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DAMPING THE HIGH ORDER MODES IN THE PUMPING CHAMBER OF THE PEP-II LOW ENERGY RING*

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Abstract

The Low Energy Ring of the PEP-II B-factory operates with extremely high currents of short positron bunches. Any discontinuity in the vacuum chamber can excite a broad-band spectrum of high order modes (HOM). A temperature rise has been found in the vacuum chamber elements in one junction of straight and arc chambers. The power in the wake fields was high enough to char beyond use the feed-through for the titanium sublimation pump (TSP). This pumping section is 5.5 m long and consists of the beam chamber and an ante-chamber. Electromagnetic fields, excited in the beam chamber penetrate to the ante-chamber and then through the heater feed-through come out. To be sure that these electromagnetic fields are present a small ceramic tile with a high loss tangent was placed near the TSP feed-through outside of the pumping chamber. A thermocouple that was attached to this tile showed a strong temperature rise. A short wire antenna was also placed there. The antenna was connected directly to a spectrum analyzer. Measurements show a wide frequency HOM spectrum with a maximum in the 2-3 GHz region. Based on these measurements a special water cooled HOM absorber was designed and installed in the vacuum chamber. As a result, the HOM power in the section decreased and the temperature rise went down. The power loss in the absorber reaches 1200 W for a positron beam current of 2.4 A. The absorber helped to find the source of HOM. Steering the beam on the vertical collimators upstream of the absorber resulted in the significant HOM power change in the absorber.

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Abstract

The Low Energy Ring of the PEP-II B-factory operates with extremely high currents of short positron bunches. Any discontinuity in the vacuum chamber can excite a broad-band spectrum of high order modes (HOM). A temperature rise has been found in the vacuum chamber elements in one junction of straight and arc chambers. The power in the wake fields was high enough to char beyond use the feed-through for the titanium sublimation pump (TSP). This pumping section is 5.5 m long and consists of the beam chamber and an ante-chamber. Electromagnetic fields, excited in the beam chamber penetrate to the ante-chamber and then through the heater feed-through come out. To be sure that these electromagnetic fields are present a small ceramic tile with a high loss tangent was placed near the TSP feed-through outside of the pumping chamber. A thermocouple that was attached to this tile showed a strong temperature rise. In order to study the spectrum of the fields, a short wire antenna was also placed there. The antenna was connected directly to a spectrum analyzer. Measurements show a wide frequency HOM spectrum with a maximum in the 2-3 GHz region. Based on these measurements a special water cooled HOM absorber was designed and installed in the vacuum chamber. As a result, the HOM power in the section decreased and the temperature rise went down. The power loss in the absorber reaches 1200 W for a positron beam current of 2.4 A. The absorber helped to find the source of HOM. Steering the beam on the vertical collimators upstream of the absorber resulted in the significant HOM power change in the absorber.

HIGH ORDER MODES

The SLAC PEP-II B-factory is operating with progressively higher electron and positron currents [1]. Figure 1 shows the positron current in the Low Energy Ring (LER) during the period from November 2002 to June 2004. During 2002-2003 run we found a strong temperature rise in one of the transitions between the straight and arc chambers. This junction consists of a several different kinds of elements: a straight shielded bellows, a vacuum valve with a round vacuum chamber, a transition from round to elliptical beam chamber, an arc bellows with an elliptical cross section and an arc drift section. This drift section is 5.5 m long and consists of the beam chamber and an ante-chamber with a titanium sublimation pump (TSP). HOM heating in this region was high enough to char beyond use the TSP feed-through. Additionally the temperature of several arc bellows was very high and air cooling was installed for these bellows. We used a small high frequency absorber (high loss tangent ceramic tile) with an attached thermocouple as an RF detector. We put this detector at the TSP feed-through to sense the HOM fields coming through the heater wires of the TSP connector. Thermocouple readings from the RF detector showed a temperature rise with the positron current growth. It became clear that the wake fields, which are excited in the beam chamber, penetrate to the ante-chamber and then, through the heater wires of the TSP connector go.

