DAMPED STRUCTURE FOR JLC MAIN LINAC

T.Taniuchi, M.Yamamoto*, K.Kubo, T.Higo and K.Takata
National Laboratory for High Energy Physics (KEK)
**The Graduate University for Advanced Studies*

Oho1-1, Tsukuba-shi, Ibaraki-ken, 305, Japan

Abstract

In the Japan Linear Collider (JLC), strong long-range wake fields induced in the X-band accelerating structure by passed bunches will easily make the emittance large and lower the luminosity. One of the ways to reduce the effect of wake fields and preserve the emittance along the linac is to damp the induced wake fields before the arrival of the next bunch. The tolerable maximum Q value for the most serious dipole mode,TM110, is about 15.[1] It was found to be able to achieve this Q value in a damped structure with four damping waveguides in a cell while suppressing the reduction of the Q value for the accelerating mode as low as 15%.

Introduction

In order to achieve a high luminosity which is needed to obtain desired event rate for a high energy linear collider, a multi-bunch operation is adopted in the JLC.[2] The number of bunches per pulse will be 10 to 20. In this operation, longitudinal and transverse wake fields induced by passed bunches will act on the following bunches and cause an energy spread and a deflection of bunches, respectively. One of the solutions for this problem is the damped structure. This structure has very low Q value for higher order mode (HOM), so that the wake fields induced by a bunch in the structure is damped sufficiently before the arrival of the next bunch.

Table 1 shows the relevant wake fields in the JLC X-band linac with $a/\lambda=0.14$.[3] In the table, the tolerable maximum Q value are listed in the last column. TM110-like mode should most seriously be studied in a sense that the required Q value is the lowest and the resonant frequency is minimum of all the listed modes. We concentrate on this mode to obtain its Q value less than 15, in this paper, while trying not to degrade the characteristics of the accelerating mode much.

Table 1 Relevant long range wake fields.($a/\lambda=0.14$)

Mode	Freq.	Wake	Q (Target)
Longitudinal	(GHz)	($\times 10^{15}$ V/C/m)	
TM010	11	0.5	
TM020&011	26	0.05	
TM021	36	0.09	270
Transverse	(GHz)	($\times 10^{17}$V/C/m^2)	
TM110	16	1.1	15
TM111	26	0.18	38
TM121	36	0.12	61

There are various types of the damped structures studied before.

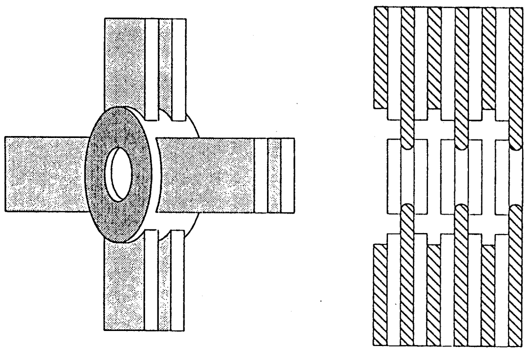
A single-mode cavity, such as proposed by Weiland[4] dose not work in a multi-cell structure of JLC since the escaped wake from a cell will excite the neighboring cells and not damp easily. A structure with crossed beam pipes proposed by Kageyama[5] is very effective for damping dipole modes but cannot be used for a multi-cell structure. A structure with slots in the disk proposed by Palmer[6] is especially good for damping of the TM110-π mode and is suited for a multi-cell structure. However, if we stick to the partially slotted disk to prevent the slots from a penetrating the beam hole area, the Q value for the TM110-π mode is too sensitive to its geometry.[7]

On the other hand, the structure with damping waveguides attached radially to each cell has been investigated[7],[8] and reported to be favorable to the JLC X-band linac.[7] In this structure, many large waveguides were found to deteriorate the Q value of the accelerating mode seriously. As the next step, this type of structures were investigated in this paper where the excited HOM damp effectively while preserving the Q value and the R/Q value of the accelerating mode. Damping performance of TM110 and characteristics of the accelerating mode for this type of structures are discussed in the following section.

