MOVEMENT OF BPMS DUE TO THERMAL STRESS IN KEKB

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Abstract

Movements of Beam Position Monitors due to thermal stress in high beam current operation were observed in KEKB. For high luminosity operation of KEKB, the beam current as high as 1.7 A is accumulated in the positron ring and a precise control of the beam orbit based on the BPM system is required. Though every BPM chamber is fixed firmly on a support of each quadrupole magnet, the BPM chamber moves several hundred microns from the setting position depending on the beam current due to heating of beam pipe by strong synchrotron light irradiation. Such movement introduces an unavoidable offset error in the BPM measurement, and is a serious problem not only for KEKB but also for the next generation of B-factory operated with extremely high beam current. We report the measurement of the movement by gap detectors and an attempt to correct the BPM offset error in real-time operation.

INTRODUCTION

The KEK B-factory (KEKB) is an energy-asymmetric electron-positron double ring collider at KEK. The stored beam currents of KEKB achieved to 1.7 A in the low energy ring (LER) and 1.28 A in the high energy ring (HER), and the peak luminosity was recorded 1.53 x 10^{34} cm^2 s^{-1} which is highest value in the world. In order to maintain a stable collision condition of the KEKB, the beam position monitor (BPM) system has been regularly operating to measure the beam positions with high resolution and a sampling period of about four seconds to correct the closed orbit distortion (COD) [1]. The HER and LER are equipped with 443 and 454 BPM pickups, respectively. In the last spring, we have found that some discontinuous points have always appeared on the COD plots after of beam abort as shown in Fig. 1.

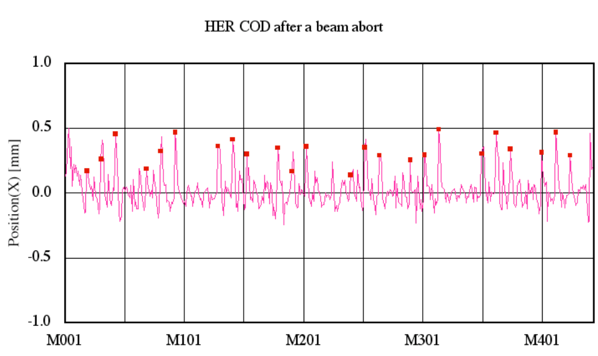

Figure 1: HER horizontal COD after beam abort. Red points are readings of BPMs located just down stream at the twin bending magnets.

Almost all BPM pickups are firmly and precisely supported on the table installed at the end of a quadrupole magnet (QM). The table made of aluminium moulding was designed to withstand against strong force such as a few hundred kilograms. We suspected that the movement of BPM caused these discontinuities, and we have investigated the problem thoroughly.

In this paper, we report the result of the investigation concerning the cause for the movements of BPM before and after beam abort and some measures against the movements.

MEASUREMENT FOR THE BPM MOVING

We have attached two gap detectors to a QM to measure the horizontal and vertical movements of a BPM as shown in Fig.2. For the measurement, capacitance type gap detector was employed to avoid the radiation damage and the magnetic field because the measurement place is under the radiation and the leakage magnetic field. The gap detector was used to measure a gap from the capacitance between the detector and the measuring object, which has excellent performance as followings; the gap rating is 0 ~ 2.0 mm, the resolution is 1μm and the non-linearity is 0.25 % / 2 mm.

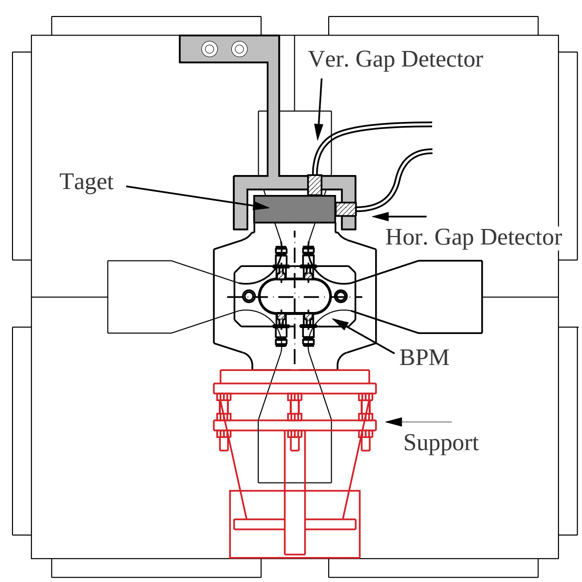

Figure 2: Gap detectors attached to QM

Fig. 3 shows the movements of the BPM measured by the gap detector. After beam abort in HER, the BPM pickup moved about 0.5 mm horizontally, and did not move almost vertically. Since beam was restored in the

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HER, the BPM pickup was moving continually to opposite direction, and returned to the original position after about 10 minutes. Fig. 4 shows the horizontal and vertical beam positions measured by the BPM for the same period as Fig. 3. The horizontal beam position also changed in the contrary direction. Close agreement between the movement of the BPM and the change of the measured beam position was obtained. These measurements indicate that the discontinuous beam position after the beam abort was induced by the movement of the BPM.

