MODEL CAVITY INVESTIGATIONS AND CALCULATIONS ON HOM FOR AN X-BAND HYBRID DIELECTRIC-IRIS-LOADED ACCELERATING STRUCTURE*

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Abstract

Some model cavities have been further developed and investigated for an X-band (f=9.37GHz) hybrid dielectric-iris-loaded accelerating structure based on the calculated results about the effect of the dimension tolerance on the frequency. The dispersion curve fitted by using the measurement value is consistent with the one calculated. The r/Q values of the dipole modes have been calculated by Mafia code. The theoretical results show that the r/Q values of dipole modes for the new accelerating structure are lower than those for the iris-load accelerating structure.

INTRODUCTION

An extremely small accelerator has found wider and wider applications in high energy physics research, industrial and medical fields. The many advantages of using higher RF frequencies (X-band) for electron linear accelerators include higher shunt impedance, higher breakdown threshold level, smaller size etc. The most commonly studied structure is a conventional iris-loaded copper structure. However, in all the iris-loaded structures, the peak surface electric field Es is in general found to be a factor of 2 larger than the axial acceleration field Ea [1, 2]. If the peak surface electric field exceeds the breakdown limit at the operating frequency, it can cause damage to the irises through arcing and detune the structure.

A X-band (f=11.424GHz) hybrid dielectric-iris-loaded accelerating structure which reduced surface electric fields was proposed and simulated by Mafia code [3].

In our lab, based on the preliminary measurement results for the new structure [4], the design and manufacture for the model cavity have been made again. The machining precision of the structure dimension was improved. And the experimental studies were performed. In addition to, the r/Q values of dipole modes for the new accelerating structure were calculated.

MODEL CAVITY INVESTIGATION

This device for the new structure is shown in figure 1. The RF properties vs the geometric sizes at f=9.37GHz are shown in table 1. The effect of the dimension tolerance on the frequency has been calculated. Varying the structure dimension, the frequency variety δf as the functions of δb , δa , $\delta \varepsilon$, δhh are shown from figure 2 to figure 5 respectively. The changing laws are as follows:

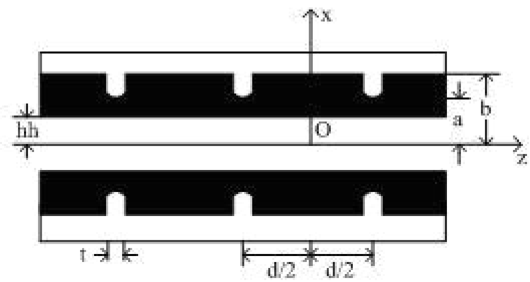

Figure.1: Schematic drawing of a hybrid dielectric-iris-loaded accelerating structure.

Table 1 RF Properties of a Hybrid Dielectric-Iris-loaded Periodic Structure with t=1.5mm, d=10.67mm and λ = 32.017 mm

a (mm)	b (mm)	hh (mm)	ε_r	E_s / E_a	R (MΩ/m)	Q
4.5	6.547	2.5	5.81	1.01	53	5068

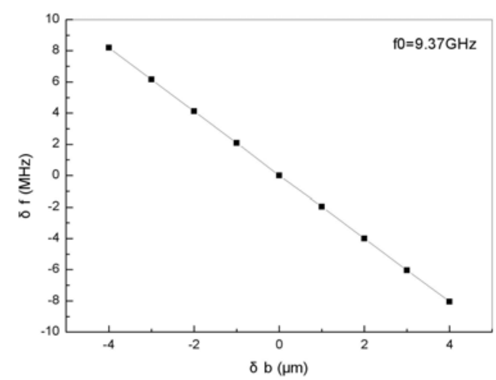

Figure 2: The δf as a function of δb

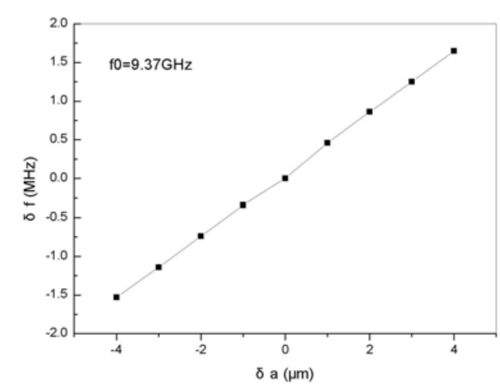

Figure 3: δf as a function of δa

*Work is Supported by the National Nature Science Foundation of China, Grant No. 10375060 and 10675116
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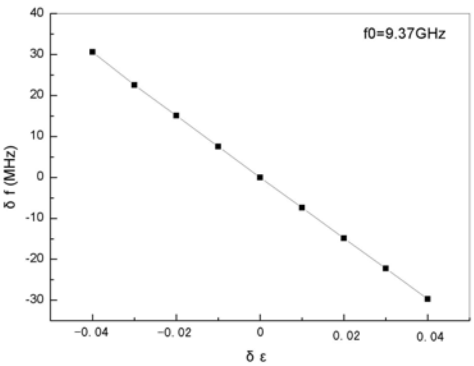


