Beam Position Monitoring System using PIN Diode Switches

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Abstract

We have developed a BPM system that uses PIN diodes for switching and attenuating RF-signal, being intended as more high-speed and reliable than using mechanical switches instead. This system has already been working in the SOR-RING of ISSP. Large unevenness of BPM data that would unexpectedly occur in a case of mechanical switches has never been observed. Moreover, relative accuracy of the order of sub-micron has been attained with this system.

1. Introduction

A third-generation VUV ring with a low emittance of several nm·rad is being designed at the SRL of ISSP in close collaboration with the Photon Factory of KEK. In such a ring that can supply highly collimated synchrotron light to experimental stations, the beam position monitor (BPM) would take a more important role than ever, e. g., to measure a tiny drift of beam orbit and to correct it. As one of the R&D's for the future plan of the high-brilliant source, we have developed a BPM system that uses PIN diodes for switching and attenuating RF-signals from pickup electrodes. The purpose of using PIN diodes is to obtain more high-speed and reliable than using mechanical coaxial switches.

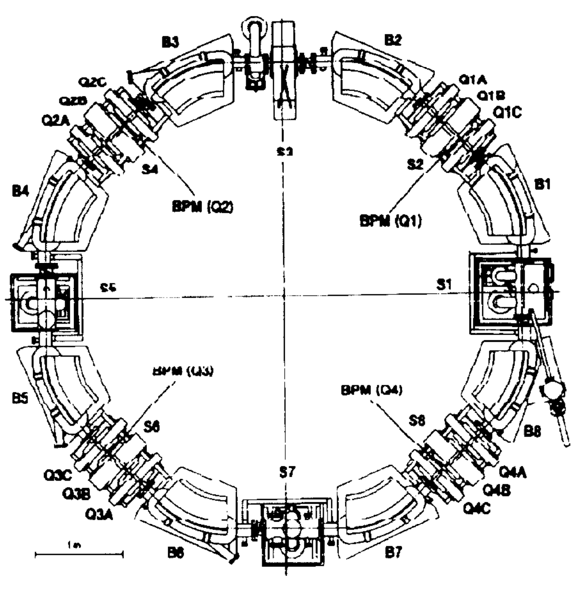

Fig. 1 Plan view of SOR-RING

This system has been installed into SOR-RING (Fig. 1) in the 1992 summer shutdown in order to test it with a real beam and to measure the closed orbit of the ring where there was no working BPM system until then. The present system has been designed to detect 120-MHz spectrum in RF signals from BPM's as the RF frequency of SOR-RING is about 120 MHz, while the RF frequency of the future ring will be around 500 MHz. The operational status of SOR-RING and the machine study using the BPM system are reported in Ref. [1]. Given in this paper are the BPM system and its actual performance.

The BPM system includes four BPM's fixed on newly fabricated vacuum chambers for quadrupole triplets and each BPM consists of four pickup-electrodes of a button type. Four BPM's are located in narrow spaces between quadrupole magnets as seen in Fig. 1. We did not intend the BPM's to be precisely positioned in the ring, for example, much less than 0.1 mm, first because the aim of this BPM system is to test the performance of PIN diodes, and next because there is no good reference point for alignment. Before installing the BPM's into the ring, their sensitivity to the beam position was calibrated on a test bench. It was found from the calibration data that the physical position (x, y) of the beam center is well estimated with a fifth order polynomial of U and V. More details are described in Ref. [2]. Separately from the BPM calibration, a performance test of PIN diode switches and attenuators was made and their insertion losses were carefully measured. In addition, a little nonlinear response of the RF-signal detector was calibrated using a RF-signal generator and later using a real beam. The nonlinearity is compensated for on the BPM system computer when the detected RF-signals are processed.

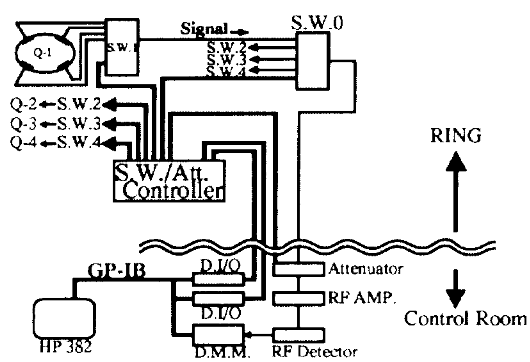

Fig. 2 Schematic of the BPM system

2. BPM System

A. Overview

Figure 2 shows a schematic of the whole BPM system that is working at SOR-RING to test its performance with a real beam. The first-stage PIN diode switches multiplex RF-signals from four pick-up electrodes of a BPM and the second-stage PIN diode switches (S.W.0) then multiplexes signals from four BPM's. The multiplexed signal is sent to a 120-MHz RF amplifier through an attenuator that also uses PIN diode switches. Finally, the signal is detected by a heterodyne detector (RF Detector) and read by a digital multimeter (DMM) that can remove noises with the power line frequency (CMR = 160 dB, NMR = 60 dB for > 1PLC (Power Line

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Cycle)). The multiplexing PIN diodes and those used in the attenuator are controlled by a controller (S.W./Att. Controller) and two digital I/O modules. The multiplexing PIN diodes and S.W./Att. Controller are placed in the ring, while the other electronic modules are placed in the control room. The modules that treat RF-signals are connected each other by semi-rigid 50-Ω coaxial cables. A workstation, HP382, converts the data from DMM to the beam position (x,y) and displays it on the CRT. The whole BPM system is also controlled by the workstation.

