

# DAMPING OF HIGHER ORDER MODES IN A PLANAR 30 GHZ ACCELERATING STRUCTURE

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## Abstract

A 30 GHz Planar accelerating structure has been designed for the Compact Linear Collider (CLIC). It is a traveling wave, constant impedance structure, designed for the  $2\pi/3$  mode. Higher Order Modes (HOM) are classified with a horizontal and with a vertical plane of polarisation of the electrical field. For each polarisation different damping waveguides are needed once in vertical and once in horizontal direction. For both cases calculations of the longitudinal and transverse wake potential and the corresponding impedances are performed. The proposed arrangement fulfills the damping requirements of the CLIC accelerating structure.

## 1 INTRODUCTION

A planar accelerating structure (PAS) was developed for CLIC [1]. The geometrical sizes of the accelerating cells of the 30 GHz PAS were determined after a study of the RF-parameters [2]. A model consisting of 37 cells was tested in the CLIC Test Facility II (CTF2) at CERN [3]. The results have shown that, at present, a maximal accelerating gradient of 60 MV/m can be achieved.

In a next step the present paper investigates the possibilities for HOM damping. All computations of the HOM are performed by means of the GdfidL code [4]. For definition of sufficient HOM absorption in the PAS the requirements for CLIC [5] are used. It is necessary that the induced field in the structure is suppressed by a factor 100 between bunches in the train  $-0.67$  ns (which corresponds to a distance of 20 cm between bunches).

## 2 DISPERSION

The PAS has two planes of polarisation of the electrical field in z-direction. The modes with horizontal polarisation (HP-modes) have electric and magnetic boundary conditions in the planes  $x=0$  and  $y=0$ , respectively, and the vertically polarised modes (VP-modes) have the boundary conditions interchanged, Figure 1 and Figure 2.

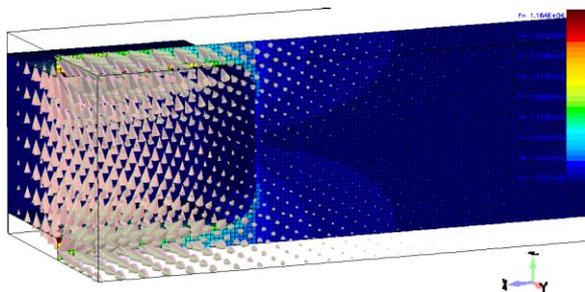


Figure 1: VP-mode in the accelerating cell.

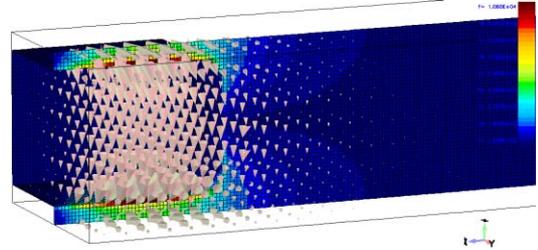


Figure 2: HP-mode in the accelerating cell.

The Fig. 3 shows the Brillouin diagram for the pass bands below 50 GHz. In this frequency range there are two first dipole modes (HP-mode and VP-mode) and the fundamental mode. The radio frequency parameters for the three synchronous modes are presented in table 1.

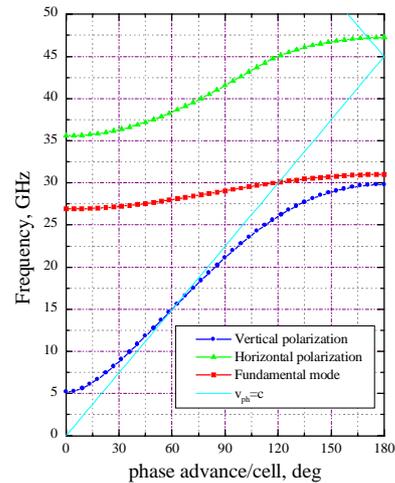


Figure 3: The Brillouin diagram.

