DAMPED STRUCTURE FOR JLC X-BAND LINAC

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Abstract

Accelerating structures with damping ports for higher mode have been investigated to apply to JLC X-band linac. The external Q values were evaluated by Slater's tuning method using the computer code MAFIA. It was found that the structure with circumferential waveguides of 11mm wide was effective to damp the TM110 mode by examining the dependence of the external Q value on the geometry of the iris of the damping ports. The external Q values for some of the other higher modes were evaluated and it was found that TE111 mode is hard to damp in such a structure, though its impedance is expected not to be so high. To estimate the degradation of the accelerating mode due to the damping ports, the dependence of the Q value and r/Q value on the geometry of the damping port were also calculated. Those were about 16% and 4.2%, respectively.

Introduction

The multi-bunch operation is adopted to achieve high luminosity in the Japan Linear Collider (JLC). In this operation, the wake field excited by the preceding bunches acts on the following bunches and causes the energy spread and the deflection of bunches. The relevant transverse wake potentials in the typical X-band(11.424GHz) disk-loaded structure with $a/\lambda=0.14$ are shown in Table 1.[1] In all the listed transverse modes, the TM110-like mode should most heavily be damped in a sense that the wake potential is the largest and the resonant frequency is minimum. To suppress the emittance growth originated from the injection error within a factor of $\sqrt{2}$ and to increase the misalignment tolerance of the cavity up to 80μm, the Q value of TM110 mode should be less than 15.[2]

TABLE 1
Transverse Wake Potentials ($a/\lambda=0.14$)[1]

Mode	Frequency [GHz]	Wake potential $\times10^{17}$[V/C/m^2]	Q_{ext} Target
TM110	16.25	1.28	15
TE111	21.59	0.06	60
TM111	25.84	0.25	38
TE121	30.78	0.005	—
TM120	31.58	0.12	60
TM121	36.09	0.24	54
TM130	39.10	0.11	80

In this paper, we discuss about the damped structure as a candidate for escaping from these wake field effects. The damped structure with slots was first proposed by Palmer for the linear collider.[3] For the JLC main linac, a damped structure with slots in each disk was investigated. This type of structure has advantages in the accelerating mode compared with that with circumferential slots in the outer wall of the cell. However, it was found that the Q_{ext} of TM110-π mode was too sensitive to the change of the dimension and hard to apply to the real design.[4] Therefore, we investigate in this paper a damped structure with circumferential slots in the cell.

Damped Structure with Circumferential Slots

The shape of a damped structure is shown in Fig.1. An accelerating cell has four damping waveguides. The width of the waveguide was chosen to be 11mm where the cutoff frequency of TE10 mode is 13.5GHz. This frequency is set higher than the frequency of the accelerating TM010 mode, 11.424GHz, and lower than that of TM110 mode, about 16GHz. Two waveguides are located in a line to hold the up-down or left-right symmetry of a cell and two lines in a cell are perpendicular with each other to damp both modes with different polarization. Each waveguide couples with the accelerating cell through an iris which forms a circumferential slot when seeing from the inside of the cell. In such a slot, TM-like modes in a cell couple with TE10 modes of the waveguide by the magnetic field.

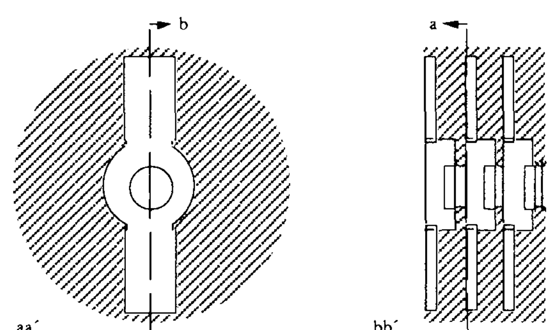

Fig. 1 Schematic view of damped structure

Evaluation of the External Q Value

The Q_{ext}'s of HOMs were evaluated by Slater's tuning method[5] using 3D electromagnetic field code, MAFIA[6]. In this method, the Q_{ext} can be obtained from the releation of the resonant frequency to the length of the waveguide. These data were plotted in the form suggested by Kroll.[7] The Q_{ext}'s and the resonant frequencies were obtained by fitting these plots.

Dependence on the Iris Width

There is an iris in the entrance of the waveguide to adjust the coupling between cavity and waveguide. The Q_{ext}'s of HOMs were calculated by changing the opening width of the iris. The height of the waveguide was fixed at 2mm. Fig. 2 shows the result of Q_{ext}'s where the beam hole radius is 4.5mm (a/λ=0.17). It was found that all the Q_{ext}'s decrease exponentially except for TE111 mode. The Q_{ext} of TM110-π mode is the largest in these modes but in the case of the iris opening width larger than 9mm, it is less than 15 which satisfies the criterion for the JLC main linac. On the other hand, it is more complicated in the case of TE111 mode where the Q_{ext}'s do not decrease exponentially as the iris width increases. But the TE111 mode excited by the beam has its phase shift per cell near $4\pi/5$ and the corresponding Q_{ext} will be near 100. As the r/Q value of this mode ia very low compared to that of the TM110 mode, this Q value can be acceptable, though the realistic Q value and the r/Q value should be evaluated for an actual design. Moreover, the TE111 mode is actually not pure but is mixed with the TM110 mode. Therefore, those modes as TE111 and TM110 should be treated simultaneously for the actual evaluation of the wake field from those modes.

