THE NEW BPM SYSTEM AND ITS COMMISSIONING AT PF RING

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Abstract

We describe the new beam position monitor (BPM) system built for the brilliance-upgraded Photon Factory storage ring. The new system was designed to enable precise and fast measurements to correct the closed orbit distortion (COD), as well as to feed back the orbit position during user-runs. There are 42 BPMs newly installed, amounting to a total of 65 BPMs. All of the newly installed BPMs are 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 the old-type BPM. In the signal-processing system, PIN diode switches are employed in order to improve the reliability. In the commissioning of the ring, new BPM system is capable of measuring COD within about 10 ms, and this fast acquisition will allow fast suppression of the vertical beam movement for frequencies up to 1 Hz using a fast global feedback system.

1 INTRODUCTION

The Photon Factory (PF) ring is a 2.5 GeV electron/positron storage ring dedicated for synchrotron radiation experiments. It was planned to provide much brilliant synchrotron radiation by reducing the ring emittance from 130 to 27 nmrad, and the various components of the PF ring had been reconstructed [1].

Accompanying this brilliance-upgrading project, the beam position monitor (BPM) system has been renovated. The purpose of the BPM system is to accurately measure the beam position in order to correct it for any closed-orbit distortion (COD), to stabilize the beam position using feedback, and to correct the lattice optical functions such as the betatron or the dispersion functions. 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 [2].

The new BPM system comprises electrostatic pickup units, a signal-processing system, digitizing unit and timing system. The pickup unit for the normal-cell sections were doubled in number and these 42 new-type pickup units had four button-type electrodes and had been mounted on newly fabricated vacuum chambers. There were also 23 old-type units unchanged, to the amount of 65 BPMs in total. As for the signal-processing system, the circuit units are to be distributed in 12 local control racks around the ring.

2 BPM SYSTEM

The system's block diagram is shown in Fig.1. The signals from the pickup electrodes are transmitted to the processing system, and at the front end of the system one of the signals is selected by PIN diode RF switches. The detected signals are multiplexed and digitized by the analog-to-digital converter (ADC) in the VME module situated near the controlling computer. The timing signals to switch the electrode and to digitize the detected signals were originated from the timing system and sended to the electrode switching and digitizing units by the optical fiber.

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. The vacuum chambers are also replaced by new ones and accordingly 42 BPMs are newly installed. The installed pickup unit had four button-type pickup electrodes and it was designed to fit into the narrow space between the magnets. A commercial product (from KYOCERA Corporation) was adopted for the electrode assembly, which consists of a button electrode (10.3 mm diameter), a feedthrough and an SMA-type connector. The button is set at the center of the assembly within ±50 μm. Each BPM unit is fixed to an end of the

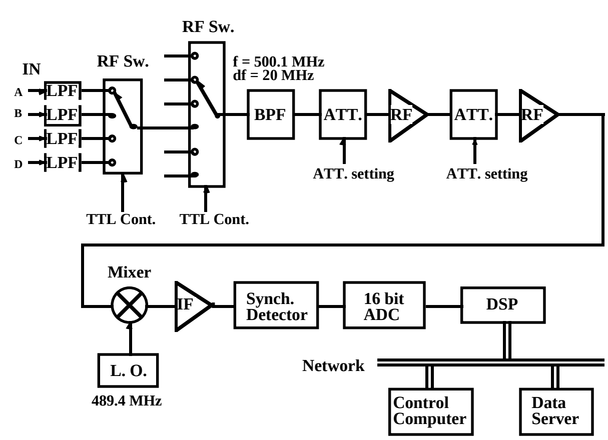

Fig.1 Block diagram of the new BPM system

quadrupole magnet. The electric center offsets of every new BPM pickup units were measured at a calibration bench before installations into the ring.

2.2 Signal-processing system

Signal-processing circuit units are to be distributed in 12 local control racks around the ring. Four beam signals from each pickup unit are switched and transmitted to the processing system. At the front end of the system, one of the signals from several BPMs is selected again. To improve the reliability, the currently used mechanical coaxial switches were abandoned, and PIN diode switches had 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 part consists of a super-heterodyne circuit with synchronous detection, the 16 bit ADC and the Digital Signal Processor (DSP) for culculation of the beam position. All signals from five or six BPMs are detected with a common detection circuit. The bandwidth of the signal detection is determined by the response time (~ 3 ms in 10-90% 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 ms, which is determined by the sum of the switching time, the response time of the detection circuit and the conversion time of the ADC. This very fast acquisition will allow us fast suppression of the beam movement using a global feedback system [3].

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 an 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 estimate the position sensitivity.

