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FAST BEAM ORBIT MONITORING SYSTEM DURING BEAM ABORT AT THE SPRING-8 STORAGE RING *

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Abstract

In the SPring-8 storage ring, a beam abort event due to an orbit shift has occurred as a rare event. In most cases, we could find any trouble in accelerator devices as a source of the beam orbit shift: e.g. failure of a magnet power supply. However, in a rare case, we could not find any evidence after the beam abort. Sources of such a beam abort considered to be arisen by a sudden change of some magnet power supplies like a spike signal. In order to identify the source of such an event, we have developed a system which observe beam orbit along the storage ring during beam abort. The system was realized by modification of digital part of the existing COD measurement system. Every 1 ms, the system measures beam positions at all BPMs with the position resolution of 1 micron or less and records on-board ring-buffer. This system enabled us to identify the source when beam abort due to orbit shift with a time constant of longer than a few mill-seconds. Furthermore, this system is applicable to survey sources of beam orbit fluctuation during stable operation. In this proceeding, we describe the system, beam orbit data during beam abort and source analysis.

INTRODUCTION

SPring-8 storage ring is the 3rd generation synchrotron radiation source, which stores 8-GeV electrons with a beam current of 100 mA and is stably operated for more than 15 years for user-operation. There are 48 cells and 288 BPMs in the ring. For the 3rd generation synchrotron light source, in which dedicated insertion devices are installed, a stability of beam orbit is quite important issue since fluctuations of beam orbit propagate to fluctuation of a photon beam axis and result in a reduction in a photon beam flux or an effective emittance.

A closed orbit scheme automatically corrects the orbit to that of reference with a fixed period in order to correct a slow orbit drift. Besides the orbit correction, photon beam from the insertion devices are so intense that vacuum components would be damaged if the electron orbit largely shifted and hit the beam pipe. In order to avoid such a trouble, an interlock system is equipped and in operation during the user-operation. The interlock system turns off the RF acceleration signals within 0.5 ms and leads to beam abort within 0.5 ms when the beam orbits at insertion devices exceed pre-defined window.

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In 2012 and 2013, beam abort events due to the interlock system have occurred several times as a rare event. Though in most cases we found trouble in accelerator devices as the source of the beam orbit shift, sometimes we could not find any evidence after the beam abort when the source of the orbit shift was restored by itself in a short time. In order to identify the sources of such aborts, we have developed a system which observe beam orbit shift along the storage ring just before the beam abort. The system was realized by modification of the digital part of the existing COD measurement system which is in operation since 2008.

MODIFIED COD SYSTEM

In Fig. 1, a block diagram of one of existing BPM electronics racks is shown [1]. We have 24-sets of BPM racks along the 1.4-km ring. In the system, a multiplexing method is employed and signals of 12 BPMs are switched sequentially.

An outline of the system is as follows; One of 12 BPM signals are switched sequentially and detected by ADC during COD measurement. The switches are controlled by a digital signal processor (DSP: Texas-Instruments C6713). So switching duration is programmable on the DSP.

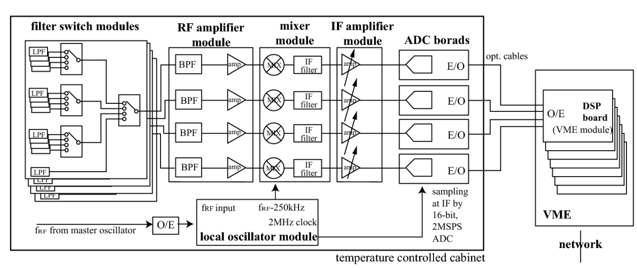

Figure 1: A block diagram of existing BPM electronics.

There are 48 DSPs in the ring and they operate roughly in synchronous and parallel. Before the modification, it took about 15ms to switch every BPM signals and to process all BPMs' data. This time is too long to obtain the beam orbit just before the beam abort. So we modified the switching time from 1ms to 70us. Then the all bpm positions are processed every 1ms and recorded to a ring-buffer on the DSP board.

