DESIGN OF AN S-BAND HIGH POWER PILLBOX TYPE RF WINDOW

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Abstract

An rf window is under development to handle transmission power of up to 100 MW. The studies have been performed on window geometries to reduce the electric field normal to the ceramic surface and resulting multipactor electron bombardment on the ceramic disk. It was found that the long type geometry is effective on reducing the perpendicular electric field by using computer code MAFIA.

Introduction

In the Japan Linear Collider (JLC) S-band linacs will be used as pre-accelerators with an accelerating gradient of 40 MV/m. Such a high gradient can be obtained from the high power rf source which comprises a SLED[1)] and a klystron with a peak output of 85MW, pulse duration of 4.5μs and a repetition rate of 150 pps . One of the most difficult problems in the practical use of such rf sources is the high power rf window to handle a transmission power of up to 100 MW.

The rf window failure typically occurs in the range of a few tens of MW region and despite many studies over the last 50 years, the mechanism has not yet been fully expounded. One feature is clear, that breakdown is caused by multipactor electron bombardment on the ceramic disk, and depends on material imperfections such as voids, impurities and surface conditions of the ceramic disk *e.g.* contamination and micro cracks.[2, 3)]

The rf window geometries so as to reduce electromagnetic field that causes multipactor electron bombardment on the ceramic surface have been designed by using a computer code MAFIA. This paper discribes design of one of these geometries which is the long type pillbox window .

Calculations of the long type rf window

As seen in simulations of multipactor on the ceramic surface[3)], multipactor electron bombardment is primarily due to the component of the electric field normal to the ceramic surface. For the standard type rf window this component appear between edges at both sides of the transition from rectangular to circular waveguide. The "long" type rf window geometry makes use of a long pillbox to reduce its influence of edges.

Design method

MAFIA can calculate the standing-wave electromagnetic fields in a finite volume with conducting or open boundaries. The electric field of a traveling-wave propagating rf window, E_{TW}, can be calculated by the following equation:

$$E_{TW} = E_{odd} \sin(\omega t) + E_{even} \cos(\omega t) \tag{1}$$

where ω is the angular frequency of the propagating mode, E_{odd} and E_{even} are the electric field of the standing wave calculated from MAFIA with open and shorted boundary conditions, respectively, as shown in Fig.1.

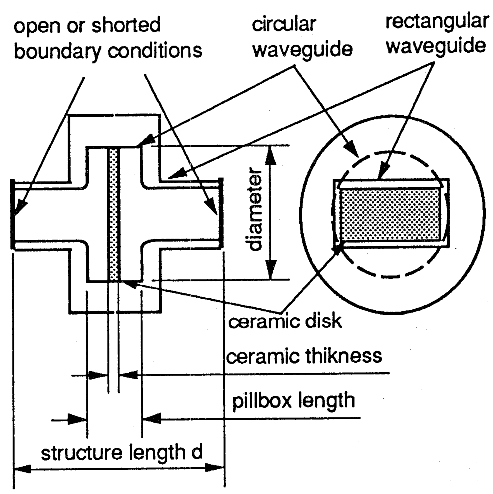

Figure 1 Parameter of the pillbox type rf window structure.

The frequency response is calculated along the following procedure[6)]. The structure length, d_o and d_s, are calculated with both the open and the shorted boundary conditions, respectively, as a function of resonant angular frequency ω. The complex reflection coefficient R are calculated from each d_o and d_s as a function of ω expressed in the following equation:

$$R = \frac{e^{j(\phi_o - \phi_s)} - 1}{e^{j(\phi_o - \phi_s)} + 1} \qquad (2)$$

where $\phi_o = 2\pi d_o / \lambda_g$, $\phi_s = 2\pi d_s / \lambda_g$ and λ_g is the guide wave length at each ω. Input VSWR as a function of ω is calculated from reflection coefficient, R. Input VSWR of the rf window become minimum at angular frequency, ω obtained at $d_o = d_s$.

Frequencies and the field distributions of the ghost mode are calculated as cylindrical resonant modes excited in the pillbox cavity.

The results of calculation

To compare the standard type with the long type for the field distributions and frequency band width, these two are the same pillbox diameter of 86 mm. Other dimensions are summarized in Table 1.

Table 1
Dimensions of the long and standard type rf windows

		Long type	Standard type
Diameter	mm	86	86
Length	mm	178	24.4
Ceramic thickness	mm	2.42	3.50

The electric field distributions of the standard and the long type rf window are shown in Fig. 2. E_{even} and E_{odd} are the electric field distributions of the rf window with open and shorted boundary conditions, respectively. (a), (b) and (c), (d) in Fig. 2 are of the standard type and of the long type, respectively. As can be seen in Fig. 2- (b), the electric field normal to the ceramic surface is exist for the standard type. In case of the long type, the perpendicular components in Fig. 2- (b) are not exist, we conclude that the reduction of the perpendicular component can affect to eliminate maltipactor electron bombardment.

