INPUT COUPLER DESIGN FOR C-BAND ACCELERATING STRUCTURE

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Abstract

To increase an electric field symmetry in a coupler cavity, a very simple structure of two-iris coupler cavity was proposed by H. Matsumoto in 1994. MAFIA 3D code is useful to simulate Slater's tuning curve method, which is used to determine the dimensions of the coupler cavity such as iris aperture and cavity diameter. It was find that MAFIA simulation results show that two-iris method will realize a good symmetrical electric field with very simple structure as well as no difficulties for fabrication. This type of double feed coupler will be used for Choke-mode type damped accelerating structure at C-band (5712 MHz) and rf-gun for linear collider.

1 INTRODUCTION

An e^+e^- linear collider such as energy range of 0.5 to 1 TeV C.M. will require very high luminosity of several times of $10^{33}/cm^2/s$ necessary for physics experiment. Multi-bunched beam operation will be essential to obtain such high luminosity. Thus, it is very important to accelerate a low emittance beam in a main linac to achieve a nano-meter size beam at collision point. However, this is not easy because of the wake field power that accumulates in the accelerating structure.

Choke-mode damped structure at C-band frequency was proposed by T. Shintake in 1992, that will positively eliminate the wake field in the structure [1]. An S-band Choke mode structure was tested up to the maximum accelerating gradient of 50 MV/m with beam loading in 1994 at KEK-ATF (Accelerator Test Facility) with no problem [2].

The field asymmetry due to the coupling iris can be a serious problem. It will kick the beam during passage through the coupler cavity even if the beam is aligned to the cavity axis, leading to the emittance growth.

To eliminate the field asymmetry in the coupler cavity, two-iris coupler came back again at several laboratories such as DESY, KEK, and SLAC with different feeding methods [3,4,5]. An original idea was proposed at SLAC when they planed the two mile linear accelerator, but there has been no actual application until recently years.

In 1994, two-iris coupler cavity, such as shown in figure 1, was proposed by H. Matsumoto to apply the accelerating structure and rf-gun. As can be seen in the figure, its structure is very simple and it requires no additional equipment such as a power divider. It was tested up to the accelerating gradient of 60 MV/m without any problem at S-band frequency [6]. It is very clear that important considerations on the design of coupler cavity is not only the field symmetry but the simplicity of the structure, because no laboratories have any experience on more than 8000 accelerating structures in one accelerator.

This paper will describes the design procedures of the coupler cavity for C-band Choke-mode structure using the Slater's tuning curve method with MAFIA 3D code.

2 C-BAND ACCELERATING STRUCTURE

The main parameters of the accelerating structures for the C-band linear collider at the energy of 500 GeV C.M. are listed in table 1 [6]. The short-range wake-field is a strong function of the beam aperture (2*a*), approximately proportional to $a^{-3.5}$ [7]. To prevent the single-bunch emittance growth, relatively large beam aperture is chosen compared to conventional structures. The average 2*a* (16 mm) allow alignment tolerance of 30 μm, which can be achieved with conventional fabrication techniques of the disk loaded structure. Two 50 MW klystrons with an rf-compression system is planned to generate the accelerating gradient of 31 MV/m (including beam loading) at the beam aperture. The two-iris coupler was designed according to these parameters.

Table 1: Parameters for accelerating structure.

Frequency	f_0	5712	MHz
Phase shift per cell	βD	$3\pi/4$	
Field distribution		C.G.	
Number of cells		91	Cell
Active length		1.8	m
Quality factor	Q	9950	
Average shunt impedance	Rs	53.1	MΩ/m
Attenuation parameter	τ	0.53	
Filling time	t_f	286	nsec
Groupe velocity up-stream down-stream	v_g/c	0.035 0.012	
beam aperture up-stream down-stream	2*a*	18.2 13.1	mm
Inner diameter up-stream down-stream	2*b*	44.7 42.5	mm

3 DESIGN OF COUPLER CAVITY

3.1 Concept

Figure 1 shows the coupler cavity and the 1st regular cavity. Two irises are located on opposite sides of the caivty at vertical direction in the figure, connected to the

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narrow wall of a J-shaped rectangular waveguide. The dimension of the J-shaped waveguide is determined as follows: (1)The width is chosen so that the phase length between the two irises is $2\lambda_g$. (2)The radius is set as large as possible to minimize the internal reflection. (3)The height is the same as the iris to allow accurate fabrication. A standard rectangular waveguide EIA-WR-187 (47.55x22.15 mm) is used to feed the rf power.

