OPTIMIZATION ON WAKEFIELD DAMPING IN C-BAND ACCELERATING STRUCTURE

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Abstract

Multi-bunch acceleration in the future e^+e^- Linear Collider projects requires sufficient suppression of transverse wakefield for high luminosity. The C-band accelerating structure consists of the choke-mode cavity to damp the wakefield. In order to achieve the maximum damping, optimization of wakefield absorber was necessary. After the optimization, the transverse wakefield is sufficiently damped below the desirable level.

1 INTRODUCTION

In the future e^+e^- linear colliders, multi-bunch operation is necessary for high luminosity. In multi-bunch operation, long-range transverse wakefield, which is generated by the leading bunches passing the accelerating structure with an finite offset, deflects the orbit of the following bunches. In order to prevent the degradation of the luminosity due to the orbit deflection, the wakefield must be sufficiently damped after the bunch spacing with practical alignment tolerance.

Long-range ringing of the wakefield can be shortened by broadening its spectrum. There are two promising techniques to increase the spectrum width of the wakefield in an accelerating structure: detuning and damping. In the former scheme, the distribution of the higher order mode (HOM) frequency in one or more accelerating structures is deliberately arranged to realize fast smear out of the wake field. In the latter scheme, on the other hand, the HOM's are damped and the HOM spectrum becomes broad even for one cell.

In the C-band linear collider project [1,2], choke-mode cavity [3] is adopted for the accelerator structure in the main linac. Figure 1 shows the C-band accelerating structure. The whole accelerating structure is constructed by stacking axially-symmetric cells. The wakefield generated by a bunch goes out of the cell through the radial line, whereas the accelerating field is confined by the choke. The wakefield is absorbed by the SiC ring at the outside of the choke. The choke-mode cavity is sometimes referred to as "heavily damped structure" because of its high damping performance.

The C-band accelerating structure is now under fabrication [4] to be tested at ASSET in SLAC, where the long-range transverse wakefield will be measured using a driving bunch and a witness bunch passing through the accelerating structure with an offset.

In this paper, its design procedure relating to wakefield damping is presented. First, the optimization of the wakefield absorber for a single cell is described in section 2. Next, the transverse wakefield averaged over the accelerating structure is calculated in section 3.

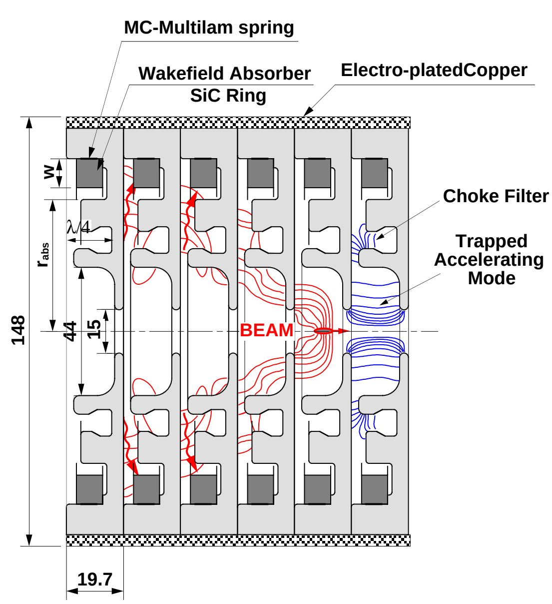

Figure 1: C-band choke-mode structure.

2 OPTIMIZATION PROCEDURE OF SINGLE-CELL DAMPING

The frequency of HOM's is not constant along the accelerating structure since it is a semi-constant gradient structure. The result of the optimization is different depending on the dimensions of the cell.

2.1 Reflection of the Wakefield by the Choke

A part of the wakefield is reflected at the choke even

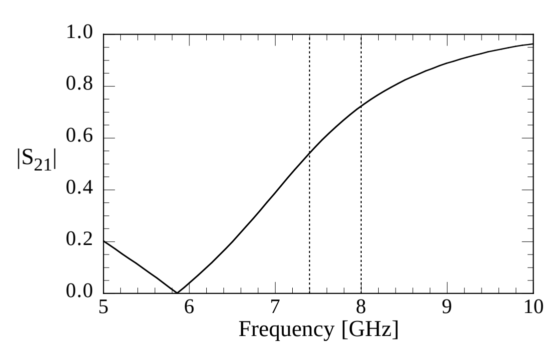

Figure 2: Dipole transmission of the choke.

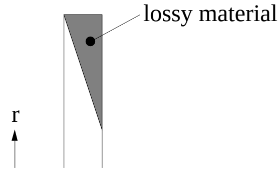

Figure 3: Dummy absorber for calculating optimum reflection coefficient.

though the radial line of the choke-mode structure effectively extracts the wakefield. This can be a serious problem when the main frequency component of the wakefield is near the dipole stop frequency of the choke. In our case, the main contribution to the transverse wakefield comes from TM110, whose peak frequency ranges from 7.4 to 8 MHz depending on the iris aperture $2a$.

