A HOM DAMPED PLANAR ACCELERATING STRUCTURE

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Abstract

The problem of a very fast Higher Order Mode (HOM) suppression, in the order of 1ns, was investigated for a planar 30 GHz accelerating structure. Both, damping and detuning were considered. A sufficient suppression could be achieved by damping waveguides in every cell in both vertical and horizontal direction. Finally, a scaled-up 10 GHz model was built. It is an aluminum structure 35 cm long, which was machined by high-precision milling. In order to reduce the surface gradient on the input/output coupling irises a symmetrical RF coupler was developed. The HOM damping is accomplished by coupling six damping waveguides to each accelerating cell. Each waveguide is loaded by a low resistivity RF load. The whole structure with waveguides and loads was optimized by means of the computer code GdfidL [1]. The paper gives the design criteria and the results of S-parameter measurements.

INTRODUCTION

The Planar Accelerating Structure (PAS) consists of two symmetrical plates. Each plate carries cells of equal depth and width (structure with constant impedance) [2]. The geometrical sizes of the accelerating cells are chosen so, that at 30 GHz a phase advance per cell of 120 grades is obtained [3]. The dipole modes have vertical or horizontal polarization [4]. The first dipole mode with a horizontal polarization (HP) and the first dipole mode with a vertical polarization (VP) are in the range of 36 to 48 GHz and 8 to 30 GHz, respectively.

DAMPING WAVEGUIDES

In this case the damping of HOM´s is realized by coupling six damping waveguides to each cell of the structure, two in vertical and four in horizontal direction, Fig. 1.

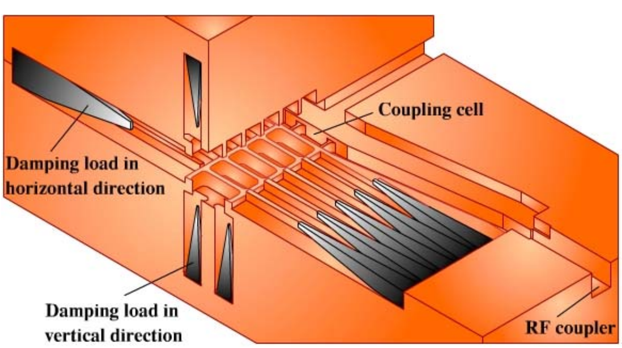


Figure 1: The planar 30 GHz accelerating structure.

The dipole modes of both polarizations propagate in the damping waveguides in horizontal direction. Their cutoff frequency is 28 GHz when excited by the VP-mode and 33 GHz when excited by the HP-mode [5].

The damping waveguides in vertical direction have a rectangular cross-section of 4.1 mm x 1 mm with a cut-off-frequency for the H_{10}-Mode of 37 GHz. This is above the fundamental mode but below most HOM´s. The distance between two waveguides in the each plate of the structure is 1.4 mm.

The computed transverse wake potential and the real part of the longitudinal impedance of a 153-cell structure are shown in Figures 2 through 4. For both polarizations the transverse wake potential is damped in a distance of less than 18 cm.

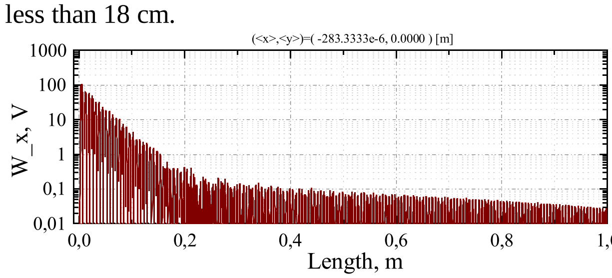


Figure 2: Transverse wake potential of HP-modes.

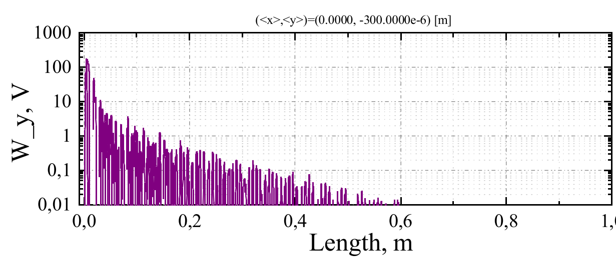
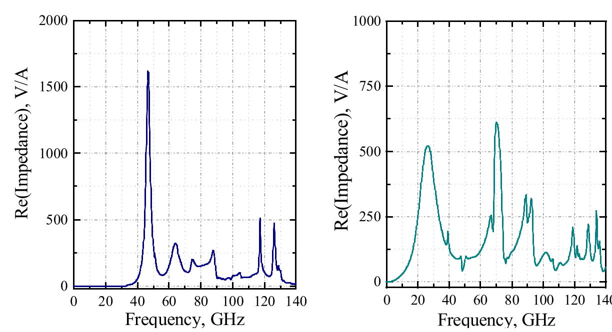


Figure 3: Transverse wake potential of VP-modes.



a) HP-modes b) VP-modes

Figure 4: Real part of the longitudinal impedance.

