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LOSS FACTOR OF THE PEP-II RINGS*

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Abstract

An RF power balance method is used to measure the synchrotron radiation losses and the wake field losses. We present the history of the losses in the Low Energy Ring (LER) and the High Energy Ring (HER) during the last several runs of PEP-II.

INTRODUCTION

Intensity dependent effects play an important role in operation of high luminosity colliders. Achieving a luminosity of more than 10^{34} cm^{-2} sec^{-1} in the PEP-II B-factory was partially due to the increase of operating currents [1]. Higher current means more power in coherent and incoherent radiation. This power dissipates in the vacuum chamber elements and is taken out by a water-cooling system.

At the end of the PEP-II run the LER current was increased to a new world record of 3.2 A. Single LER beam was stable and we were able to measure the HOM power in the LER bellows-absorbers, which are described in reference [2]. We had installed four of them just after the collimators in region 4 and region 10. Measurements showed that at the record LER current the HOM power captured by each of the absorbers reached almost 2.5 KW. As the efficiency of the bellows-absorber is 40% [2], then the generated power from each collimator is of the order of 6 kW. The HOM power from all the collimators (we have 6 six of them in the LER) could well be 36 kW. This power is mainly in the transverse fields. Since the collimators are a small fraction of all the elements in the ring we might assume that this is only 10% of the total HOM power generating in the ring.

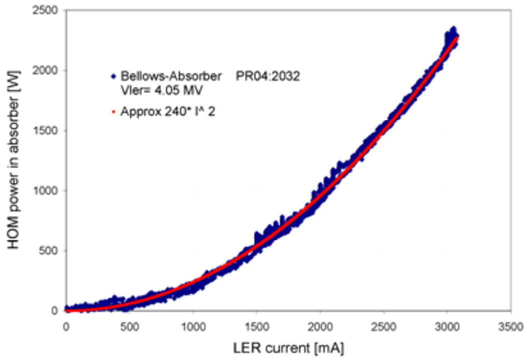

Figure 1: HOM power captured by the bellows absorber (blue diamond) and fitted quadratic function (red line)

Fig. 1 shows the captured HOM power (blue diamonds) in the absorber. Red line in the plot shows the fitted quadratic function. It is clear that the HOM power goes as the square of the LER current. We used this current dependence for the measurement of the total HOM power [3].

RF POWER BALANCE

PEP-II has eight cavities in the LER and twenty-eight cavities in the HER. When the cavity phases are mismatched, electromagnetic power may be delivered from one cavity to another through the beam partial acceleration and deceleration. For this case we need to include all cavities in the power balance equation

$$\sum_{cav} P_{cav}^{forward} = \sum_{cav} P_{cav}^{reflected} + \sum_{cav} P_{cav}^{loss} + P_{beam}$$

A total sum also helps to decrease the stochastic error. The power, which is delivered to the beam, immediately radiates as incoherent and coherent radiation. Due to incoherent radiation (synchrotron radiation) the beam loss power has a linear term, and due to coherent radiation (HOM losses) it has a quadratic term

$$P_{beam} = U_{S.R.} \times I + Z_{HOMs} \times I^2$$

There, naturally, can be some limitations on HOM power measurements. For example, at the interaction region (IR) the power can be transferred from one beam to another through the excitation of IR parasitic cavities. We observed this effect at several resonant frequencies during the spectrum IR measurement. Fortunately, these resonances have a low Q-value. Another effect is bunch lengthening, which may distort the quadratic current behavior of the HOM losses.

SYNCHROTRON RADIATION

The history of the synchrotron radiation (SR) energy losses in LER and HER rings is shown in Fig. 2.