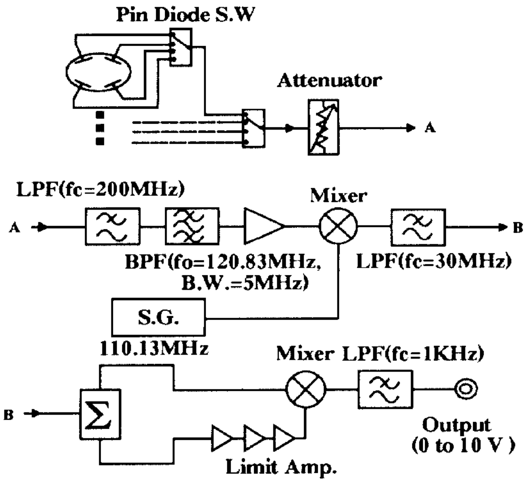

Fig. 3 Block diagram of RF circuit

A block diagram of the RF circuit is shown in Fig. 3. Before heterodyne detection, the RF-signal is filtered by LPF (low-pass filter) that rejects higher harmonics of RF frequency, and further filtered by BPF (band-pass filter) with a bandwidth of 5 MHz; the revolution frequency is about 17 MHz. After filtered by the final-stage LPF with a cutoff frequency of 1 kHz, the output DC signal is sent to a digital multimeter (DMM). By a bench test, it was found that the input/output response of the RF circuit is almost linear but with a small nonlinearity of 0.1 % in the range of the output voltage between 0.1 and 10 V.

B. PIN diode

We chose PIN diode switches, DAICO 100C 1248 SP4T, (four input signals, one output) as the switches to multiplex RF-signals from BPM. The PIN diode switches can be driven by a trigger with TTL level, and each input port is terminated with 50 Ω impedance when the port is switched off. The specifications of the PIN diode switches are; maximum switching speed = 2.5 μsec, typical insertion loss = 0.8 dB for 20 - 200 MHz, minimum isolation = 85 dB for 20 - 200 MHz, VSWR = 1.1 at 120 MHz. The insertion losses were measured for the switches we purchased. Its result is listed in Table I. As the deviations of insertion loss from the average are small, we have not taken account of these data to compensate for the BPM data. The switching speeds were also measured, and it was proved that RF-signals may be multiplexed at 100 kHz without losing their accuracy.

We chose DAICO 100C1595 as the attenuator, the specifications of which are; the attenuation range = 63.5 dB with a setting step of 0.5 dB, typical insertion loss = 3.5 dB, typical switching speed = 5 μsec, VSWR = 1.1 at 120 MHz. We checked the reproducibility of attenuation. The standard deviation measured was about 0.001 dB. As the beam position is calculated from the ratio of detected signals, however, the quality would not affect the beam position.

So far, both PIN diode switches and attenuator are working well without any failure for several months.

3. Beam Test at SOR-RING

After the BPM system was installed in SOR-RING, we measured again the linearity of output response to input signals that were sent by a RF-signal generator from the input ports of PIN diode switches. The nonlinearity in the measured response is compensated for on the BPM system computer when the detected signals are converted to the beam position. The compensation curve is shown in Fig. 4. Just after the beam test began, we found that 120-MHz RF noise on the ground line got mixed in the BPM system and gave rise to false signals in it. This trouble was however fixed by isolating the RF circuit from the ground line.