Figure 2 is the transmission coefficient of the choke for the lowest dipole mode calculated with MAFIA 2D time-domain solver (T2). The peak frequency of TM110 is in the region between the two dashed lines, which indicates that only 1/3~1/2 of the energy of TM110 wakefield is transmitted to the absorber. Because of this effect, simple matched (no reflection) absorber at the outer end of the radial line does not provide sufficient damping. This problem was solved by deliberately introducing reflection to the absorber.

2.2 Optimum Reflection from the Absorber

Before designing a realistic absorber, a simple wedge-shaped lossy material, which is shown in Fig. 3, was used in the calculation of the optimum reflection coefficient. The amplitude and phase of the reflection coefficient can be changed by the imaginary part of the permittivity and the radial position of the lossy material, respectively. Then the transverse wakefield and impedance were calculated by MAFIA T2. The optimum reflection coefficient was determined where the peak height of TM110 becomes the lowest. Typical amplitude of the optimum reflection coefficient is 0.55.

Table 1: Parameters of the C-band accelerating structure. The form $n1$ - $n2$ indicates $n1$ at upstream and $n2$ at downstream.

Frequency	5712	GHz
Phase Shift per cell	$3\pi/4$	
Field distribution	semi C.G.	
Number of cells	91	
Iris aperture ($2a$)	17.4 - 12.54	mm
Cavity diameter ($2b$)	45.3 - 43.3	mm
Disk thickness (t)	3	mm
Group velocity	0.035 - 0.012	c
Quality factor	10.7 - 10.3	10^3
Shunt impedance	53.0 - 67.3	MΩ/m

2.3 Determining the Absorber Dimensions

As shown in Fig. 1, the wakefield absorber is an ring of SiC ceramics with a rectangular cross-section. This simple shape was adopted for three reasons: (i) it is easy to fabricate, (ii) the reflection coefficient at the TM110 frequency can be easily changed by changing its width w, and (iii) the reflection coefficient above the TM110 frequency is relatively low. The width of the SiC ring is determined to realize the amplitude of the optimum reflection coefficient at the frequency of TM110. Although the reflection coefficient is optimized only at the frequency of TM110, absorbing all the field energy is sufficient for smaller peaks at higher frequency as can be seen in the next section.

The calculated transverse wakefield is shown in Fig. 4 for the most upstream cell ($2a$ = 17.4) and the most downstream cell ($2a$ = 12.54). In the figure, the thin lines are the wakefield with a matched absorber and the thick lines are with the optimized absorber. With an optimized absorber, the damping time is 2 or 3 times shorter than with a matched absorber. The damping time of the upstream cell is longer than that of the downstream cell since the frequency of TM110 is lower at the upstream cell.

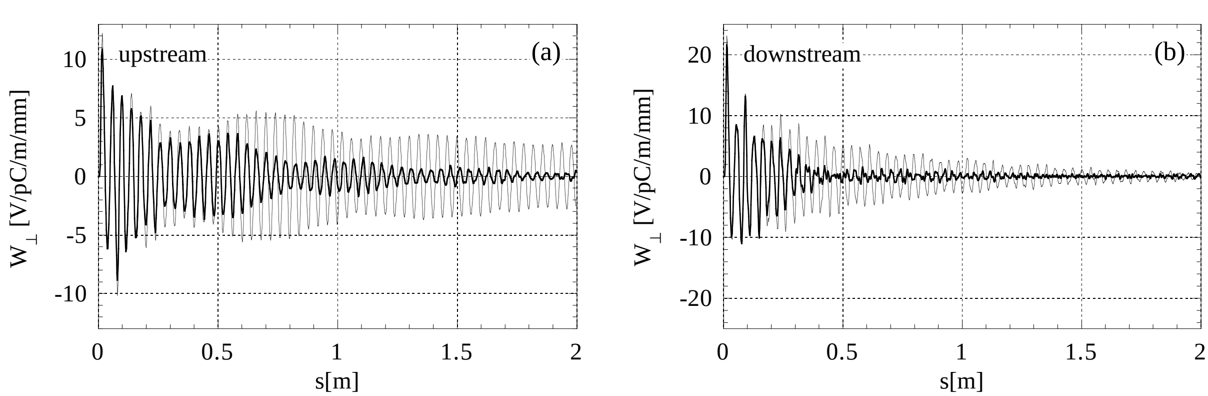

Figure 4: Dipole wakefield calculated by MAFIA T2 for (a) the most upstream cell ($2a$ = 17.40) and (b) the most downstream cell ($2a$ = 12.54). The thin lines are the wakefield with the matched (no reflection) absorber and the thick lines are with the optimized absorber.

