Single-Pass Monitoring of Beam Position at SOR-RING

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Abstract

Recent status of single-pass monitor R&D at ISSP, the University of Tokyo is reported. The R&D is being carried out at SOR-RING, a 500-MeV electron storage ring dedicated to synchrotron radiation experiments. There are four BPM's in the ring and three BPM's in the beam transport line between the injector synchrotron and the ring. For the single-pass monitoring, the beam signals from four button electrodes at a BPM are fed into a 4-channel digital oscilloscope and then sent to a workstation for the beam position calculation. The relative accuracy of 0.2 mm has been obtained with this system.

1 INTRODUCTION

A third-generation vacuum ultraviolet and soft X-ray synchrotron radiation source (VSX Light Source in short) is being designed at the University of Tokyo, in collaboration with the Photon Factory (PF) of KEK [1]. The proposal for constructing the accelerator facility will be submitted to Japanese government in this year. The accelerator scheme consists of a 300-MeV linac, a 2.0-GeV booster synchrotron and a 2.0-GeV storage ring. The storage ring has a circumference of about 390 m and an emittance of 5 nm·rad [2].

Single-pass monitors of beam position are expected to play an important role in commissioning and tuning of the accelerator facility. Recently, we have tested a single-pass measurement of beam using a fast digitizing oscilloscope. This same method is also adopted in the Photon Factory storage ring [3]. Presented in this paper are the single-pass monitoring system and its actual performance at SOR-RING.

2 SINGLE-PASS MONITOR SYSTEM

2.1 BPM of SOR-RING

Figure 1 shows a schematic view of SOR-RING. SOR-RING is 17.4 m in circumference and consists of eight bending magnet (B1-B8) and four quadrupole triplets (Q1-Q4). The RF frequency is about 120.9 MHz and the harmonic number 7. Electron beam of 308 MeV is injected into the ring from Electron Synchrotron (ES) of the Institute for Nuclear Study (INS). ES is a 21 Hz rapid-cycle machine with a maximum energy of 1.3 GeV. The injected beam is accelerated up to 500 MeV and then stored.

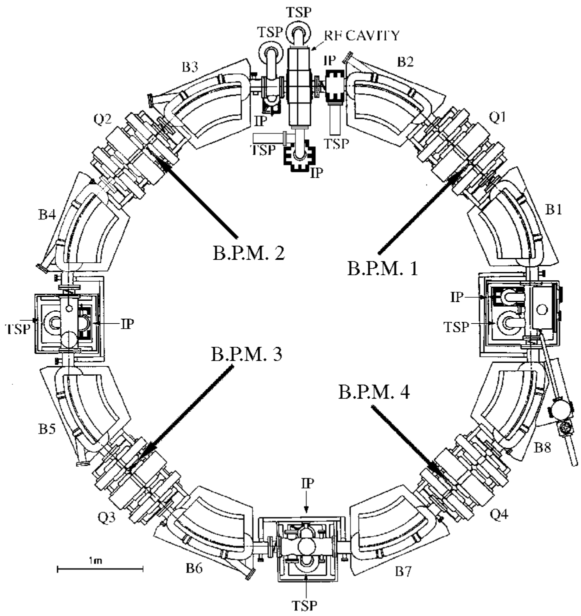

Figure 1 : Plan view of SOR-RING.

As shown in Fig.1, SOR-RING has four BPM's (BPM1 - BPM4) fixed on vacuum chambers of quadrupole triplets. Each BPM consists of four pickup electrodes of a button type. Figure 2 shows the cross-sectional view of the BPM. The button diameter is 20 mm. The position sensitivity of the BPM's were calibrated by scanning an RF antenna on a test bench. The design and calibration of the pickup electrode are described in detail elsewhere [4]. The BPM system is usually used for multi-turn measurement, i.e. C.O.D. measurement, where the button signal is detected by a heterodyne method and then sent to a digital multimeter. The relative accuracy of the order of sub-micron has been attained with this system. The detailed description of the multi-turn measurement appears in ref. [5].

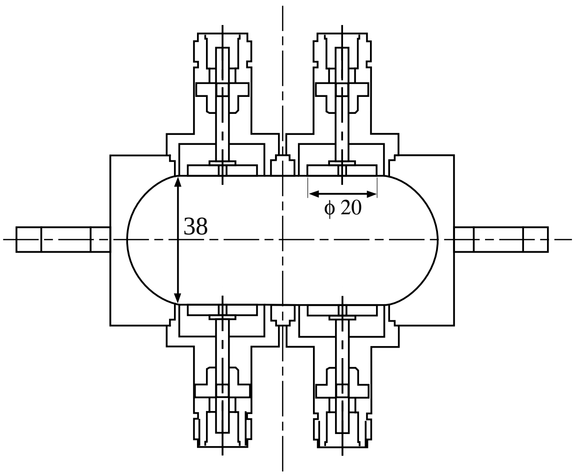

Figure 2 : Cross-sectional view of a BPM at SOR-RING.

