COMMISSIONING AND STATUS OF NEW BPM ELECTRONICS FOR COD MEASUREMENT AT THE SPRING-8 STORAGE RING

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Abstract

At SPring-8 storage ring, BPM electronics for closed orbit measurement and a part of its control system were replaced during summer shutdown period of 2006. In the new electronics, one of four beam signals at the frequency of 508.58 MHz, which is the acceleration frequency of the SPring-8, is selected by a multiplexer and down-converted to IF frequency. The IF signal is sampled by 2 MSPS 16-bit ADC and detected with DSP. On the DSP, spurious frequencies are eliminated by digital filter and effective band-width can be changed by averaging. During the commissioning of the new circuit after the summer shutdown, DSP parameters such as number of averaging were decided to measure beam positions at all BPMs in 3 seconds, although the new circuit was designed with a target repetition of a few 10 Hz or around 100 Hz with resolution of sub-microns. With the DSP parameters, position resolution of less than 0.5 micron is achieved. In this paper, we also describe current dependence and gain dependence of the amplifier of the new circuit in addition to the position resolution and measurement repetition.

INTRODUCTION

SPring-8 storage ring is the 3rd generation synchrotron radiation source, which stores electrons at the energy of 8 GeV and is stably operated for 10 years for user-operation. For a synchrotron light source, stability of beam orbit is very important since fluctuation of beam orbit propagate to fluctuation of photon beam and result in a degrade of photon beam flux or effective emittance.

Original electronics for BPM signal processing were in operation since the commissioning of the SPring-8. In the design of the original BPM electronics, following issues were taken into consideration; a function of single pass measurement for tuning of the injection orbit and machine studies, sufficient position resolution even in a very low beam current during machine commissioning and stable operation during user time. But now, SPring-8 is operated very stably in a top-up mode, in which beam current are kept at 100 mA with its stability of 0.1%[1]. Therefore, there was some margin which was to improved performance like position resolution and repetition rate if the function of single pass measurement and position resolution at very low beam current are sacrificed.

ELECTRONICS

There are 288 BPMs for the COD measurement in the ring. These BPMs were processed by 24 sets of the original electronics which were located outside of the accelerator tunnel. We replaced these 24 sets of the original electronics by 24 sets of new electronics.

In the new electronics, amplitude of pick-up signal at the frequency of the acceleration frequency is detected. One of pick-up signals are selected by an RF switch and its frequency band is limited by BPF with the center frequency of 508.58 MHz. After that, the frequency of the signal are converted to 250 kHz and its amplitude is adjusted to meet ADC input range. Then 16-bit ADC digitizes the signal for 1 ms with a sampling rate of 2 MSPS. The digitized signal are sent to DSP board equipped as VME module and its amplitude and beam position are calculated on the board.

In each set of the new circuit, 4 RF switches, band pass filters, amplifiers, mixers, IF amplifiers and ADCs are equipped. Four signals out of 48 pick-up signals are processed simultaneously. A time needed to detect all pick-up signals and calculate all of beam positions is corresponding to the time which takes switching 12 pick-up signals. Thus, it takes 15 ms to detect the amplitude of all BPMs. In the time of 15 ms, settling time of the RF switch are included in addition to the sampling time.

DSP switches 12 signals sequentially.And also, DSP is programmed to repeat the measurement up to 1000 times and calculate average and the number of averaging is set through VME bus. That is, when data are averaged 10 times on the DSP 150 ms is elapsed.

In addition to these issues, there is over-head time such like data transferring time through the network, processing time by control program operated in a control room, and access time to / from data base system, in which all COD data are stored. These over-head time should be kept short.

Since the new BPM electronics detect pick-up voltage by switching sequentially 4 pick-up signals, the BPM electronics must avoid the timing of the beam injection in order not to be affected by change in beam current. For that purpose, a trigger signal which is synchronized to the beam injection trigger with proper delay time is distributed to DSP boards. Time to set trigger signal and time to wait trigger signal are so long compared to the over-head time of control system. We can measure the COD every 2 second even when the number of averaging is 1.

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PERFORMANCE OF THE NEW BPM ELECTRONICS

We have already checked performance of the new electronics using a proto-type electronics[2]. The test measurement was carried out using one set of the proto-type one and signal of a low noise signal generator was regarded as the pick-up signal. We also measured several characteristics of the new electronics in an actual beam operation condition.