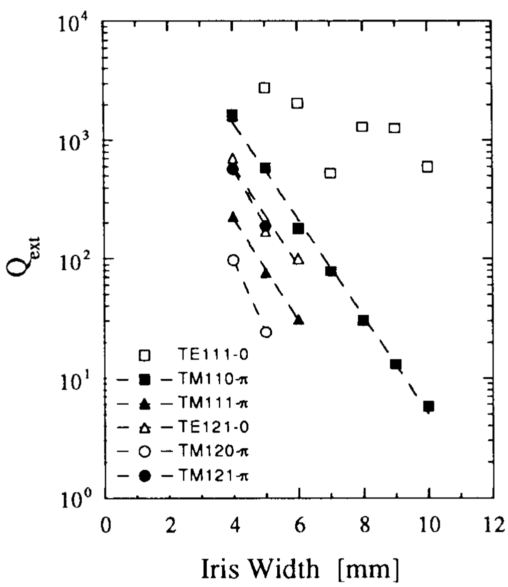

Fig. 2 Dependence of Q_{ext} on iris width. (a=4.5mm, boundary condition for TM110-π mode)

The dependence of the accelerating mode on the iris width was also calculated where the frequency of the accelerating mode was adjusted to 11.42GHz ±0.5% by changing the cell radius. A result of Q value is shown in Fig.3. When the iris opening width is 9mm which satisfies the requirement for Q_{ext}'s, the degradation of the Q, r/Q and r value of the accelerating mode from the structure without damping ports were about 16%, 4.2% and 20%, respectively.

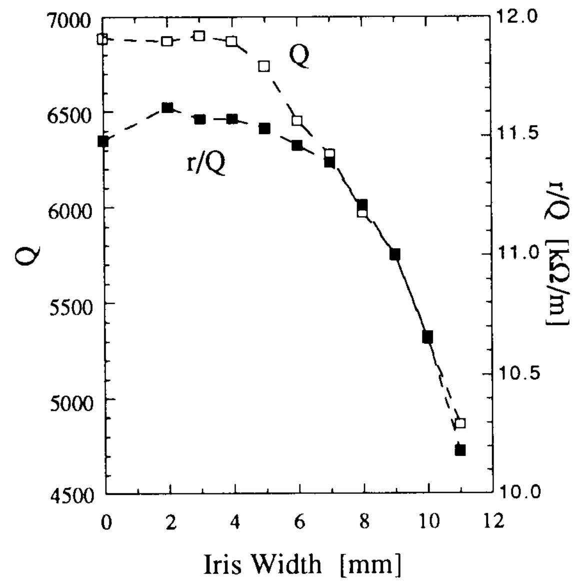

Fig. 3 Dependence of Q and r/Q value of accelerating TM_{010}-$2\pi/3$ mode on iris width. (a=4.5mm)

The dependence on the beam hole radius was also calculated. Fig. 4 shows Q_{ext} of TM_{110}-π mode for the beam hole radius of 4.0, 4.5 and 5.0mm. It seems that there are not large differences among them. A little difference comes from the difference of the iris thickness. The Q_{ext}'s of other TM-like modes should not be so different from those in the beam hole radius of 4.5mm. Therefore, the same damping port can be used for every cell in such a structure as the constant gradient structure. It should be noted, however, that the Q_{ext}'s of TE-like modes become higher as the beam hole radius becomes smaller.

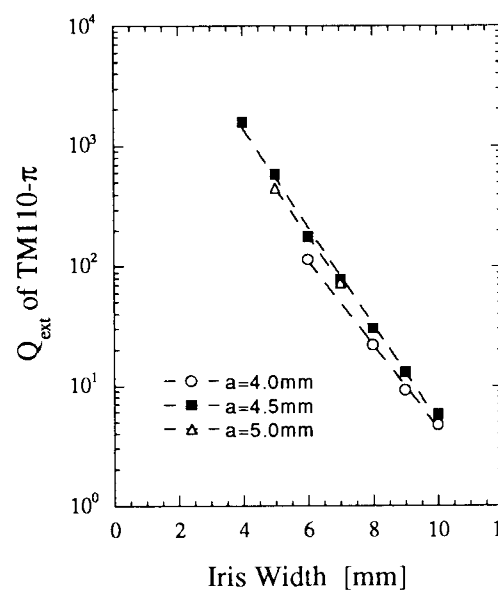

Fig. 4 Dependence of Q_{ext} of TM110-π mode on iris width. (a=4.0, 4.5, 5.0mm)

Dependence on the Waveguide Height

The dependence of Q_{ext} of TM110-π mode on the waveguide height is shown in Fig. 5. The iris width was fixed at 9mm. The Q_{ext} is almost constant in excess of the height of 2mm. However, it should be noted that the waveguide height should be lower than half of the gap length for such modes as TM111 and TM011 where there is a node at the center of the cell.