Table 1: RF-parameters of the structure (The offset from axis for transverse Rsh is  $\Delta x, \Delta y = 322 \mu\text{m}$ ).

F, GHz	$Q_0$	$\frac{R_{sh} \parallel}{M\Omega\text{ms}}$ $m$	$\frac{R_{sh} \parallel / Q_0}{k\Omega\text{ms}}$ $m$	$\frac{R_{sh} \perp}{M\Omega\text{ms}}$ $m \cdot \text{mm}^2$	$\frac{R_{sh} \perp / Q_0}{k\Omega\text{ms}}$ $m \cdot \text{mm}^2$
14.957	6200			1270	206
29.991	5200	119.6	23		
47.158	5100			703	139

Studies of the first two dipole modes have shown, that they have a very low coupling in x-direction, where the absorbing loads are supposed to be placed.

First dipole VP-mode: for low phase shift, 0-80 degrees, the field extend in the x-direction. For high phase shift, 80-180 degrees, the field is concentrated near the accelerating cell. This wave passes through the accelerating cells of the structure and couples after the last cell to the  $H_{10}$ -mode of a wide rectangular waveguide. This waveguide mode is reflected from the beam pipe

(BP) port and comes back into the structure. The geometrical sizes of the BP-Inp/Output ports ( $axb=3.6 \times 3.6$  mm) are made for the flange size of the CLIC structure (Fig. 4). The ports have a cutoff frequency for the  $H_{10}$ -mode of  $F=41.64$  GHz. If the x-width of the BP-port could be increased by a factor of three, the first dipole mode could pass through the port. The cutoff frequency for this case is  $F=13.88$  GHz. Since it is not allowed to increase the width of the beampipe, the wave has to be coupled somehow in x-direction.

Investigation of the first dipole HP-mode has shown, that only the field with a phase shift near " $\pi$ "-mode do not extend far into the region where damping loads are placed. The decay of the electrical field of these modes in x-direction is practically like that of the fundamental mode. The damping waveguide (DW) in x-direction (Fig. 4) is made for damping of the HP-mode. The DW has such geometrical dimensions, that all HOM can propagate in it, but the fundamental mode can not.

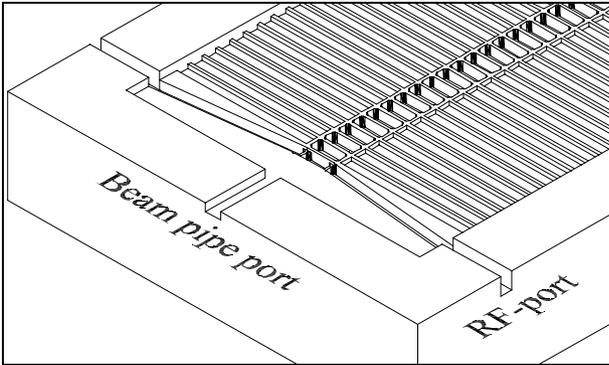


Figure 4: The planar 30 GHz accelerating structure.

However, computation of the transverse wake potential with such DW (with boundary conditions satisfying only excitation of the HP-modes) shows that the transverse wakepotential decreases, by a factor of 100 on a distance of 1 meter only. The real part of the impedance shows existence of three resonances with high quality Q. After classification of the electromagnetic field in these frequencies, the names are given (Figure 5).

$F=47.16$ GHz	$F=76.1$ GHz	$F=124.3$ GHz
$E_{210}$ - mode	$E_{211}$ - mode	$E_{212}$ - mode

Figure 5: Field pattern of the three HOM with high Q.

The iris between DW and accelerating cell was chosen as small as possible i.e. 0.35 mm. However in this case HP-modes have also low coupling in x-direction. After investigation of the damping properties of such DW, we come to the conclusion, that more complicated damping devices are needed.

