DEVELOPMENT OF WINGED HOM DAMPER FOR MOVABLE MASK IN KEKB

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Abstract

In a high luminosity lepton machine such as the KEK B-factory (KEKB), the vacuum components are likely to be annoyed by intense higher order modes (HOM) due to the high beam currents. A winged HOM damper equipped with SiC HOM absorbers was developed to absorb unnecessary HOM, especially TE mode like HOM with a power of several kW. Four dampers were installed in the KEKB ring near movable masks and relieved heating of bellows and pump elements effectively at the beam current up to 1.5 A.

INTRODUCTION

The KEK B-factory (KEKB) is an electron-positron collider with asymmetric energies consisting of two rings, that is, the High Energy Ring (HER) for 8.0 GeV electrons and the Low Energy Ring (LER) for 3.5 GeV positrons [1]. To realize the high luminosity, 10 nb^{-1} s^{-1}, the design currents are larger than those of conventional colliders and are 1.1 A and 2.6 A for HER and LER, respectively. The commissioning of KEKB started in December 1998 [2,3]. At the beginning of May 2003, the achieved stored beam currents were about 1.1 A and 1.5 A for HER and LER, respectively, with 1284 bunches. The KEKB is now able to serve the world-record peak luminosity of 10.3 nb^{-1} s^{-1} for the BELLE detector, which surpassed the design luminosity [4].

As increasing the stored beam current during the commissioning, the heating of vacuum components, such as bellows and pumps got apparent gradually due to the intense higher order modes (HOM) excited by the high currents [5]. The HOM in special problem is the TE mode like HOM since the RF shield of bellows (finger type) and the axial slots of pump port can shield well the TM mode like HOM [6,7]. To solve these problems, therefore, a new HOM damper specialized for the TE mode like HOM with a power of several kW was developed and installed. The developed dampers are working as expected now at the stored beam current of 1.5 A and will be also available for future high current operation.

TROUBLES DUE TO HOM

Heating of Bellows

A movable mask (or collimator) of KEKB is a device that captures spent electrons/positrons just near the beam orbit and reduces the background noise in the BELLE detector [8,9]. The mask head is protruded from the side wall of beam chamber and positioned just near the beam orbit (a few mm). The intense HOM, especially TE mode like HOM, therefore, is excited there. A typical loss factor of a movable mask is about 0.6 V pC^{-1} (6 mm bunch length) and the beam current of 1.4 A with 1200 bunches, for an example, brings the energy loss of about 10 kW.

During operation, the bellows near the movable masks were apparently heated up compared to those far from masks [5]. The average temperature of some bellows at the beam current of 1.3 A was 57 °C while that of the other bellows far from the masks was less than 30 °C. The temperature showed a resonance phenomenon and depended on the bunch fill pattern, the bunch current and also the position of mask head.

Abnormal Vacuum Pressure Rise

Another example is the abnormal pressure rise near the movable masks again observed at the beam currents higher than 1.3 A in LER. The region that showed the abnormal pressure rise extended from about 30 meters downstream side to about 20 m upstream side of a block of movable masks (see Fig.4 later). It was also found that the main gas was hydrogen and the temperature of non-evaporable getter (NEG) pumps, the main pumps of the KEKB [5,6], was higher near movable masks than others. The pressure rise, therefore, was explained as the gas desorption from the NEG element heated by the HOM, again especially the TE model like HOM, excited at the movable masks. The element of NEG in the pump chamber is nearly insulated thermally and even a weak power (several tens W) can easily heat the NEG element over 100 °C.

DEVELOPMENT OF HOM DAMPER

Design

To solve the problems described above, a new beam chamber equipped with HOM absorbers (HOM damper) was developed specializing for TE mode like HOM. The damper has delta-type wings and two SiC rods (ϕ 55 mm $\times$ 400 mm) are installed inside the both wings as shown in Fig.1. The design is based on the grooved beam pipe scheme successfully applied to the KEKB ARES cavity system [10,11]. The SiC ceramics has the typical real and imaginary part of the relative dielectric constant of 21 and 5, respectively, at 1 GHz [12]. The SiC rod had been tested preliminarily up to the input power of about 4 kW using a 1256 MHz microwave. The test model was designed for the LER and the beam channel has a circular cross section with a diameter of 94 mm as other usual beam chamber [6]. The total length and width of the

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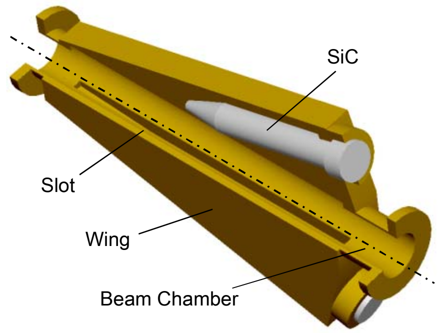

Figure 1: Structure of winged HOM damper.