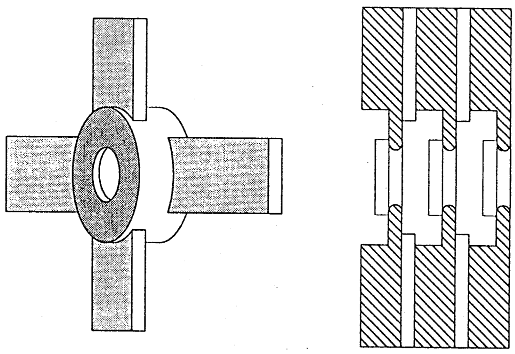
Structures with Waveguides for HOM Damping

Two types of structures named type A and type B were investigated in this work. The results of type A were already reported.[9] Figure 1 shows their geometries. In both structures, an accelerating cell has the waveguides with the cross section, 11mm $\times$ 2mm, where the cutoff frequency of TE10 mode in the waveguide is 13.5 GHz. The width of waveguides was determined as the cutoff frequency of TE10 mode was higher than the frequency of accelerating mode, 11.4GHz and lower than that of TM110 mode, about 16GHz.

The waveguides of type A are located in four direction and divided into two groups by a septum of its thickness 2mm at the middle of the cell. The septum is supposed to be effective for damping such modes as TM111 and TM011 where there is a node at the center of the cell. The waveguides of type B are located in a line and two lines in a cell are perpendicular with each other. The number of waveguides is 8 in type A and 4 in type B in a cell. Each waveguides couples with the accelerating cell through an iris. Optimization was performed to search a structure with low Q value for HOM while that of the accelerating mode kept high by changing the opening width of this iris.



Type A



Type B

Figure 1 The geometries of damped structures investigated.

Resonant frequencies of these damped structures were calculated by computer code MAFIA[10] for various positions of shorting plane and plotted on the $\phi-\omega$ plane. ϕ is the phase change along the waveguide and ω is the frequency. The external Q for TM110 mode was obtained by fitting the $\phi-\omega$ plots with Slater's formula[11] which is given by

$$\frac{\phi}{\pi} = \frac{2}{\lambda_g}(d-d_0) - n = \frac{1}{\pi}\,\mathrm{Arctan}\sum_a \frac{\frac{1}{Q_{ex,a}}}{\frac{\omega}{\omega_a} - \frac{\omega_a}{\omega}} \qquad (1)$$

where d and d_0 are the position of shorting plane and its origin, n the number of branch in the waveguide and ω_a the angular frequency of a mode. The parameters of the fitting are Qex's and frequencies of the first two modes and the position of origin d_0. An example of these fittings is shown in Figure 2. In this case, the Qex and frequency of first resonant mode (TM110) are 15 and 16.7GHz. Those of the second mode (TE111-like) are 171 and 24.1GHz. And the position of origin is 6.2mm from the center of a cell. The Qex for TE111-like mode seems to be large, but the R/Q of this mode is considered to be very small the from field pattern. It is necessary to estimate the R/Q quantitatively to make sure.

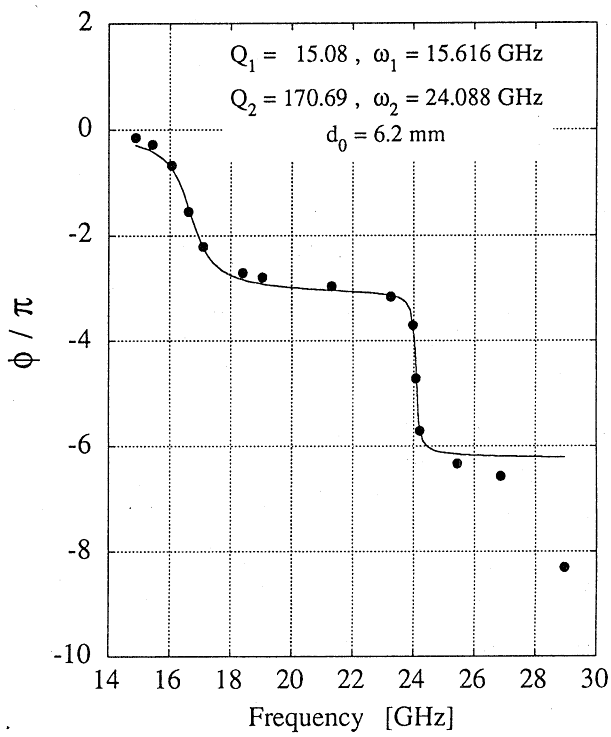


Figure 2 Phase variable ϕ as a function of frequency ω for a structure of type B with its iris opening width 8mm.

The same calculation was performed by changing the opening width of the iris. The obtained external Q values for TM110 and the Q values for the accelerating mode were compared in Figure 3.