2.2 BPM of the BT-line

Recently, we have installed three BPM’s in the beam-transport (BT) line between ES and SOR-RING. The cross-sectional view of the BPM chamber at the BT-line is shown in Fig. 3. It is a cylindrical position monitor of 58mmϕ and the diameter of button electrodes is 20 mm. A beam position is calculated from the voltage ratio of the pickup electrodes, U and V. U and V are given as follows;

$$U=\left(\frac{B-A}{B+A}\right)+\left(\frac{D-C}{D+C}\right), \quad V=\left(\frac{A-C}{A+C}\right)+\left(\frac{B-D}{B+D}\right).$$

Here, A, B, C and D stand for the peak voltages of the corresponding electrodes in Fig. 3. We estimated the position sensitivity of the BPM’s analytically. The horizontal and vertical positions are given as;

$$x\ [\mathrm{mm}] = 10.25U, \quad y\ [\mathrm{mm}] = 10.25V.$$

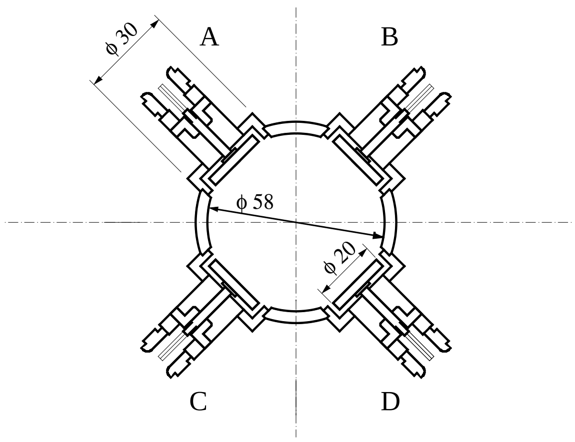

Figure 3 : Cross-sectional view of a BPM at the BT-line.

2.3 Single-pass monitor system

For the single-pass monitoring, the bunch signals from four button electrodes are directly fed into a digitizing oscilloscope through semi-rigid coaxial cables (Cable length is 2 m for the ring and 20 m for the BT-line). The cable attenuation is 30 dB/100m at 100 MHz. The digitizing oscilloscope (Digital Real-time Oscilloscope, TDS684A by Tektronix) has four independent inputs. Each channel has a 8-bit digitizer with a maximum sampling rate of 5G samples/s and an analog bandwidth of 1 GHz. A maximum record length is 15000 points per channel. The digitized data are sent to a workstation (HP715) by GP-IB interface bus, and the beam position is calculated from the peak heights of the four signals.

Figure 4 shows an example of four button signals (BPM3 of SOR-RING) for an electron bunch. It was taken at a beam current of 10 mA in the single-bunch operation. Total charge of the bunch was about 6×10^{-10} C.

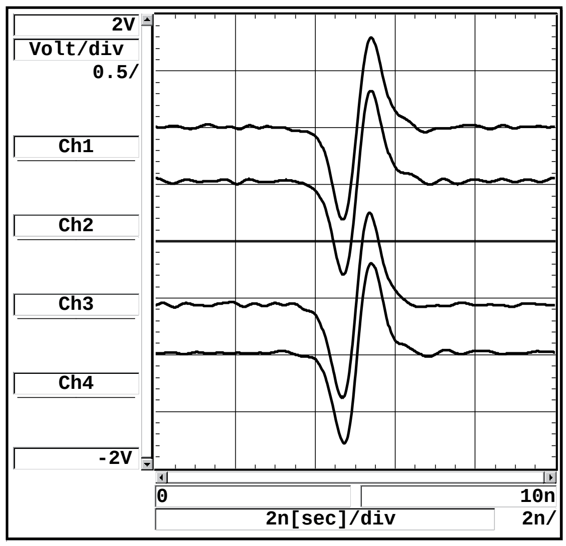

Figure 4 : An example of four button signals of a BPM.

3 PERFORMANCE

Figure 5 shows the measured beam positions at BPM3 for five different cases of beam orbit. The beam orbit was changed by a beam steering at the Q1 section. The single-bunch beam current was fixed at about 10 mA in this measurement. The open circle and the dots are the positions obtained by the multi-turn measurement and the single-pass measurement, respectively. The way to calculate beam position from four bottun signals for the single-pass measurement is same as for multi-turn measurement in ref. [4]. In this figure, x_{mt} and y_{mt} are the values of multi-turn measurement and x_{sp} and y_{sp} are the average values of single-pass measurement. The figure shows that the values of single-pass measurement and of multi-turn measurement are consistent, though x_{mt} are relatively smaller than x_{sp} and y_{mt} larger than y_{sp}. These discrepancies might be caused by various offsets in each channel of the oscilloscope.

