

DAMPED STRUCTURE FOR JLC MAIN LINAC (II)

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Abstract

For JLC X-band linac, an accelerating structure which can damp the higher order modes has been investigated. The dependence on the dimension of the damping port was obtained. The external Q value of the most serious mode, TM₁₁₀- π mode can be less than 15. A low power model was measured. The result indicates a reliability of the evaluation of the external Q value.

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 80 μ m, the Q value of TM₁₁₀ mode should be less than 15.^[2] In this paper, we discuss about the damped structure as a candidate for escaping from these wake field effects. In the damped structure, the wake field excited by a bunch is sufficiently damped before the arrival of the next bunch. For this purpose, the damped structure has some damping ports to extract the higher order modes (HOMs). 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.

Mode	Frequency [GHz]	Wake potential $\times 10^{17}$ [V/C/m ²]	Q_{ext} Target
TM ₁₁₀	16.25	1.28	15
TE ₁₁₁	21.59	0.06	60
TM ₁₁₁	25.84	0.25	38
TE ₁₂₁	30.78	0.005	—
TM ₁₂₀	31.58	0.12	60
TM ₁₂₁	36.09	0.24	54
TM ₁₃₀	39.10	0.11	80

Table 1 Transverse wake potentials^[1]($a/\lambda=0.14$)

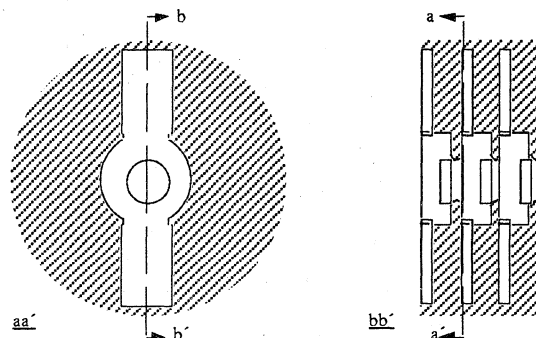


Fig. 1 Schematic view of damped structure

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.

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 resonant frequency as a function of 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 ($a/\lambda=0.17$). 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 must be 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.

The dependence of the accelerating mode on the iris width was also calculated where the frequency of the accelerating mode was adjusted to $11.42\text{GHz} \pm 0.5\%$ 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.

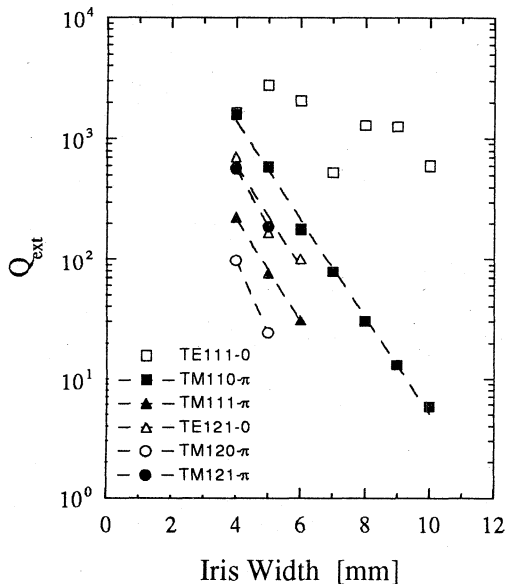


Fig. 2 Dependence of Q_{ext} on iris width. ($a=4.5\text{mm}$, boundary condition for TM₁₁₀- π mode)

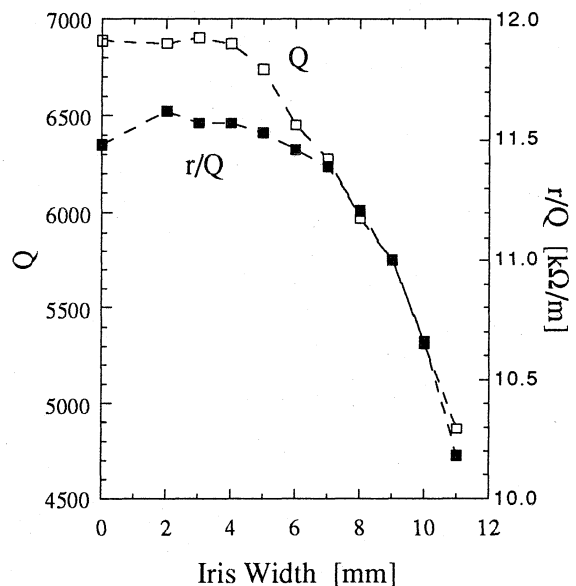


Fig. 3 Dependence of Q and r/Q value of accelerating TM₀₁₀- $2\pi/3$ mode on iris width. ($a=4.5\text{mm}$)

Dependence on the Waveguide Height

The dependence of Q_{ext} of TM₁₁₀- π mode is shown in Fig. 4. 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.

