LATTICE EFFECTS DUE TO HIGH CURRENTS IN PEP-II*

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Abstract

The very high beam currents in the PEP-II B-Factory have caused many expected and unexpected effects: Synchrotron light fans move the beam pipe and cause dispersion; higher order modes cause excessive heating, e-clouds around the positron beam blow up its beam size. Here we describe an effect where the measured dispersion of the beam in the Low Energy Ring (LER) is different at high and at low beam currents. The dispersion was iteratively lowered by making anti-symmetric orbit bumps in many sextupole duplets, checking each time with a dispersion measurement where a dispersive kick is generated. This can be done parasitically during collisions. It was a surprise when checking the low current characterization data that there is a change. Subsequent high and low current measurements confirmed the effect. One source was believed to be located far away from any synchrotron radiation in the middle of a straight (PR12), away from sextupoles and skew quadrupoles and created a dispersion wave of about 70 mm at high current while at low current it is negligible.

INTRODUCTION

The high current of up to 2450 mA in the LER seems to change the orbit at many places around the ring. Some are fast changes (minutes), some are slow (about an hour). Since beam characterization data are typically taken with a low current it is tricky to understand the real behavior at high current.

Some measurements can be taken at high current with single rings, like oscillation data or orbit response data, where a few or many correctors are changed and the orbits get saved. Excitation data, like betatron phase advance or MIA data (Model Independent Analysis) can not be taken, since fast transverse feedbacks have to be turned of for this measurement and that would make the beam unstable. Dispersion data can even be taken with colliding beams, since there is typically no dispersion at the interaction point (IP). First we will discuss the different possible sources for orbit movements, and then we will discuss the difference between high and low current dispersion data.

ORBIT MOVEMENTS

The absolute beam orbit in the LER is still pretty big [1], but after many optical fixes, this orbit gives the highest luminosity. A few efforts resulted in a better, flat orbit, but much lower luminosity, so we have to work gradually with this orbit, repairing optics as we go. At some places where the y amplitude exceeds 8mm the synchrotron fan can miss the water-cooled photon stop and hit the aluminum beam pipe. This can cause the beam pipe to bend, which will move magnets or even creates small vacuum leaks (see Fig. 1). The applied correcting 8 mm bump caused also some dispersion and therefore temporary luminosity loss, which was fixed by small closed bumps in nearby sextupoles.

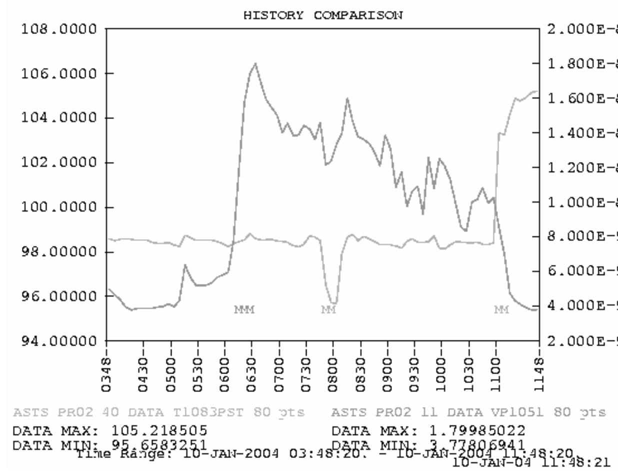

Figure 1: Temperature of T1083 photon-stop and vacuum pump reading at 1051 versus time. A 8 mm bump at 1092 brought the photon power back on to the photon stop and closed the leak about 30 m down stream.

A few months later some beam motion was also observed that in that region. At high current the orbit is flat compared to a reference since we steer continuously, but at lower current there starts an oscillation right at 1052 (Fig. 2). A feedback which keeps the orbit stable in the nearby sextupoles is closed much better than the observed motion. The oscillation amplitude of 0.6 mm will create dispersion at different sextupoles around the ring.