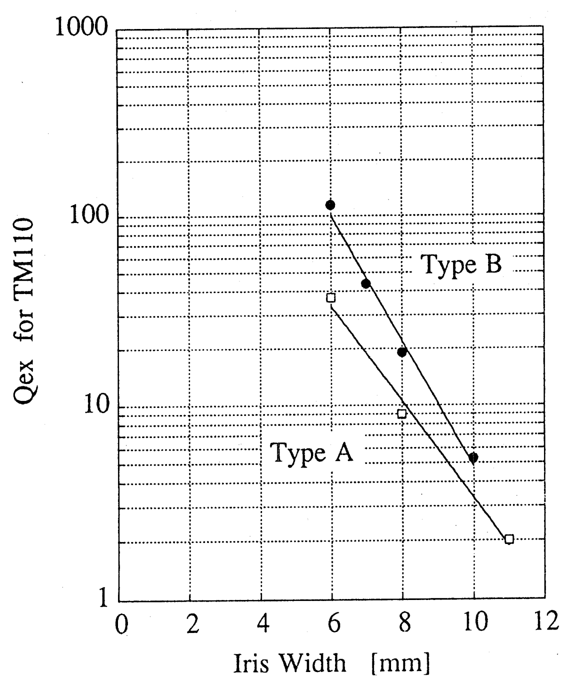


Figure 3.a Qex for TM110 as a function of iris width.

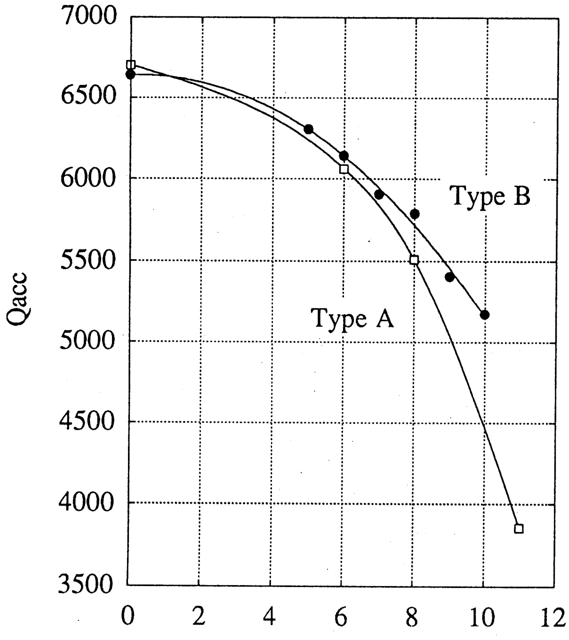


Figure 3.b Qacc as a function of iris width.

Discussion

The external Q for TM110 mode can be easily less than 15 with large width of the iris. But the Q value for the accelerating mode is reduced as the width of iris becomes larger. In the case of the structures which fulfill the requirement on the Q value for HOM, 15, Qacc's are about 5600~5700. The reduction of Qacc is about 15% compared to the Qacc without damping waveguides, about 6700. The difference between two types of structures seems to be small. The degradation in R/Q of the accelerating mode should also be estimated. These remain to be performed.

Conclusion

Damped structures with damping waveguides for the JLC X-band linac were investigated. The Qex for TM110 mode and Qacc were calculated and their dependences on the iris width were obtained. As a result, it was found to be able to achieve required Qex for TM110 mode with 15% reduction of Q value for the accelerating mode. The Qex's for other modes remain to be investigated. The calculations of the accelerating mode, such as the R/Q value, should also be examined more carefully. The configuration of the damping waveguide other than the two types described above should also be studied.

References

[1] K.Yokoya, Proc. of the First Workshop on JLC, KEK, 1989.

[2] K.Takata, Proc. of the Linear Accelerator Conference, Albuquerque, 1990.

[3] T.Higo et al., Proc. of the Linear Accelerator Conference, Albuquerque, 1990.

[4] T.Weiland, DESY 83-073,1983.

[5] T.Kageyama, Proc. of the 15th Linear Accelerator Meeting, Japan, 1990.

[6] R.B.Palmer, SLAC-PUB-4542, 1989.

[7] T.Higo et al., Proc. of the 1991 IEEE Particle Accelerator Conference, San Francisco, 1991, KEK-preprint 91-32.

[8] H.Deruyter et al., SLAC-PUB-5322, 1990.

[9] T.Taniuchi et al., Proc. of the 16th Linear Accelerator Meeting, Japan, 1991.

[10] K.Klatt et al., Proc. of the Linear Accelerator Conference, SLAC-Report-303, 1986, p276-278.

[11] J.C.Slater, Microwave Electronics (Van Nostrand, New York, 1950), Chapter 5.