COHERENT BEAM OSCILLATION IN THE FREQUENCY REGION FROM 0.1HZ TO 50 HZ AT KEKB RING

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Abstract

Before the Belle installation, collisions were successfully tried, but a disturbance in the orbit due to the leakage fields of the KEK Proton Synchrotron (PS) prevented collision with high luminosity.

Magnetic shield and compensation steering magnets cured the vibration due to the Proton Synchrotron.

1 INTRODUCTION

On April 16th, 1999, just before the Belle detector installation, a collision tuning had been started on KEKB. Then the vertical beam oscillation was observed in LER and it made difficult to get the stable collision.

The observed beam oscillation is remarkable only in the vertical direction of LER. Horizontal oscillation and HER vertical oscillation were not so big. From the analysis of KEKB logging data, we finally found the oscillation frequency is around 0.5 Hz and there is a strong correlation to the operation of KEK Proton Synchrotron. (Figure 1) The perturbation was given under the M5 service building, which contains power supplies for PS main ring magnets and energy monitoring magnet.

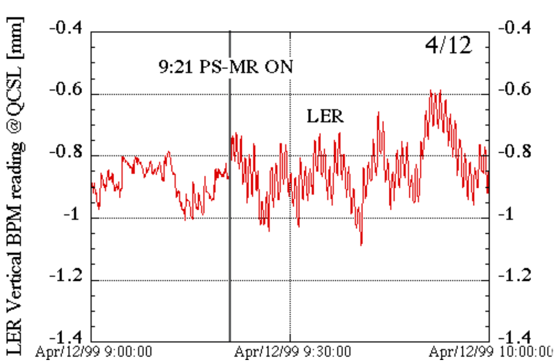

Figure 1: Correlation between LER beam oscillation and PS operation

2 THE EFFECT OF THE LEAKAGE MAGNETIC FIELD FROM PS

2.1 Observed beam oscillation in KEKB in April 1999

Because the colliding beam size is 2-3µm in vertical and 100-200µm in horizontal, the vertical beam oscillation is a critical problem. The amplitude of the observed beam oscillation was approximately 1-1.2 µm at collision point. It took a long time to identify the oscillation, because KEKB beam position monitors measure the beam position every 4 seconds in the normal operation. While the single pass beam position monitor which measure the beam position every revolution (10 µsec), need more than 200000 data to measure 0.5 Hz beam oscillation.

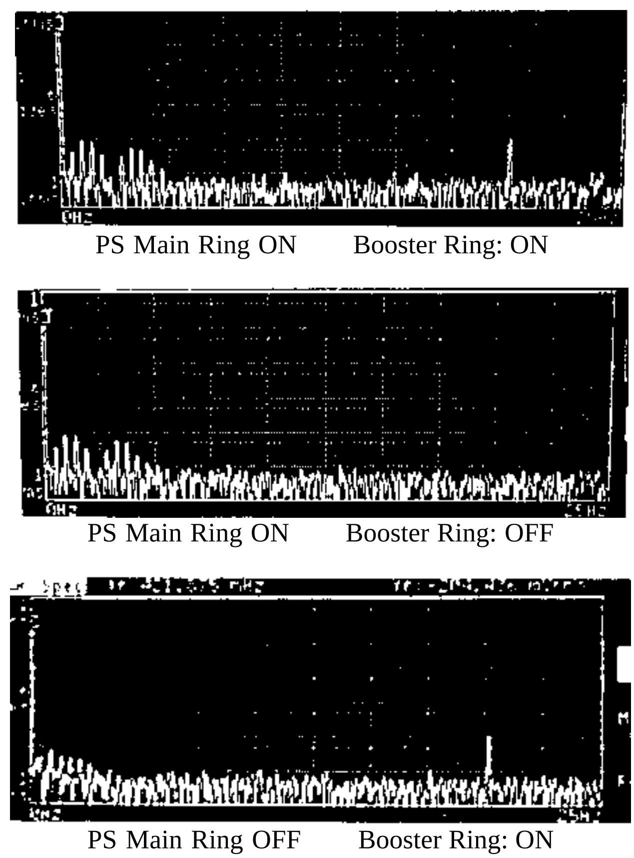

Figure 2: Power spectra of synchrotron light interferometer signal

After many efforts, the 0.5 Hz beam oscillation was identified by two independent beam monitors, the synchrotron light interferometer and the single pass monitor by changing sampling rate. Figure 2 shows FFT output of the synchrotron light interferometer signal from 0 Hz to 25 Hz. From this output, not only 0.5 Hz beam oscillation, but also 20 Hz component were observed. The booster ring caused the 20 Hz oscillation and the PS main ring caused 0.5 Hz component.