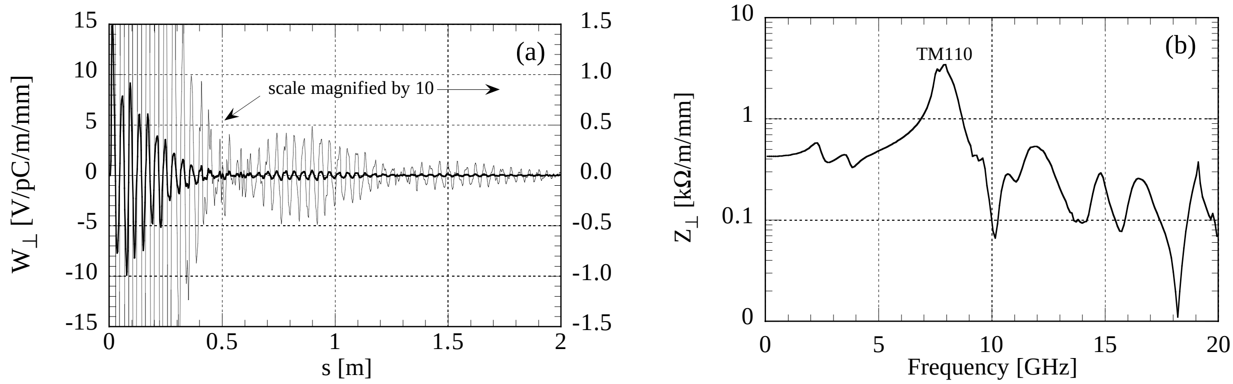

Figure 5: (a) The dipole wakefield averaged over the whole accelerating structure. (b) The impedance calculated from the wakefield.

3 DAMPING OF THE WHOLE STRUCTURE

The parameters of the C-band accelerating structure is summarized in Table 1. The iris aperture 2*a* changes linearly with the cell number from 17.4 to 12.54 and the cell diameter 2*b* also changes to keep the frequency of the fundamental mode constant. This variation of the cell structure introduces detuning of HOM's and additional spectrum broadening. All the choke dimensions including its radial position are the same for the whole structure.

3.1 Absorber Dimensions

For simplicity of the absorber design, the whole structure is divided into four regions of equal length. In each region, the absorber dimensions are determined by the optimization procedure descried above at the center cell.

Table 2: Optimized absorber dimensions. w and r_{abs} are defined in Fig. 1.

cell No.	2 - 22	23 - 45	46 - 68	69-90
w	10.0	10.0	10.0	10.0
r_{abs}	46.5	46.5	45.5	44.5

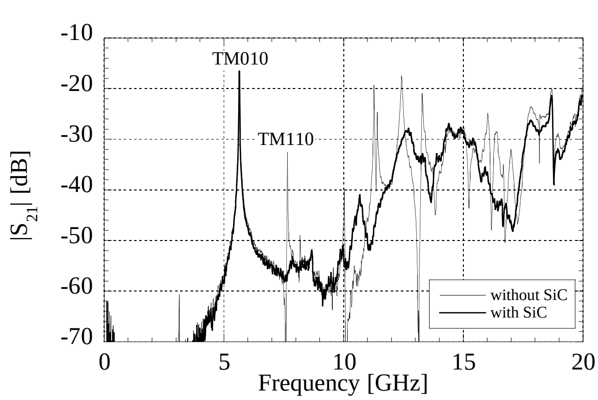

Figure 6: Measured transmission spectrum of the 44th cell.

The result of the optimization is listed in Table 2. The width of the SiC ring is decided to be constant along the accelerating structure since the optimized amplitude of the reflection coefficient was almost the same for the four regions.

3.2 Total Wakefield

The wakefield of the whole accelerating structure is obtained approximately by averaging the wakefield calculated at equally spaced 12 points. Figure 5 shows the averaged transverse wakefield and impedance. The peak of TM110 is still the highest one even after the optimization.

In the case of C-band main linac, the bunch separation is 2.8 nsec (0.84 m). The upper limit on the transverse wakefield corresponding to 30 μm alignment tolerance is 0.7 V/pC/m/mm at s = 0.84 m. From Fig. 5(a), the averaged wakefield is below this upper limit.

4 LOW-LEVEL MEASUREMENT

The transmission of a single cell was measured with two antenna-type probes on both sides of the cell. The distance of the probes from the center axis of the cell is 5 mm and their azimuth is the same. An example of measured spectrum with and without SiC absorber is plotted in Fig. 6. With SiC, sharp peaks are all damped. Further wake measurement for the whole accelerating structure will be done at ASSET.

REFERENCES

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[4] H. Matsumoto et al., "A Fabrication of the C-band (5712 MHz) Choke-Mode Type Damped Accelerator Structure," in this conference.