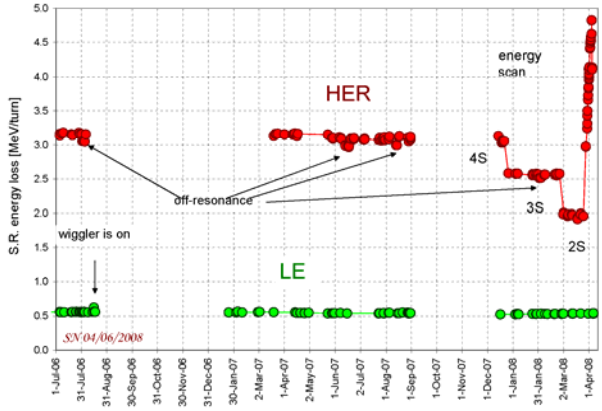

Figure 2: Synchrotron radiation energy losses in the PEP-II rings.

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During nearly all of the PEP-II runs the energy of the rings were kept constant (LER: 3120 MeV and HER: 8985 GeV) to have the collision energy at the 4S resonance. From time to time the HER energy was changed by 0.75% down to go off resonance. This corresponds to 3% the SR power because it goes as the fourth power of the energy. We clearly see these changes in our measurement (Fig. 2). During the last run of the PEP-II the HER energy was changed much more: from 8 GeV to 10 GeV to study 3S and 2S resonances and to do an energy scan above the 4S resonance. This was a good opportunity to check how well our measured data corresponds to the fourth order dependence. Results are shown in Fig. 3.

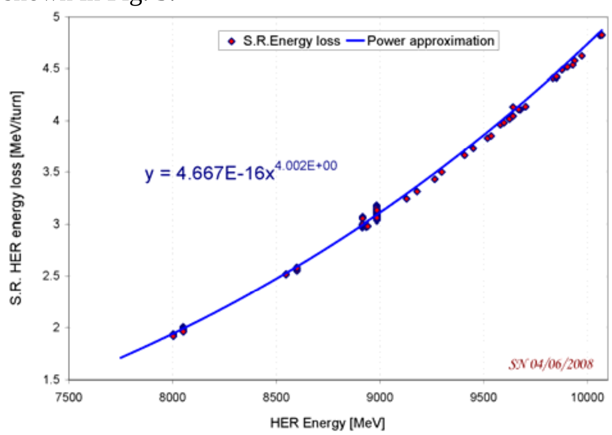

Figure 3: Synchrotron radiation energy loss per turn as a function of the HER energy

Red diamonds show the measured S.R. energy loss per turn and a blue line shows an interpolation function. Two parameters of the function: amplitude and power increment were varied in order to get the best fit. The exponent was found to be very close to four.

LOSS FACTOR OF THE PEP-II RINGS

A history plot of the HOM loss factor in the PEP-II rings is shown in Fig. 4.

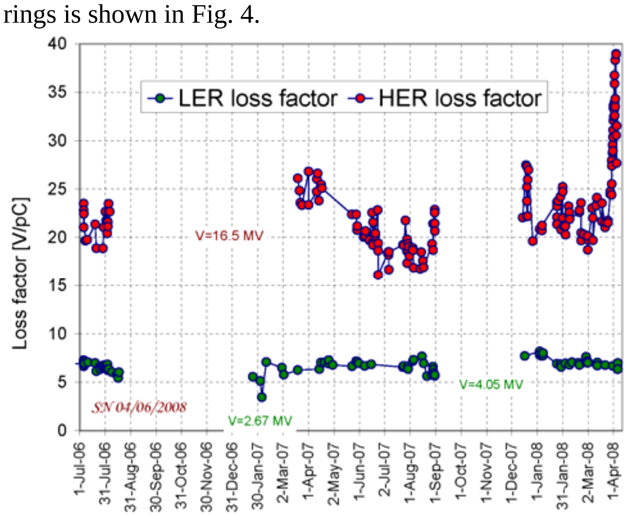

Figure 4: Loss factor of PEP-II rings over the last two years.