Figure 2: Winged HOM damper combined with horizontal–type movable mask.

winged damper are 1200 mm and 505 mm, respectively. The angle between the axis of SiC rod and the beam orbit is 15°. By making the axes of SiC rod and beam channel almost parallel, the HOM can be absorbed uniformly all over the SiC rod. The wing and the beam channel are connected with a long slot (20 mm wide × 707 mm long) and the TE modes with a polarization perpendicular to the wings can be absorbed efficiently. Whole view of a winged HOM damper together with an LER horizontal-type movable mask is presented in Fig.2.

RF Property

The calculation using the HFSS simulation code optimized the whole structure. The S_{21} (transmission) and S_{11} (reflection) parameter of a winged HOM damper for the TE_{11} mode in a circular wave guide is presented in Fig.3 for the frequencies from 2 GHz to 6 GHz. For that elementary mode, the absorption rate of the damper is more than 10 dB in average for the wide frequency range. The loss factor is estimated as less than 0.01 V pC^{-1} at the bunch length of 10 mm and much smaller than that of the other components such as a movable mask.

RESULTS

Effect of Installed HOM Damper

Two pairs of the winged dampers were installed into the LER in 2002 as a test putting a block of four movable masks (two horizontal-type and two vertical-type) between each pair. The schematic locations of the HOM dampers (Damper 1 – 4) and movable masks are shown in Fig.4. The distances between a pair of dampers and between two blocks are about 25 m and 50 m, respectively. Since the pump ports are at the bottom of beam chamber, the wings were placed vertically and near the horizontal mask as shown in Fig.2.

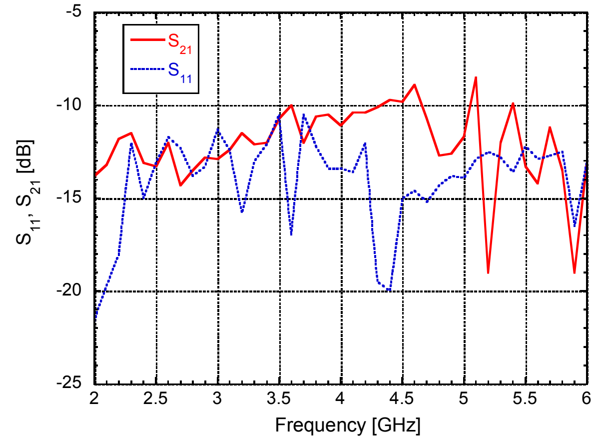

Figure 3: S parameters of winged HOM damper.

The powers absorbed by each HOM dampers at the beam current of 1.4 A are written down also in Fig.4 and the total power was about 11 kW. The total loss factor of four horizontal movable masks is about 2.4 V pC^{-1} and the corresponding energy loss is about 40 kW. Two pairs of HOM dampers, therefore, absorbed about 20 % of the power generated at four horizontal masks although the absorbed power in each HOM damper was somewhat scattered. Be careful that the power estimated from loss factor should include the whole HOM and the absorption rate for the TE mode like HOM will be higher. Measurements and identifications of modes in the beam chamber by carefully inserted antenna or experiments by rotating the winged HOM dampers may help the more accurate estimation.

After the installation, the temperatures of bellows just outside the paired dampers were measured. The temperature rises reduced to a half (from 33 °C to 16 °C) at the beam current of 1.3 A. The remained temperature rise of bellows should be due to the HOM that cannot be absorbed by the installed HOM dampers with vertical wings. The abnormal pressure rise near the mask was also disappeared outside of the HOM dampers even at 1.5 A.

Distribution of Absorbed Power

Although the effectiveness of the HOM damper was demonstrated, there was an interesting phenomenon on the distribution of the absorbed powers. As shown in Fig.4, the absorbed HOM power of the HOM dampers at downstream side of a block of masks (Damper 2 and 4, *D*-dampers here after) are larger than that at upstream side (Damper 1 and 3, *U*-dampers) by a factor 2. This tendency has been also recognized by the range showing abnormal pressure rise.

