DESIGN OF A HOM BROADBAND ABSORBER FOR TESLA

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Abstract

For the TESLA FEL operation very short intense bunches of electrons have to be accelerated. These bunches excite a broad spectrum of HOM (Higher Order Modes) up to frequencies of some THz. Two HOM couplers per cavity are foreseen in the present design proposal in order to extract some of the low frequency HOM from the superconducting accelerating structure. In this contribution an additional HOM broadband absorber is suggested which is to be installed between two cryogenic modules at a temperature of $70\,$K. Its task is to prevent that the really high frequency HOM are absorbed in the accelerator structure at the $2\,$K level. The absorption characteristics and the short range wake of four structures which make use of SiC as absorbing material are investigated using the MAFIA computer code. The proposed structures are easier to manufacture and better suited for the operation under vacuum conditions than the recently suggested waveguide array absorber.

1 INTRODUCTION

It is planned to operate TESLA in the FEL mode with very short bunches ($\sigma = 25\,\mu$m) [1] which excite wakefields with spectral components up to some THz. If we do not extract these fields from the accelerating structure by a special absorber we expect a considerable reduction of the quality factor of the superconducting cavities because the photon energy gets larger than the binding energy of the Cooper pairs for frequencies larger than $700\,$GHz.

This phenomenon would consequently lead to an excessive energy deposition in the $2\,$K cooling circuit which has to be prevented for the following reason: The time averaged power deposition due to the wakefields is about $25\,$W per module [1]; and a typical refrigerator requires about $800\,$W of wall plug power per Watt dissipated at $2\,$K [2]. Thus we would have to supply $20\,$kW of cooling power per module which is not tolerable.

A HOM absorber which is sketched in Fig. 1 has already been proposed in [2]. This absorber consists of an array of outward directed rectangular waveguides surrounding the beampipe. The extraction of the high frequency wakefields from the beampipe by such an array has been investigated in detail in [3]. The outward propagating waveguide fields are attenuated by the ohmic losses of the stainless steel waveguides which are considerably high for frequencies above the cutoff frequency of the fundamental waveguide mode which is $100\,$GHz. Note that low frequency spectral components cannot penetrate much into the absorber.

A cutoff frequency of $100\,$GHz corresponds to a width of the waveguides of $1.5\,$mm. The waveguide height is only $0.3\,$mm in order to have a high attenuation of the waveguide modes. Furthermore it is obvious that the waveguide walls should be as thin as possible for a good efficiency of the absorber. A wall thickness of $0.1\,$mm has been proposed which seems to be the lower limit from the mechanical point of view. The TESLA beampipe has a radius of $35\,$mm; and approximately $100\,$mm of space are available for the absorber in the axial direction. Therefore the actual absorber consists of an array of about 140×250 waveguides in the azimuthal and the axial direction, respectively.

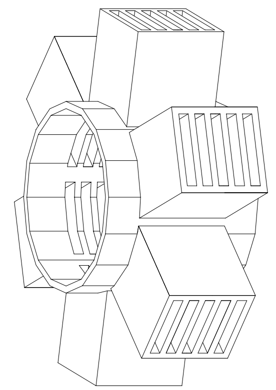

Figure 1: Schematic drawing of the waveguide array absorber.

The manufacturing of such a structure is very difficult even if etching techniques are applied [2]. Moreover the problem of cleaning the waveguide array before it is installed in the TESLA vacuum system has yet not been solved. Thus four new absorber structures are proposed which do not have these disadvantages. The MAFIA computer code [4] is used in order to study their absorption characteristics as well as their contribution to the short range wake.

2 PROPOSED ABSORBERS

The absorbers which are investigated in this contribution are shown in Figs. 2-5. In each of these configurations the actual absorbing structure is accomodated in a shielding which is similar to a single cell of the TESLA accelerating structure. For the simulations we have assumed $r_{iris} = 30\,$mm, $r_{cell} = 100\,$mm and $l_{cell} = 100\,$mm.

We have chosen SiC as absorbing material because it is suitable to be used in a vacuum system; and it has a large loss-tangent which is about 0.3. This number has been confirmed by measurements at room temperature up to a frequency of $20\,$GHz. For our simulations we assume that it is still valid in the THz region and that it does not change significantly if the absorber temperature is $70\,$K.

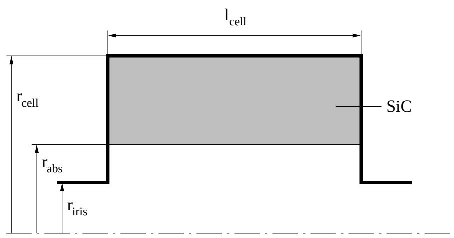

Figure 2: Solid SiC absorber.

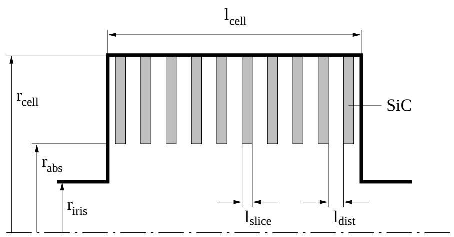

Figure 3: Laminated SiC absorber.