Using the boundary element method[4], we simulated the response of the BPM to the electric field induced by the beam. The potential and induced charge density of each element were caluculated and summed to the induced charges of the four electrodes A-D. The beam position data are given as the ratio

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

and

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

of these induced charges. The simulated results are shown

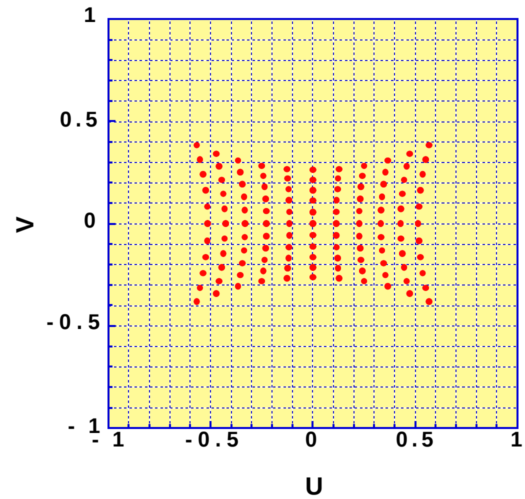

Fig.2 Simulated response of the new BPM.

in Fig. 2. 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 derived values of the horizontal and the vertical BPM sensitivity are $S_x = 0.0575\ \mathrm{mm}^{-1}$ and $S_y = 0.0283\ \mathrm{mm}^{-1}$, respectively.

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 in the simulated offset ~200 µm.

4 CALIBRATION MEASUREMENT

Before installing the 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 [5]. 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

The BPM assembly was mounted vertically on the stand. A steel wire of diameter 300 µm 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. The RF signals emerging from the

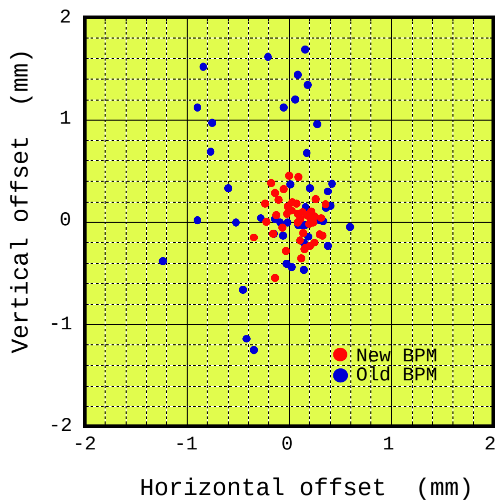

Fig.3 Distribution of the measured offsets of the electrical center relative to the mechanical center.

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 the simulation based on the boundary element method.

4.2 Distribution of the measured offsets

Figure 4 shows the distribution of measured electrical-center offsets for the new-type BPMs. The horizontal and the 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 ~200 µm. The offsets of the electrical centers for old-type BPMs are also shown in Fig. 3 for a comparison. The offsets for the new-type BPMs were about 1/2-1/3 of those of the old type.

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

5 COMMISSIONING OF THE NEW BPM

After the calibration of the electrical offsets of the pickup units, the beam ducts were installed in the ring. Each pickup unit was fixed directory to the end of the quadrupole magnet. The setting error of each pickup unit was measured and recorded in order to correct the measured beam position. In parallel with the installation, the wiring of the signal cables and timing cables were carried out.

In the commissioning of the new BPM system, the electrode switching period was set to the 250 µs, and beam position measuring time was set to 10 ms. This measuring time was limited by the synchrotron oscillation (frequency of 30 kHz) which caused the beam position change during the electrode switching faster than this oscillation. In order to improve the resolution, the beam position data was displayed and stored in the data server at every one second by averaging 100 measurements.

A fast global feedback system was also installed and tested[2]. This system could suppress the vertical orbit fluctuations up to 1 Hz. In order to improve the bandwidth of the feedback system, we will try to speed up the measuring time of the COD together with avoiding the synchrotron oscillation.

6 CONCLUSION

The BPM system has been renovated for the upgraded PF ring and worked well in the commissioning mode. All the measured electrical offsets are typically 200 µm in both directions, which is 1/2-1/3 of those of the old-type BPM. PIN diode switches have been adopted in order to improve the reliability, and the fluctuation of the insertion loss is less than 0.01 dB, which corresponds to a position error of 3 µm. The fast acquisition mode of this system, together with the fast global feedback system, allows us to suppress the beam movements for frequencies up to 1 Hz .

In order to determine the BPM offsets accurately, a beam-based calibration method seems to be very useful. This method has the advantage of eliminating such various error sources as the mechanical alignment errors of the BPM assemblies and the residual offsets of the signal-processing electronics.

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