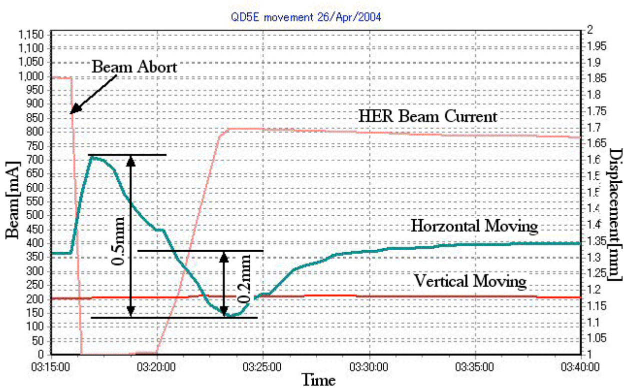

Figure 3: Readings of gap detectors after a beam abort.

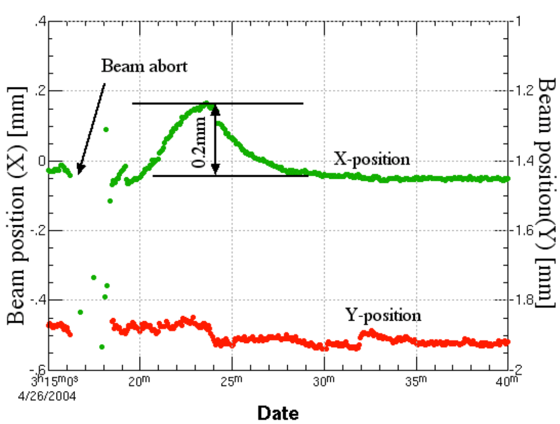

Figure 4: Change of BPM readings after a beam abort.

MOVEMENT OF BENDING MAGNET CHAMBERS

The movement of the BPM is enhanced at 24 BPMs located just downstream of twin bending magnets in the HER (Fig. 5). The corresponding BPM data are indicated in Fig. 1 by red points. The thermal deformation of beam chambers in these magnets is expected to large because vacuum chambers near these BPMs are irradiated by stronger synchrotron light than those in other location of HER. To measure the beam chamber movement against the bending magnet, the gap detector attached to the bending magnet observed very large movement of the beam chamber in the bending magnet before and after beam abort as shown in Fig. 6, where about 1.4 mm movement is observed. The beam chamber is deformed by big change of the thermal stress due to rapid drop of temperature at beam abort. Although we have vacuum bellows between the bending chamber and the BPM, big stress by the big amount of the beam chamber deformation moves the BPM and causes the errors in the beam orbit measurements as shown in Fig. 1. To decrease BPM movement, these 24 BPMs have been fixed more firmly with additional upper support on each QM as shown in Fig. 7. With this reinforcement of the BPM support, the horizontal BPM movement is decreased within a few ten μm.

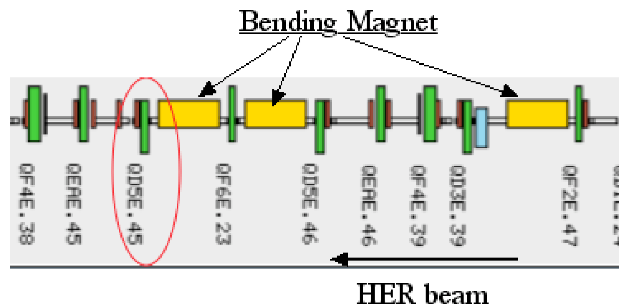

Figure 5: BPM located just down stream at the twin bending magnets.

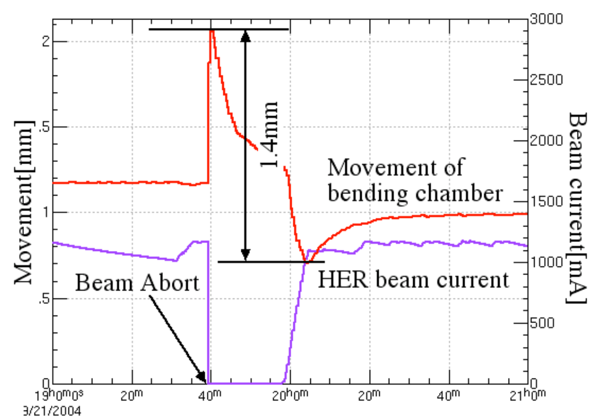

Figure 6: Gap detector measured displacement of bending chamber before and after beam abort in HER