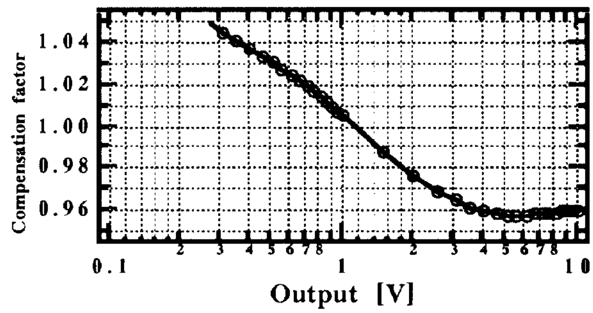

Fig. 4 Compensation curve of the BPM system

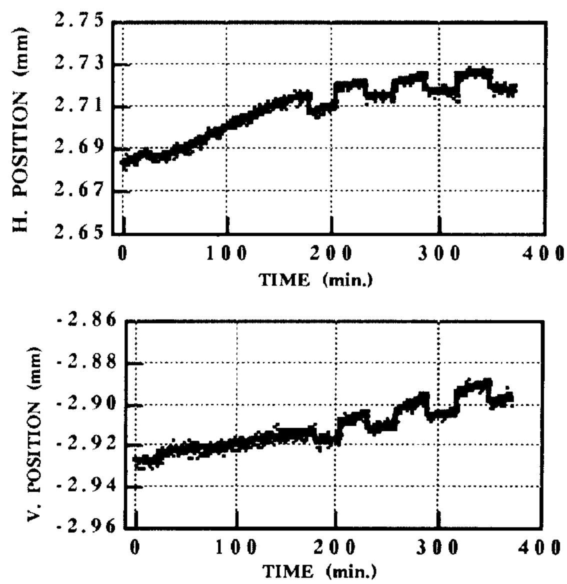

Fig. 5 Orbit drift of SOR-RING
(a): horizontal orbit of a BPM vs. time. (b): vertical orbit of BPM vs. time. The cause of rectangular changes has not been identified yet.

Horizontal C.O.D. measured with the BPM system has a maximum of 3 mm and vertical C.O.D. about 4 mm. The C.O.D.'s along the ring as well as the corrected ones are shown in Ref. [2]. Figure 5 shows an example of the orbit drift measured with the BPM system. The data were taken during a normal user run with a high beam current. The measurement shows that the beam position of SOR-RING slowly drifts about a few tens of μm for the storage mode and jumps by a several tens μm at injection, unless there is no variation in the data caused by the system's drift. For such a user run at SOR-RING, the beam is continuously fluctuating due to a longitudinal instability and ion-trapping phenomena that give rise to an AC noise in the beam position signals.

Therefore, the data of orbit drift were taken at a low current less than several mA in order to check the relative accuracy (resolution) and long-term drift of the BPM system itself, . The DMM that reads DC signals was set at the integration time of 10 PLC and the resolution of 7. 5 digits. The measured data indicated that the orbit drift measured is actually caused by the beam itself but not by apparent drift in the BPM system. Deviations of measured data from the average taken in a short period were also displayed on a histogram. Figure 5 is an example of such a histogram. The standard deviations are about 0.3 μm in the horizontal direction and about 0.4 μm in the vertical direction. Thus we may conclude that the BPM system has the relative accuracy of sub-micron.

We also measured a low-frequency fluctuation in the beam position by inserting a hybrid circuit between a BPM and a PIN diode switch. This measurement is described in Ref. [2].

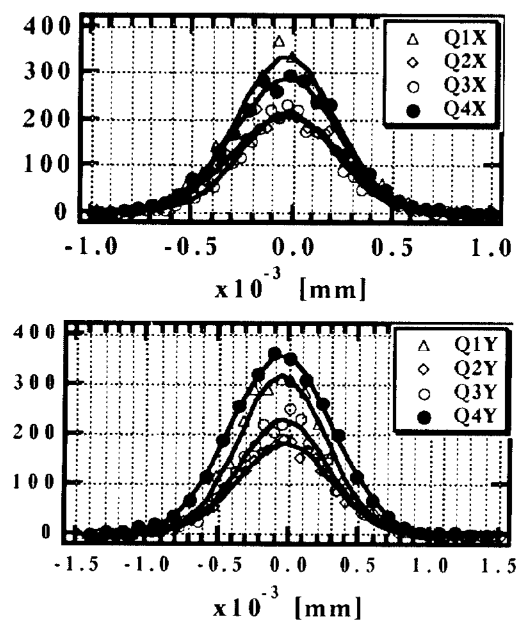

Fig. 6 Relative accuracy of the BPM system
(a): horizontal accuracy of BPM's. (b): vertical accuracy of BPM's. The data were taken for 500 minutes.

4. Summary

A BPM system using PIN diodes has been developed and tested with a real beam at SOR-RING. So far, we have obtained the relative accuracy of the order of sub-micron. Next step of the R&D is to make the data acquisition faster, but probably at expense of accuracy; this may be accomplished by improving the digital circuit and by replacing DMM with ADC.

5. Acknowledgements

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6. References

(1) K. Shinoe et al.: *Design and Calibration of Pickup-electrodes for Beam Position Monitoring at SOR-RING,* in these proceedings.

(2) H. Kudo et al.: *Measurement of the Orbit Parameters at SOR-RING,* in these proceedings.

Table I. Insertion losses of PIN Diodes

serial No.	J No.	Insertion loss [dB]
1316	1	0.4788
(S.W.0)	2	0.48268
	3	0.48975
	4	0.50054
1317	1	0.50054
(S.W.2)	2	0.48343
	3	0.48574
	4	0.47962
1318	1	0.48642
(S.W.3)	2	0.46967
	3	0.47802
	4	0.49302
1320	1	0.49508
(S.W.4)	2	0.49111
	3	0.47709
	4	0.47723
1321	1	0.47403
(S.W.1)	2	0.48796
	3	0.48590
	4	0.48510