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DESIGN OF HOM POWER ABSORBERS FOR THE KEK B-FACTORY

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Abstract

The Higher-Order-Mode (HOM) power deposition is one of most crucial problems in the KEK B-factory to achieve a total beam current of 2.6A at the Low Energy Ring (LER). The estimate shows that the HOM power of about 20 kW can pass at any point in the arc of the ring. A particular worry is the Interaction Point (IP) where the maximum tolerable heat deposition of the IP chamber is only 200 W. Two and one types of HOM power absorbers have been studied to protect the beamline components at the arc and the IP chamber, respectively. One structure for the arc consists of a radial line connected a coaxial pipe where an absorbing material is housed. Another one has an absorbing material directly attached to the inner surface of the copper chamber. The absorbing material is segmented to a dozen pieces of pencil shape, each being titled by 30-45 degrees for good couplings with both TM and TE modes. Calculations with MAFIA and HFSS show that they have absorbing efficiencies more than 10% and the loss factors of 0.1-0.2 V/pC. Our choice of absorber for the Interaction Region (IR) is a conventional cylindrical SiC attached to the IR chamber. It has an absorption rate of 70% in the wide range of frequency.

1 INTRODUCTION

KEKB is an asymmetric e+e- collider at 8x3.5GeV energy for study of B-meson physics[1]. The large beam currents (2.6 A in LER and 1.1A in the High Energy Ring (HER)) for a very high luminosity of 10^{34} $cm^{-1}s^{-1}$ requires serious efforts to minimize the coupling impedance of beamline components in the design stage to avoid beam instabilities and to reduce wall heating. In fact, as the result of the successful reduction of the coupling impedance at KEKB, the conventional beam instabilities based on the beam-chamber interaction can now be suppressed by the radiation damping or by the feedback system. The main concern, in turn, is the new types of beam instabilities such as the fast ion instability and the photo-electron instability[1] which are caused by effects of ionized gas and photo-electrons, respectively.

Our estimate shows that the HOM power of about 200 kW will be created in the arc section of LER by various beamline components[1]. Its frequency spectrum has a broad peak around 10GHz. Assuming the energy dissipation only in the chamber wall, the HOM power can run typically for about 300 m along the ring in an e-folding attenuation time. It implies that the HOM power of about 20kW can pass at any point in the ring. The leakage of even a fractional part of this HOM power into beamline components such as bellows may cause a catastrophically large heat deposition in their inner structures. It arises a serious concern whether we should protect these components from the HOM power penetration.

Two crotches in the IR and the IR chamber itself create HOM powers of 3kW and 4kW, respectively. Most of them can drift through the double-walled beryllium IP chamber. It is difficult to estimate how much power will be deposited in the IP chamber, but even a 3% deposition out of 7kW exceeds the tolerable power of beryllium IP chamber (200W) determined by the thermal stress at the Si detectors. In addition, there will be more power flow from the nearby arc section to the IP. Since the IR chamber has the largest aperture at the crotches, some HOM modes may be trapped and become a cause of coupled-bunch instabilities.

Two and one types of HOM power absorbers have been studied for the arc sections and the IR, respectively. It is not yet decided whether HOM absorbers will be implemented at the entire are section, since no beamline components have been found so far in which the heat deposition due to the HOM power leakage amounts to an intolerable level. It is, however, strongly expected to put two HOM absorbers in the IR between the crotches and the IP, and several HOM absorbers in the adjacent straight sections on both sides of IR to stop the HOM power flow from the arc sections to the IP.

2 HOM ABSORBERS AT ARC

There are three basic requirements for the performance of HOM absorbers: (1)high absorption efficiency (2)small loss factor (3) “self-cleaning function” (i.e., to leave a little or no HOM power created by itself inside the chamber). The requirements (1) and (2) tend to conflict to each other and it is necessary to find an optimal point between them. Assuming that several absorbers are installed at every 300 m (corresponding to about one-tenth of the ring) at the arc, an absorption efficiency of 10-20% makes the total HOM power absorbed by the absorbers comparable to that lost on the chamber wall. From the outgassing point of view, the absorption efficiency of 30-40% would be the maximum. A typical loss factor per absorber in mind is around 0.1V/pC, which increases the total HOM power by about 50% if several tens of absorbers are installed into the LER.

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2.1 Radial Line + Coaxial Pipe Type

This type of HOM absorber has been studied by the KEK RF group to be used for choke-mode cavities[1]. Figure 1 shows its schematic view. A radial line is inserted into a disconnected vacuum chamber and then bended to guide fields to an attached coaxial pipe where an absorbing material is housed. Merits of this type are (1) there is no cutoff frequency for electromagnetic fields to be absorbed out (2) the absorbing material is not directly exposed to a beam and thus its fragments or dust when cracked will not disturb the beam. It is, however, foreseen that the absorbing efficiency will be limited to an order of 10% due to a mismatching of impedance at the entrance of the radial line. A larger gap size at the entrance will improve the matching at the cost of a larger loss factor.

