AN X-BAND DISK-AND-WASHER ACCELERATING STRUCTURE FOR ELECTRON ACCELERATORS

Yuan Hu*, Chuanxiang Tang, Huaibi Chen, Yuzheng Lin, Dechun Tong
Tsinghua University, Beijing 100084, PR. China

Abstract

X-band electron linacs are an excellent choice for portable accelerators. In this pager we present an X-band Disk-and-Washer standing wave structure is studied in this paper for a low energy accelerating tube. The DAW cavities are optimized to obtain the largest shunt impedance and quality for the TM020 mode. A set of differential equations is used to describe the optimizing process. The optimized results of a DAW structure working at 9300MHz are given using SUPERFISH and MAFIA400. Four radial stem supports are adopted. The modes near to the working frequency are given with and without supports. The electromagnetic fields building process was analyzed with T3 of MAFIA400. OFC model DAW cavities are built and the first test results are described.

1 INTRODUCTION

Disk-and-washer standing wave accelerating structures have outstanding features including high effective shunt impedance and high stability[1,2,3]. Although the measured shunt impedances are not as high as calculated when the washer supports are added, the strong coupling between cavities still makes it attractive to study DAW structures of x-band for its stability and ease of fabrication.

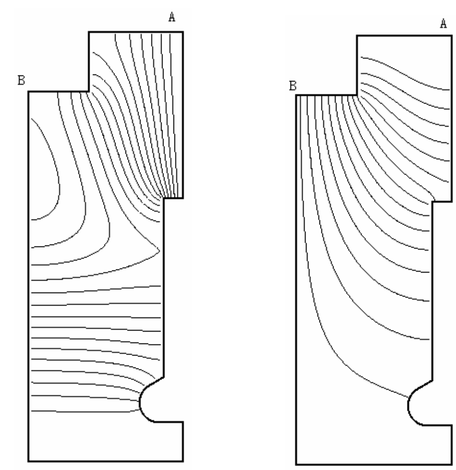
Several x-band sw electron tubes of low energy and low current have been manufactured, tested and used in the NDT portable electron linear accelerators. For an x-band sw structure, the microwave properties are much more sensitive to the fabrication precision. The coupling coefficient between DAW cavities can exceed 40%[4,5], making the tolerance of cavities larger and the cavity fabrication easier.

2 SIMULATION

During the x-band DAW structure simulations, SUPERFISH[6] and URMELT are used for the DAW structures without supports and MAFIA400 is adopted when the supports are added. Fig. 1 gives the SUPERFISH results of the accelerating and coupling modes.

2.1 Cavity Optimization

Figure 2 gives the dimensions that can be changed to obtain maximum shunt impedance and quality for a DAW cavity. Because of the fabrication limit for a DAW cavity working at 9300MHz, the dimensions that can be optimised include g, t_D, R_C, R_D and R_W[7,8,9]. The frequencies of the accelerating and coupling modes and the shunt impedance and quality of the accelerating mode can be written as functions of the five variables (see Eq. 1).



(a) (b)

Figure 1: Electric flux of (a) accelerating mode and (b) coupling mode calculated by SUPERFISH

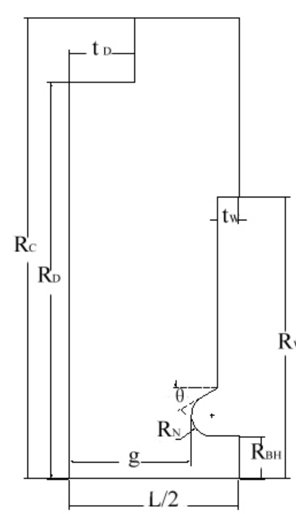


Figure 2: Dimensions of the DAW cavity

*huyuan99@mails.tsinghua.edu.cn

$$
\begin{aligned}
Q &= Q(g, t_D, R_C, R_D, R_W) \\
ZT^2 &= Z(g, t_D, R_C, R_D, R_W) \\
f_a &= f_a(g, t_D, R_C, R_D, R_W) \\
f_c &= f_c(g, t_D, R_C, R_D, R_W)
\end{aligned}
\quad (1)
$$

