A NEW Q2-BELLOWS ABSORBER FOR THE PEP-II SLAC B-FACTORY*

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Abstract

A new Q2-bellows absorber will damp only transverse wake fields and will not produce additional beam losses due to Cherenkov radiation. The design is based on the results of HOM analysis. Geometry of the slots and absorbing tiles was optimized to get maximum absorbing effect.

INTRODUCTION

A lot of Higher Order Mode (HOM) power is generated in Interaction Region (IR) in the PEP-II SLAC B-factory. One of the reasons for this is wake field generation due to conjunction of the beam pipes of Low Energy Ring (LER) and High Energy Ring (HER). To damp this HOM power special absorbers (Q2-bellows) were installed near the crotches. The absorbers, which were installed during a PEP-II construction period, consist of ceramic absorbing tiles exposed to the beam. As ceramic tiles have a high dielectric constant, they generate additional HOM power in the form of Cherenkov radiation. To achieve luminosity of more than 10^{34} cm^{-2}sec^{-1} we increased LER current up to 2.94 A and HER current up to 1.74 A [1]. Consequently we found more HOM power in the IR. We also discovered that one of these absorbers was responsible for anomalous high radiation beam aborts [2]. To decrease the HOM power generated due to exposed ceramic tiles we designed a new Q2-bellows absorber, which is free of Cherenkov radiation.

IP WAKE FIELDS AND CHERENKOV RADIATION

PEP-II IP region has very complicated structure due to conjunction of LER and HER beam pipes and various types of synchrotron radiation masks. We estimated this geometry with a 2-d model for wake field calculations using a computer program [3]. Geometrical loss factor results are shown in Fig.1. For "long" bunches (6-14 mm) loss factor is an inverse quadratic function of the bunch length or linear with rf voltage. In IP HOM measurements we observed this dependence. For "shorter" bunches (1-6 mm) quadratic dependence changes to 3/2. A loss factor κ allows determination of the HOM power P_{IP} generated at the IP for given currents I_{eff} and bunch spacing τ_b

$$P_{IP} = \kappa \cdot \tau_b \cdot I_{eff}^2 \qquad (1)$$

We may assume that fields generated by the LER beam are not coherent with fields generated by the HER beam, then the effective current is determined by the formula

$$I_{eff} = \sqrt{I_{LER}^2 + I_{HER}^2}$$

To estimate the Cherenkov radiation power we use formulas which were derived for a "thick" dielectric tube of radius a and length L [3]. In the case of a bunch length σ larger than the effective dielectric wavelength $s = \frac{a\sqrt{\varepsilon - 1}}{2\varepsilon}$, the loss factor is described by the formula

$$\kappa = \frac{cZ_0 L}{2\pi a^2} \cdot \frac{s}{\sqrt{\pi}\sigma} \approx \frac{cZ_0}{4\pi^{3/2} a} \cdot \frac{L}{\sigma\sqrt{\varepsilon}}$$

where the Z_0 is the free space impedance and c is the speed of light.

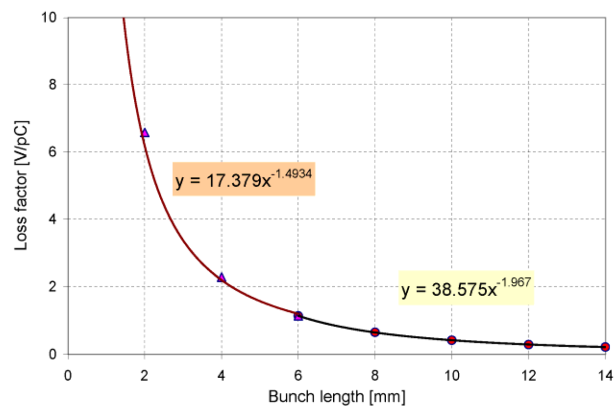

Figure 1: IP geometric loss factor vs bunch length.

The dielectric constant of ceramic tiles is still high $\varepsilon \sim 22$ at higher frequencies (8 GHz). For a beam radius of 50 mm the mentioned condition works well for a bunch length of 13 mm and the additional radiation loss factor is estimated to be 0.187 V/pC for the total tile length of 112 mm. This number is comparable with geometric loss factor 0.248 V/pC. That means we almost double the HOM power at IP only because ceramic tiles are exposed to the beam. According to (1) the total IP HOM power is of order of 20 kW for $I_{eff} = 2.7A$ (bunch spacing τ_b is 4.2 nsec). We will compare this number with results of experimental measurement.

