

New BPM System and Its Calibration for Upgraded PF Ring

Kaiichi HAGA, Tohru HONDA, Mikito TADANO and Toshio KASUGA
 High Energy Accelerator Research Organization (KEK)
 Institute of Materials Structure Science, Photon Factory
 1-1 Oho, Tsukuba, Ibaraki 305, JAPAN

Abstract

Accompanying the brilliance-upgrading project of the Photon Factory storage ring, the beam position monitor (BPM) system will be newed. The new system was designed to enable precise and fast measurements to correct closed orbit distortion (COD), as well as to feed back the orbit position during user-runs. There will be 42 BPMs newly installed, making a total of 65 BPMs. All of the BPMs will be calibrated on the test bench using a coaxially strung metallic wire. The measured electrical offsets are typically 200 μm in both direction, which is 1/2 - 1/3 of those of old-type BPM. In the signal-processing system, PIN diode switches are to be adapted in order to improve the reliability. In the fastest mode, this system is capable of measuring COD within about 10 msec, and this fast acquisition will allow us fast suppression of the beam movement for frequencies of up to 50 Hz using a global feedback system.

1 Introduction

Photon Factory (PF) ring is a 2.5 GeV electron/positron storage ring dedicated for synchrotron radiation (SR) experiments. It was planned to provide much brilliant SR by reducing the ring emittance 130 nrad to 27 nrad, and reconstruction of the various components of the PF ring is now in progress. Accompanying the brilliance-upgrading project, the beam position monitor (BPM) system will be newed. The purpose of the BPM system is to accurately measure the beam position in order to correct for any closed-orbit distortion (COD), to stabilize the beam position using feedback, and to correct such optical functions as the

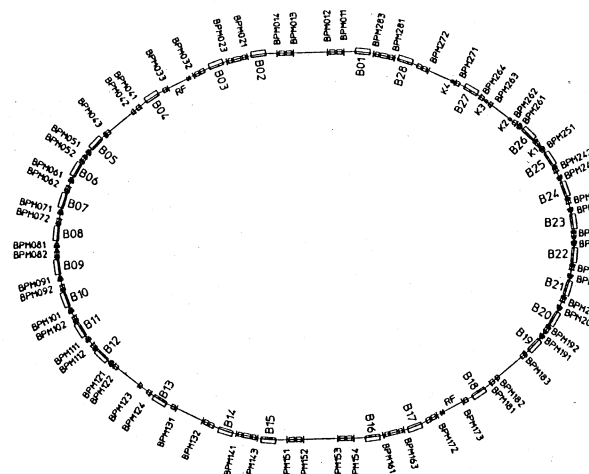


Fig. 1 Planned location of BPMs in the upgraded PF storage ring.

dispersion function. The new system was designed to enable precise and fast measurements to correct the COD, as well as to feed back the orbit position during user-runs.

New BPM system comprises electrostatic pickup units and a signal-processing system. The pickup units includes 42 new-type ones on newly fabricated vacuum chamber and 17 old-type ones. Calibration measurement of new BPMs was made on a test stand in order to know the offset of electrical center. In addition, the response of the new BPM to the beam-induced field was calculated using a method of Boundary Element Method (BEM) to deduce the position sensitivity.

2 BPM System

2.1 Pickup Unit

The pickup units for the normal cell sections are to be doubled in number, according to the addition of the quadrupole magnets in the same sections. Vacuum

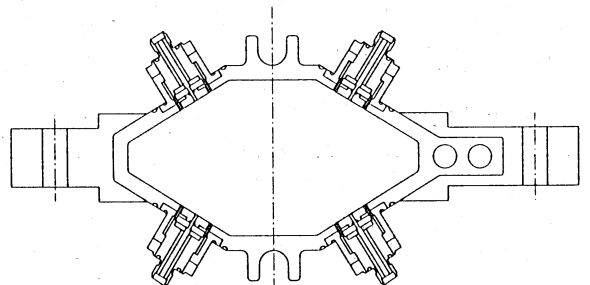


Fig. 2 Cross-sectional view of a pickup unit for new PF BPM.

chambers are also replaced to new ones, therefore 42 BPMs are newly installed, making a total of 65 BPMs. The newly installed pick up unit has four pickup-electrodes of a button type. The whole BPM location in the upgraded PF ring was shown in Fig.1.

A cross-sectional view of the new BPM unit is shown in Fig. 2. It was designed to fit in the narrow space between the magnets. A commercial product (from KYOCERA corp.) was adopted for the electrode assembly, which consists of a button electrode (10.3 mm in diameter), a feedthrough and an SMA-type connector. The button is set at the center of the assembly within $\pm 50 \mu\text{m}$. Each BPM unit is fixed to an end of the quadrupole magnet. All of the BPMs will be tested at a calibration bench where the electric center of each BPM will be identified with an overall accuracy of about 100 μm using a coaxially strung metallic wire.