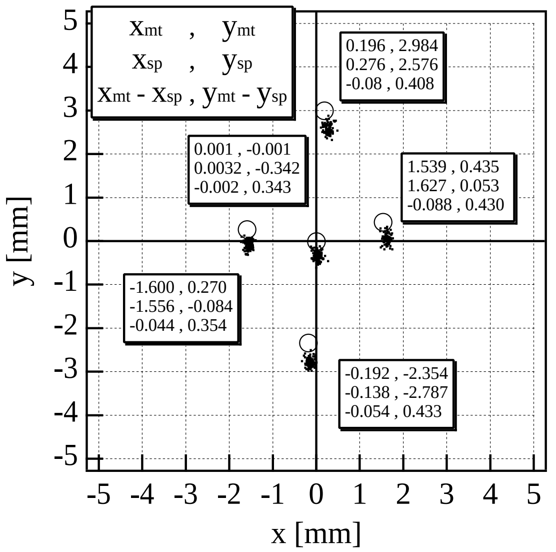

Figure 5 : Beam positions in the Q3 straight section.

In order to estimate the relative accuracy of the single-pass monitor system, the beam position data of BPM3 were taken at a low beam current of less than 5 mA in the single bunch operation. Horizontal and vertical deviations from the average value are shown in Fig. 6. Standard deviations are 0.2 mm for both horizontal and vertical directions.

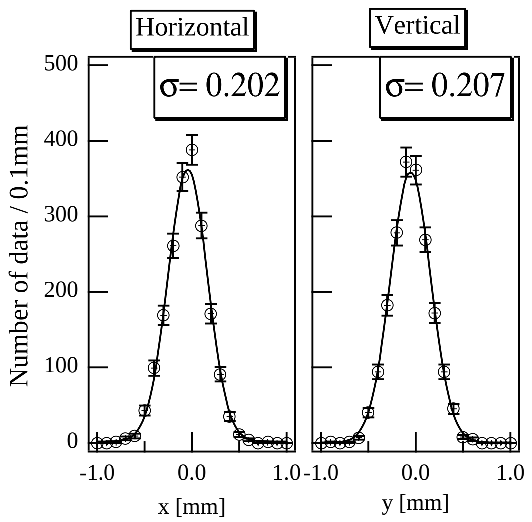

Figure 6 : Relative accuracy of the single-pass monitor system. The total number of data is 1000.

Figure 7 shows the BT-line schematically. Electrons are extracted from ES and injected into SOR-RING with a repetition of 1 Hz. The beam positions measured by single-pass monitors at each BPM are also shown in this figure. The distribution shape of measured positions is not Gaussian and deviation is the order of mm. The cause would be that the beam positions in the BT-line are fluctuating pulse by pulse. But then the single-pass monitor system is very useful to study a relation between beam orbit and injection efficiency.

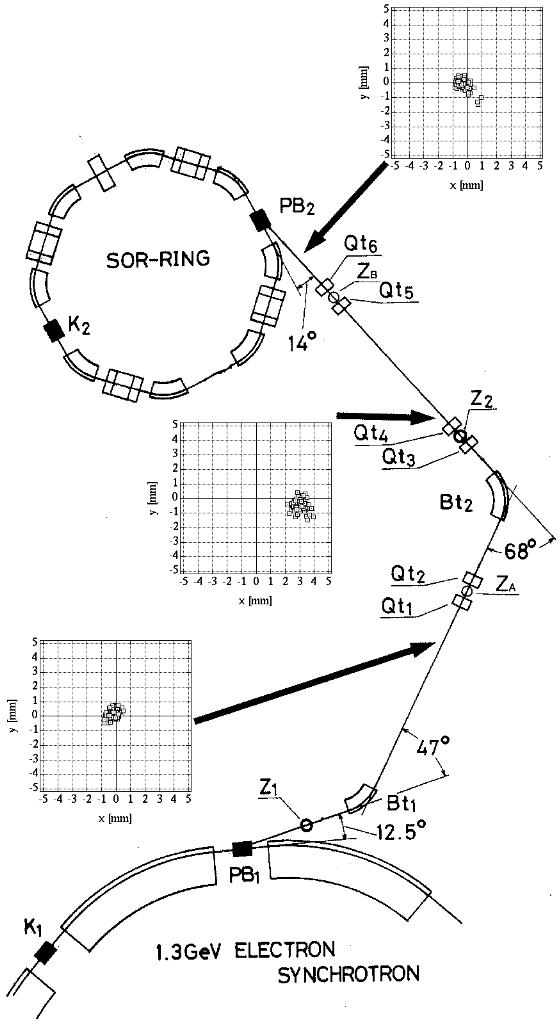

Figure 7 : The schematic view of the BT-line and results of the single-pass monitoring of beam positions.

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