The LER loss factor stayed more or less constant. It changed only when the RF voltage was changed. We found that the loss factor scales linearly with the RF voltage (Fig. 5). The average value of the LER loss factor is 6.8 V/pC at the RF voltage of 4 MV. The maximum HOM power reached 280 kW at a LER current of 3 A

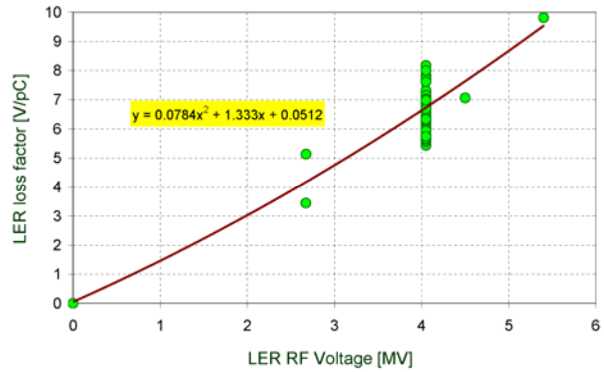

Figure 5: The LER loss factor as a function of the RF voltage.

The HER loss factor varied considerably, especially during the last two runs. Its average value is 20 V/pC at the 4S resonance. In 2007 the loss factor changed because we installed two new RF cavities and the HER part of the IR was modified. The maximum HOM power was 350 kW. After that run, during the shutdown time, we changed almost all (187 out of 192) flexible omega RF seals [4]. As it was mentioned before, during the 2008 run the HER energy was varied from 8 to 10 GeV. We know that the beam energy spread depends upon the energy. It must be smaller at lower energy and larger at higher energy. Consequently, the bunch length will change linearly with the energy spread. (The bunch length measurement will be discussed in the next section). The loss factor will also change with energy, as it varies inversely with the bunch length in some power. Therefore, the loss factor must be larger at lower energy and smaller at higher energy.

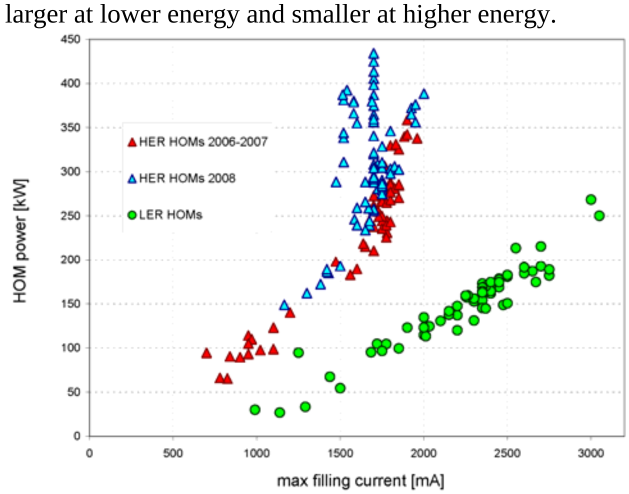

Figure 6: HOM power for the peak filling LER and HER currents.

However, the measured HER loss factor shows an opposite behavior, especially at higher energy. It nearly doubles at the top of the energy scan when the HER energy was 10 GeV. Such behavior needs more analysis of the beam dynamics during the energy scan. We can suggest that the real beam orbit changed with increasing energy and the wake fields, if they are of the transverse type, may increase. HOM power measured at the peak filling current for the LER and HER is shown in Fig. 6. It is important to mention that the slope of the HER HOM power jumps up at the current of 1.7-1.8 A during the last two runs.

LER AND HER BUNCH LENGTH

We also measured the LER and HER bunch length using the beam spectrum [5]. We saw the bunch lengthen in both rings (Fig. 7 and Fig. 8.); however, some part of lengthening was due to the synchrotron frequency variation with beam current [6]. The solid lines in these plots show the calculated bunch length using a quasi-Green wake functions or i.e. wake potentials of smaller (1 mm) bunches. We used the algorithm in reference [7] for these calculations.