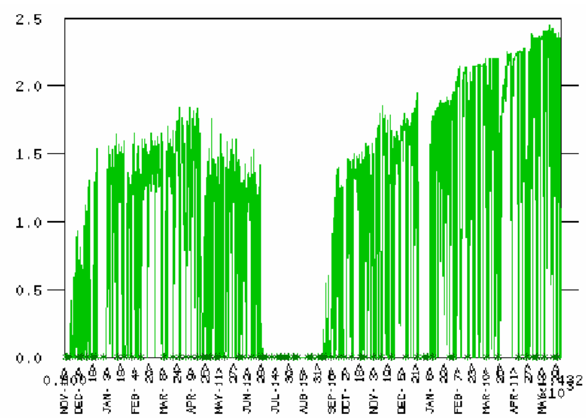

Figure 1: Positron current (A) in the PEP-II Low Energy Ring. Time interval is from 11/2002 to 06/2004.

In order to study the frequency spectrum of the fields, a short wire antenna was placed near TSP connector. The antenna was connected directly to the spectrum analyzer.

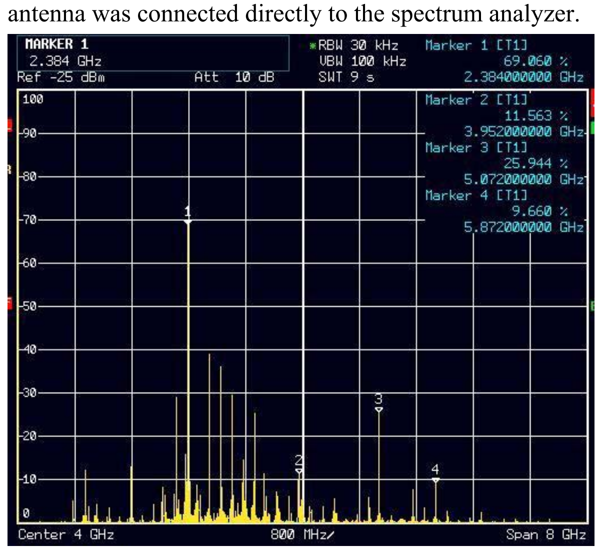

Figure 2: Spectrum of HOM fields leaking through TSP heater wire (linear scale). Positron current is 1200 mA.

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Measurements showed a wide frequency HOM spectrum with a maximum in the 2-3 GHz region (Fig.2). There are also noticeable resonance lines at the frequencies of 5.072 GHz and 5.872 GHz. We also observed nonlinear behaviour of the HOM amplitudes with beam current. Fig.3 shows the impedance (amplitude divided by current) of the 2.38 GHz harmonic during injection (increasing current) and coast running (decreasing current).

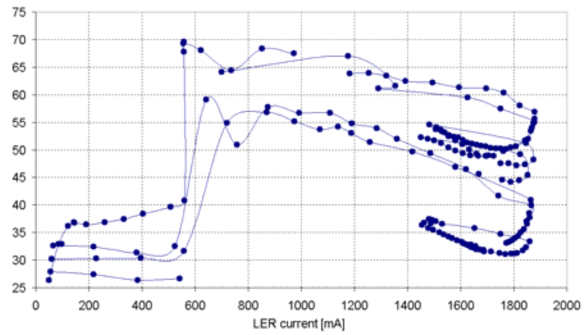

Figure 3: Impedance of the 2.38 GHz mode vs. positron current.

WATER-COOLED HOM ABSORBER

Based on the spectrum measurement we designed a HOM absorber. We chose ceramic tiles with a high loss tangent (Ceraloy) to be the main absorber material. We made a prototype of HOM absorber and did "cold" RF measurements in a spare pumping chamber. In these measurements the beam chamber ends were closed by metal plates with small input and output antennas. The absorber prototype was inserted in the ante-chamber. It was found that a small angle to the beam chamber improves damping. Fig. 4 shows the HOM spectrum of the pumping chamber without the absorber (left plot) and with the absorber (right plot). In the frequency range of 2 GHz to 3 GHz an absorber of 30 cm effectively damps high order modes in a 5.5 m long pumping chamber.

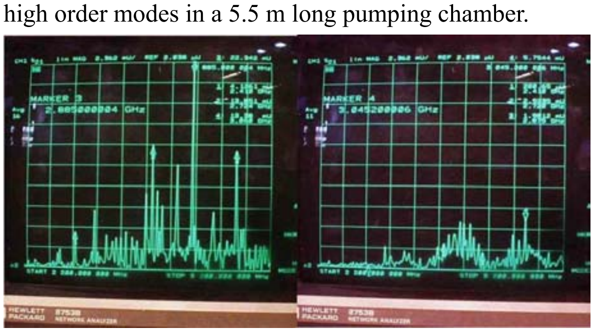

Figure 4: "Cold" measurement of the chamber spectrum without an absorber (left plot) and with an absorber (right plot). Amplitudes are presented on a linear scale. The frequency range is from 2 GHz to 3 GHz.

