380MHz MODEL

Q_∞ of 2380MHz cavity with 4-T stem was 70% of that with non-stem as shown in fig 3. Because the stems were made of brass and had rather rough surface, two-cell-Q value was measured with polished stem and Q_∞ increased to 77% (assuming the same slope as before). There was good agreement between Q value from SUPERFISH calculation and measured Q_∞ of the cavity with non-stem, using conversion factor from Al alloy (5052) to Cu. The Al alloy conductivity(35% of that of Cu) was taken from data sheet.

1300MHz MODEL

Fig.4-5 shows the case of 1300MHz model with Al "T" stem. The slope for biperiodically compensated case is easier than no-T case (Fig.4). This means that the endplate loss 1/Qe was smaller than non-stem case, which is completely axisymmetric case. It was thought that the biperiodic reduction of Rd made the field in cell with stem larger than that with non-stem, and the current distribution on the wall was changed. Fig.5 shows the modified compensation case which was even reduction of Rd at Rd=15.4cm. The gap length was still biperiodically reduced at cell with stem. The field

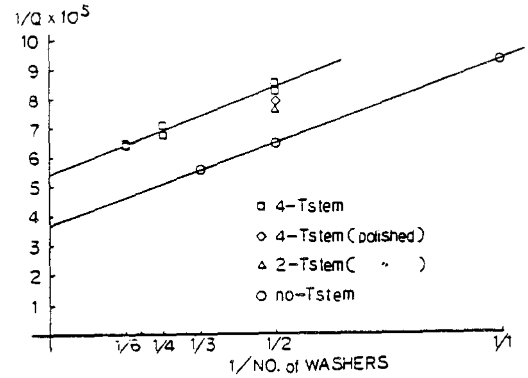

Fig.3 1/Q as a function of the reciprocal of the number of cells for 2380MHz test cavity.

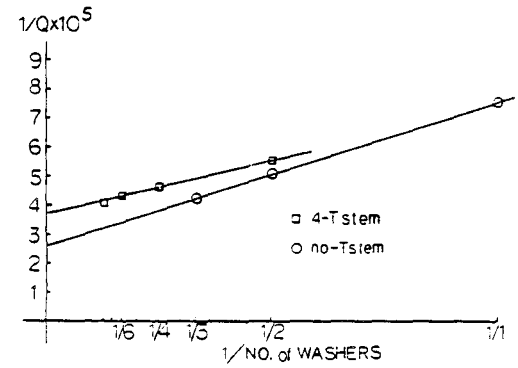

Fig.4 1/Q as a function of the reciprocal of the number of cells for 1300MHz test cavity. The disk radius was biperiodically reduced to compensate the coupling mode frequency.

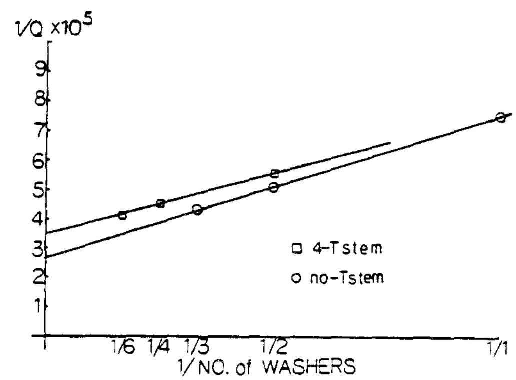

Fig.5 1/Q as a function of the reciprocal of the number of cells for 1300MHz test cavity. The disk radius was evenly reduced to compensate the coupling mode frequency.

strength unbalance between cells was about -4% at cells with stem (minus means weaker field at cell with stem than that with non-stem). Q value was improved to 76% of Q_∞ of no stem. The value 76% seems fairly good, considering the screw clamped stem contact. With SUPERFISH calculation, Q value with stem loss can be evaluated, assuming that the stem perturbation is small enough for the additional loss to be calculated only as eddicurrent loss on the stem. With stem of 1cm diameter at root and 0.8 cm diameter at branch, the value was 81.3% of original value.

The washers can be turned over and, the reduced gap-length cell can be at no-stem position. The unbalance increased to -14% and the Q_∞ decreased to 73%. Instead of the gap length, the field unbalance can be adjusted by moving the stem-attaching radius Rs.

Reducing the Rs by 1mm increases the field about 3%. Symmetric washers were also tested and evenly compensated geometry with about 2mm reduced Rs seems preferable. The perturbation of "Y" shaped stem was larger than that of "ϒ", and Q_∞ was about 70% of that with no stem.

COUPLING FREQUENCY

Because of the cavity termination and the stem periodicity, the ideal coupling mode was difficult to be achieved in finite length cavity. The coupling mode frequency fc with incomplete periodicity is shown in fig.6 as a function of ratio r_{sn} of number of cells with stem to that with no stem. Because of the termination, the periodicity for ratio of "1/2" (which means one cell with stem in two cells) is; stem, stem, non-stem, non-stem, stem, stem, and so on, namely SSNNSSNN···. That for ratio r_{sn} of "2/4" (which means two cells with stem in 4 cells) is; SNSNNSNSNNSNS···. The coupling mode frequency of "2/4" was slightly lower than that of "1/2". Rd required for complete coupling mode frequency compensation seems slightly larger than 15.5cm for this geometry including stem. Tentative mode spectrum is shown in Fig. 7. The mode overlapping on the accelerating mode was solved.

