MEASUREMENT OF INJECTION ORBIT USING A SINGLE PASS BPM SYSTEM AT THE PF RING

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Abstract

A single-pass beam-position monitor (BPM) system for the injection beam was developed. The injection orbit during the 1st turn to the 4th turn could be measured with a single injection pulse. The resolution of the measurement was estimated to 0.15 mm for the electron beam. The injection orbit at the usual operation condition was measured and was confirmed to coincide with the design orbit. A trial of the on-axis injection with a dc bump was performed. The orbit correction based on the single-pass measurement was attempted by using the best corrector method.

1 INTRODUCTION

The Photon Factory (PF ring) is a 2.5-GeV electron storage ring dedicated to a synchrotron-radiation source. At present, large reconstruction for a lower emittance lattice is in progress. [1] The reduced emittance is to be achieved by replacing the quadrupoles and sextupoles in the FODO cells. In the normal-cell sections, vacuum ducts are to be replaced by new ones; the number of quadrupole magnets and BPMs will be doubled.

The purpose of the single-pass BPM system is the correction of the injection orbit error in advance of the beam storage at the commissioning of the new lattice. In the low-emittance configuration, there is a weak point of a small dynamic aperture. This small aperture would demand a strict correction of the injection beam orbit in the storage ring. So a COD correction in advance of the beam storage will be inevitable.

In the following sections we report on the signal processing method for the single-pass measurement and some injection orbits measured at various conditions.

2 SIGNAL PROCESSING METHOD

The signal processing scheme to obtain the beam position was shown in figure 1. The outline of the processing was same as that of the previously reported. [2][3] Bipolar bunch signals extracted through button electrodes were recorded in real time using a high-speed waveform digitizer compatible with the VXI bus. The digitizer has four channels with four analog-to-digital converter (ADC). Each channel is an 8-bit ADC which has a maximum sampling rate of $5X10^9$ samples/s and an analog bandwidth of 1 GHz. The duration of the bipolar bunch signals of the injection beam was 3 or 4 ns, so the sampling rate was fast enough to store the waveform. The intensity of the specific button signal was determined as a peak-to-peak amplitude of the bipolar shape, and the beam position was calculated from the peak-height ratios.

The signals from 8 BPMs were combined by the aid of RF power combiners and were measured with one waveform digitizer. The button signals made discrete pulse trains, and were well resolved on the time axis. The record length of the digitizer was $1.5x10^4$ words for each channel. On the other hand the revolution period of the ring was 625 ns. When the signal is digitized at the maximum sampling rate, about 4 turns of bunch signals could be stored in the memory. We used two waveform

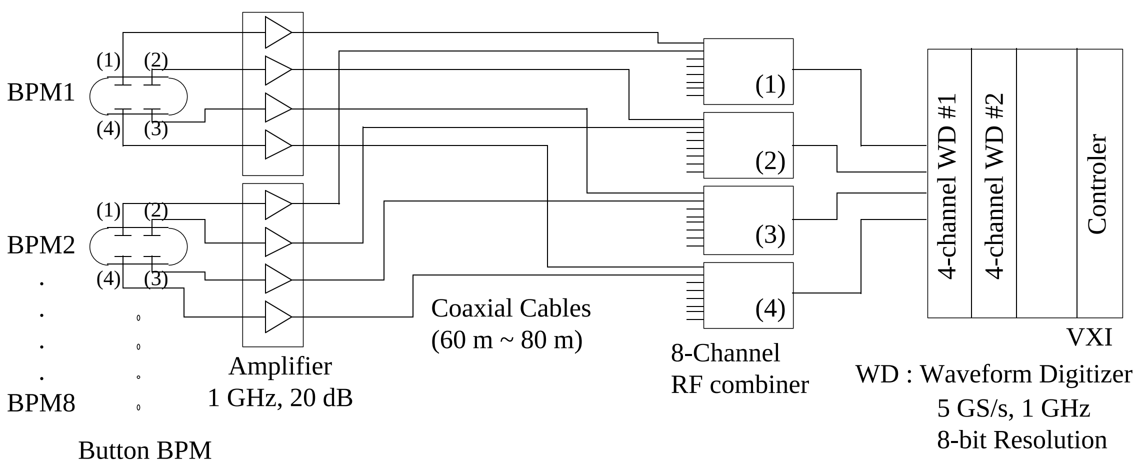

Figure 1 : Signal processing scheme of the single-pass BPM system.

digitizers and the beam position of 16 BPMs could be measured with a single injection pulse.