HOM power measurement

To measure the HOM power dissipated in the Q2-bellows we use thermocouples installed at supply and returned water-cooling channels. Also we measure the water flow. Measurements showed 12 kW power at the right side of the IP and 6 KW at the left side. After replacing Q2 bellows we found approximately same amount of dissipated power, even though the Q2-bellows at the left side has half the number of ceramic tiles. The HOM power as a function of the effective current is shown in Fig 2. Quadratic approximation is also shown in

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this figure. We may introduce an effective impedance Z_{eff} to characterize the HOM power

$$P = Z_{eff} \cdot I_{eff}^2$$

This parameter depends upon rf voltage, bunch spacing (number of bunches) and beam position in the Q2 chamber. For rf voltage of 4.05 MV at LER and 15.4 MV at HER and 1722 bunches, the effective impedances on left and right IP sides are:

$$Z_{eff}^L = 900 \text{ Ohm} \quad Z_{eff}^R = 1500 \text{ Ohm}$$

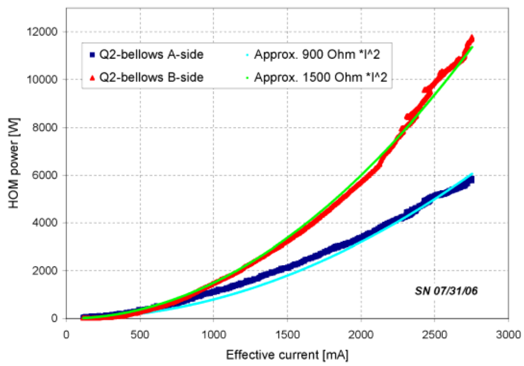

Figure 2: HOM power in the “old” Q2-bellows. LER rf voltage is 4.05 MV, HER rf voltage is 15.4 MV, number of bunches is 1722.

SIMULATION MODEL

We use the algorithm described in [5] to calculate rf properties of the Q2-bellows. The simulation model is shown in Fig. 3 along with results for absorbing coefficients for different propagating waveguide modes. Average absorption of the longitudinal mode is around 40% in the frequency range of 2 to 6 GHz. Dipole mode absorption is important since this is the main mode which can penetrated inside the vertex bellows. In the same frequency range we have on average 26% and 24% of the dipole mode power absorbed in two types of polarization. Absorption of the quadrupole mode is on average 43% in the frequency range of 2.5-6.5 GHz. Large absorption in monopole mode means large longitudinal impedance that is realized as Cherenkov radiation.

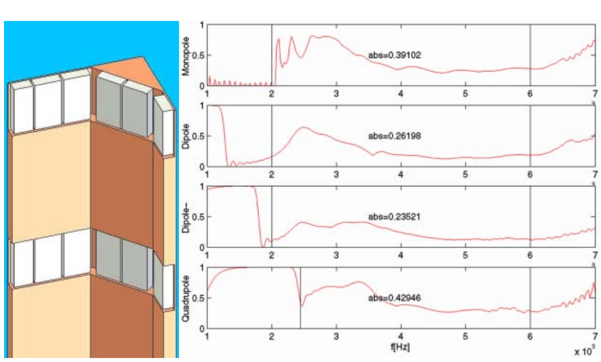

Figure 3: Computer model of the old Q2 (one quarter) and absorbing parameters.

Slot Length Study

A simple solution to cancel Cherenkov radiation is to isolate ceramic tiles from the beam by a metal tube with longitudinal slots. We determine the required slot length to keep the same absorption for dipole and quadrupole modes. Results are shown in Fig. 4. Horizontal lines represent the absorption level for exposed tiles. We need approximately 6 inches. Unfortunately we don’t have such space in the vacuum chamber.

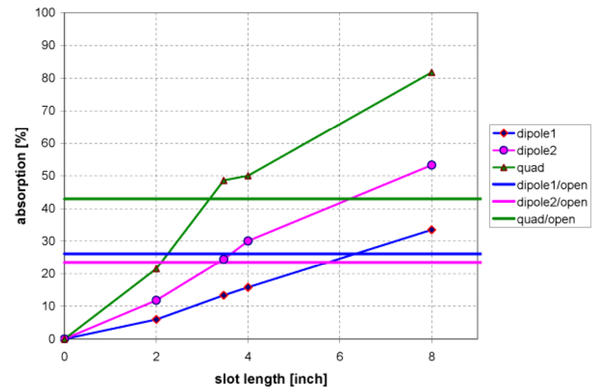

Figure 4: Absorption vs slot length and absorption levels of exposed tiles.

Final Model

We studied several models, trying to optimize the absorption parameters. Last version is shown in Fig. 5

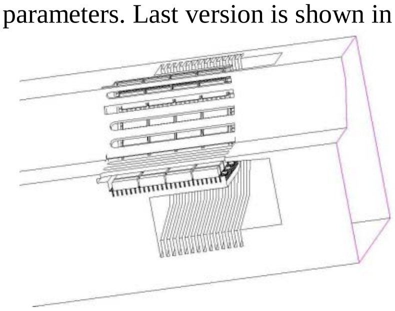

Figure 5: Computer model. (one quarter).

Absorbing parameters of this model are shown in Fig. 6.