Number of Averaging

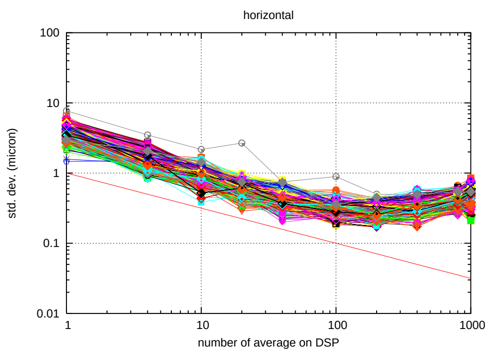

Figure 1: Position resolution of each BPM for horizontal direction measured at averaging number of 1, 4, 10, 20, 40, 100, 200, 400 and 1000 times (line with markers). Red line corresponds to a slope of inverse square root of averaging.

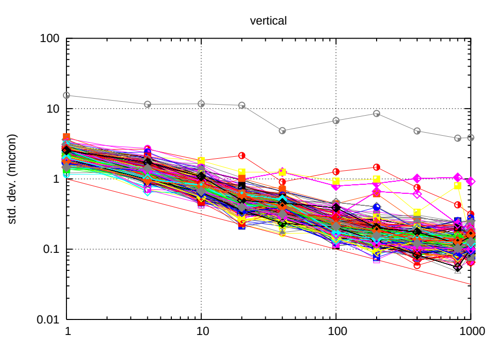

Figure 2: Position resolution for vertical direction. Others are same with Fig. 1. Data of several BPMs deviate from general situation.

At first, we measured position resolution with changing the number of averaging on the DSP. During this measurement, at 100 mA of electron beam was stored in the ring and COD correction was turned off intentionally. That is because new current values are set to steering magnets during the COD measurement, it is very difficult to distinguish the error is caused by imperfection of the BPM electronics or the COD correction. Instead, the beam orbit drifts without the COD correction, and longer time is elapsed for the measurement amount of orbit drift becomes larger. So we measured 20 COD data for each number of averaging. From obtained data root mean square (RMS) for difference of consecutive COD data was calculated and we considered the RMS as a measure of position resolution of the BPM electronics. In Fig. 1 and 2, calculated RMS is shown for horizontal and vertical direction, respectively. In the figures, each line with markers indicates dependence of position resolution of each BPM and a line which is proportional to square root of the number of averaging is also given. The slope of data for vertical direction agree with that of square root of the number of averaging except for several BPMs. That situation is true for horizontal direction at smaller number of averaging than 100, however, at more than 100 times averaging position resolution deviates from the line.

The reason why the position resolution for horizontal direction deviates at larger number of averaging is not understood yet. This behavior might be explained by a difference in frequency component of orbit fluctuation between horizontal and vertical directions, since this BPM electronics measures beam position by switching 4 pick-up signal of one BPM. We adopted 100 times of averaging as a standard parameter for COD measurement.

Reproducibility

In the previous measurement, position resolution at a fixed number of averaging seemed to have distribution. We measured COD 450 times at 100 times averaging in order to estimate contribution from position resolution of the electronics itself. The condition of the beam operation during the measurement was same with the previous one.

In Fig. 3, RMS which was calculated in the same way with Fig. 1 and Fig. 2 are plotted as a function of the BPM serial number. There are two large peaks for vertical RMS data. These are corresponding to data which largely deviated from other data in Fig. 2. Although these two data does not agree quantitatively, these BPMs are obviously abnormal.

As we can see in the figure, there seems to be periodic pattern for horizontal and vertical directions. These periodic pattern reflects the modulation due to betatron function[3]. As discussed in detail in ref [3], the resolution contribution from the electronics itself was estimated as 0.1 μm or less.