The dispersion of the measurement was estimated to be 0.6 % as the voltage ratio for the typical electron beam of about $2x10^{-10}$ C supplied from the 2.5 GeV linac injector. As the relative resolution of the beam position, that value corresponded to ΔX = 0.13 mm and ΔY = 0.39 mm according to the conversion factor of the BPM.

3 MEASUREMENT RESULTS

3.1 Injection Orbit of the PF ring

Figure 2 is the measured injection orbit at the usual operation condition of the PF ring. In this report, all the measurements were performed without the RF acceleration power and the average values of 20 injection pulses were plotted. Horizontal axis of each graph is the distance along the beam orbit. The origin of the horizontal axis corresponds to the injection point of the storage ring. And the full scale corresponds to the 4 turns just after the injection.

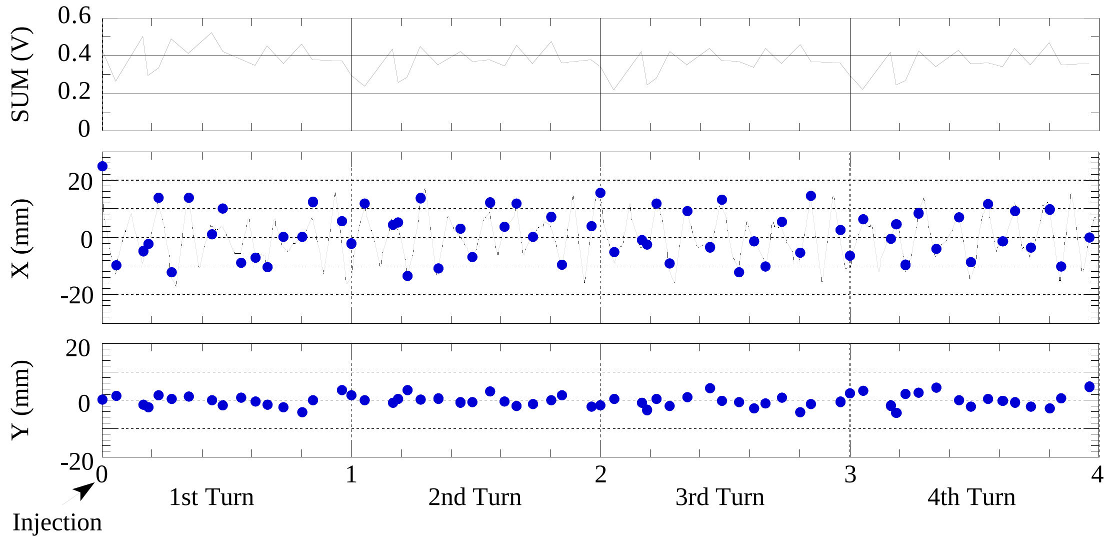

Figure 2 : Measurement of the regular injection orbit.

The topmost graph shows the summation of the four button signals as a measure of beam loss. Because this was the measurement at the normal injection condition, any beam loss was not observed in the four turns. The horizontal (X) and the vertical (Y) beam positions were shown as solid circles in the 2nd and 3rd graphs, respectively. 16 data points were plotted in a single turn. The solid line of the 2nd graph is the injection orbit calculated based on the design parameters of the ring, not including the injection bump. The measurement points well lie on the calculated line except for the first data point. The first point of each turn was the position of the BPM in the kicker bump. The kicker bump falls completely within 4 turns after the injection. The data points of the vertical direction were distributed in the range of 2 or 3 mm. The vertical orbit error should be

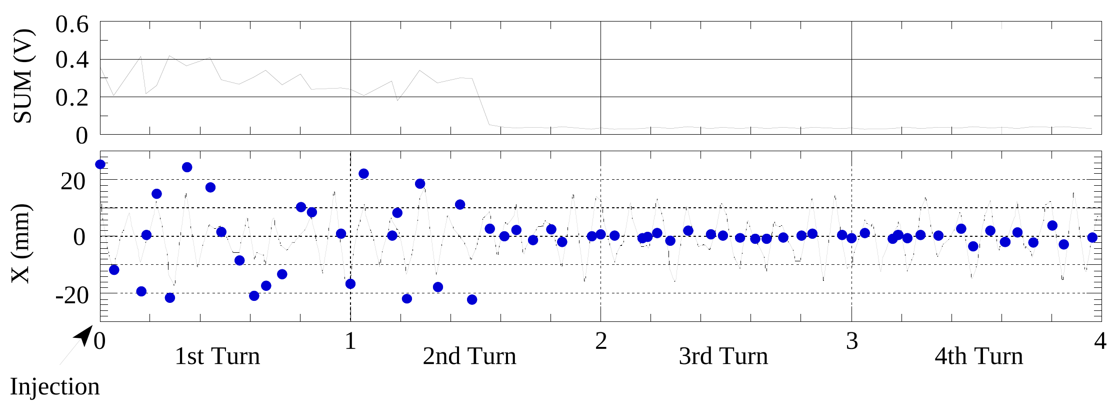

Figure 3 : Example of an irregular injection orbit.

zero ideally. These distribution contained not only the injection orbit errors but also the offsets of the single-pass measurement.