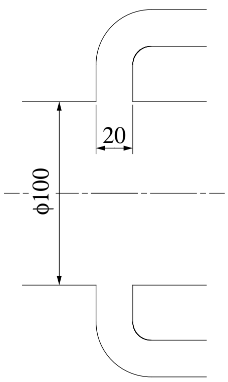

Figure: 1 Schematic view of the radial line + coaxial pipe type.

The absorbing efficiency has been computed as a function of frequency up to 20 GHz using the HFSS code. The HOM power is assumed to propagate inside the radial line as either TEM, TM01, or TM02 modes. The result is shown in Fig. 2. It can be seen that a good absorbing efficiency in a range of 15% is obtained in the wide range of frequency. The loss factor was calculated using ABCI and found to be 0.2V/pC.

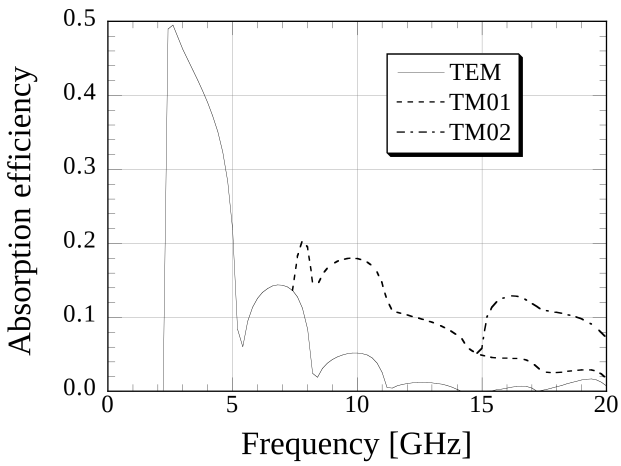

Figure: 2 Absorption efficiency of the radial line + coaxial pipe type.

2.2 Tilted Slots Type

A conventional (hollow) cylindrical absorber attached to the inner surface of the vacuum chamber can offer a large power absorption, while tending to have a large loss factor as well. A too large absorption efficiency (50-100%) is not desirable in the present case, since it may allow a power deposition in a single absorber more than the maximum tolerance and may cause the heat breakdown and the outgas problems. A way to control both the absorption efficiency and the loss factor is to partially screen the surface of the cylinder by the copper coating so that the absorbing material is exposed to a beam only through tilted slots placed azimuthally along the vacuum chamber. See Fig. 3.

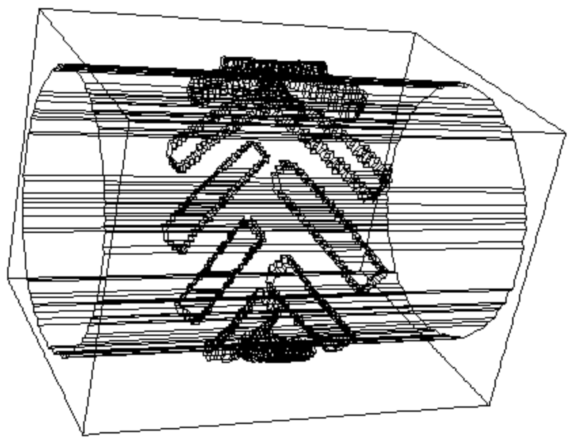

Figure: 3 Illustration of the tilted slots type.

The tilting angle should be determined for an optimal coupling with both TM and TE modes (30-45 degrees are found to be a good angles). The geometrical parameters assumed for computational study are: a 94mm inner diameter with 10 slots tilted by 45 degrees, each of which is 5cm long and 1cm wide. CERASIC-B (a brandname of SiC) is assumed as an absorbing material. We have computed the absorption efficiency for TE11 and TM01 modes at 3 and 8 GHz using the MAFIA code. The results are summarized in Table 1 below:

Table: 1 Absorption efficiency of the tilted slots type for TE11 and TM01 modes.

Frequency	*Absorption*	*efficiency (%)*
(GHz)	*TE11*	*TM01*
3	8	13
8	6	13

From plots of the power distribution on the absorbing material, which are not shown here, we have found that the power is almost uniformly deposited along the beam axis in the TE11 mode. On the other hand, the power deposition of TM01 mode takes place mainly in the upstream of the absorber (the side closer to the source of the power). The loss factor was computed by MAFIA and found to be 0.16V/pC.

The absorption efficiency for the TE11 mode may be improved by decreasing the tilting angle, say, to 30 degrees, at the cost of reducing that for the TM01 mode. The loss factor can be also reduced (the analytical estimate[2] for the 30 degrees tilting case gives the loss factor to be 0.1 V/pC).