The sketch and photos of the real design of the water-cooled HOM absorber are shown in fig. 5. Ceramic tiles are brazed to a copper body from two sides. A stainless still pipe is brazed around the copper body. The ends of the pipe come out though a vacuum flange.

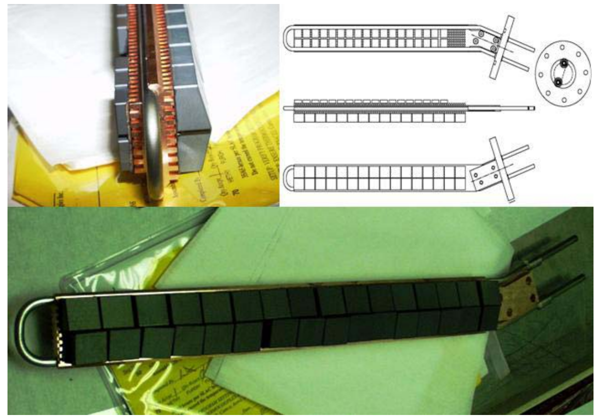

Figure 5: Photos and sketch of the water-cooled HOM absorber.

A photo of the LER arc pumping chamber with the HOM absorber is presented in Fig.6. In order to measure the HOM power damped in the absorber we attached two thermocouples to the water pipe ends and installed a digital water flow meter.

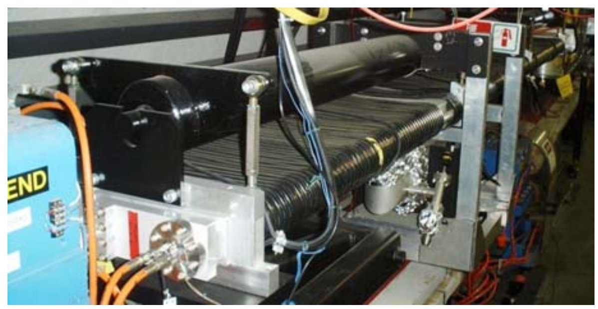

Figure 6: HOM absorber in the LER arc pumping chamber.

SPECTRUM, TEMPRATURE AND POWER MEASUREMENT

After installing the HOM absorber we repeated the spectrum measurement.

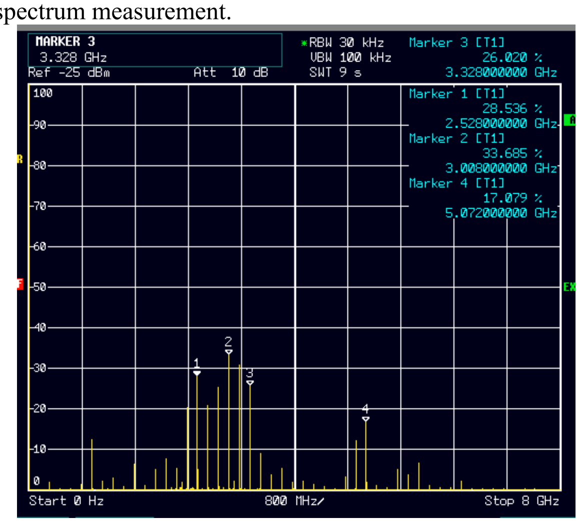

Figure 7: HOM spectrum after the HOM absorber is installed (linear scale). The positron current is 1200 mA.

We found that HOM amplitudes had decreased significantly. New spectrum is presented in Fig.7. To make a good comparison with previous spectrum the new spectrum was taken under the same conditions as previous one (Fig.23): the same positron current and the same bunch spacing. As a result of the HOM damping the temperature of the TSP feed-through went down. Thermocouple readings from the RF detector are shown in Fig.8. The left side of the plot is the temperature before the HOM absorber was installed and the right side shows the temperature after the HOM absorber installation. The temperature rise decreased by at least a factor of two even though the positron current increased by 40% (Fig.1 has the same time interval).

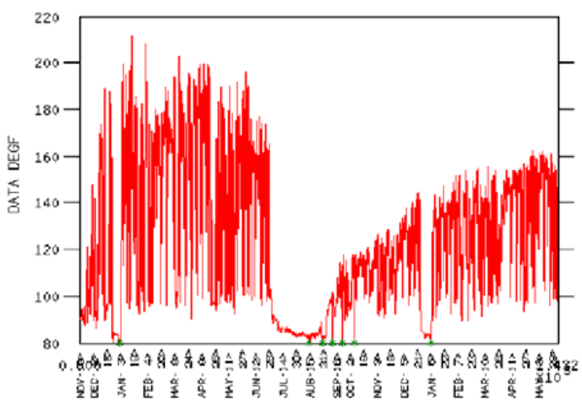

Figure 8: RF detector thermocouple readings before and after HOM absorber is installed. Time interval is from 11/2002 to 06/2004.

