PRESENT STATUS AND UPGRADE OF BPM SYSTEM IN THE PHOTON FACTORY

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Abstract

In the Photon Factory 2.5 GeV electron storage ring at KEK, the upgrade project of its straight sections is underway. In the project, we improve the beam-position monitors (BPMs) and the global orbit feedback system. New BPMs are designed and installed in the straight sections and the orbit stabilization system is improved. The effect RF phase modulation to the beam position fluctuation is also observed with turn by turn BPM.

INTRODUCTION

The Photon Factory storage ring has been operating since 1982 as a dedicated synchrotron light source. The original beam emittance of 460 nm-rad was reduced twice with the major upgrade of the ring, namely, 130 nm-rad in 1987 and 36 nm-rad in 1997[1]. We started new upgrade project form 2002. Figure 1 shows an outline of the new upgrade project. Goal of this project is to equip new short straight sections and enlarge the existing straight sections[2,3]. The total number of straight section will increase from 7 to 13. The newly installed short straight sections plan to use for short-period and narrow-gap undulators.

In this project, two-thirds of the vacuum ducts those are used over 20 years will be renewed. We also install new quadrupole magnets which is shorter and stronger than the previous one. The replacement will be performed during the shutdown period beginning from Mar/2005.

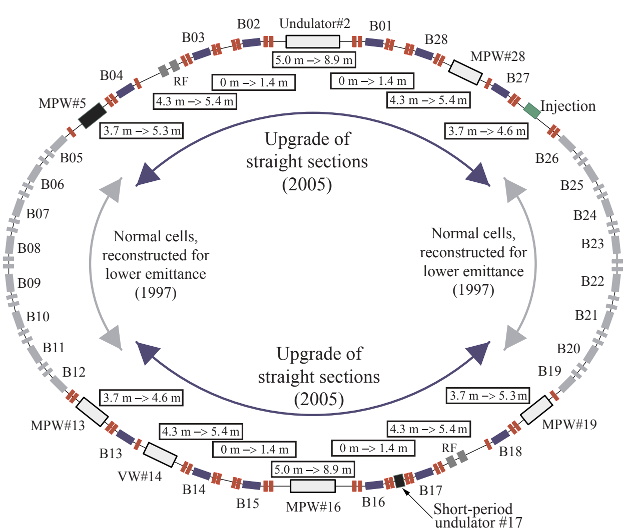

Figure 1: Outline of upgrade project of the straight sections. The arc-sections of the ring (normal cells) remain unchanged.

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As a part of the project, we improve the beam-position monitors (BPMs), and the global orbit feedback system.

IMPROVEMENT OF BPMS

We install a new arrangement of BPMs electrodes and increase the total number of BPMs. Figure 2 illustrates a cross sectional view of vacuum duct with arrangement of pick-up electrodes. Two different arrangements of the electrodes were used before, a 6-electrode type with BNC feedthroughs (left) and the 4-electrode type with SMA feedthroughs (right upper; type "A"). With the 6-electrode type BPMs, we use two electrodes in upon top and bottom for the detection of vertical position and four electrodes in the side to horizontal detection. With following reasons, we decided to remove 6-electrode type BPMs 1). We have no space to install the 6 electrodes BPMs. 2) 4-electrode type have enough sensitivity for horizontal and vertical. 3) Since we use switching circuit in front of the super-heterodyne detectors [4], we can decrease the readout time if the number of electrode reduced from six to four. We will use four electrodes arrangement for new BPMs.

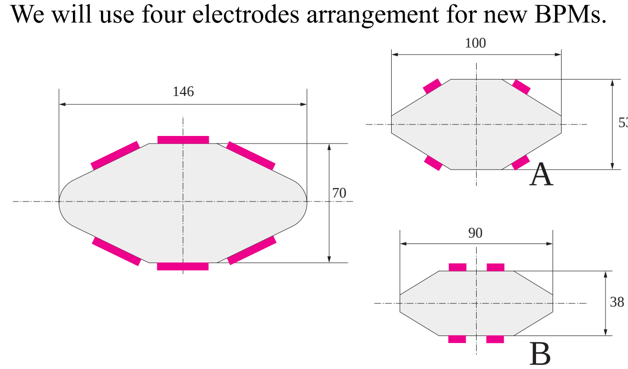

Figure 2: Cross-sectional view of the vacuum duct. The 6-electrode type (left) BPM at the normal cell section was repaced with the 4-electrode type “A” (right, upper) in 1997. We install the new type “B” (right, lower) in the straight section.