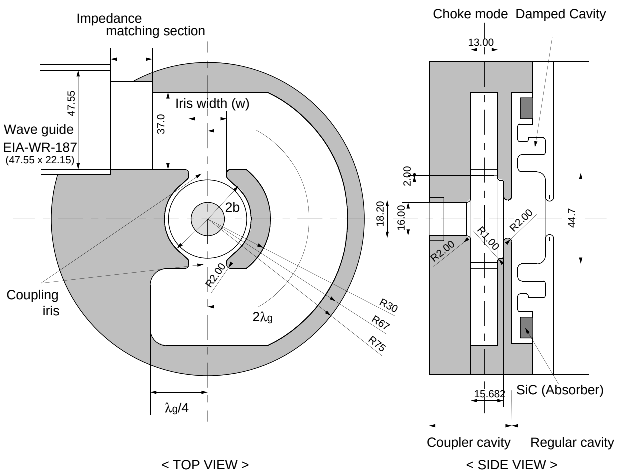

Figure 1: Cross sections of C-band accelerating structure.

A simplified equivalent circuit model of the two-iris coupler is shown in figure 2. This type of coupler uses the conventional impedance change along waveguide [5]. The suceptances iB_1 and iB_2 correspond to the irises. The length between the two irises is chosen as $n\lambda_g$ (n=1,2,3...), and the length from the short end to the second iris is $m\lambda_g/4$ (m=1,3,5...). Then the impedance of the short end seen from the irises become infinite. Finally, when the loss of transmission line between iB_1 and the short end is negligible this system can be modified to a simle parallel circuit and the same power is fed into the cavity from the two irises.

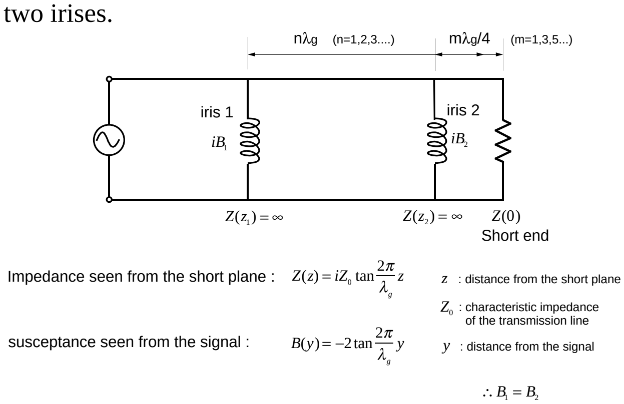

Figure 2: Simplified equivalent circuit model of two-iris coupler.

3.2 Design parameter for coupler cell

According to the equivalent circuit analysis on the coupled-cavity model [8], resonant frequency f_c is given by

$$f_c = f_0\left(1+\frac{1}{2}k\cos\beta D\right),$$

where f_0 is the rf-frequency (5712 MHz) and k is the coupling constant between the input coupler cavity and the 1st regular cavity. The external Q (Q_{ext}) is expressed as

$$Q_{ext} \approx \frac{\beta D}{v_g / c}.$$

Using these equations and table 1, coupler cavity parameters are calculated as listed in table 2, where k was given by the relation $v_g / c = \frac{1}{2}k\beta\ D\sin\beta D$.

Table 2: Parameters for coupler cavities.

		Input	Output
Frequency (MHz)	f_c	5627.2	5682.9
External Q	Q_{ext}	67.3	196
Coupling constant	k	0.0420	0.0144

4 DESIGN WORK OF COUPLER CAVITY

The dimensions of the coupler cavity was determined by 3D-MAFIA code to obtain the target values of f_c and Q_{ext}. First, the guide wavelength was set to $2\lambda_g$ at 5712 MHz adjusting the waveguide width. Next, the coupling iris width (*w*) and inner diameter (2*b*) were determined by Slater's tuning curve method.

4.1 Waveguide width

To obtain the guide wavelength of $2\lambda_g$ at 5712 MHz, the resonant frequency of the waveguide was calculated by changing the waveguide width. The geometry used in the calculation is shown in figure 3. From this calculations, determined width is 37.0 mm. In this case the attenuation is as small as 0.06 dB/m. To confirm the absence of internal reflection, the resonant frequencies under the electric and magnetic boundary conditions were compared. Their differences was within 10 MHz, which indicates that no critical reflection occurs.

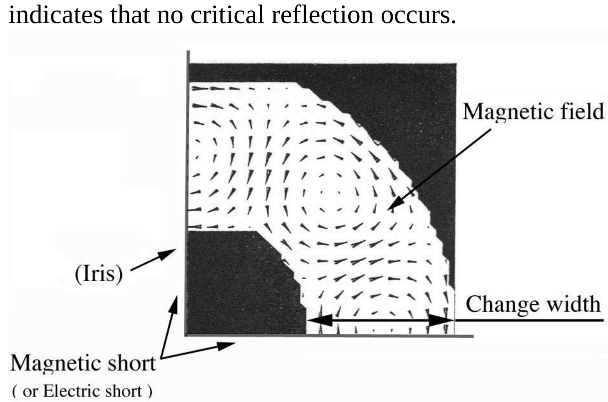

Figure 3: Geometry used in waveguide calculation by MAFIA. The arrows indicate the magnetic field under magnetic boundary condition.