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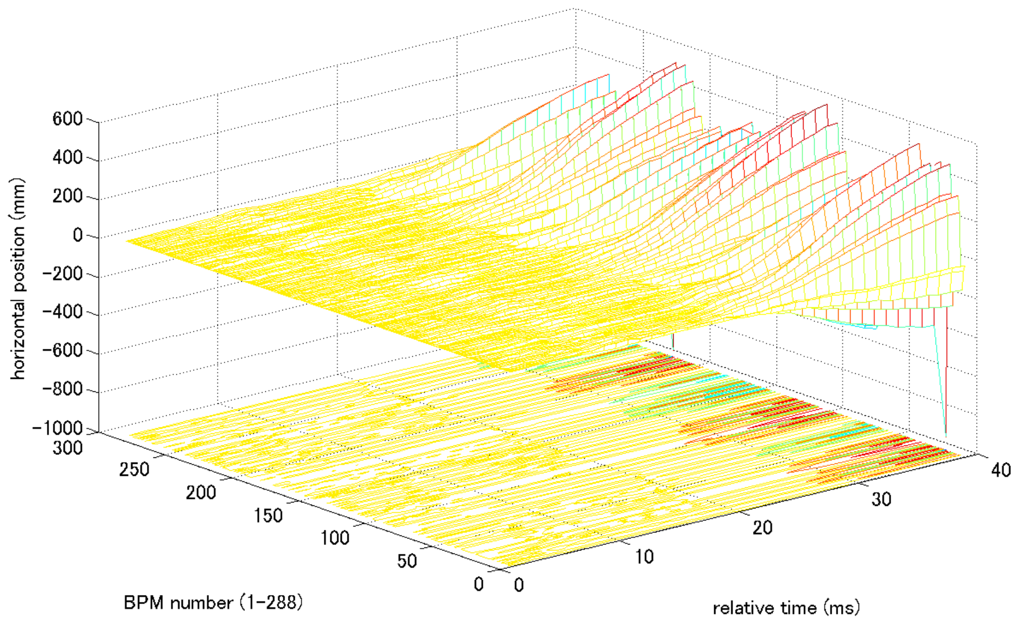

Figure 2 :Horizontal closed orbit grew more than 500 μm in 10 ms and the beam was aborted by the interlock system. By the modification, closed orbit data is stored every 1 ms and used for analysis of beam orbit shift.

Moreover, the DSP became idle state after the COD measurement was finished. We modified the DSP sequence always calculate beam positions every 1 ms. And only when the DSP detects voltage drop of BPM sum signal lower than a pre-defined threshold and stops ring-buffer update. After the DSP stopped, from analysis of the ring-buffer data we can identify the source of beam orbit shift. Fig.2 shows orbit shift obtained by the

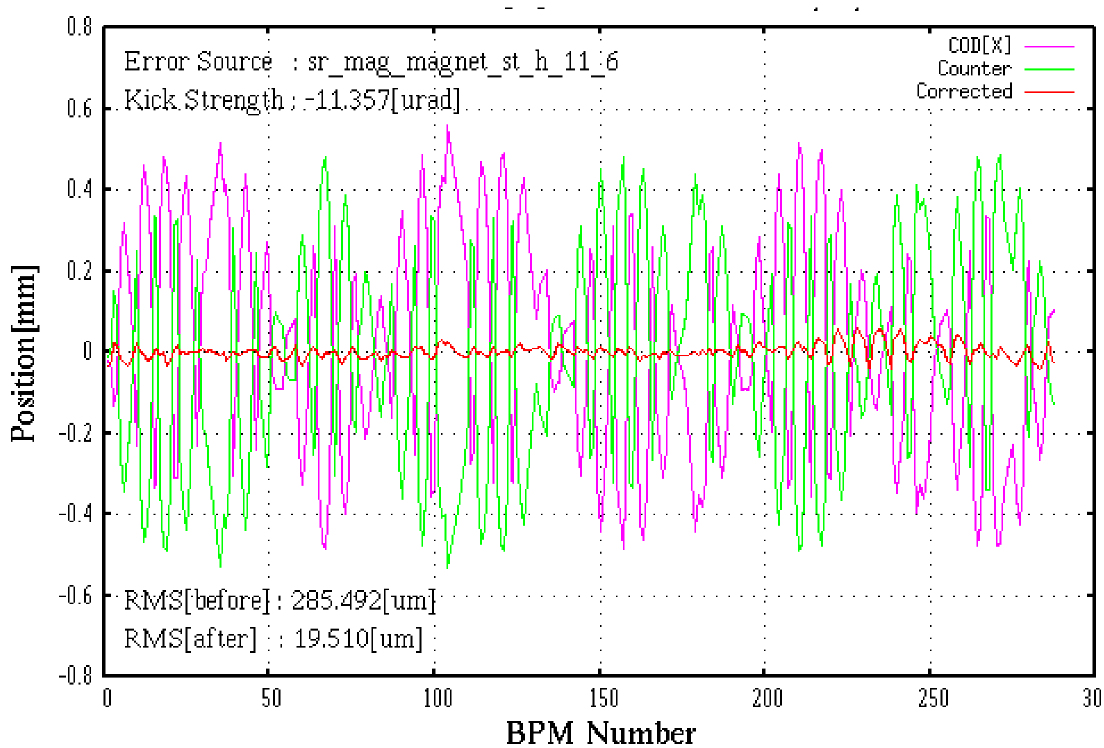

Figure 3 :Horizontal closed orbit grew more than 500 μm in 10 ms and the beam was aborted by the interlock system. By the modification, closed orbit data is stored every 1 ms and used for analysis of beam orbit shift.