A set of total differential equations can be derived :

$$
\begin{aligned}
dQ &= \frac{\partial Q}{\partial g}dg + \frac{\partial Q}{\partial t_D}dt_D + \frac{\partial Q}{\partial R_C}dR_C + \frac{\partial Q}{\partial R_D}dR_D + \frac{\partial Q}{\partial R_W}dR_W \\
dZ &= \frac{\partial Z}{\partial g}dg + \frac{\partial Z}{\partial t_D}dt_D + \frac{\partial Z}{\partial R_C}dR_C + \frac{\partial Z}{\partial R_D}dR_D + \frac{\partial Z}{\partial R_W}dR_W \\
df_a &= \frac{\partial f_a}{\partial g}dg + \frac{\partial f_a}{\partial t_D}dt_D + \frac{\partial f_a}{\partial R_C}dR_C + \frac{\partial f_a}{\partial R_D}dR_D + \frac{\partial f_a}{\partial R_W}dR_W \\
df_c &= \frac{\partial f_c}{\partial g}dg + \frac{\partial f_c}{\partial t_D}dt_D + \frac{\partial f_c}{\partial R_C}dR_C + \frac{\partial f_c}{\partial R_D}dR_D + \frac{\partial f_c}{\partial R_W}dR_W
\end{aligned}
\quad (2)
$$

Thus, the cavity optimisation becomes a problem of finding the extremum of the equations. The optimised results of the x-band DAW cavity, with and without supports, are given in Table1.

Table 1 Optimised x-band DAW cavity with and without supports

	Q	ZT^2 ($M\Omega/m$)	f_{TM01} MHz	f_{TM02} MHz
With supports	14665.3	154.025	9302.771	9296.894
Without supports	22040.8	175.047	9300.299	9299.538

2.2 Dispersion Curve

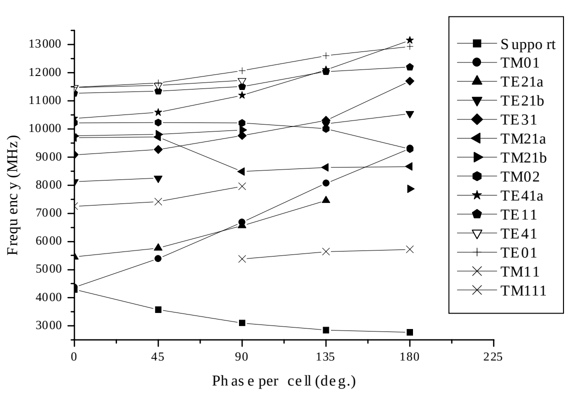


Figure 3 Dispersion curves of modes near the accelerating modes calculated by MAFIA400 , with 4 radial supports

The calculated dispersion curves are shown in Fig.3. Four radial stems are used to support the washer in the DAW cavity. The passbands of $TE_{21\perp}$, $TE_{21//}$ and TE_{31} are close to the operating frequency.

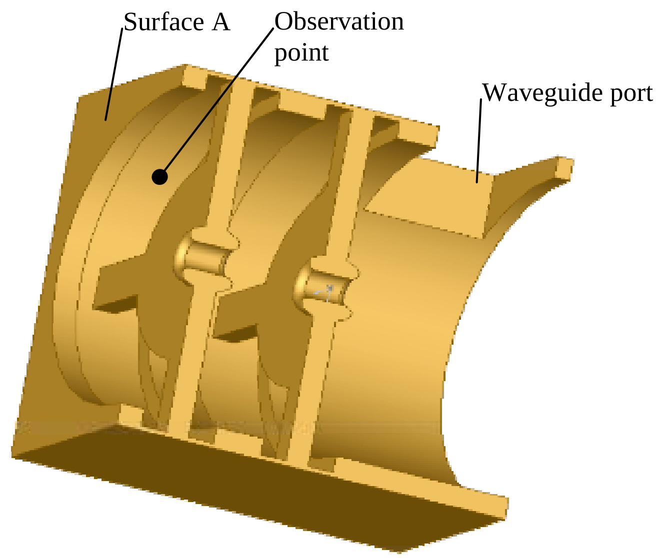
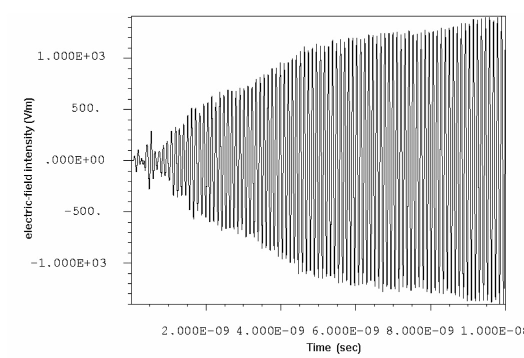


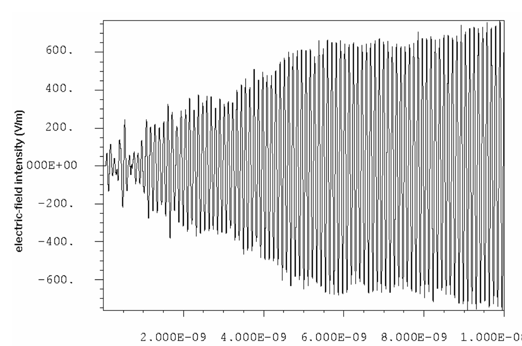
Figure 4 DAW structure for T3 simulation

