PROGRESS TOWARDS A 9.37GHZ HYBRID DIELECTRIC-IRIS-LOADED STRUCTURE FILLED WITH LOW LOSS DIELECTRIC*

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Abstract

One of the major concerns in the development of hybrid dielectric-iris-loaded structure is the performance of the used dielectric. The previous dielectric is machinable but the loss tangent is slightly high. So we adopt the new dielectric *(Mg-Ca-Ti-O)* with loss tangent of about 2e-4. Because of its high hardness and brittleness, the machining technology and methods are attempted. Here we present some research results of the structure with the new dielectric. Especially, the coupler for the structure with this dielectric is designed with Frequency domain solver of the Microwave Studio (MWS) based on the Kyhl method. This calculation method can save much more time under the same precision than other methods. The experimental results show that the SWR＜1.02 at the operation frequency and SWR＜1.1 at arrange of 20 MHz frequency bandwidth.

INTRODUCTION

There are obvious advantages for the X-band accelerating structure compared with the S-band one. First, the shunt impedance per unit length of X-band is higher than that of S-band. Second, the maximum permissible electric field strength is also higher.

The hybrid dielectric-iris-loaded structure may have lower ratio of peak surface electric field at the iris to axial accelerating electric field by optimizing the geometric parameters, while r/Q of the new structure being comparable to iris-loaded accelerating structure.

Using machinable dielectric whose dielectric constant being 5.81, the model cavities and coupler were investigated by large numbers of experiment with the help of MAFIA code and MWS T-Domain Solver [1], [2]. But the loss tangent of this dielectric is slightly high. We studied the hybrid dielectric-iris-loaded structure with the new dielectric of its loss tangent being about 2e-4 instead of the above dielectric.

The RF coupler is an important component for an accelerator structure. Originally the coupler design is performed experimentally by Kyhl method [3]. This cost one too much more time. Some numerical calculation methods based on 3D-code such as MAFIA had been discussed in detail [4, 5]. However, by these means it is inconvenient to model a complicated 3D structure. The calculation time for getting the results is long with time domain method in MAFIA. By using the PBA (Perfect Boundary Approximation) and TST (Thin Sheet Technology) for mesh generation and F-Domain Solver in MWS, we can get the same accuracy quickly compared with the one in MAFIA.

In general, to iris-loaded waveguide structure, the position of the short plunger for detuning is in the centre of the coupler cavity. Large numbers of calculations for the new structure show that the coupler cavity cannot be detuned when the plunger is set in the centre of the cavity. The investigations of the simulation and experiment for the new coupler are made. The above results are presented.

RF COUPLER DESIGN

The operating frequency is chosen to be 9.37GHz. The dimensions of the regular cells in our model have been designed for that frequency at the $2\pi/3$ phase shift per cell. The sketch of the accelerator cavities are shown in figure 1. The RF Properties of new structure is given in Table 1. The ratio of peak surface electric field at the iris to axial accelerating electric field is equal to 1.1.

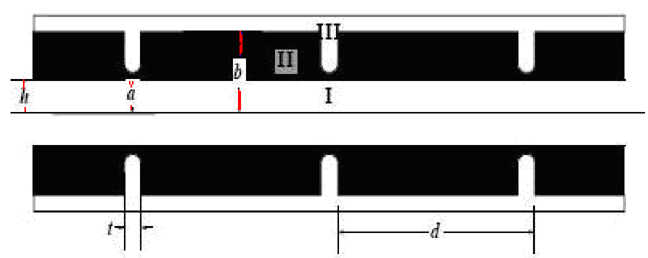

Figure 1: Sketch of regular accelerator cavities. In the figure, region I is vacuum; region II is ceramic with dielectric constant ϵ_r; region III is copper, a is the disk radius, b is the outer radius, and h is the beam hole radius. t is the thickness of the disk, and d is the length of one cell.

Table 1: The Properties of the New Structure With t=1.5mm, d=10.665mm and λ =32.017 mm

a (mm)	*b (mm)*	*h (mm)*	ϵ_r	*Es/ Ea*	*R (MΩ/m)*	*Q*	*vg (c)*
4.5	6.376	2.5	6.45	1.1	50.78	5068	0.048

Because of high hardness and brittleness of the new dielectric, diamond tools were used for machining. The structure consisted of two accelerating cavities and two half of cavities located at both sides is used to measure the operating frequency. The reflection parameter S_{11} vs the frequency was got through Network Analyzer Hp8722D, which is shown in Fig. 2. The $2\pi/3$ mode frequency is 9.36325GHz. Considering the influence of the coupling probe, temperature and humidity, the actual frequency is close to 9.37GHz.