Figure 4: δf as a function of $\delta\varepsilon$

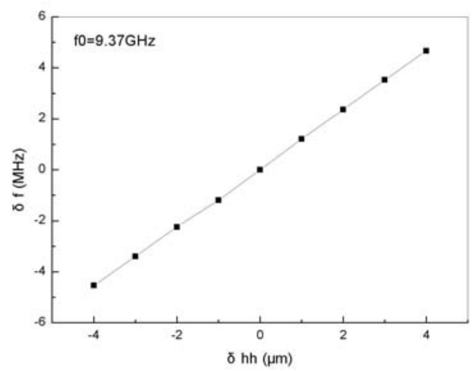


Figure 5: δf as a function δhh

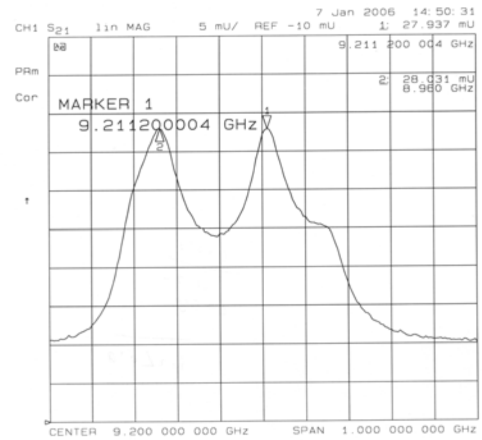
$$\partial f/\partial b = -2.03 MHz/\mu m \quad (1)$$

$$\partial f/\partial a = 0.4 MHz/\mu m \quad (2)$$

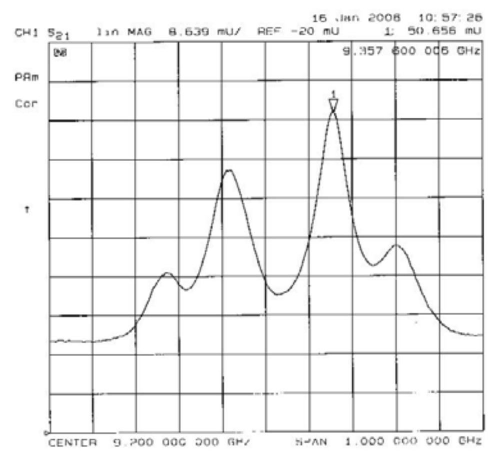
$$\partial f/\partial \varepsilon = -0.7465 MHz \quad (3)$$

$$\partial f/\partial hh = 1.2 MHz/\mu m \quad (4)$$

Figure 6: the component of the model cavity



(a) b=6.547mm



(b) b= 6.500mm

Figure 7: The measurement results of S_{21} vs frequency with two model cavities two half cavities.

The inspections of the calculated results show that the effect of the cavity radius tolerance on the frequency is very obvious. According to the sizes in table 1, the model cavities (figure. 6) have been made and measured with Network Analyzer Hp8722D under the conditions of the b size being changed little. The typical measured results of three cavities (two whole cavities and two half-cavities) are shown in figure 7. From figure 7, the resonance frequency is $f_{2\pi/3}$ =9.2112 GHz at b=6.547mm; when b=6.500mm, the resonance frequency is $f_{2\pi/3}$ =9.3576 GHz, and the resonance peak is sharper obviously than the one in [4] because the machining precision of the structure dimension was improved. If considering the effects of air and the probe on resonance frequency, the resonance frequency for $2\pi/3$ mode is close to the design frequency.