The result of the measurement of the HOM power dissipated in the absorber is given in Fig.9 and it is shown by the blue lines. The green lines show the positron current.

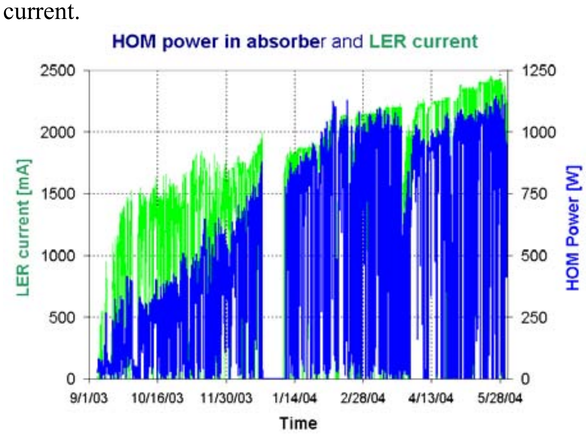

Figure 9: HOM power dissipated in the HOM absorber and the positron current during 2003-2004 run.

The HOM power does not exactly follow the positron current because the power also depends upon the number of bunches and the RF voltage, which changed during this time interval. Measurements indicate that the HOM power is almost linear with the RF voltage (Fig.10) and inversely proportional to the number of bunches. These relations give approximation for the HOM power P

$$P = 0.07 \times I^2 \times \frac{V_{RF}}{N_{bunches}}$$

were I is the positron beam current, $N_{bunches}$ is the number of positron bunches and V_{RF} is the RF voltage.

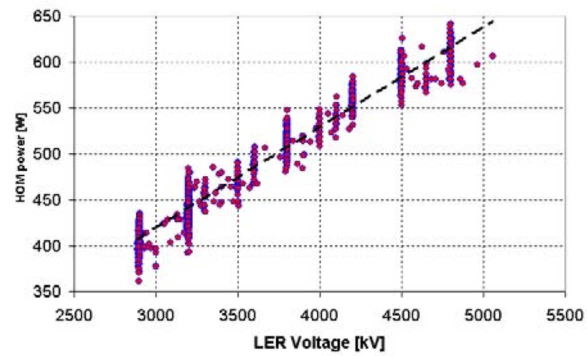

Figure 10: HOM power vs. RF voltage for a positron current of 1400 mA.

Currently the HOM power reaches 1.2 kW for a positron current of 2400 mA. Estimation for future upgrades of the PEP-II B-factory gives 10 kW power for a positron current of 4500 mA and RF voltage of 6.4 MV.

We did not find any significant correlations of the HOM power with the beam position in the vacuum chamber, but we found a strong correlation with the vertical beam position near vertical collimators which are far away from this chamber. Fig.11 show HOM power in absorber (red line) and vertical beam position near 15m collimator (blue line) and 65m collimator (green line). It can be seen that 10 mm change of the vertical position near closer collimator reduced the HOM power almost two times. The same (~ 10 mm) change of the beam position in the 65 m collimator changed power in the absorber by additional 10%.

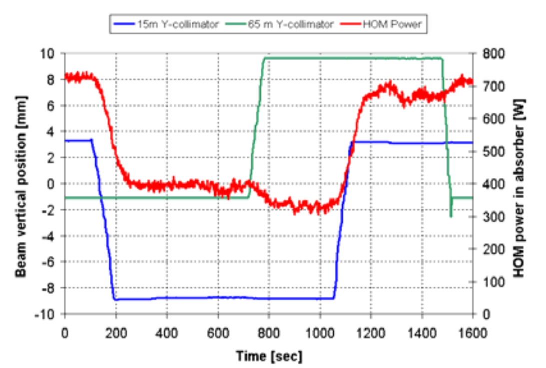

Figure 11: HOM power in absorber (red line) and vertical beam position near 15m collimator (blue line) and 65m collimator (green line).

REFERENCES

[1] J. Seeman, *et all.,* "Progress of the PEP-II B-factory", PAC'03, Portland, USA, May 2003, p. 2297.