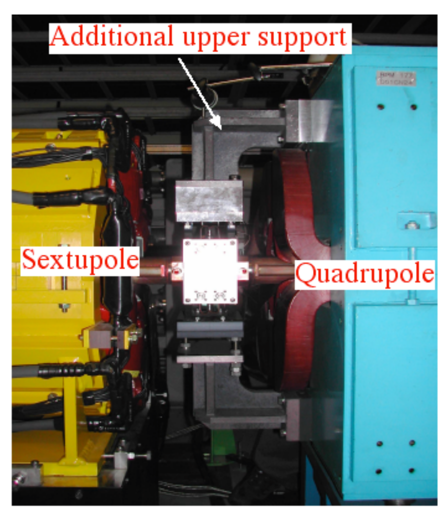

Figure 7: Additional upper support was fixed on a QM

MOVEMENT OF BPMS NEAR LER LOCAL CHROMATICITY CORRECTION SECTION

We also attached gap detectors to four sextupole magnets (SLs) in the LER local chromaticity correction section to measure the BPM displacement as shown in Fig. 8. The measured BPM movements against SLs have been compensated in the beam position data to stabilize the beam orbit relative to the sextupole centers. These compensations are very effective to stabilize the machine operation because the orbit error in the chromaticity correction section is very sensitive to the betatron tune.

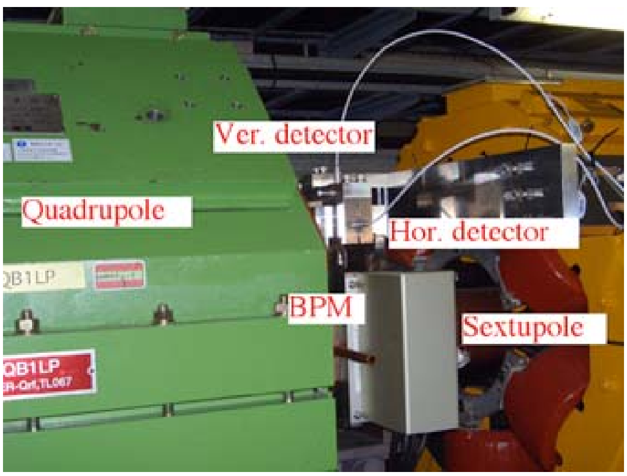

Figure 8: Gap detector attached to a sextupole magnet

The vertical beta functions β_y at the SLs are as high as about 400m to correct the chromaticity efficiently. These large beta functions produce substantial tune change if the orbit at the SLs changes horizontally. As the closed orbit is corrected every 20 sec using BPM readings, if the position of the BPMs adjacent to the SLs is moved, the orbit at SLs also deviates by roughly a same amount of the displacement of the BPMs and consequently the vertical tune changes. In order to check the measurement of the displacement, the vertical betatron tune change $\Delta\nu_y$ was calculated from the data of the gap detectors as

$$\Delta\nu_y = \frac{1}{4\pi}\sum_i \beta_{y,i}\cdot K_{2,i}\cdot \Delta x_i, \qquad (1)$$

where $K_2\,(=B''l/B\rho)$ is the strength of a SL and Δx is the reading of the gap detector at a BPM adjacent to a SL. Suffix i is an identifier of the SLs.

Fig. 9 shows the tune change calculated by (1) and the measured vertical tune change as a function of time. The calculated tune change agrees well with the measured tune change. Small difference between the calculated and measured tune change may be caused by the displacement of BPM adjacent to other sextupole magnets than SLs.

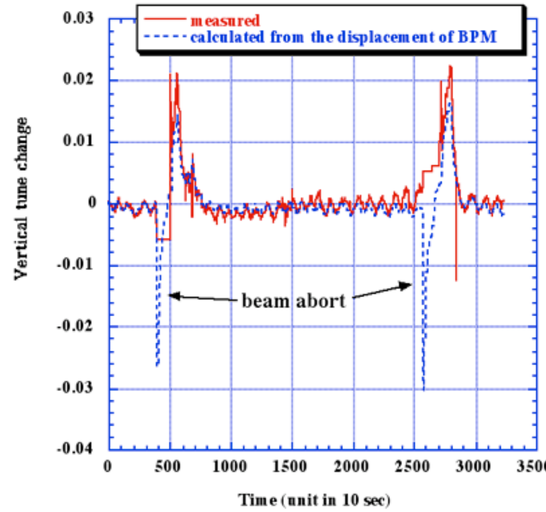

Figure 9: Vertical tune change calculated from the reading of the gap detectors and measured vertical tune change.

DEVELOPMENT OF NEW GAP DETECTOR

Commercial gap detectors employed to measure the movement of BPMs in KEKB are too expense. In our future plan, Super-KEKB will need a lot of detectors for more high current operation. We started development of the inexpensive gap detector with requirements as follows;

- Free from magnetic field.
- Radiation resistance.
- Resolution less than 1μm.
- Gap rating over 2mm.

SUMMARY

Gap detector measured the movement of the BPM pickup at HER. The BPM pickups were moved a several hundred μm from the setting position due to the heating up of beam chamber. The 24 BPMs, located just downstream at the twin bends, have been fixed more firmly with additional upper support on each QM. Movement of BPM pickups at LER local chromaticity correction section have been also measured and compensated in the measured beam position data.

Compensation of BPM movement is important technique for the operation of high current machine such as super-KEKB. We will attach gap detectors to all BPMs of super-KEKB.

REFERENCES

[1] M.Arinaga, et al, “KEKB Beam Instrumentation Systems”, NIM, A499 (2003) 100-137