Gain Dependence

In addition to the position resolution and repetition of measurement, beam position dependence on amplifier gain is not acceptable from a point of view of stable beam orbit in various operation condition. We measured 2 COD when the gain of the amplifiers are changed. Since 30 minutes were taken to measure the 2 CODs. around 10 microns of drift in beam orbit could be supposed. So we compared difference of 2 CODs which reflects gain dependence of the BPM electronics with difference COD between before

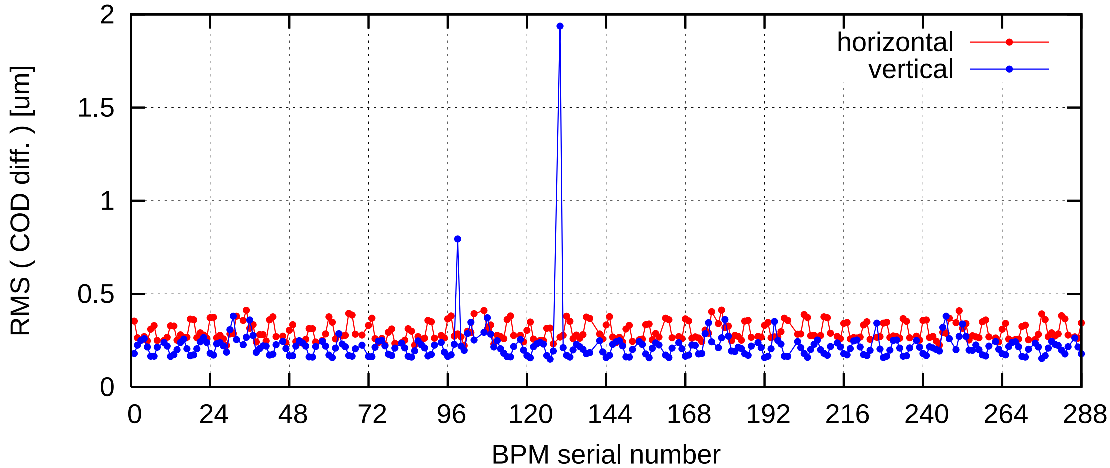

Figure 3: Reproducibility of BPM electronics.

and after the measurement, as shown in Fig. 4. Pattern of 2 difference CODs are similar each other. These facts suggest that the gain dependence of the BPM electronics is comparable with or smaller than the orbit drift during the measurement. The dependence of the electronics can be considered to be 5 micron or less.

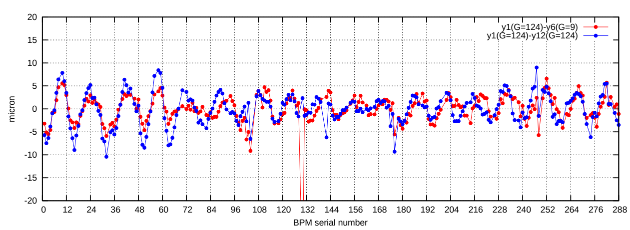

Figure 4: Difference of measured orbit in vertical plane.

Current Dependence

Since SPring-8 is usually operated in top-up operation in which beam current is stabilized within 0.1 %, this parameter does not play an important role for user operation. But in cases of the machine tuning, tuning of insertion devices and commissioning of new beam lines, there is possibility that the storage ring is operated in a low beam current. We measured COD for vertical direction with changing the beam current. In Fig. 5, measured data at least 10 mA are plotted and compared as difference COD from that at 99 mA. As is shown in Fig. 5, all difference orbit have similar pattern, which were shown at gain dependence measurement, except for several BPMs. Although two of them (BPM #99 and #130) are corresponding to BPMs whose reproducibility are so large, we have no idea for others (BPM #13, #39 and #154). Besides, current dependence for BPM from #85 to #96 were relatively large compared with others. This origin might be the electronics because these 12 BPMs are processed by one set of electronics. As a whole, current dependence of most of BPMs are 5 microns or less.

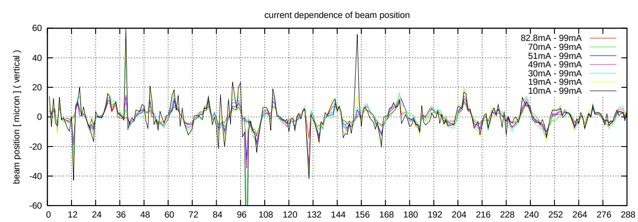

Figure 5: Current dependence.

SUMMARY

A BPM electronics for a closed orbit was replaced in summer 2006. For a target of sub-microns resolution and faster repetition rate. Performance of the electronics were evaluated under the actual machine operation and using beam. A few sub-microns of position resolution with a repetition of 4 seconds was achieved. In addition, gain of amplifier dependence and current dependence were also evaluated as 5 μm or less for both parameters. Although several BPMs showed abnormal behavior, most of BPMs behaved well. Estimation of resolution of the BPM electronics itself combined with beam optics parameters would be useful method as a diagnostics of the BPM system.

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