3 HOM ABSORBER AT IR

As stated in the Introduction, the HOM power of about 3kW will be produced by two crotches on the both sides of IR. The tapered IR chamber itself will create another 4kW. In order to stop the power flow to the IP chamber and reduce Q-values of trapped modes near the crotches, a HOM power absorber is planned to be installed on each side of the IR between the crotches and the IP chamber. In contrast to the HOM absorbers at the arc, a large absorption efficiency (70-100%) is required even at the cost of a large loss factor to stop the power flow as much as possible. Our solution is a simple SiC cylinder attached to the inner surface of the copper chamber. Water channels run through the outer surface of the copper chamber for cooling. A proto-type of the absorber has been fabricated by the RF group and was installed to the Tristan Accumulation Ring (AR) in April, 1996, in the upstream of the ARES cavities for a beam test. Its schematic view is illustrated in Fig. 4.

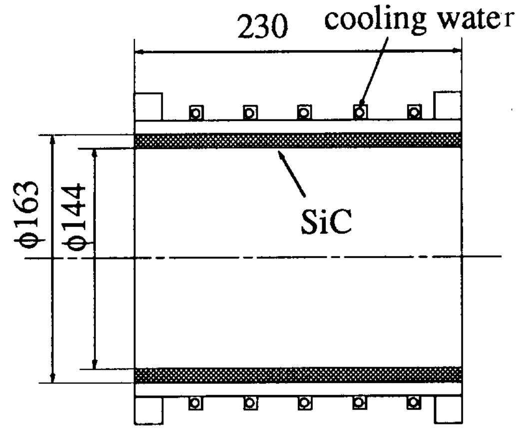

Figure: 4 Illustration of the HOM power absorber at IR.

Although the ferrite has a similar power absorption performance as SiC, SiC is preferable for a larger heat conductivity (CERASIC-B: 100W/mK, ferrite: 6.3W/mK) and a smaller outgas rate by an order of magnitude.

The absorption rate was calculated using the HFSS code for the structure with the diameter of 100 mm and the length of 100 mm for different SiC thickness. The results are plotted in Fig. 5. It can be seen that the absorption rate is rather insensitive to the SiC thickness and remains around 70% in the frequency range of 5-15GHz. The loss factor was calculated to be 0.5V/pC per absorber using the analytical formula. This corresponds to an additional 7kW×2=14kW power. It leads that the total HOM power to be taken care by the two absorbers hikes to 21KW (or 10kW by each). We have also calculated the temperature rise in the SiC surface relative to the cooling water temperature for various absorbed power. The heating is assumed to take place uniformly inside the SiC plate and the copper conductor. We have found that the relative temperature rise is about 30 degrees for the power absorption of 10kW. Therefore, the temperature rise and the resulting outgas from the SiC should cause no problem.

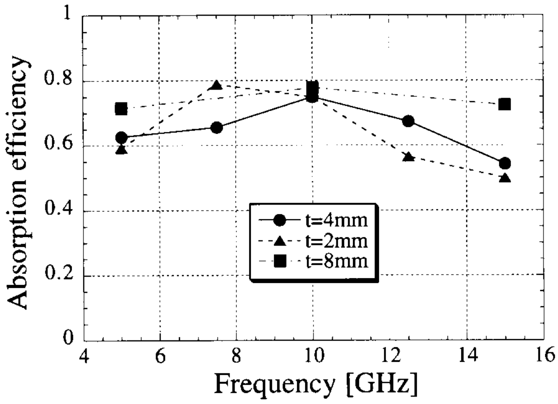

Figure: 5 Absorption efficiency of the cylindrical HOM absorber at the IR.

4 CONCLUSIONS

We have studied two types of HOM absorbers for the arc sections of KEKB ring. The calculation results using the HFSS and MAFIA codes demonstrate the proof of principle that they can fulfill our requirements. Namely, both of them offer relatively good absorption efficiencies of 10-15% in the wide range of frequency (5-15 GHz). The loss factors are found to be around 0.1-0.2V/pC per absorber. These values are slightly larger than the design goal, but, still stays in the acceptable range. The optimization of their geometry are in progress. RF power test of full size models should be conducted at the AR in a near future.

The design of HOM absorber at the IR is more straightforward. A conventional cylindrical SiC absorber fits our demands and the computer simulation results show that it can handle the HOM power more than required, while the outgas rate is well under control. Its proto-type was installed into the AR next to the ARES cavities and a series of beam tests are under way.

REFERENCES

[1] 'KEKB B-Factory Design Report', KEK Report 95-7, August 1995.
[2] S. S Kurennoy and Y. H. Chin, KEK Report 96-169, 1995 and to be published in Particle Accelerators.