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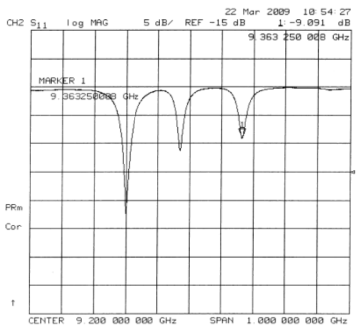

Figure 2: The measurement result of 2π/3 mode frequency vs. S_{11}.

The idea of "the phase numerical simulation calculation for matching RF coupler" is inspired from the experiment design, i.e., Kyhl method [3]. According to the impedance analysis, an important basis for the optimal matching and tuning of coupler is shown in Fig.3 by Smith-chart. Three frequencies ($f_{\pi/2}, f_{2\pi/3}, f_{mean}$) should be taken into account. Here $f_{mean} = (f_{\pi/2} + f_{2\pi/3})/2$. Detune the coupler cavity with the usual metallic plunger, and determine the "detuned short" position in the input regular waveguide. Detune the following cavity, and determine the positions of f_{mean}, $f_{\pi/2}$ and $f_{2\pi/3}$.

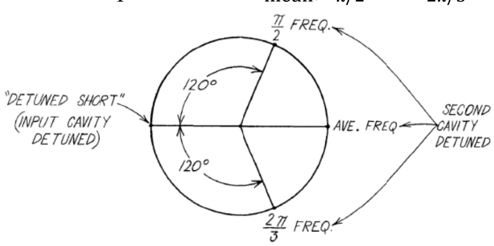

Figure 3: Smith chart plot, first cavity properly coupled and tuned.

Figure 4 shows the sketch of the coupler. There are three dimensions to be determined: the coupler cavity radius b, the coupler aperture h and its thickness t.

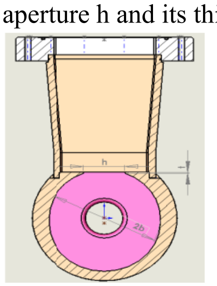

Figure 4: Sketch of the coupler.

In numerical simulation design the coupling and tuning status of RF coupler can be realized from the phase relations of the several modes as described below to determine the optimization direction of the key sizes of RF coupler.

1) Detune the coupling cavity by a short metallic plunger (Fig.5), and calculate the phase of f_{mean} whose result is shown in Fig. 6 by MWS F-Domain solver. Especially, large numbers of calculations for the new structure show that the position of the plunger should be apart from the coupler cavity centre (3mm forward the electric gun) for detuning. To iris-loaded waveguide structure, the position is in the centre of the cavity.
2) Detune the first accelerating cavity, calculate the phase of f_{mean} and change 2b till to $\Delta\varphi_{meam} = 180^0$.
3) Keep the plunger in the first accelerating cavity, calculate the phase of $f_{\frac{2\pi}{3}}$ and change h till to $\Delta\varphi_{\frac{2\pi}{3}} = 240^0$.
4) Repeat steps 1, 2 and 3, till the coupler is tuned and matched. Fig.7 shows the S-parameter polar plot simulated by MWS after tuning and matching the coupler cavity.

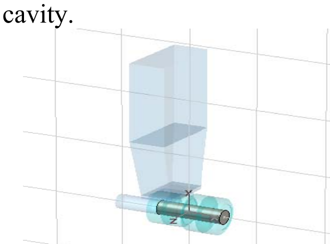

Figure 5: Detuning the coupling cavity simulated by MWS.

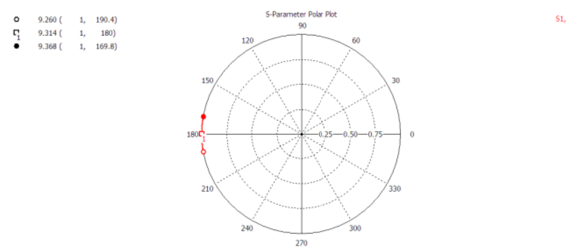

Figure 6: S-parameter polar plot by detuning the coupling cavity simulated by MWS.

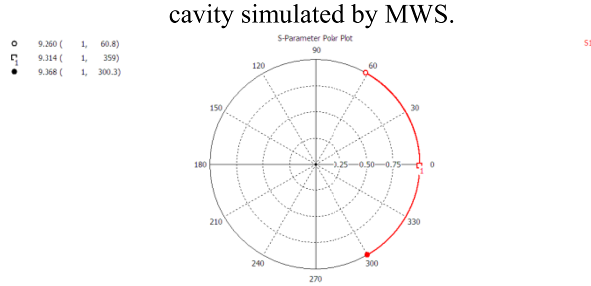

Figure 7: S-parameter polar plot after tuning and matching the coupler cavity simulated by MWS.