For three cavities, the four peak values of resonance frequency ($\phi = 0, \pi/3, 2\pi/3, \pi$) may be measured[5] (shown in figure 7b). In order to verify the above results, the dispersion curve was fitted by using the measurement value. The dispersion curve can be expressed as：

$$f = C_0 + \sum_{n=1}^{\infty} C_n \cos n\Phi \tag{5}$$

Where C_0, C_1, ……C_n are constants.
thus:

$$\begin{cases} f_0 = c_0 + c_1 + c_2 + c_3 \\ f_{\pi/3} = c_0 + c_1/2 - c_2/2 - c_3 \\ f_{2\pi/3} = c_0 - c_1/2 - c_2/2 + c_3 \\ f_\pi = c_0 - c_1 + c_2 - c_3 \end{cases} \tag{6}$$

Figure 7(b) shows that $f_0 = 8.972$ GHz, $f_{\pi/3} = 9.1203$ GHz, $f_{2\pi/3} = 9.3576$ GHz, $f_\pi = 9.5$ GHz. From (5) and (6) we obtain

$$f = 9.2379 - 0.2551\cos\Phi \\ -0.0019\cos 2\Phi - 0.0089\cos 3\Phi \tag{7}$$

In terms of (7), the dispersion curve was drawn as the dashed line in figure 8. The calculated dispersion curve by MAFIA code was pictured as the real line in figure 8. Comparing the two lines, we conclude that the curve fitted by the measured result is consistent with the one simulated with MAFIA code.

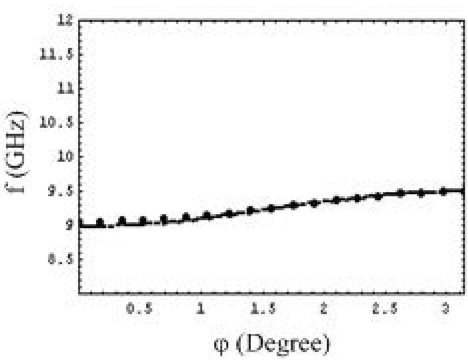


Figure. 8 The frequency f vs. the phase ϕ.

CALCULATION FOR HOM

The coupling between the wave and the charged beam is controlled by an appropriate design of the cavity. The coupling is described by the loss factor k_p, which is characteristic for each mode p. The parameter r/Q is often used, which is related to the loss factor through the equation[6]:

$$\left(\frac{r}{Q}\right)_p = \frac{4k_p}{\omega_p} \tag{8}$$

Where r is the shunt impedance.

The dispersion curves of the dipole modes for the new structure were calculated by MAFIA code as shown in figure 9. Thus the parameters for the dipole modes can be obtained by MAFIA code and are compared with the ones of the disk-loaded structure (table 2). We conclude that the r/Q values of dipole modes for the new accelerating structure are lower than those for the iris-load accelerating structure.

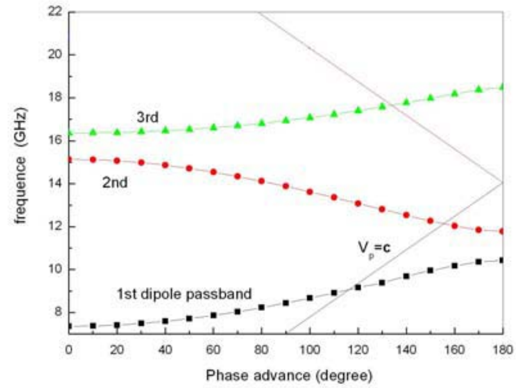


Figure 9: Dispersion diagram of the dipole modes for the new structure.

Table 2: The comparison for the dipole modes

Mode	New structure		Disk- loaded structure	
	f (GHz)	r/Q (Ω/mm^2)	f (GHz)	r/Q (Ω/mm^2)
1	9.13	11.71	18.12	41.59
2	10.948	13.73	28.24	5.54
3	14.125	8.52	28.98	22.97

SUMMARY

The dispersion curve fitted by using the measurement value is good agreement with the one calculated. The theoretical results show that the r/Q values of dipole modes for the new accelerating structure are lower than those for the iris-load accelerating structure.

The above results will provide some beneficial data for the design and manufacture of X-band hybrid dielectric-iris-loaded travelling-wave accelerating structure. Further studies of the new structure are in progress.

REFERENCES

[1] Wilson, P. B., RF-Driver Linear Colliders, Proceedings of 1987 IEEE Particle Accelerator Conference, Washington,D.C, PP.53-58,1987.
[2] Wang, J. W., Adolphsen, C., Bane, K.L., etc., "Accelerator Structure R& D for Linear Colliders," Proceedings of 1999 Particle Accelerator Conference, New York, pp3423-3425,1999.
[3] Zou, P., Xiao L., L., Sun X. et al. J.Appl. Phys., 2001,90(4):2017-2023.
[4] Cong-Feng Wu, Lin Hui, Sai Dong, Proceedings of the 2005 Particle Accelerator Conference (IEEE, Knoxville, Tennessee,2005), p. 2747.
[5] Chongguo Yao, Electric Linear Accelerator (Chinese), 1986.
[6] Baboi N, Studies on higher order modes in accelerating structures for linear colliders, 2001.