We designed a new 4-electrode type BPM as illustrated in Fig.2 (right bottom, type "B") for new vacuum duct of quadrupole magnets. We still have a type "A" in the existing section (from B05 to B12 and B19 to B26). The sensitivity for the vertical direction of type "A" is worse than that for the horizontal direction. The new type "B" has same sensitivity for both planes. We have 77 BPMs in total, and we will use 65 BPMs for the closed orbit measurement. Remaining 12 BPMs are used for feedback of insertion devices and diagnostics, for example, pickup for the bunch-by-bunch feedback system (longitudinal and transverse), turn-by-turn beam oscillation monitor and the phase space monitor.

IMPROVEMENT OF ORBIT FEEDBACK SYSTEM

We currently utilized the vertical global orbit feedback system which consists of DSP and fast-corrector magnets for the users operation [5]. Figure 3 show the block diagram of the system. The signal from electrode is detected by the heterodyne detector, and output voltage of it is sampled by 16-bit ADC and converted into the beam position trough a calculation of DSP. Since the feedback period of the system is 12 ms, we can suppress the vertical orbit fluctuations up to about 8 Hz. With this condition, the system becomes unstable in rarely. For a stable operation, we limit the bandwidth of the system with PID parameters. With previous system, the number of the fast-corrector magnets is 28, and this number is not enough to compensate the drifts of the beam orbit in some place of the ring. We increase the number of fast corrector magnet to 32 in order to perform good orbit stability. Furthermore, we will use of slow corrector previously existing in the ring together with the fast corrector to perform a slow orbit correction for both horizontal and vertical plane. The algorithm for the synchronous operation of fast and slow feedback is carefully designed to avoid the conflicts between two feedback loops. The block diagram of the two feedback scheme is also shown in Fig.3. The feedback period for the workstation-based system is estimated to 10 to 30 second, and this period will be tuned via the beam study.

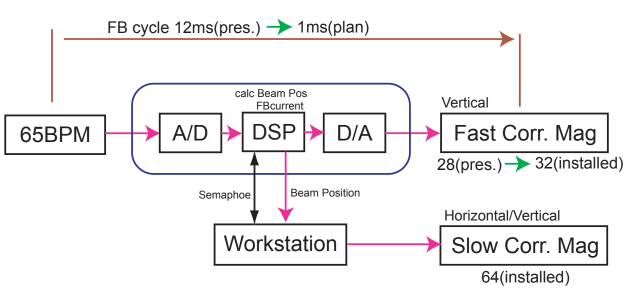

Figure 3: Block diagram of the feedback system.

Since replacing the old controller for switching unit of the 6 electrode BPMs by controller system for 4 electrodes BPMs, total feedback system components can be operated with up to 1 kHz, we plan to increase the feedback cycle. The frequency of coherent synchrotron oscillation in the PF which induced by the longitudinal coupled-bunch instabilities is similar frequency, we mast take care for this influence in this case.

Developments of the fast local feedback system for insertion devices are also in progress. We are evaluating the FPGA-based system that can handle the feedback cycle faster than 1 kHz.

BEAM OSCILLATION OBSERVATION

In order to measure the beam oscillation in variety of frequency range, we installed a beam position monitor named "Digital BPM 2" developed by Instrumentation Technologies Company [6]. We can measure the beam position in turn-by-turn or average of several turns by changing the settings of digital filter. We used the BPM located between B08 and B09. The detected beam position by the system is analyzed in offline.