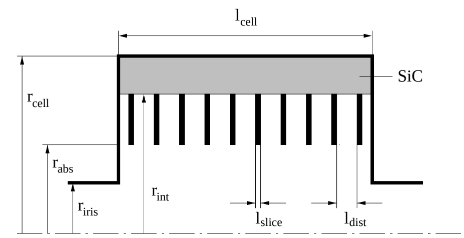

Figure 4: Combined absorber.

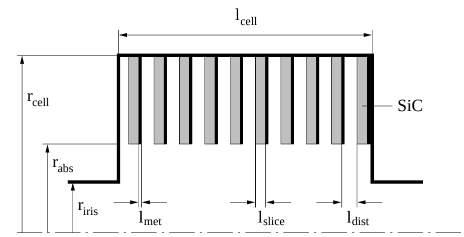

Figure 5: Metallized laminated SiC absorber.

For each proposed HOM absorber we are going to consider two versions. In the original version we have $r_{abs} = r_{iris}$. This seems to be favourable for a good coupling between the absorber and the HOM. On the other hand, the absorber itself also contributes to the beam impedance. This contribution can be decreased if we hide the absorbing structure behind the iris of the shielding cell. A bunch does not see the actual absorbing structure if the relation $r_{abs} - r_{iris} \geq \sqrt{5 l_{cell} \sigma}$ is fulfilled. In this case the short range wake of the HOM absorber is equal to that of a single accelerating cell. Bearing in mind that a module contains 72 such cells, the additionally introduced beam impedance due to the HOM absorber seems to be tolerable.

Note that in the above relation $r_{abs} - r_{iris}$ is proportional to $\sqrt{\sigma}$ which means that the absorbing structure may be arranged close to the beampipe for short bunches. Nevertheless it must also be possible to operate TESLA with 1 mm long bunches for which the condition for $r_{abs} - r_{iris}$ cannot be satisfied if we are interested in a good coupling between the HOM and the absorber. Thus we have to find a trade-off between the efficiency of the absorber and its contribution to the beam impedance. For our simulations we choose $r_{abs} - r_{iris} = 5$ mm.

The first proposed absorber is a solid SiC tube accomodated in the shielding cell. This configuration is shown in Fig. 2. Since the permittivity of SiC is large ($\varepsilon_r \approx 30$) we expect considerable reflections at the SiC-vacuum interface. Therefore the second structure which is presented in Fig. 3 consists of a stack of 50 SiC washers with $l_{slice} = l_{dist} = 1$ mm in order to reduce the effective permittivity of the absorbing structure.

The idea of the combined and the metallized laminated absorber which are shown in Figs. 4 and 5 is basically different than that of the first two structures in which all spectral components of the HOM are damped by the absorbing material in the shielding cavity. The combined and the metallized laminated absorber additionally contain a stack of stainless steel parallel-plate waveguides which attenuate the really high frequency HOM by ohmic wall losses similar to the previously discussed waveguide array absorber. In these structures SiC is used to suppress the long range wake. For this purpose it is sufficient that it has good damping properties up to a frequency of some 10 GHz. Hence the required bandwidth of the absorbing material is much less for these structures than that for the solid and the laminated absorber.

The difference between the combined and the metallized laminated absorber is that in the latter one the low frequency fields are continuously damped by the absorbing material while they are propagating outwards whereas they are absorbed at the ends of the waveguides in the combined absorber. The parameters of both structures read: $l_{slice} = l_{dist} = 1$ mm and $r_{int} = 80$ mm. Note that the actual thickness of the metallization l_{met} which is very thin can be neglected for the field analysis. In the MAFIA simulations we have assumed that l_{met} is equal to the thickness of one mesh layer.

3 SIMULATION RESULTS

The absorption characteristics of the proposed absorbers are given in Fig. 6. Here it is assumed that $r_{iris} = r_{abs}$.

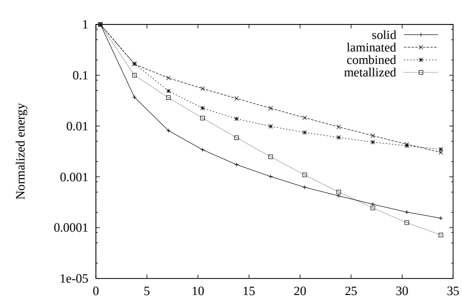

Figure 6: Absorption characteristics of the investigated structures.

The curves represent the total energy normalized to its value at the time $t = 0$. At this time the exciting bunch has just left the absorber cell. The transient behaviour is then computed for the next 33 ns. An ultra-relativistic particle just travels 10 m during this time interval.

Two classes of absorbers can be well-distinguished with respect to their absorption efficiency. In the solid and the metallized laminated absorber the energy drops to about 10^{-4} of its initial value after 33 ns. On the other hand, the absorption of the laminated and the combined absorber is approximately two orders of magnitude less.