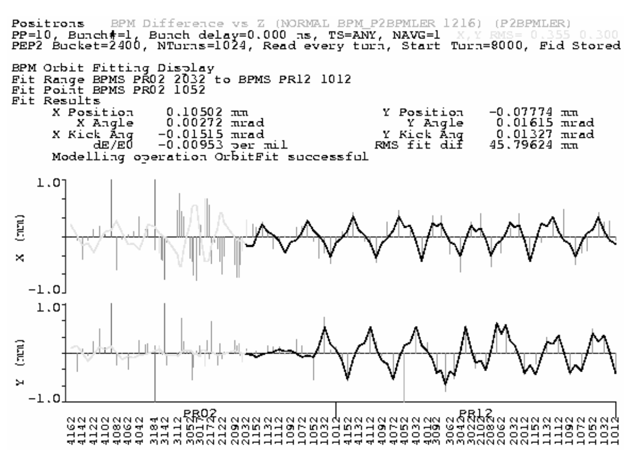

Figure 2: Difference orbit between low and high current showing an orbit kink at 1052. This kink of 13 µrad in y indicates a 150 µm magnet motion.

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Besides the movements which kink the orbit, we have also heating effects, which seem to make a local bump in *x*. In the middle of arc 5 are two beam position monitors (BPMs) which move slowly up to 0.6 mm over one hour (Fig. 3). The two BPMs have a ratio (1.45mm/0.55mm) which is consistent with a closed bump and there is no further oscillation leaking out of this area. There is big air cooling tunnel of six feet diameter right in this area which might be the root cause of this movement. The problem is to figure out whether the beam pipe just moved and we should not steer in this area, or whether that bump is really an orbit bump and we should steer it back since there is a sextupole in this area. The sensitivity to sextupole bumps is about 50-100 μm for a detectable (2%) change in luminosity.

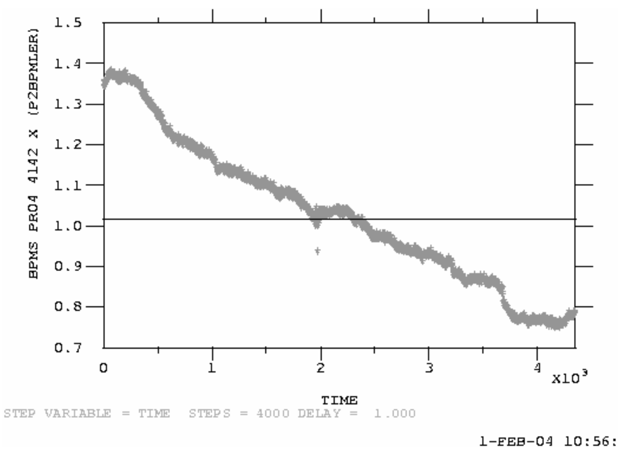

Figure 3: Orbit drifts over 600 μm in one hour.

VERTICAL DISPERSION

An anti-symmetric bump in a sextupole pair (180° apart) creates dispersion, so any orbit oscillation will give rise also to dispersion generation, which will increase the beam size in two different ways. First any dispersion (η) at the interaction point (IP) will add in quadrature the size $\eta\sigma_E$. Second, dispersion waves increase the emittance. While the first effect can be tuned out from nearly any place in the ring, the second has to be localized and corrected as close to the source as possible. Fig. 4 shows a typical dispersion measurement, where the ring RF frequency is changed by ±300 Hz, which corresponds to about a 0.1% energy change. The vertical oscillation up to 250 μm (equal 250 mm dispersion) will increase the emittance.

They were reduced by first fitting kinks at the sextupoles with the online orbit fitting package and then making the corresponding bumps at high current. Fig. 5 shows the result where the left side of the IP got reduced.

The right side had quite some challenges. Fitting the right side indicated quite a big kick in the middle of a straight section (PR12). Figure 6 shows this fit. The problem is that there are no sextupoles which could easily generate this dispersion and also fix it. Even making a bump which was 30% not closed and only 60% of the strength indicated some problem.

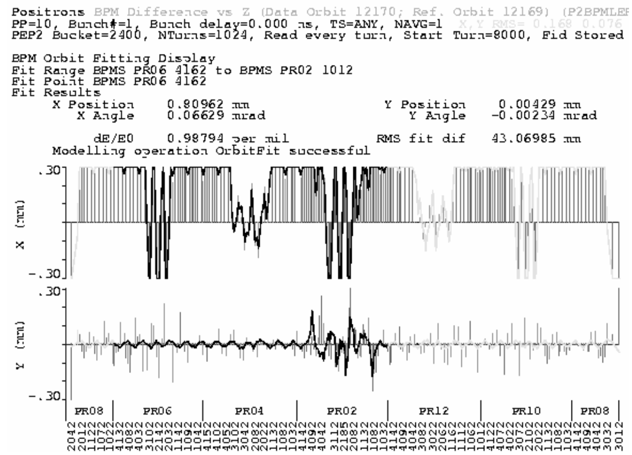

Figure 4: LER dispersion measurement. In *x* the arcs and straight are visible and in *y* there should be only non-zero dispersion except close to the IP (PR02).