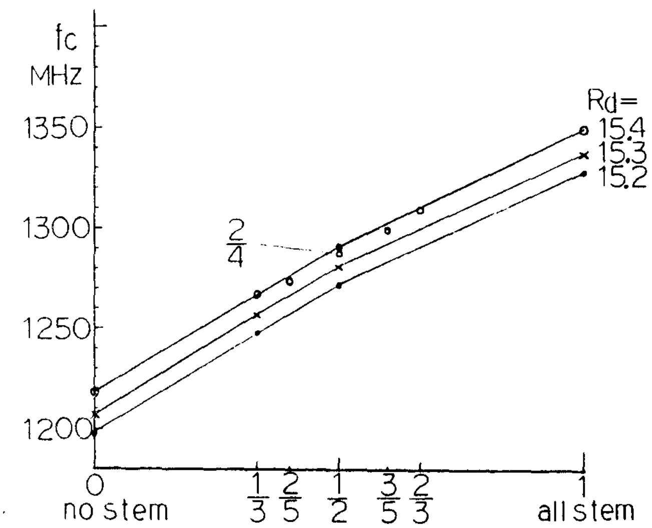

Fig.6 Coupling frequency with various configuration.

DISCUSSION

Measurement of the shunt impedance was not thought to be needed to evaluate the stem effect, because the perturbation to field distribution was much smaller than radial stem which lies parallel to electric field.

If the cooling and mechanical situation permits the use of smaller radius stems, the Q degradation will be reduced. For a low duty factor application or a low frequency band application, the cooling limitation will not be serious. For small radius stem, thin stainless steel pipe with copper-plating will be suitable.

Because of the large radius of the cavity, the mode density around the operating frequency is high. Further beam cavity interaction study[6] is required particularly for application to recirculating machine.

The successive work is going on to fabricate a power tank for electron acceleration.

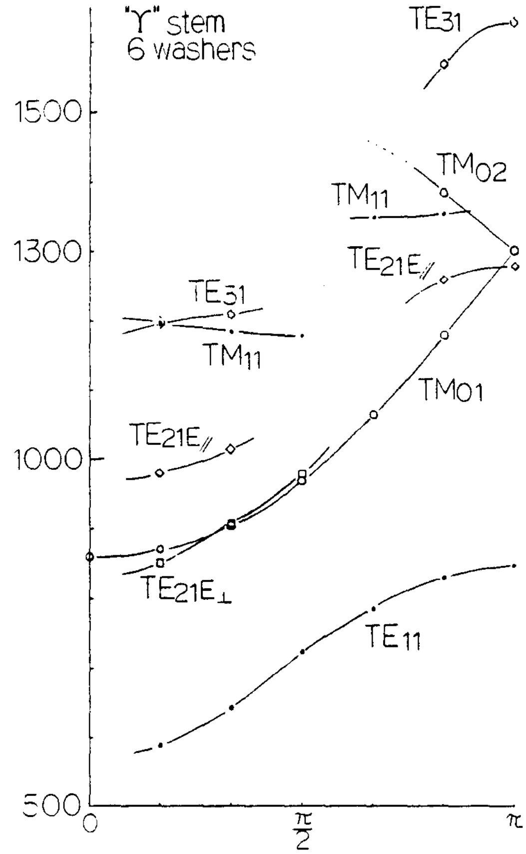

Fig.7 Tentative mode spectrum of 1300MHz cavity with 4T stem configuration. The coupling mode frequency was compensated within 15MHz by even reduction of Rd. The washer nose was not symmetric.

ACKNOWLEDGMENT

The authors thank D. A. Swenson for his supports. They also thank R. A. Jameson, and S. O. Schriber in Los Alamos National Lab.

REFERENCES

1. R.K.Cooper, Y.Iwashita, J.M.Potter, S.O.Schriber, D.A.Swenson, J.M.Watson, L.C.Wilkerson and L.M.Young, "Radio-Frequency Structure Development for the Los Alamos/NBS Racetrack Microtron", Los Alamos National Laboratory document LAUR-83-95(Jan. 1983).
2. Y.Iwashita, "DISK-AND-WASHER LINAC STRUCTURE WITH BIPERIODIC T-SUPPORTS", IEEE Trans. Nucl. Sci.,NS-30(4),3542(1983).
3. S.O.Schriber, "INTEGRAL RADIAL STEMS ON ALUMINUM β=1 DISK-AND-WASHER STRUCTURES", IEEE Trans. Nucl. Sci.,NS-30(4),3539(1983).
4. S.Inagaki, T.Higo, K.Takata, H.Nakanishi, S.Noguchi, T.Furuta, K.Kitagawa, E.Ezura, Y.Kojima, and T.Takashima, "DEVELOPMENT OF DISK-AND-WASHER CAVITY IN KEK", IEEE Trans. Nucl. Sci.,NS-30(4),3572(1983).
5. V.G.Andreev, V.M.Belugin, S.K.Esin, L.V.Kravchuk, and V.V. Paramonov "PARASITIC MODES REMOVAL OUT OF OPERATING MODE NEIGHBOURHOOD IN THE DAW ACCELERATING STRUCTURE", IEEE Trans. Nucl. Sci.,NS-30(4),3575(1983).
6. Y.Iwashita, S.O.Schriber, J.M.Potter, D.A.Swenson, and G.S.Mavrogenes, "BEAM CAVITY INTERACTION MEASUREMENTS IN A DAW STRUCTURE", IEEE Trans. Nucl. Sci., NS-32(5),2846(1985)