The transient absorption behaviour of the combined and the metallized laminated absorber and the corresponding hidden structures are compared in Fig. 7. It is expected that

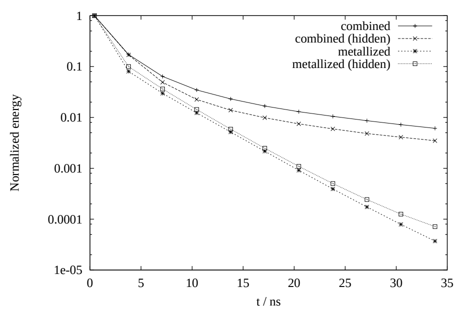

Figure 7: Comparison between the original and the hidden structure.

the hidden structures are less efficient than the corresponding absorbers with $r_{iris} = r_{abs}$. It is found that this is in fact true for the metallized laminated absorber. Nevertheless the efficiency of the hidden version of this absorber is only slightly less than that of the original structure. For the combined absorber it even turns out that the absorption can be improved a little bit if we hide the absorbing structure.

In order to illustrate the different absorption mechanisms of the metallized laminated and the solid absorber the relation between the total energy and that which is stored in the beampipe is shown in Fig. 8. Both energies are approx-

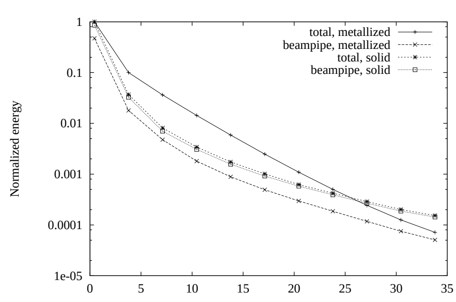

Figure 8: Total energy and energy which is stored in the beampipe.

imately the same for the solid absorber. This means that the electromagnetic field cannot penetrate significantly into the absorbing material because it is absorbed in the immediate vicinity of the dielectric-vacuum interface.

On the other hand the total energy is much larger than the beampipe energy in the metallized laminated absorber because the electromagnetic field propagates a considerably large distance into the parallel-plate waveguides before it is finally absorbed.

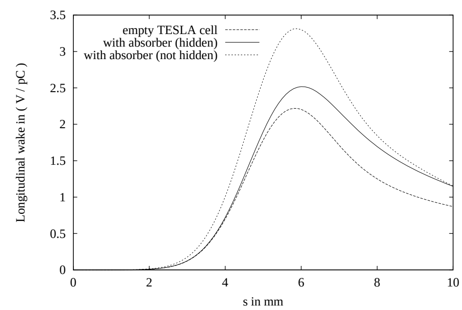

Figure 9: Short range wake of various structures for $\sigma = 1$ mm.

Fig. 9 shows the longitudinal short range wake of the empty TESLA cell, the laminated absorber with $r_{iris} = r_{abs}$ and the hidden version of this structure. The wake of the empty cell, which has a maximum value of 2.2 V/pC, is smaller than that of the two other structures as it is expected. The wake function corresponding to the non-hidden absorber is about 50% higher than this value. On the other hand, the short range wake is only 15% increased for the hidden version of the absorber which is acceptable.

4 CONCLUSIONS

Four types of HOM absorbers for TESLA which are easier to manufacture and more appropriate to be used in a vacuum system than the previously suggested waveguide array absorber have been investigated in this contribution. It has turned out that two of the absorbers, namely, the solid and the metallized laminated absorber have good absorption properties; and that the efficiency of the absorbers is not significantly decreased if we hide the absorbing structure behind the iris of the shielding. The short range wake of such a hidden structure is equal to that of a single TESLA accelerating cell for short bunches; and it is still tolerable for an intermediate bunch length. The solid absorber is less complicated concerning manufacturing and installation than the metallized laminated one. Nevertheless the simulation results for the solid absorber are based on the assumption that SiC has the same favourable attentuation properties in the THz region at a temperature of 70 K as in the frequency range up to 20 GHz at room temperature.

5 REFERENCES

[1] *R. Brinkmann et al. (ed.), Conceptual design of a 500 GeV e^+e^- linear collider with integrated X-ray laser facility, DESY 1997-048, 1997.*

[2] *M. Dohlus, N. Holtkamp, A. Jöstingmeier, H. Hartwig and D. Trines, "Design of a HOM broadband absorber for TESLA", Meeting note: 31 Linear collider project meeting at DESY, 1998.*

[3] *A. Jöstingmeier, M. Dohlus, N. Holtkamp and M. Shahabadi, "Application of the mode matching technique for the computation of the beam parameters of an infinite periodic structure", will be published as TESLA report, 1998.*

[4] *The MAFIA collaboration, User's Guide MAFIA Version 3.2, CST GmbH, Lauteschlägerstr. 38, D64289 Darmstadt.*