2.3 Fields Building Process

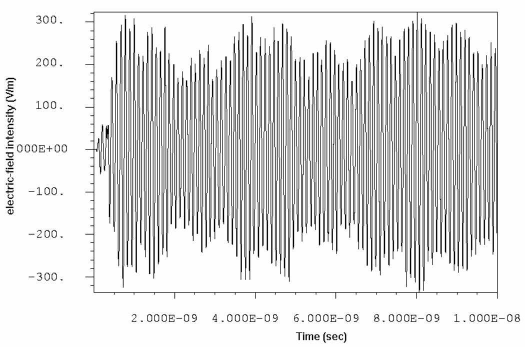
In a DAW accelerating structure, the accelerating mode and the coupling mode exist simultaneously. Simulations are done in a structure using T3 module of MAFIA400 as shown in Fig.4. We detect the electric field at a point at the middle of a washer, also shown in Fig.4. The results of the first 10^{-8} seconds are shown in Figure 5.



(a) variation of electric field in x direction



(b) variation of electric field in y direction



(c) variation of electric field in z direction
Figure 5 variation of electric field at observation point in first 10^{-8} seconds

Electric boundary is adopted on surface A.

3 FIRST MEASUREMENT RESULTS

Model cavities of OFC were fabricated and the first measurement was undertaken. Figure 6 provides a picture of the disk and washer of the model.

Figure 6: OFC model of the washer and disk

The harmonic frequency and the dispersion curve were measured. Fig 7 shows the dispersion a whole cavity and two half-cavities at both ends.

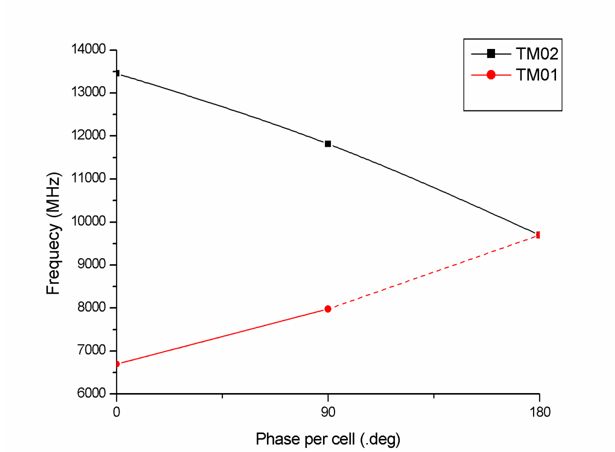


Figure 7: First measured dispersion curve of the model

The model will be modified to make the harmonic frequency of coupling and accelerating mode both equal to 9300MHz.

4 SUMMARY

High coupling coefficients make x-band DAW standing wave accelerating structures very attractive for use in low energy and low current electron linear accelerators. X-band DAW cavities are easy to fabricate and have higher shunt impedance. Four radial stems are used to support the washer, which requires no direct cooling. We are currently investigating techniques of fabrication and designing experiments to prove the thermal properties of the x-band DAW cavities.

5 REFERENCES

[1] Andreev V G et al. “Study of High-Energy Proton Linac Structure”, LA-5115, Proc. 1972 Proton Linac Conf., LA-5115, 114(1972).
[2] J.J.Manca and E.A.Knapp, “Optimization of The Disk and Washer Accelerating Cavities”, Los Alamos Scientific Laboratory report LA-7407(Sep 1978).
[3]J.M.Plotter, S.O.Schriber, and F.J.Humpary, “Experimental and Calculated RF Properties of the Disk-and-Washer Structure”, LA-UR-79-683.
[3] S.Inagaki, “Disk-and-Washer Cavities for an Accelerator”, N.I.M. A251(19986) 417.
[5] S.O.Schriber, “Room-temperature Cavities for High-beta Accelerating Structure”, Proc. of Conf. on Future Poss. for Electron Accel. , Univ. of Virginia, L-1(Jan. 1979).
[6] S.Inagaki, “Design of a DAW Cavity”, Tristab Design Note, TN-80-022, (Feb,1981)
[7] Lin Yuzheng, Li Derun, Chen Hao, et al “A novel traveling wave DAW accelerating structure” CEBAF-Report-89-001 U.S.A.(1989)620.
[8] Iwashita Y, Noda H A etc. “Fabrication of Biperiodic DAW Cavity” PAC’99(1203).
[9] S.O.Schriber “High Beta Linac Structures”, Proc. 1979 Linac Conf., Montauk, NY, Sept.