As a first step, we measured a beam position with the bandwidth of 300 Hz. Figure 4(a) shows a result of power spectral density (PSD) of the horizontal beam position, and 4(b) the vertical, respectively. The numerical integration of the PSD, as shown in Fig. 4(c), represents the corresponding rms beam motion. The range of the integration is from 0 Hz to 300 Hz. In the horizontal plane, oscillation peak around 15 Hz is observed as shown in Fig. 4 (a), and this peak makes a first step in the integrated curvature as shown in Fig.4(c). Previously, we investigated the mechanical vibration of the magnet girder, and we found the source for beam oscillation in 15Hz is mechanical vibration of the girder of the quadrupole magnet [7].

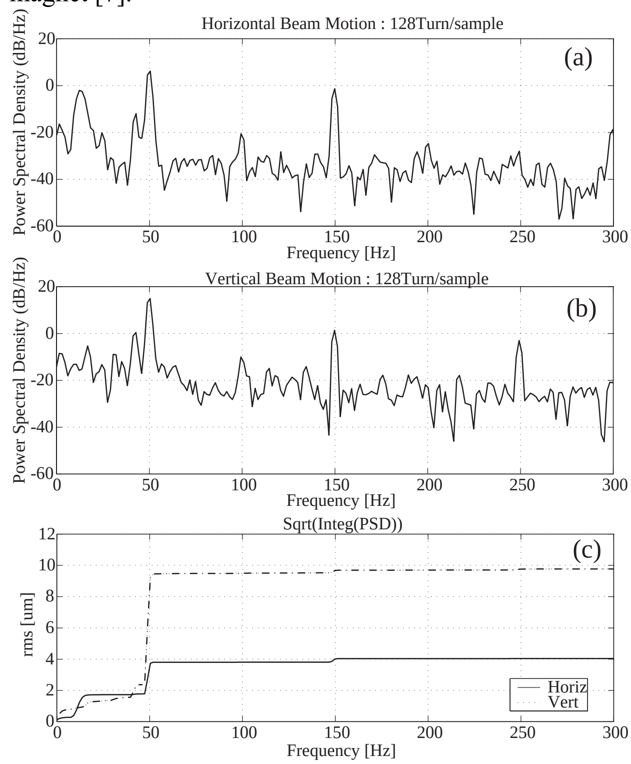

Figure 4: Power spectral density (PSD) of the beam motion in horizontal (a) and vertical (b) direction. The integration from 0 to 300Hz of each PSD is plotted in (c).

The required orbit stabilities from users are at least one-tenth of the beam size. The typical beam size at the bending magnet source is 390µm in the horizontal and 60µm in the vertical. As shown in Fig. 4(c), the fluctuations of beam position below 50 Hz are less than 2µm, and this is small enough for users. As mentioned in the previous section, our global orbit feedback system stabilizes the vertical fluctuation of the beam position. We plan to expand the system to stabilize the horizontal fluctuation and to extend the bandwidth to suppress the various oscillations up to 100 Hz.

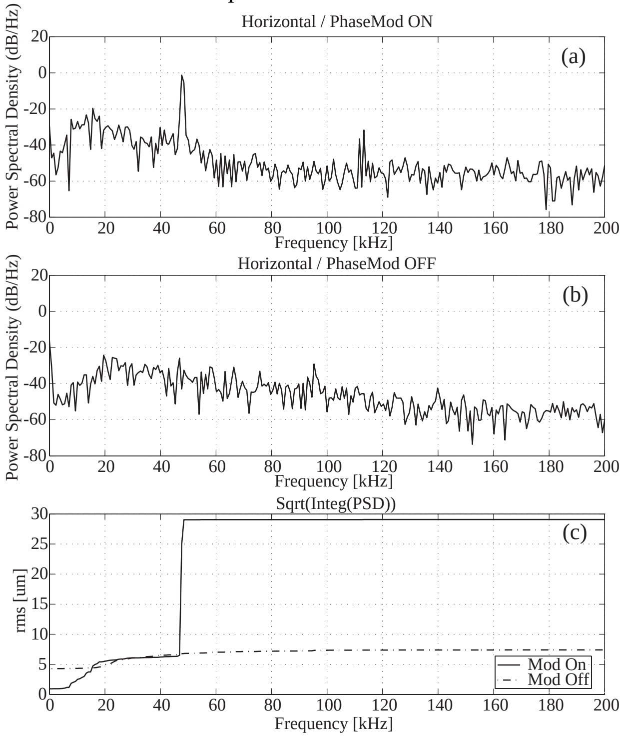

Figure 5: PSD of horizontal beam motion with (a) and without (b) the RF phase modulation. The integration of PSD is plotted in (c).