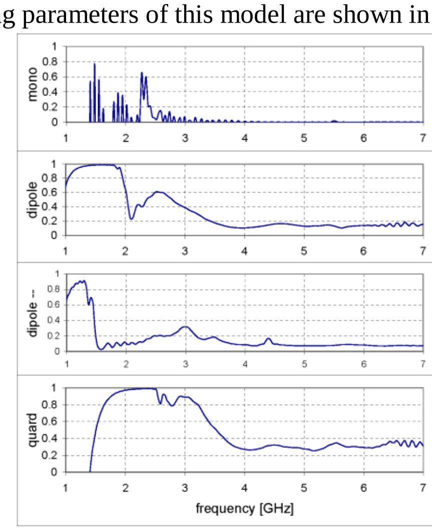

Figure 6: Absorbing parameters of a new Q2 absorber.

Additionally we calculated resonance frequencies and Q-values of trapped modes captured inside in the bellows cavity. Q-values of first 20 modes are shown in Fig. 7. Although the mechanical design of a new Q2-bellows was not optimized to minimize the Q-values, fortunately the mode with a maximum Q-value has a frequency which is not in resonance with bunch spacing frequencies. Bunch-spacing frequencies are shown in Fig. 7 by dotted vertical lines.

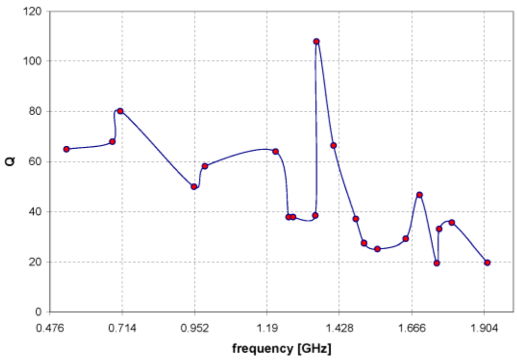

Figure 7: Q-values of HOMs trapped inside bellows cavity. Dotted vertical lines depict bunch spacing frequencies.

Based on these simulations a mechanical model of Q2-bellows was designed and fabricated. A photo is shown in Fig. 8.

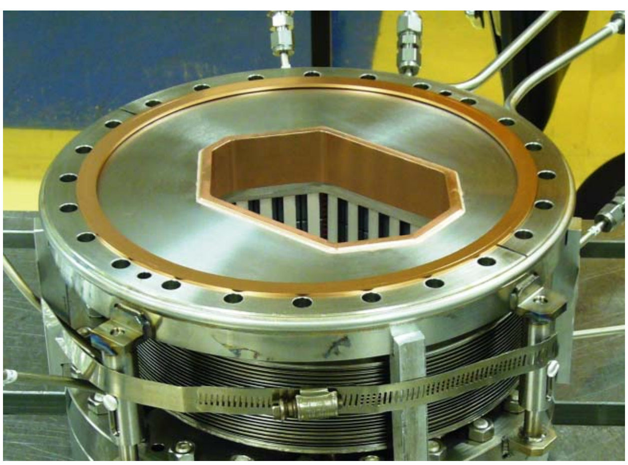

Figure 8: A new Q2-bellows absorber.

EXPERIMENTAL RESULTS

At first we install only one new Q2-bellows at the B-side of IP. Fig. 9 shows HOM power in B-side (new) and A-side (old) bellows as a function of effective current. Captured power in a new bellows decreased 5.8 times, while power in the other old bellows did not change too much. No great temperature rise was noted in IP region elements. We then installed a new bellows at the A-side of the IP. Results of HOM power measurements in all new bellows are shown in Fig. 10. The power in a new A-side bellows went down by 4.8 times. At the B-side the bellows showed same power as before.

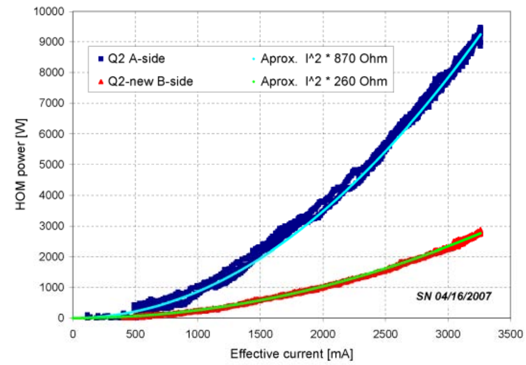

Figure 9: HOM power in one old and one new Q2-bellows.

It is very important to note that we did not observe any dramatic temperature change in the vertex bellows, which are situated between the Q2-bellows. This means that Q2-bellows absorb transverse fields well, not allowing them to propagate inside the IPregion.

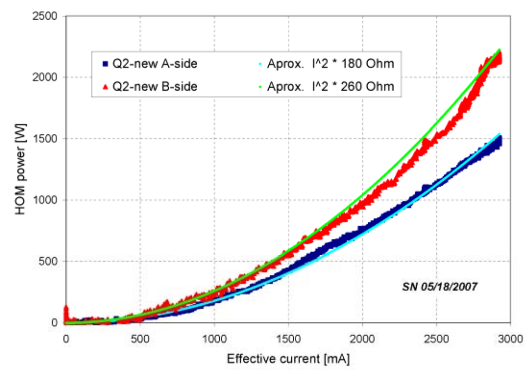

Figure 10: HOM power in all new Q2-bellows.

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