4.2 Resonant frequency and external Q

The Slater's tuning curve method was used to determine f_c and Q_{ext} [9]. In this theory, external Q is related to the frequency change of the resonance according to the distance between the center of iris and short end. The geometry used in the calculation is shown in figure 4. The differential coefficent dd/dλg of the tuning curve takes its maximum value at f_c. The external Q (Q_{ext}) is calculated from dd/dλg at f_c. The calculated values of f_c and Q_{ext} for various w and 2b are shown in figures 5 and 6. The solid and dashed lines in figure 7 show the relation between 2b vs w with f_c=5627.2 MHz and Q_{ext}=67.3, respectively. The cross point of the two lines gives the design values of 2b and w. The result is as follows: 2b is 41.55 mm, and w is 18.0 mm.

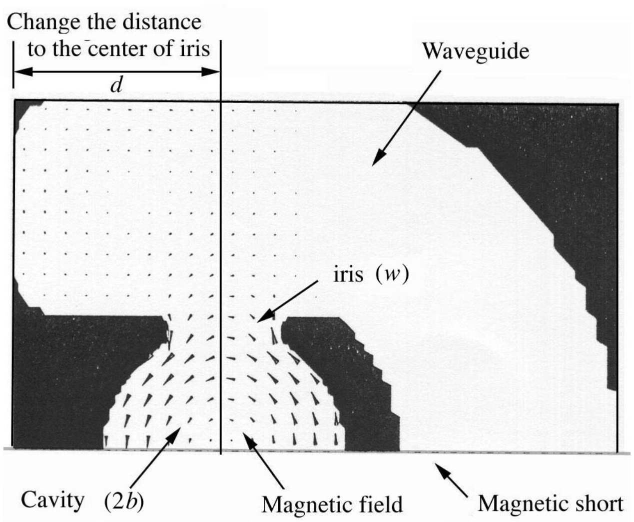

Figure 4: Cross section of the geometry used in Slater's tuning curve method in the plane normal to the beam axis. The whole geometry consists of the coupler cavity, waveguide, beam pipe, and half of 1st regular cavity.

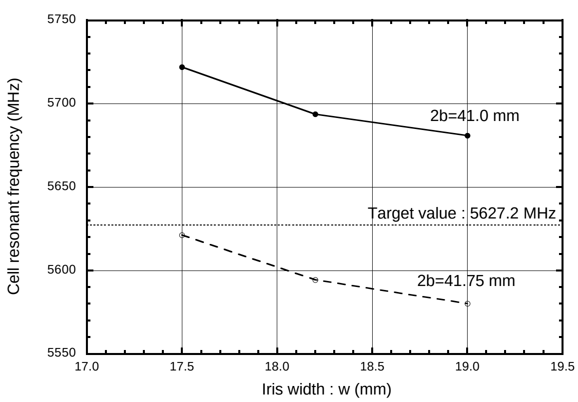

Figure 5: Resonance frequency of coupler cell.

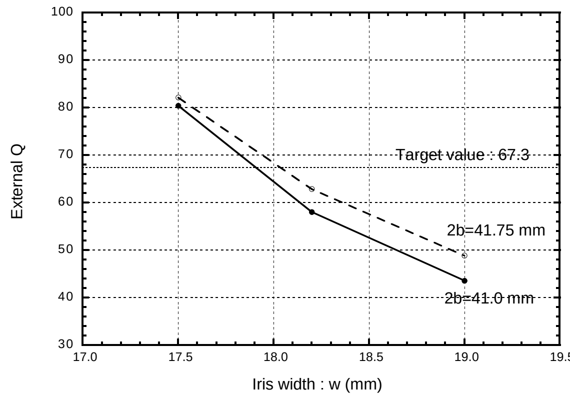

Figure 6: External Q of coupler cell.

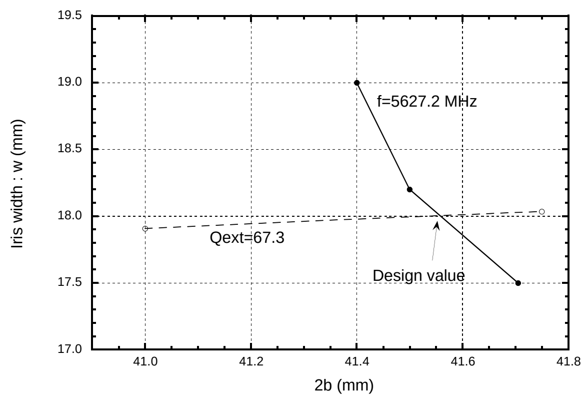

Figure 7: Determination of coupler dimensions

5 SUMMARY

The target value of f_c and Q_{ext} of coupler cell was given by equivalent circuit analysis. The coupler dimensions 2b and w were determined so that f_c and Q_{ext} take the target values using Slater's tuning curve method with MAFIA. More detailed calculation including the output coupler will be done. Final values of 2b and w will be deternimed precisely with the cold model test.

6 REFERENCES

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