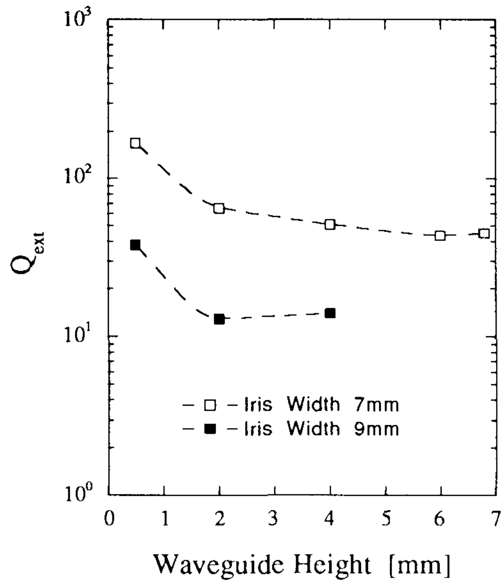

Fig. 5 Dependence of Q_{ext} of TM110-π mode on waveguide height. (a=4.5mm)

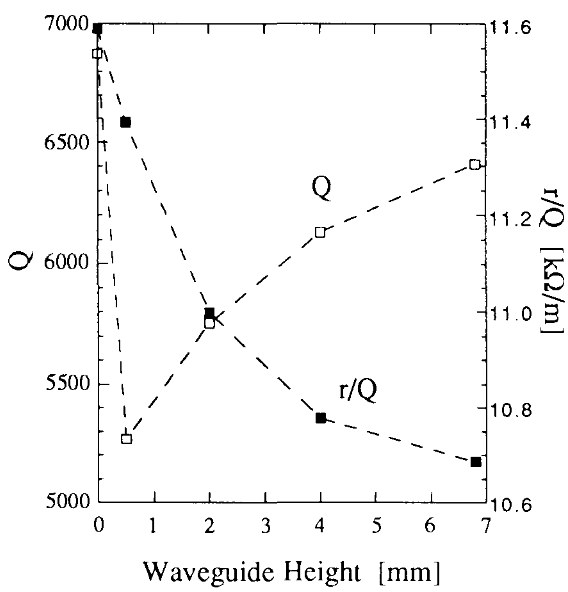

Fig. 6 Dependence of Q and r/Q value of accelerating mode on waveguide height. (a=4.5mm)

The dependence of the Q and r/Q values of the accelerating mode is shown in Fig.6. The Q value drops by 22% when even a very thin circumferential slot is opened. However, the degradation of the Q value can be recovered to the amount of 6% at maximum height of the full gap length. On the other hand, the r/Q value decreases as the height becomes large.

Measurement of a Low Power Model

A low power model of two half cells was measured by the network analyzer. Fig.7 shows the spectrum of the structure with matched load. In this configuration, TM110 mode is heavily damped in one of the half cells but little damped in another cell. As a result, the Q values of 0 and π mode at 17 and 15GHz become 40 and very low, respectively. This agrees with the calculation by MAFIA.

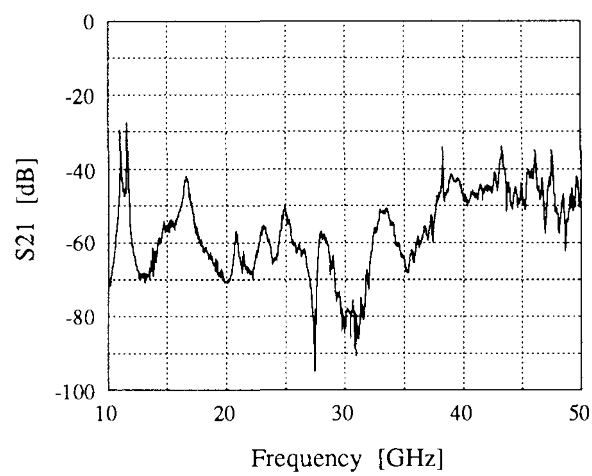

Fig. 7 Measured spectrum of a damped structure with a disk between two half cells.

Conclusion

The dependence of the Q_{ext} on the dimension of the damping ports was calculated. This structure seems to satisfy almost the requirement for the transverse HOMs. At the optimized dimension, the Q and r/Q value of the accelerating mode were about 84% and 96% of the conventional disk-loaded structure.

References

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