DETUNED STRUCTURE

Detuning of the structure is obtained by varying the transverse dimensions w and b, Fig. 5. They are changed such that the fundamental mode frequency of each cell remains constant while the dipole mode frequencies vary from cell to cell. The dipole modes are no longer coherent and a strong de-Q-ing happens.

The detuning process is explained in Fig. 5. The structure period is kept constant, and w decreases along the z-axis from w_1=6.771mm to w_n=5.771mm. This results in a frequency spread of 4.3GHz (8.5%) in case of the HP-modes and of 55MHz (0.2%) in case of the VP-Modes. Vertical damping waveguides are not used in that case.

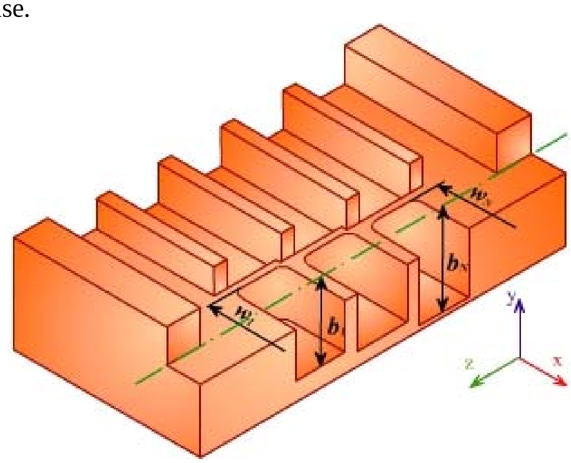


Figure 5: Detuned planar accelerating structure.

The computed transverse wake potential and the real part of the longitudinal impedance of a 21-cell detuned structure are shown in Figures 6 through 8 for both polarizations.

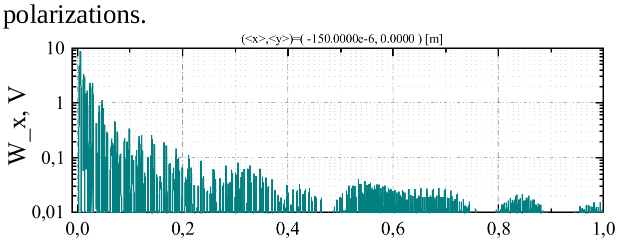


Figure 6: Transverse wake potential of HP-modes.

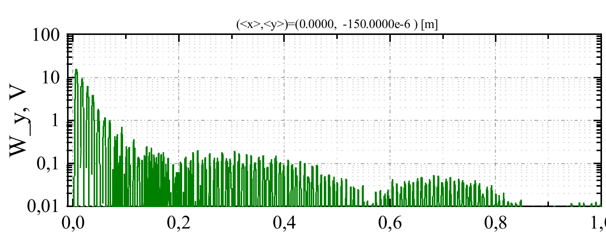
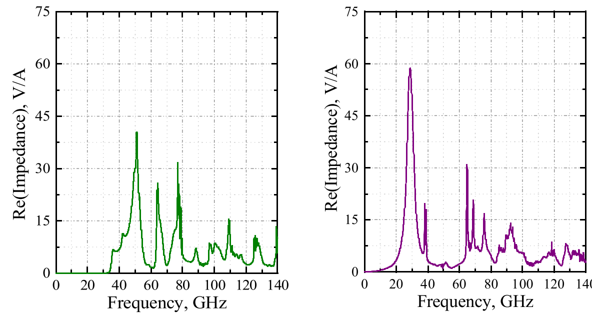


Figure 7: Transverse wake potential of VP-modes.



a) HP-modes b) VP-modes

Figure 8: Real part of the longitudinal impedance.

The transverse wake potential of VP-modes is suppressed by a factor of 100 after a distance of 30 cm. HP-modes require about 40 cm. For longer structures the decay of the wakes is even faster. In a 153-cell structure, for instance, the wakes decay by a factor of 100 within 15 cm.

SCALED-UP 10 GHZ MODEL

In order to check the computer results, a scaled-up 10 GHz model of the structure with constant impedance was built. It is a 35 cm long aluminum 23-cell structure ($\sigma_{Al}=20.3\cdot10^6$ [$1/\Omega$m]), which is machined by high-precision milling (Fig. 9). A symmetrical RF coupler was developed to reduce the surface gradient on the input/output coupling irises. The HOM damping is accomplished by six damping waveguides in each accelerating cell. The waveguides are loaded by a low resistivity RF loads.

Figure 9: Scaled-up 10 GHz model.

For the cold test measurements we had chosen HUFRAL AE80 an epoxy and magnetic composite [6] as damping material. The shape of the RF loads were optimized for low reflection, less than 10 %, over a large frequency band. They are different in the horizontal and vertical waveguides, Fig. 10.