### 3 DESIGN OF THE DAMPING WAVEGUIDES

Since we could not find DWs in x-direction, to which both kinds of HOM couple sufficiently, we chose to damp the VP-mode with DWs in x-direction, and the HP-mode with DWs in y-direction.

For absorption of the VP-modes so-called double ridge guide (DRG) are applied. The geometrical sizes of the DRG are chosen such, that the cutoff frequency is above the fundamental but below all other HOM. The DRG (Fig. 6) has a cutoff frequency of 28 GHz for the  $H_{10}$ -mode and 33 GHz for the fundamental mode (another polarisation of the electric field).

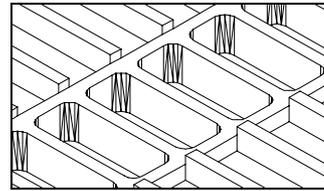


Figure 6: Design of the double ridge guide for PAS. Accelerating cells, with attached DWs in x-direction.

The cutoff frequency for the  $H_{10}$ -mode can not be lowered, since otherwise the fundamental mode would leak out. Because of the high cutoff frequency, the first VP-mode does not penetrate completely, but only partially. With DRG, the first dipole VP-mode is sufficiently damped, if the structure is at least 21 cells long. Fig. 7 and 8 show the real part of the impedance of such a 21-cell structure with DWs in x-direction attached.

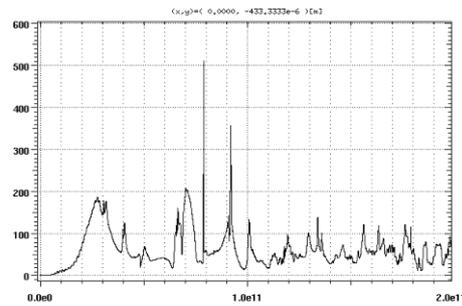


Figure 7: Real part of the impedance (VP-modes)

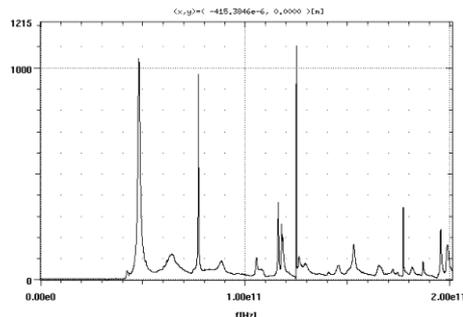


Figure 8: Real part of the impedance (HP-modes)

From these figures it is clear, that the DRG do not sufficiently damp all HOM. For both polarisations there are still resonances with high Q. For absorption of these

last modes, we attach DWs in y-direction. Figure 9 shows the complete design. In x-direction so-called DRG are attached. The distance between the cell and DRG is 0.7 mm. In y-direction two DW are attached at the bottom of each cell, and two at the top. The distance between the DWs is 1.4 mm. The cutoff frequency is 37.5 GHz. This is above the fundamental mode and below all HOM.

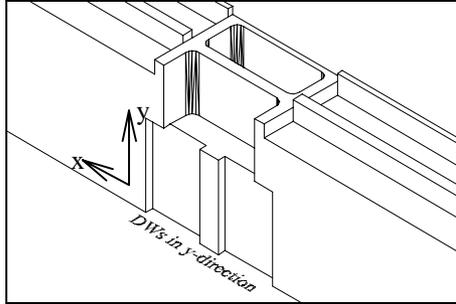


Figure 9: Design of the DW in y-direction

#### 4 CALCULATION OF TRANSVERSE WAKE POTENTIAL AND IMPEDANCE

The computed transverse wake potential and impedance (for both polarisations) of a 49-cell structure as shown in Figure 9 is shown in Figure 10 through Figure 13. The exciting bunch has a charge of  $q=1$  pC and a length of  $\sigma_z=0.7$  mm. The ultra-relativistic charge travels in z-direction through the structure with an offset of  $\Delta=0.42$  mm from the symmetry plane.