A 4-cell model is generated by MWS. The model consists of one input coupler cavity, two accelerating cavities and one output coupler cavity as shown in Fig.8. These two tapered rectangular waveguides are uniform. The simulation result by MWS T-Domain Solver shows that the (accelerating) TM01 mode has the center frequency of 9.37 GHz, where the reflection coefficient is less than -45dB and the transmission coefficient is over 99% as shown in Fig. 9.

With the help of the MWS Field Monitor, the amplitude and phase of the axial field are given in Fig. 10. From this figure, we can find that: the axial electric field in the coupler cavity is lower than the accelerating cavity, the phase shift of the four cells is about 360^0, the phase variation in each coupler cavity is nearly zero across forward half the cavity and totals to 60^0 for the whole coupler cell, the phase shift of two regular accelerating cavities is 240^0, this means the coupler is consist of half a standing cavity and half a travelling cavity.

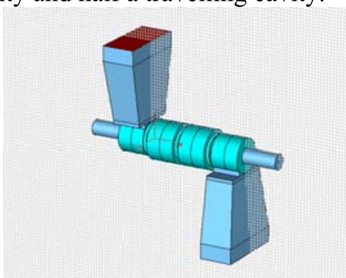

Figure 8: 4-cell model for T-Domain calculation.

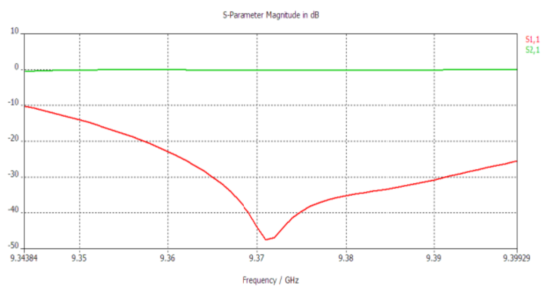

Figure 9: S-parameter properties of the X-band hybrid dielectric-iris-loaded structure (MWS simulation)

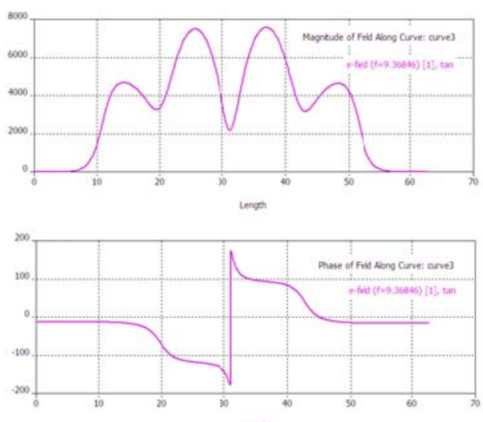

Figure 10: Plots of amplitude and phase of the axial electric field in the centre of accelerating structure (MWS simulation). The field magnitudes are normalized to 1 Watt RF power.

EXPERIMENT RESULTS

Fig. 11 shows the assembled structure for cold testing. There are five accelerating cavities and two coupler cavities in this structure. The voltage standing wave ratio (SWR) is measured with Network Analyzer Hp8722D under the condition of the coupler cavity radius b being held 5.551 mm , w being 7.6mm.and h being 1.5mm. SWR$<$1.02 at the operation frequency and SWR$<$1.1 at arrange of 20 MHz frequency bandwidth are achieved (shown in Fig. 12).

Figure 11: The assembled structure for cold testing.

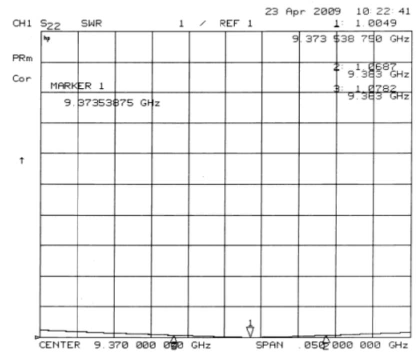

Figure 12: The measurement result of SWR vs. frequency.

The different between calculation result and the experiment one about the coupler aperture is 0.2mm. The other sizes keep unchanged. This means that the Kyhl method can give an effective theoretical instruction for RF coupler design of hybrid dielectric-iris-loaded structure. Thereby manufacture process and the experiment are greatly simplified.

SUMMARY

We have developed the X-band hybrid dielectric-iris-loaded structure based on the new dielectric. The coupler design was made quickly and accurately by using Frequency Domain Solver of MWS. Cold testing shows good transmission over the operation frequency band. The deep experimental investigations on these issues are in progress.

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