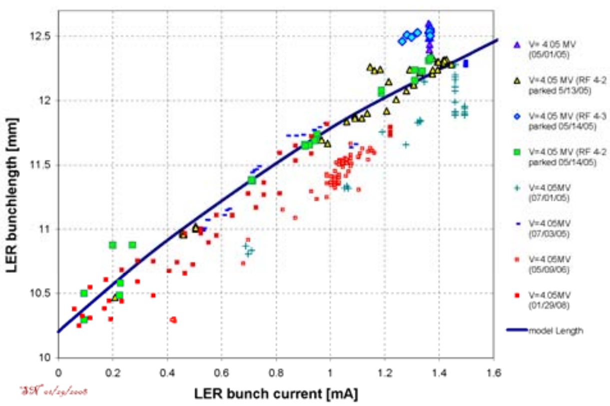

Figure 7: The LER bunch length as a function of current.

We designed these quasi-Green wake functions for the LER and HER taking into account all vacuum elements and a “model wake fields” to satisfy the measured loss factor and the bunch lengthening. These functions are shown in Fig. 9.

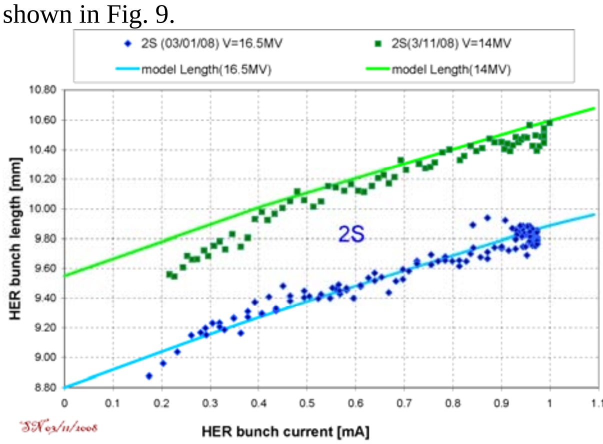

Figure 8: The HER bunch length as a function of current at the 2S and 3S resonances.

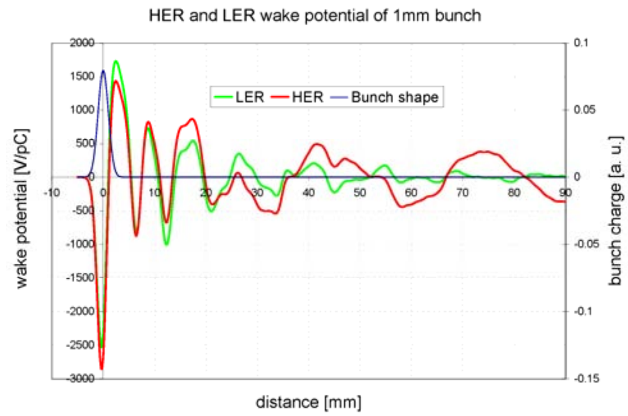

Figure 9: HER and LER wake potentials of 1 a mm bunch, which were used in the calculation of the bunch lengthening

Finally, we show the measured bunch length as function of energy. With some variations, it goes together with the energy.

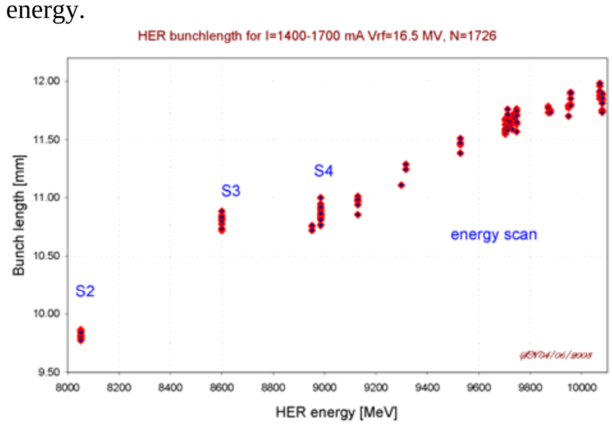

Figure 10: The HER bunch length as a function of energy.

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