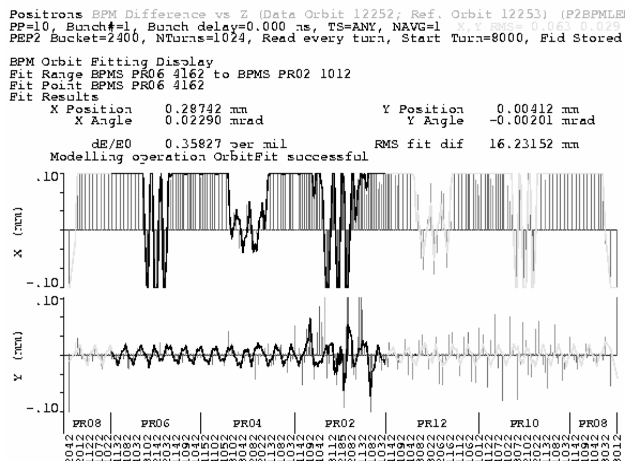

Figure 5: LER dispersion measurements at high current. The frequency was only changed by 200 Hz, so compared to 0 Hz only 1/3 of the usual amplitude is excited, therefore the scale is reduced by that amount.

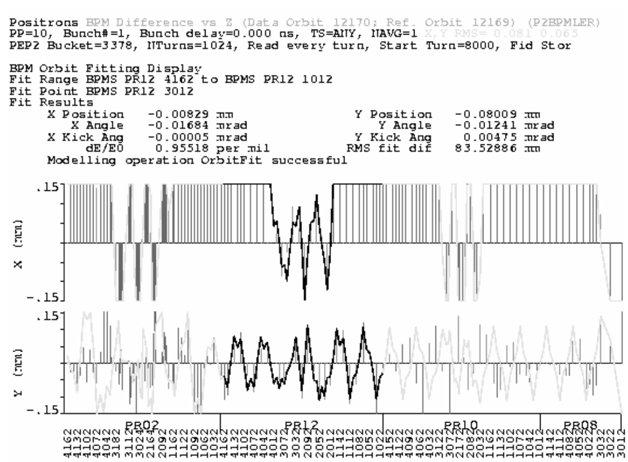

Figure 6: LER dispersion measurement with fit indicating a kick right in the middle of PR12 where no sextupoles are present.

After searching for other coupling sources like rotated magnets or partially shorted magnets poles it was found that the lattice in that region was significantly changed when moving to the ½ integer resonance. This change is not yet in the design model. At low current (Fig. 7) both sides were pretty flat, indicating a high current problem. Where it exactly starts was never determined since the attention got sidetracked to the PR12 "problem".

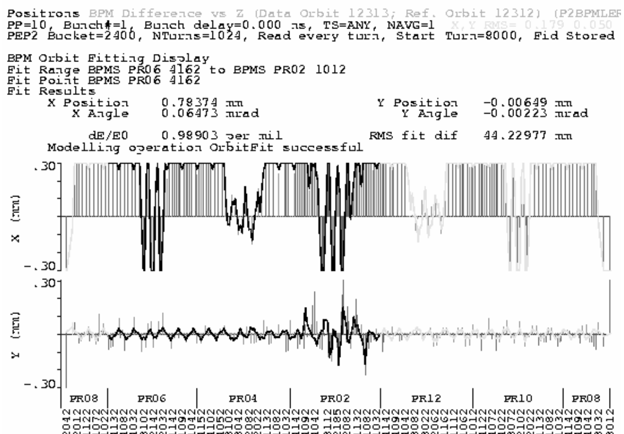

Figure 7: LER dispersion measurement after some fixes. The earlier big oscillations are greatly reduced.

Recent Movements

A recent dispersion measurement in the LER at high current (1730 mA) is shown in Fig. 8. The small oscillation is fitted well with only a small kink at 4152. The same measurement at low current (Fig. 9) shows an oscillation which is twice as big and the kink is -10 μrad bigger. The location is the same as in Fig. 3 and indicates the approach of not steering these BPMs might be actually wrong.