The next question was how PS gave the perturbation to the KEKB beam orbit. Why the oscillation is remarkable only LER vertical direction? Two possibilities were discussed. One possibility is that PS gives some effect through AC input of KEKB magnet power supply. But it was not the case. The 2nd possibility is the direct magnetic field coupling from PS. If PS causes the beam oscillation of KEKB beam directly through the magnetic field, the magnetic field on the KEKB beam line should be localized at least the order of wave length of betatron oscillation (about 15m), otherwise the effect would be canceled as the betatron phase advanced. Then the localized the magnetic field leakage source was sought.

2.2 Interference between PS and KEKB

From the observation of the phase of vertical beam oscillation, we found that the perturbation was given at the arc section between Fuji experimental hall and Oho experimental hall. The dummy magnet for monitoring the PS energy and power supplies for PS main ring magnets are locate about 10 m above the region.

2.3 Source of the leakage field

The leakage magnet field comes from mainly three sources. They are

1: The leakage field from energy monitoring magnet

In PS main ring, the beam energy is monitored by the magnet, which is connected in series to the PS main ring magnet. At the flat top, the magnetic field of the monitoring magnet is 1.77T. Because the magnet iron is saturated in this region, a part of the magnetic field is leaked to outside of the magnet. .

2: Triangle loop of current

We noticed that there was a triangle current loop above the arc region. This is one of the sources of leakage magnetic field.

3: The magnetic field produced by the cable between power supply and magnet

The last one is the cable of magnets that passed across above the KEKB tunnel.

2.4 Varying magnetic field in KEKB tunnel

The 0.5 Hz component 24 m gauss peak to peak magnetic field oscillation was observed. And 20 Hz component is measured by 300-turn coil. It was observed just under the cable tray of the booster ring magnet. The booster cycle is 20 Hz . It is not so big and the vacuum pipe attenuates it so that its effect to the KEKB beam does not cause the problem. The table 1 shows the estimation of the contribution from each source. The contribution from monitor magnet was measured by comparing with the case of bypassing the monitor magnet. The varying magnetic field became strong at the position of 365m from Fuji experimental hall. The reason why only LER has vertical beam oscillation was basically understood. It is partially because the beam energy of HER is 8 Gev and larger than 3.5 GeV in LER. And another reason is the beam in HER is shielded by 6m long bending magnet from the varying magnetic field around the peak of leakage field in KEKB tunnel. Integrated magnetic field contribution is 280mG m, which is corresponding with 2.4 µrad deflection angle.

Source of the 0.5 Hz magnetic field	Amplitude (Peak to peak)
Monitor magnet	8mG +/- 1mG
Triangle loop	6mG +/- 1mG
Cable	5mG +/- 1mG
Main ring	1mG +/- 1mG
Other	4mG +/- 1mG

Table 1: Contribution to the varying magnetic field

2.5 Cure of the system

No sooner than we identified the source of the magnetic field, the following measures were taken to solve the problem. First the rearrangement of the cable position in the cable tray had been done to cancel the magnetic field induced by the pattern current in the cable. Second, in order to cancel the magnetic field from triangle current loop, the 300-turn cable and three pieces of 100 turns of cable were lied in coils on the triangle current loop. And an extra current flow was added to the coil. Before the summer shutdown in 1999, PS leakage magnetic field on the KEKB beam line is canceled by two patterns of current flow. One is proportional to the PS bending magnet current pattern and another is proportional to the leakage field of monitor magnet. The ratio of this two-pattern current was adjusted to minimize the vertical beam oscillation of LER beam. Figure 4A shows amplitude of 0.5Hz varying magnetic field on the KEKB beam line before and after applying this cancellation.

During the summer shutdown, father measure had been taken. The cable path was changed to remove existing triangle current loop and also removed extra cable loop we added before summer shutdown. The monitor magnet is shielded by 5mm-iron plate. Figure 4B shows the varying magnetic field distribution in KEKB tunnel after and before these changes. Since there still existed the leakage magnetic field, one turn coils were assembled beside the vacuum chamber on the arc section to cancel this magnetic field.

4 OBSERVATION OF THE BEAM OSCILLATION

The effect of the varying magnetic field to LER vertical beam oscillation was measured. Although KEKB beam position monitors take the data every 4-sec, the data taking mode was switched to take the data at 8 Hz, and 0.5 Hz component was pulled out.