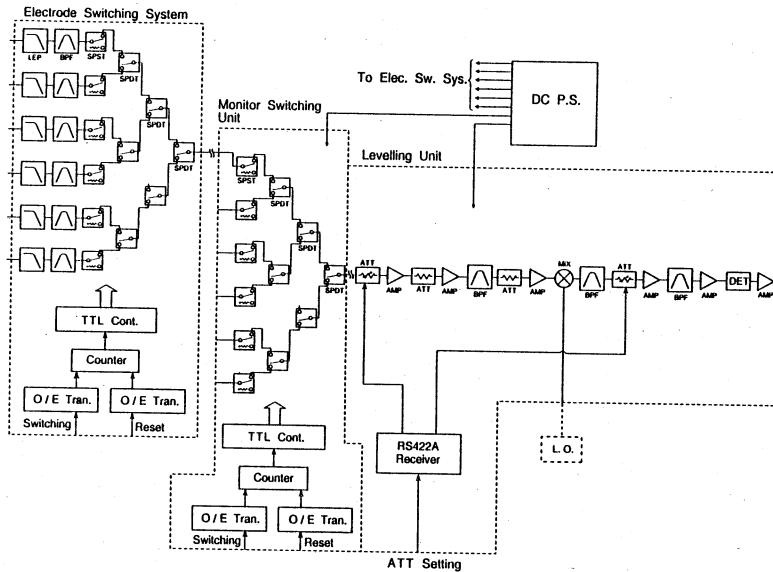


Fig. 3 Schematic diagram of the signal-processing system.

2.2 Signal-processing System

A schematic of the layout of the signal-processing system is shown in Fig. 3. These circuit units are to be distributed in 12 local control racks around the ring. The beam signals from the pickup electrodes are to be transmitted to the processing system, and at the front end of the system, one of the signals will be selected by RF switches. To improve the reliability, the currently-used mechanical coaxial switches will be abandoned, and PIN diode switches are to be adopted. The fluctuation of the insertion loss over many switchings is less than ± 0.01 dB, which corresponds to a position error of ~ 3 μm . The signal detection circuit consists of a super-heterodyne circuit with synchronous detection. The bandwidth of the signal detection is determined by the response time (~ 3 μs by 10 to 90% rise time) of a low pass filter in the final detection stage. In the fastest mode, this system is capable of measuring the COD within about 2 msec, which is determined by the sum of the switching time, the

response time of the detection circuit and the conversion time of an analog-to-digital (A/D) converter. This very fast acquisition will allow us fast suppression of the beam movement for frequencies of up to 50 Hz using a global feedback system [1].

3 Simulated Response of the New BPM

In order to measure the beam position precisely, the position sensitivity and the electrical center of the BPM should be known before installing into the storage ring. In the calibration measurement, an antenna which is connected to a rf-source is used to simulate the field of the high energy beam. However, the electromagnetic field produced by the antenna is somewhat different from that induced by a real beam. Thus, we calculated the response of the BPM to deduce the position sensitivity.

Using a method of Boundary Element Method (BEM) [2][3], we simulated the response of the BPM to electric field induced by the beam. The cross section of the beam duct was approximated with small line segments. The potential and induced charge density of each element were calculated and summed to the induced charges of the four electrodes A ~ D. The beam position data are given as the ratio (U and V): of these induced charges.

$$U = ((Q_A + Q_D) - (Q_B + Q_C)) / (Q_A + Q_B + Q_C + Q_D)$$

and

$$V = ((Q_A + Q_B) - (Q_C + Q_D)) / (Q_A + Q_B + Q_C + Q_D)$$

of these induced charges. The position sensitivities (S_x and S_y) are given by the derivatives of U and V with respect to the beam position at the center of the BPM.

$$S_x = \partial U(x,0) / \partial x, \quad S_y = \partial V(0,y) / \partial y$$

The simulated results are shown in Fig. 4. Derived values of horizontal and vertical BPM sensitivity are $S_x = 0.0575$ mm^{-1} and $S_y = 0.0283$ mm^{-1} , respectively.

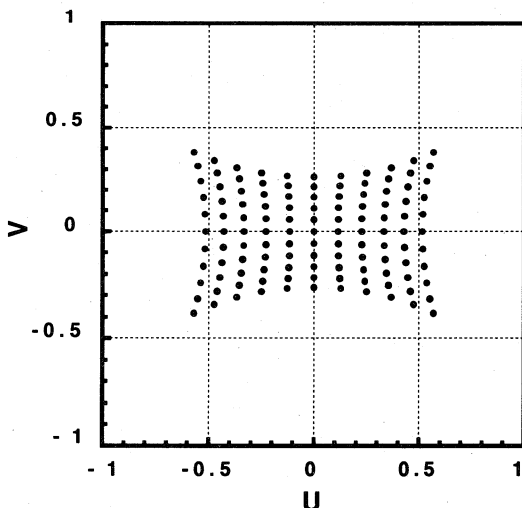


Fig. 4 Simulated response of the new BPM.