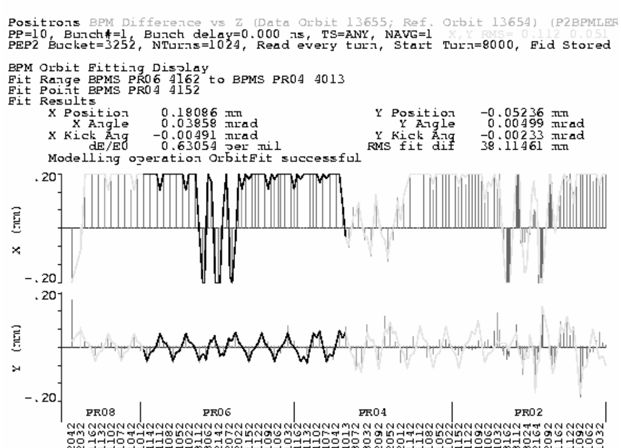

Figure 8: Recent high current LER dispersion (400 Hz). One dispersion wave fits most of the data.

OUTLOOK

The usual tuning maximizes luminosity by adjusting a bump in any sextupole in one of the six arcs (Fig. 10). A more educated choice is looking at where a dispersion is generated which tries also to reduce the vertical emittance blow up. The next step is an even more quantitative approach which will give the amount and sign of all the necessary bumps. Then the coupling has to be corrected, which will be harder to check at high currents. The goal is to get the vertical beam emittance down to the lowest possible value and then make special beam size knobs (some combination of bumps) to increase it again so it matches the beam size of the other beam at the IP.

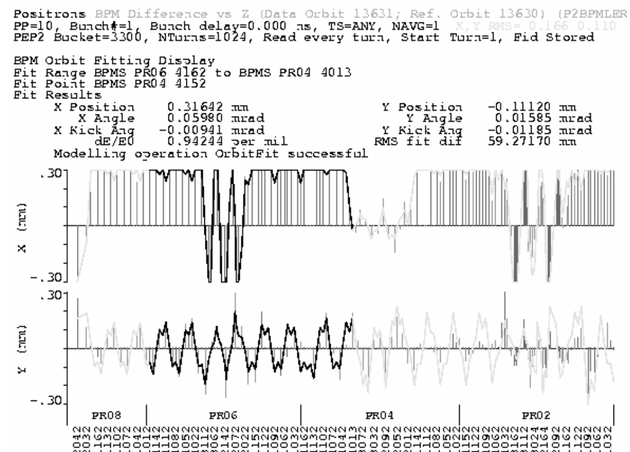

Figure 9: Recent low current LER dispersion (600 Hz). There is quite a kink necessary at 4152 in PR04 to fit the data and additionally some smaller kinks are visible.

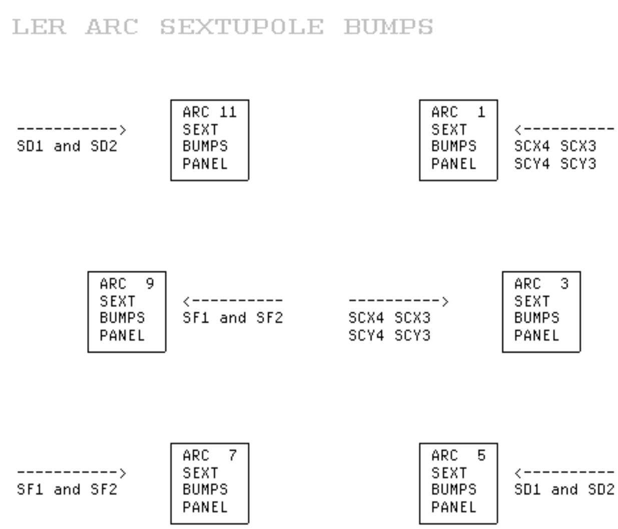

Figure 10: Sextupoles in LER arcs. Each arc contains four sextupole pairs where individual, symmetric or anti-symmetric bumps can be applied in *x* and *y*.

REFERENCES

[1] F.-J. Decker et al., "Orbit Distortions and Bumps in the PEP-II Ring", EPAC'02, Paris, June 2004.