In the PF, we applied the RF phase moderation with twice of the synchrotron frequency to improve the beam lifetime during the users operation [8]. The phase modulation increases the bunch volume, and in the same time, the increase of bunch volume has an effect to suppress the longitudinal coupled bunch instabilities. We measured the beam motion with turn-by-turn position detection. The revolution frequency of the PF ring is 1.6 MHz and we can analyze the beam motion up to 800 kHz. This measurement is useful to ensure the effectiveness of the RF phase modulation technique. Figures 5 (a) and (b) show the power spectral density of the horizontal beam fluctuations while the RF phase modulation is turned on and off, respectively. The integrations of PSD are shown in Fig. 5(c). The figure shows the results with 200 kHz bandwidth, because there are no significant peaks from 200 kHz to 800 kHz. When the phase modulation is turned on, frequency component at the frequency at twice of synchrotron frequency (48 kHz) is observed in the spectrum. The beam oscillation below 20 kHz is stabilized with the phase modulation as shown in Fig. 5(c).

The effect of the phase modulation to the vertical beam fluctuations are shown in Fig. 6. The rms value of the beam motion without the modulation is about 6 μm and this value is decreased down to less than 2 μm with the phase modulation. In the observation for phase modulation off, the frequency component near by DC is appeared as shown in Fig. 6(b). This component dominates the rms value of the beam motion via integrations of PSD as shown in Fig. 6(c). To investigate this frequency component near by DC in the vertical, we

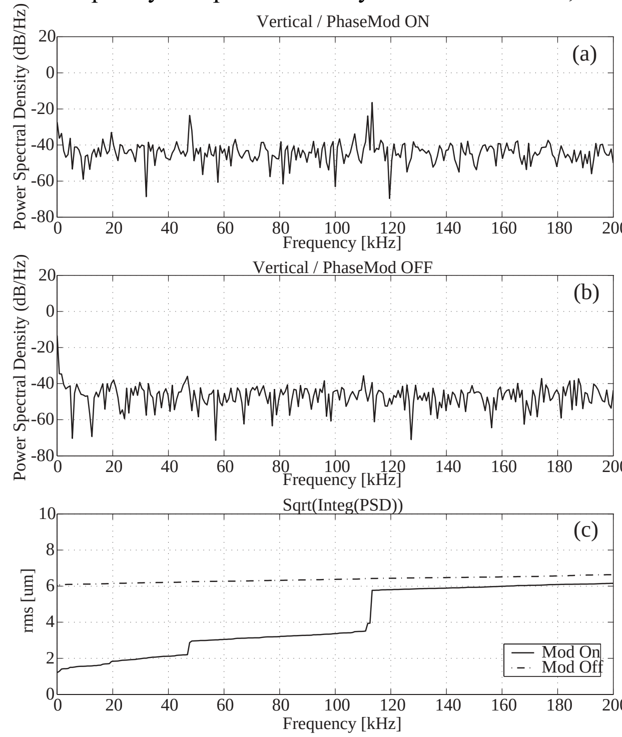

Figure 6: PSD of vertical beam motion with (a) and without (b) the RF phase modulation. The integration of PSD is plotted in (c).

plan to measure the effect of phase modulation on the slow orbit motion below 300 Hz in near future.

SUMMARY

Upgrade project of the KEK-PF is underway. The four electrodes BPMs are installed in straight sections. The total number of BPMs is increased from 65 to 77. The number of fast corrector magnets is increased to inprove the orbit stability. The slow orbit correction based on the workstation will add into the fast global orbit feedback system. We plan a fast local feedback system based on FPGA with the newly installed BPMs. The effect s of the RF phase modulation to the beam position fluctuation was observed in frequency range less than 20 kHz. We plan a further investigation for this effect.

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