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modified system. In this case the beam was aborted by the interlock system. As shown in the figure, a particular COD pattern grew in 10 ms and the beam is lost. Fig.3 shows analysis of closed orbit correction on just before

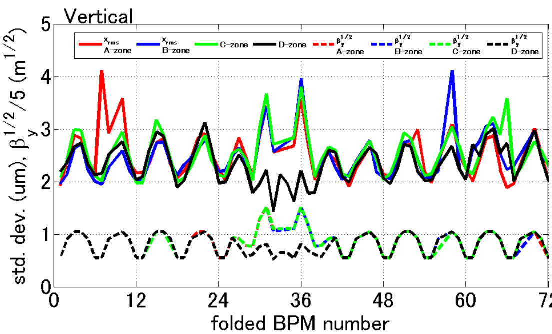

Figure 4: Standard deviation of COD data and square root of betatron function for vertical direction.

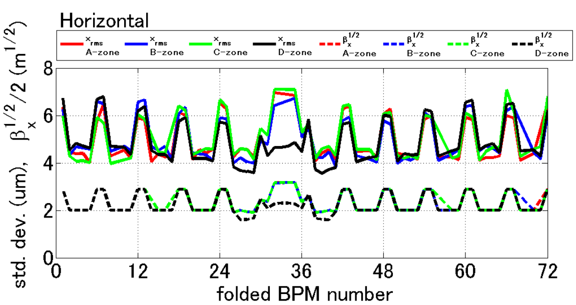

Figure 5: Standard deviation of COD data and square root of betatron function for horizontal direction.

the beam was lost. In this case, a steering magnet for the horizontal plane was expected as the source of beam orbit shift.

RESOLUTION EVALUATION

This system is applicable to survey sources of beam orbit fluctuations during stable operation. Using software trigger to stop ring-buffer update, data on the ring-buffer of all DSPs are synchronized within 1 ms. From data obtained software trigger, standard deviation of each BPM are analyzed as follows; standard deviation have similar structure with the betatron function of the ring, so standard deviation is a result of convolution of BPM electronics itself and beam orbit fluctuation as shown in Fig. 4 and 5. Using the betatron function we can estimate BPM electronics resolution based on statistics. These relations can be described as

$$\sigma_x^2 = \varepsilon_x\beta_x + \eta^2(\Delta p/p)^2 + \sigma_{sys,x}^2 ,$$
$$\sigma_y^2 = \varepsilon_y\beta_y + \sigma_{sys,y}^2 ,$$

where σ_x and σ_y are standard deviation of each BPMs for horizontal and vertical direction, ε_x and ε_y are amplitude function of orbit fluctuation, β_x and β_y are betatron function, η is dispertion function, $\sigma_{sys,x}$ and $\sigma_{sys,y}$ are resolution of BPM electronics. From this analysis, we obtained $\sigma_{sys,x} = 1.1$ µm, $\sigma_{sys,y} = 1.7$ µm, respectively. The difference of factor 1.5 between both planes comes from position sensitivity for horizontal and vertical directions.

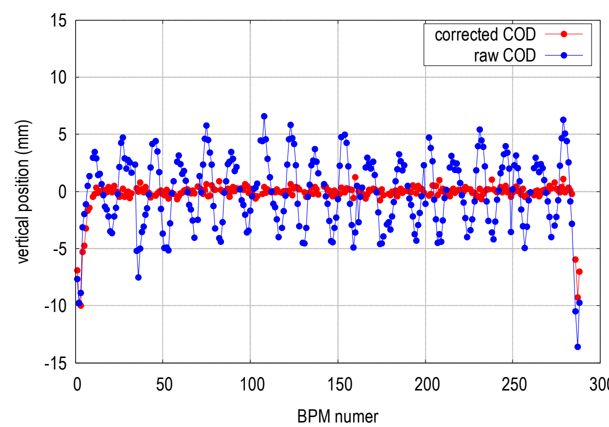

Figure 6: Beam orbit due to a abort magnet of measured (blue) and that after simulation of cod correction assuming one corrector was carried out (red).

REFERENCES

[1] T. Fujitaet al., “Upgrade if Signal Processing of BPM System at the SPring-8 Storage Ring”, EPAC 2006, pp. 1130-1132, (2006)