The frequency responses of each type rf window At their dimensions are shown in Fig. 3. Practical requirement of band width at 2856MHz is 100 MHz Since tuning frequency range of a klystron is 3%, 90MHz. Considering the harmonics frequency of a klystron output, such a wide band is practically impossible. As can be seen in Fig. 3, the band width of 100 MHz with input VSWR less than 1.1 satisfies the specification.

The ghost mode frequencies of the long type rf window are listed in Table 2. The ghost modes are undesirable since they enhance multipactoring and the stored energy will be dissipated as heat in the ceramic. So enough separation of frequencies is required between the ghost mode and the operation. As shown in Table 2 all frequencies are very close to the operating frequency. To separate them more, only one way is to make the pillbox diameter longer.

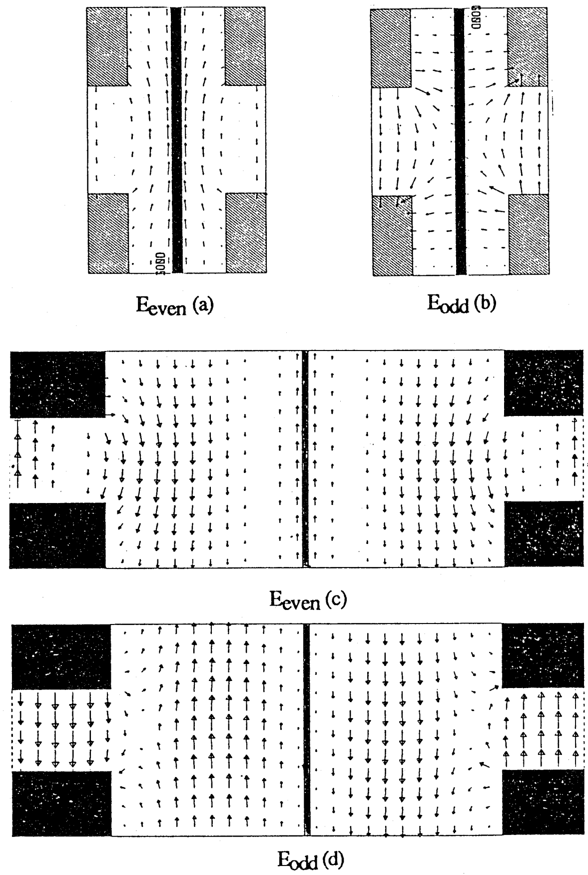

Figure 2 The electric field distributions of the standard and the long type rf window.

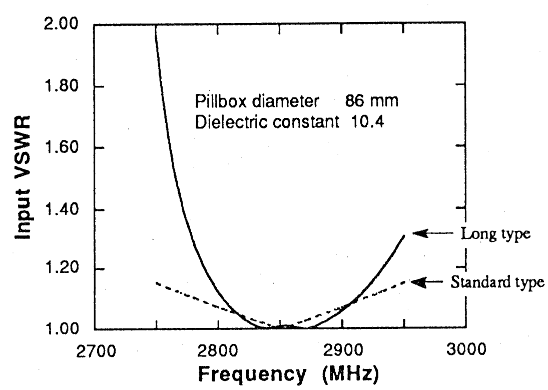

Figure 3 The calculated frequency response of the long and standard type rf windows. Solid line is for the long type, and dotted for the standard type. Dimensions of each type window are listed in Table 1

Table 2
Ghost mode frequencies of long type rf window (MAFIA)

Exciting mode	TE_{211}	TM_{011}	TE_{113}
Frequency (MHz)	2829	2844	2859

Future plan

Another geometry to reduce electric field normal to the ceramic surface which is the "higher mode" type rf window. It makes use of a higher, TM_{11} propagation mode of circular waveguide. Dimensions of the higher mode type window are now being optimized. Diameter of this type window will be about 158 mm. Large diameter gives rise to reduce the strength of electric field not only in the normal component, but also on the ceramic surface. However, difficulties in manufacturing technique, in particular brazing ceramic to the sleeve of the window will need to be overcome

Summary

It was concluded that the long type window has the practical practical band width.and vanishs the normal electric field to the ceramic surface. However, ghost mode frequencies are very near operation one. To separate them more, only one way is to make the pillbox diameter longer.

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