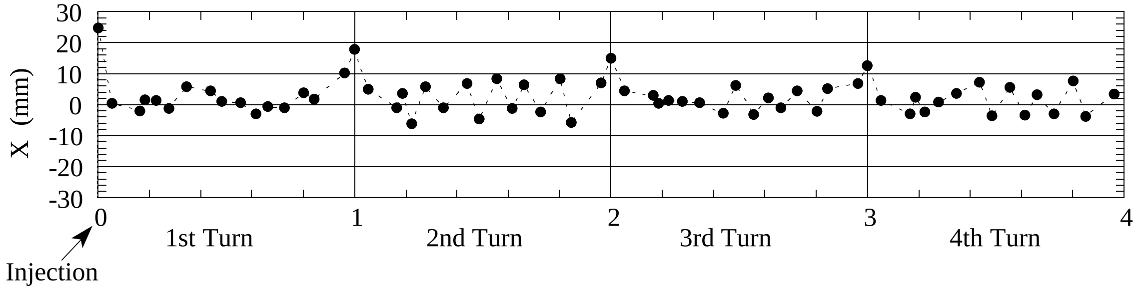

Figure 4 : Trial of the on-axis injection with a DC bump.

An example of the irregular injection orbit is shown in figure 3. One of the horizontal steering magnets located between the second BPM and the third BPM was abnormally excited. At that condition, any beam storage was impossible. The data points after the 3rd BPM oscillate with a large amplitude compared to the normal orbit (the solid line). In the halfway of the second turn, the beam disappeared suddenly. The beam loss point could be fixed between the 9th BPM and 10th BPM. We have the super conducting vertical wiggler at that location, where the horizontal aperture of the ring take a local minimum.

3.2 Trial of on-axis injection

On-axis injection mode was attempted by the aid of a local dc bump at the injection point, which was formed using auxiliary windings of the four bending magnets. The horizontal injection orbit at that condition was shown in figure 4. The betatron oscillation in the first turn was well suppressed within a small value. If the ideal on-axis injection would realized, the beam should be hit the septum wall at the beginning of the second turn, because the present kicker bump dose not yet fall within one revolution period. The setting up of the dc bump should have some errors.

In the low-emittance reconstruction, the kicker magnets are upgraded, and the pulsed bump will complete within a single turn. [4] This will enable the beam storage with the on-axis injection, that would be useful for the commissioning of the new lattice with small dynamic aperture.

3.3 Orbit correction by the best corrector method

Correction of the injection orbit using the best corrector method was attempted. Firstly, all vertical steering magnets were deexcited and the vertical injection orbit was measured. In figure 5, differences from the orbit at the normal condition were plotted as open circles. Then the correction was performed using two steering magnets based on the best corrector method. The solid circles are the beam position after the correction. The orbit error was well reduced in spite of a simple correction method. More sophisticated method, such as the singular value decomposition, would be used for more precise correction.

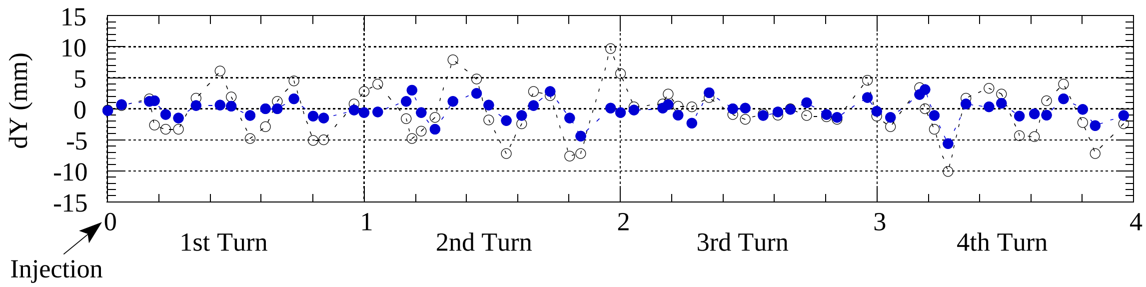

Figure 5 : Correctoin of the injection orbit by the best corrector method using two steering magnets.

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[4] Photon Factory Activity Report #13, A-13, 1995.