Before the summer shutdown, by changing the current on the cable loop, and after the summer shutdown by optimizing the current of three pieces of one turn coil assembled beside the beam line, varying magnetic field were canceled. As shown in Figure 5B, the amplitude of LER vertical beam oscillation became less than 2µm/ a m(peak to peak). It is correspond to 0.2µm (peak to peak) oscillation at interaction point.

5 CONCLUSION

The beam oscillation caused by the PS leakage magnetic field was observed. It was remarkable on LER vertical direction.

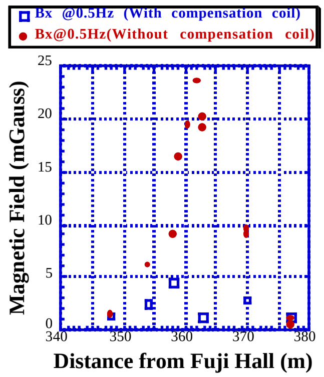

Figure 4A: Horizontal 0.5 Hz magnetic field with/without compensation coil at triangle current loop.

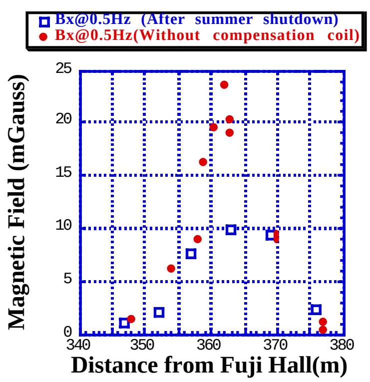

Figure 4B: Horizontal 0.5 Hz magnetic field Before/after summer shutdown

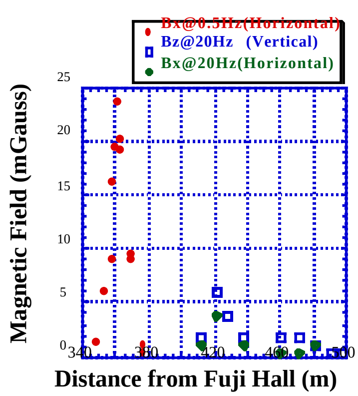

Figure 4C: Varying horizontal magnetic field in KEKB tunnel

The perturbation was given at the interaction point and below the service building where an energy monitoring magnet and power supplies for magnets of PS main ring are located. The mechanism of how to get the influence from PS at the interaction point is still not well understood. The interference at the arc region between Fuji and Oho are given by the leakage field of a monitor magnet, triangle current loop and cable for the PS magnet which lied above the KEKB tunnel. The integrated magnetic field in the KEKB beam line was 280 mG m, which correspond to 2.4µrad deflection. Beam oscillation at the collision point was 1-1.2 µm peak to peak at the first observation. After the installation of the Belle

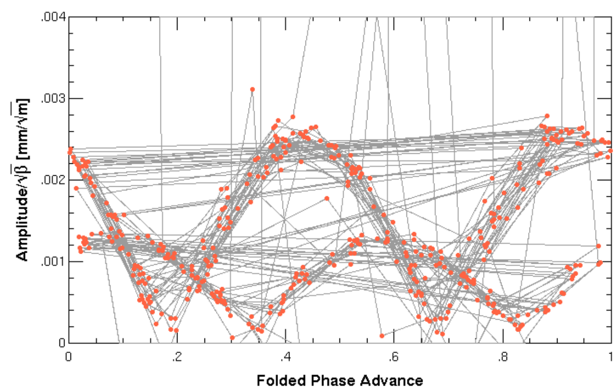

Figure 5A: LER vertical beam oscillation without one turn compensation coil

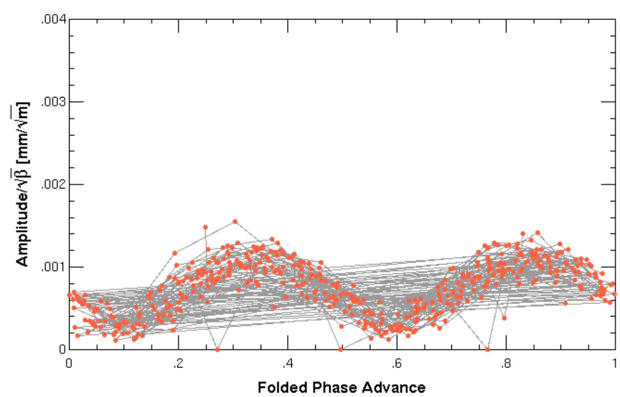

Figure 5B: Reduced oscillation with one turn compensation coil

detector, it becomes half of first observation. And after many efforts around the M5 service, it was reduced down to 12 – 15 % of first observation.