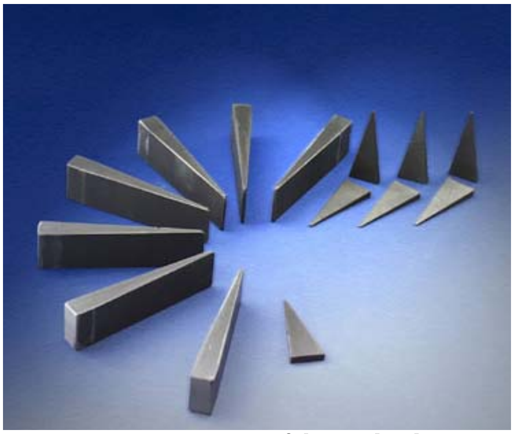


Figure 10: Forms of the RF loads.

Fig. 11 shows the test set-up with the HP-8722C network analyzer (NWA). The NWA output power is divided by means of a Magic-T. One output of the structure goes back to port 2 of the NWA and the second output is matched.

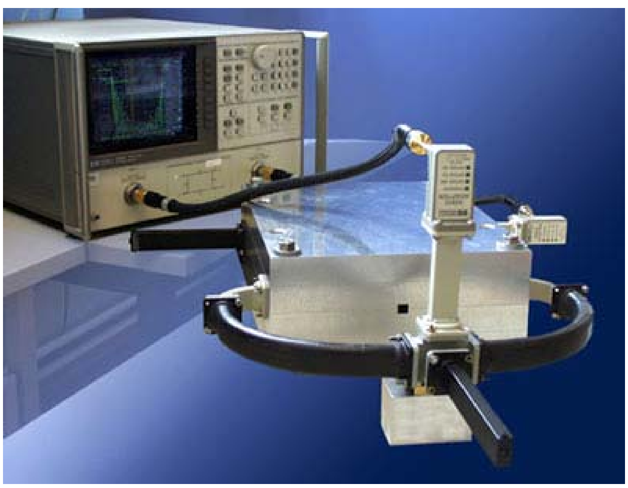


Figure 11: The test facility.

The calculated bandwidth of the accelerating mode is between 8.9 GHz and 10.3 GHz. The measured bandwidth is shifted upwards by 120 MHz (Fig. 12) with an operating frequency of 10.120 GHz. The reflection coefficient at the operating frequency is less than 15% and the transmission coefficient is -1 dB. This corresponds to the losses in the waveguide components and the attenuation in the structure of α=1.9 [dB/m].

Special care has to be taken to measure the dipole modes. Small loop antennas were used in the horizontal damping waveguides at positions where the fundamental mode is not excited.

The measurements of the S_{21}-parameter in the structure with damping loads in the frequency range up to 40 GHz show excellent results. The Q of the first dipole mode with a horizontal polarization is less than 15. The Q of the first VP dipole mode was so low that it was not measurable.

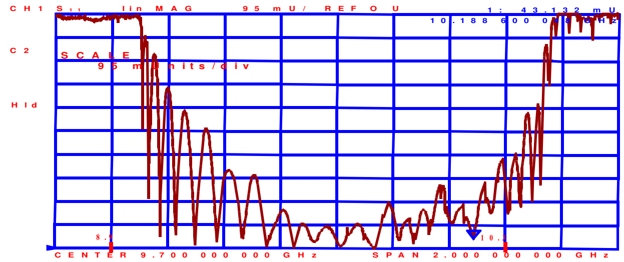


Figure 12: Measured S_{11}-parameter.

CONCLUSION

A planar structure with very heavily depressed transverse wakefields and symmetric power couplers were developed. The symmetric feeding decreases the peak electrical field on the coupler irises. Two different approaches resulted in a transverse wakefield depression by two orders of magnitude within less than 0.7 ns, i.e. less than 20 cm. One approach uses detuned cells and horizontal damping waveguides in every cell. The second approach has identical cells but needs damping waveguides in horizontal as well as vertical direction.

A scaled-up model for 10 GHz was built and measured. The results agree well with the numerical data.

REFERENCES

[1] W. Bruns. http://www.gdfidl.de

[2] R. Merte, H. Henke. „ First High Power Test of a 30 GHz Planar Accelerating Structure“, TET-Note 99/12, TU Berlin.

[3] R. Merte. “Development, fabrication and test of planar structures for particle acceleration”, Dissertation, TU Berlin, October 2000. http://edocs.tu-berlin.de/diss/2000/

[4] A. Blednykh. „Damping of Higher Order Modes in a Planar 30 GHz Accelerating Structure“, EPAC 2002, Paris, 3-7 June 2002.

[5] A. Blednykh. “Damping of Higher Order Modes in a Planar 30 GHz Accelerating Structure”, Dissertation, TU Berlin, October 2003. http://edocs.tu-berlin.de/diss/2003/

[6] Damping material. http://www.hyfral.com