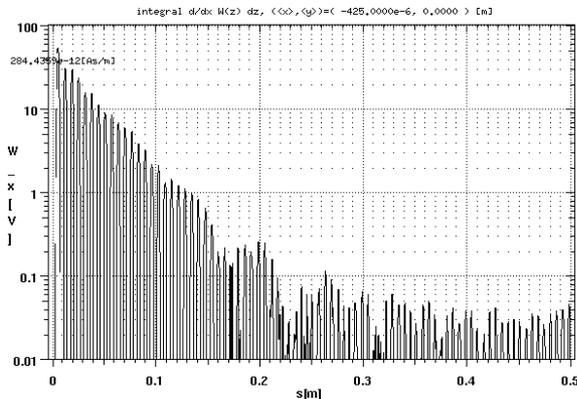


Figure 10: Transverse wake potential for HP-modes.

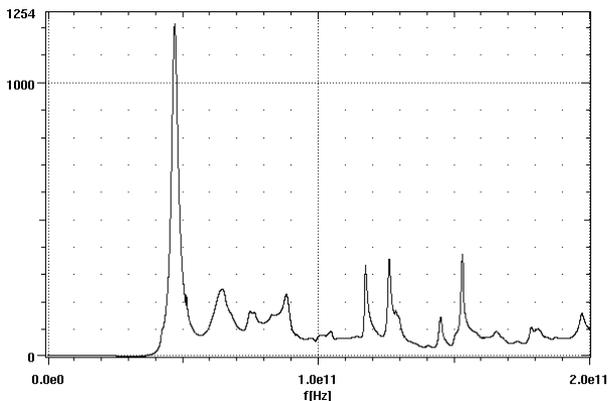


Figure 11: Real part of the impedance for HP-modes.

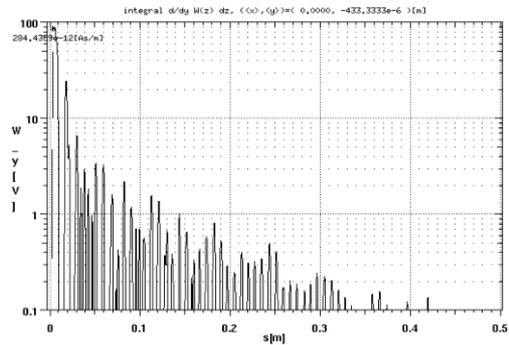


Figure 12: Transverse wake potential for VP-modes.

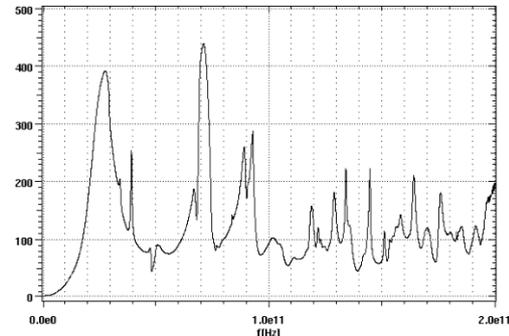


Figure 13: Real part of the impedance for VP-modes.

As it is visible from Figure 10 and Figure 12 the transverse wake potential for both polarisations is suppressed by a factor of 100 on a distance of 15 cm (that corresponds to a time interval of 0.50 ns).

#### 5 CONCLUSIONS

The proposed variant of HOM-damping devices is difficult to build. Each plate of the structure must be produced as two parts which must be subsequently soldered together. For further analysis however it is necessary to build and measure 10 GHz model of a structure consisting of 21 cells. This construction is underway

Another kind of damping, ie. detuning the structure in a random way was analysed. The most effective is the detuning of cells by a Gaussian function. Results close to the given requirements are achieved, but in this case the wakepotentials are very sensitive to the exact tuning of the cells. Also, a detuned structure is also difficult to build.

#### 6 REFERENCES

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- [5] I. Wilson, et al., "An Asset Test of the CLIC Accelerating Structure", EPAC2000, Vienna, August 2000.