The various distortion of the BPM assembly during the fabrication, especially the fluctuation in the thickness of the BPM duct, will generate the offset of the electrical center. The typical value of this fluctuation is less than 200 μm , and will result the simulated offset $\sim 200 \mu\text{m}$.

4 Calibration Measurement

Before installing new-type BPMs, every BPM assembly was calibrated on a test stand in order to determine the electrical center of the BPM relative to its mechanical center. A precise determination of the offset of each individual BPM is important for commissioning and operating the storage ring.

4.1 Test Stand for Calibration

Shown in Figure 5 is the test stand used for the calibration. The BPM assembly was mounted vertically on the stand. A steel wire of 300 μm in diameter was strung coaxially, and simulated the beam. Both ends of the wire were connected to N-type connectors. The wire was precisely aligned using a spring tensioning device located at the lower end. The calibration was performed at a frequency of 500 MHz, the signal-detection frequency of the BPM electronics. RF signals emerging from the button electrodes were multiplexed in a SP4T switch and transmitted to a network analyzer for measuring their intensities. The electrical offsets were then obtained using the BPM sensitivity, which was derived from a simulation based on the boundary element method.

4.2 Distribution of the Measured Offsets

Figure 6 shows the distribution of measured electrical-center offsets for the new-type BPMs. The horizontal and vertical offsets of each BPM are shown as closed circles. All of the measured offsets are less than 500 μm , and typically 200 μm , in both directions. This is in good agreement with a simulated result of $\sim 200 \mu\text{m}$. The offsets of electrical center for old-type BPMs are also shown in Fig. 6 for a comparison. The offsets for the new-type BPMs were about 1/2 - 1/3 of those of the old-type.

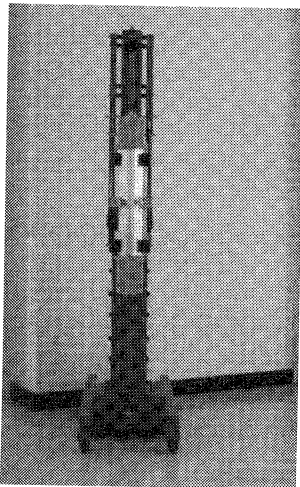


Fig. 5 The test stand for calibrating the new BPM.

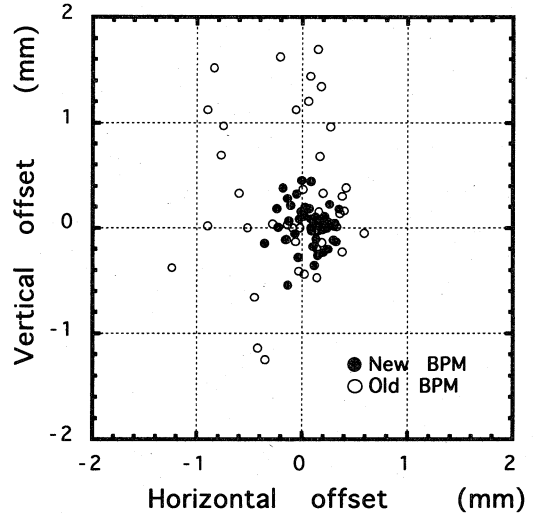


Fig. 6 Distribution of the measured offsets of the electrical center relative to the mechanical center.

4.3 Horizontal and Vertical Offsets

Both the horizontal and vertical offsets of the new-type BPMs are nearly zero on the average, which indicates that no systematic errors were introduced during the course of fabricating the Q-ducts and BPM assemblies. These measured offsets for all BPMs will be stored on a computer and used to calculate the beam position.

5 Conclusion

The BPM system will be newed for the upgraded PF ring. The 42 BPMs will be newly installed to match the new vacuum duct. In the pickup unit, the button electrode is set at the center of the assembly within 50 μm . All of the measured electrical offsets are typically 200 μm in both direction, which is 1/2 - 1/3 of those of the old-type BPM. The offsets are nearly zero on the average, which indicates that no systematic errors were introduced during the fabrication. In the signal-processing system, PIN diode switches are to be adopted in order to improve the reliability. The fluctuation of the insertion loss over many switchings is less than 0.01 dB, which corresponds to a position error of 3 μm . In the fastest mode, this system is capable of measuring the COD within about 2 msec. This very fast acquisition will allow us fast suppression of the beam movement for frequencies of up to 50 Hz using a global feedback system.

In order to accurately determine the BPM offsets relative to the magnet axis, a beam-based calibration method will be very useful. This method has the advantage that it can eliminate various error sources, including mechanical alignment errors of the BPM assemblies or residual offsets of the signal-processing electronics.

References

- [1] Photon Factory Activity Report #12, 1994, p.A-6.
- [2] The Boundary Element Method for Engineers (Pentech Press, London, 1978).
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