The dependence of the Q and r/Q values of the accelerating mode is shown in Fig.5. 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.

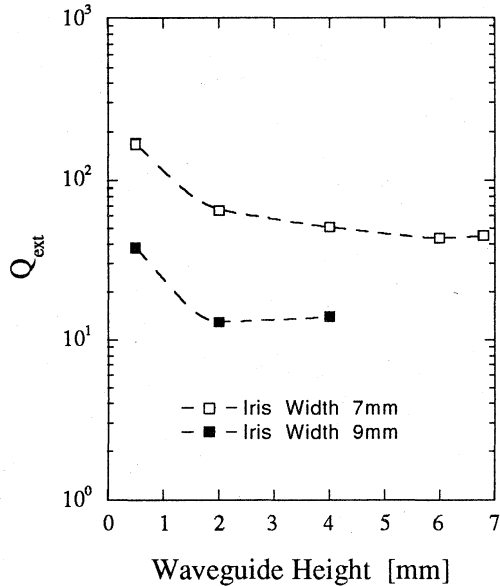


Fig. 4 Dependence of Q_{ext} of $TM_{110}-\pi$ mode on waveguide height. ($a=4.5\text{mm}$)

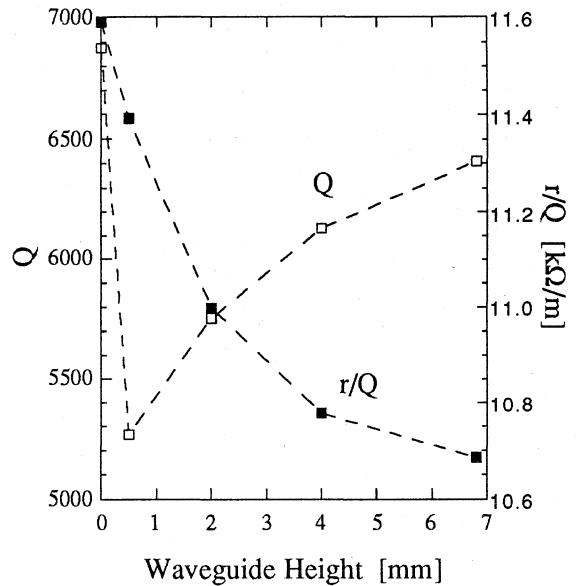


Fig. 5 Dependence of Q and r/Q value of accelerating mode on waveguide height. ($a=4.5\text{mm}$)

Measurement of a Low Power Model

A low power model of two half cells was measured by the network analyzer. Fig.6 shows the spectrum of the structure with matched load. In this configuration, TM_{110} 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 become 40 at 17GHz and very low at 15GHz, respectively. This agrees with the calculation by MAFIA.

Conclusion

This damped structure seems to satisfy almost the requirement for the transverse HOMs. On the other hand, the degradation of the Q value of the accelerating mode is inevitable. This degradation must be minimized.

References

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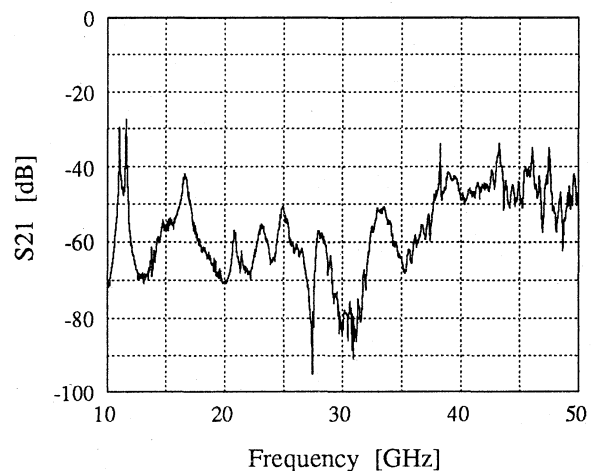


Fig. 6 Measured spectrum of a damped structure with a disk between two half cells.