To investigate the imbalance of the absorbed power, the simulation was performed using MAFIA code. Figure 5

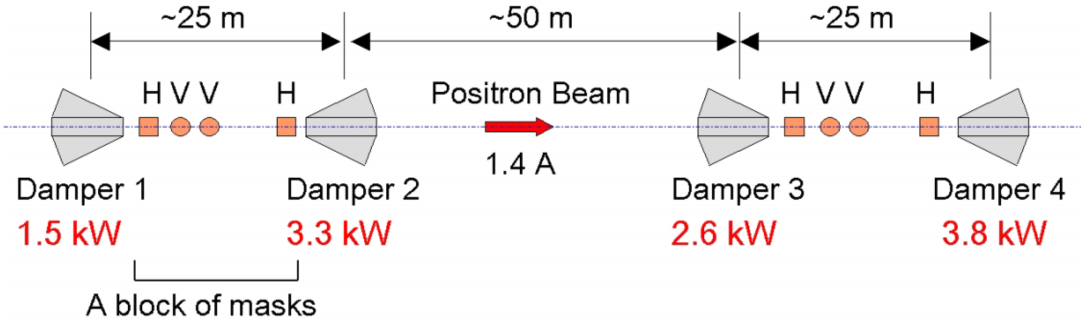

Figure 4: Locations of four HOM dampers (Damper 1-4) and movable masks in the ring, where “H” and “V” means the horizontal and vertical-type movable mask, respectively. The each absorbed power is that at 1.4 A.

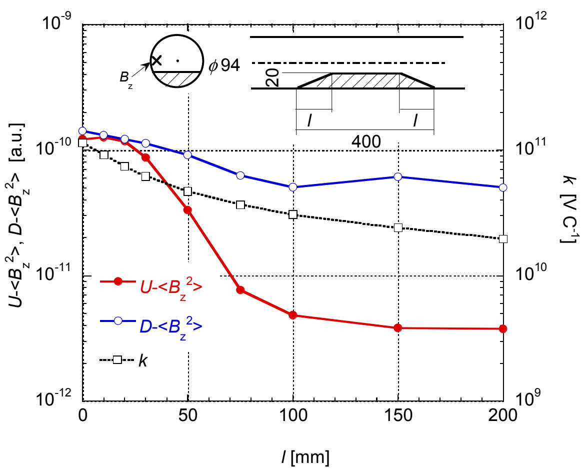

Figure 5: Intensity of axial magnetic field at downstream and upstream side, D-$<B_z^2>$ and U-$<B_z^2>$, and the loss factor, k, as a function of the ramp length, l [mm], of a trapezoidal HOM source as sketched in the figure.

shows the relative intensities of the axial component of magnetic filed at downstream and upstream side, D-$<B_z^2>$ [a.u.] and U-$<B_z^2>$ [a.u.], and the loss factor, k [V C^{-1}], as a function of the ramp length, l [mm], of a trapezoidal HOM source as sketched in the figure (10 mm bunch length). The trapezoidal HOM source is used considering the actual shape of a mask head [9]. The average intensity $<B_z^2>$ is the square of axial magnetic fields monitored at just near the side wall of beam duct (see the sketch in Fig.5) and averaged in the frequency range from 1 to 10 GHz. The distance between monitoring points and the source is 1 m. The $<B_z^2>$ can be regarded as a value in proportion to the intensity of TE mode like HOM.

As shown in the figure, the ratio of D-$<B_z^2>$ to U-$<B_z^2>$ is almost same if the ramp length is comparable to the bunch length. As increasing the ramp length, however, the ratio of D-$<B_z^2>$ to U-$<B_z^2>$ becomes larger. The higher TE mode like HOM intensity at downstream side of a trapezoidal HOM source may be explained by an interaction between the excited HOM at ramps and the passing bunched beam. Considering the actual size of movable masks, l = 130 mm, the larger absorbed power at D-Dampers is reasonable qualitatively.

Quantitatively, however, there is still some discrepancy. The calculated ratio of D-$<B_z^2>$ to U-$<B_z^2>$ for the present mask size is larger than that of absorbed powers in D- and U- Dampers. One possible explanation of the observed small power imbalance between U- and D-Dampers is that the HOM excited other than the movable masks contributes the absorbed power. Further investigations should be required.

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