SPECIAL BEAM POSITION MONITOR WITH 8-BUTTON ELECTRODES FOR THE KEKB INTERACTION REGION

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Abstract

To maintain the optimum collision condition of the two beams, two special BPMs with 8-button electrodes, called OCTOPOS, were installed inside the super-conducting quadrupole magnets (QCSs) at the interaction region (IR) of KEKB. We have commissioned the OCTOPOS BPMs for simultaneous measurements of both the electron and positron beam positions from their composite signal. A collision orbital feedback using OCTOPOS has been put into practical application since last November. The position of each beam is separable by analyzing the non-linearity of the pickup sensitivity from the signal amplitudes of the eight button electrodes. This report describes the characterization of the OCTOPOS and its performance.

1 INTRODUCTION

KEKB is an electron-positron collider which consists of two rings: a high-energy ring (HER) of 8-GeV and a low-energy ring (LER) of 3.5-GeV. In a two-ring collider like KEKB, an orbit adjustment at the interaction point (IP) is important for maintaining stable beam collisions. In the neighbourhood of the IP, the two beams pass through common beam pipes and BPMs because the orbits are not sufficiently separated. It is impossible to measure beam signals with a very small bunch spacing of less than 1 nsec in the time domain via fast switch. A finite orbit separation method [1] between the two beams was proposed to detect the beam positions of each ring with a common BPM having many electrodes. To measure the beam orbits at the IR by this method, two special BPMs with 8 electrodes were installed on both sides of the IP, as shown in Figure 1. The output signal was detected with a narrow band detector, the same electronics employed for measuring the closed orbit at KEKB [2].

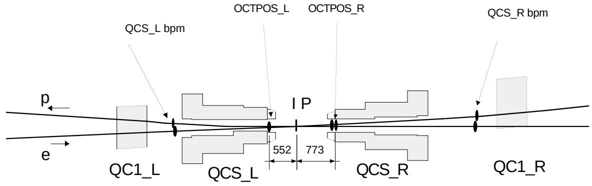

Figure 1: Schematic view of the KEKB IR

2 BPM HEADS AT IR

Near the IP, the orbit separation is so small that both beams pass through a common chamber and OCTOPOS. Due to space problems inside the QCSs, we could not adopt directional couplers to measure the positions of the two beams separately. We elected to install two special BPM heads each having eight button electrodes at the front end of the QCSs around the IP. Since the OCTOPOS is placed inside the inner bore of the QCS cryostat, the button electrode adopted was an SMA-type connector. In order to improve the contact of the connector, we changed the female structure of the central rod into a male one last summer.

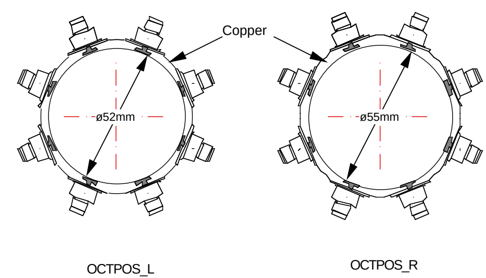

Figure 2: Sections of the OCTOPOS head

Eight button electrodes were directly welded onto a copper block with a round shape, as shown in Figure 2. They were set directly at both ends of the IP chamber. The OCTOPOS head was made from non-magnetic material because of proximity to the strong magnetic fields of the Belle solenoid coil and the QCS.

Four normal BPMs with 4 electrodes at the exit of the QCS were also incorporated into this IR BPM system as a back-up to the OCTOPOS BPMs. These BPM chambers were designated as QCSL or a QCSR chambers, which were attached to the neighbouring chambers by flanges. These BPMs are not supported firmly at the end of a magnet; as a result, heating of the vacuum chamber causes mechanical movement of the BPMs. These movements are measured by two displacement meters, and fluctuate with the intensity of the stored beam. At present, these movements are compensated in the beam position data by these displacement measurements.

3 MEASUREMENT SYSTEM

A schematic layout of the control system for OCTOPOS is shown in Figure 3. The eight electrode signals of OCTOPOS are read out by the same electronics employed in the closed orbit BPM system -- that is, a multiplexer and a signal processor module [2]. An IOC for OCTOPOS has been installed especially for fast measurement of the position as part of the collision feedback system at the IP. The signal processor detects the combined output signal of both beams, and the pickup frequency is 1018MHz, twice the accelerating RF frequency. The signal processor for the OCTOPOS BPMs perform an FFT analysis of the signals at 64 sampling points, and an average of 16 measurements are ultimately processed by the IOC controller.

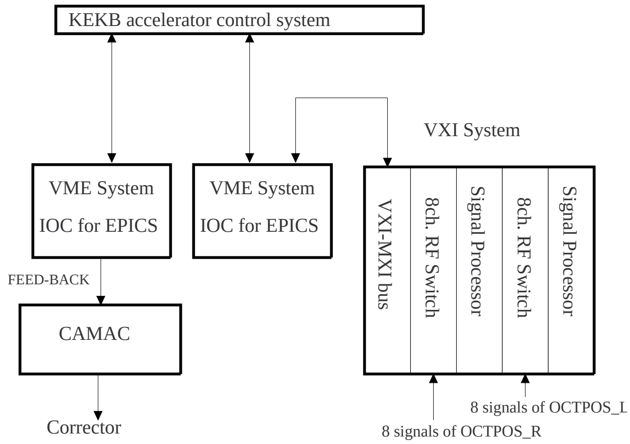

Figure 3: Schematic layout of control system for the OCTOPOS.

4 PROCCESSING METHOD

The signal process is done by non linear fitting analysis based on finite orbit separation method[1]. The output signal can be represented with a phaser, and the peak value (Vi) of the phaser is measured by the detector, as follow:

$$V_i = g_i\sqrt{\left(Q_eF_i(X_e,Y_e)\right)^2 + \left(Q_pF_i(X_p,Y_p)\right)^2 + 2Q_eQ_pF_i(X_e,Y_e)F_i(X_p,Y_p)\cos\theta},$$

where *g*, *F(X,Y)* and θ are the gain, the response function of the i-th electrode and the phase difference between two beams. (Qe, X_e, Y_e), (Q_p, X_p, Y_p) are the charge and position for positron and electron beams.

The response function was calculated from the BPM geometry. The phase difference was defined to be constant and can be calculated from the distance between the OCTOPOS and the IP. Therefore, when the eight parameters (Vi, i=1,2,,,8) are known, the remaining six unknown parameters can be obtained by a nonlinear fitting, because the unknown parameters (Q_e, X_e, Y_e, Q_p, X_p, Y_p) are fewer than the number of measured data points (8 outputs from the electrodes).

In advance, the gains were calibrated with beam based position mapping data under the condition of single-beam operation (a electron or positron beam)[3]. The gain coefficients of each electrode are shown in Table 1.

5 IMPROVEMENT OF MEASUREMENT

The gain coefficient of each electrode and the phase difference of the two beam at the OCTOPOS heads are important parameters for solving for the beam positions from the 8 output signals. We have obtained these parameters as follows.

Two beams position were measured by OCTOPOS under varying beam currents during physics run at KEKB.

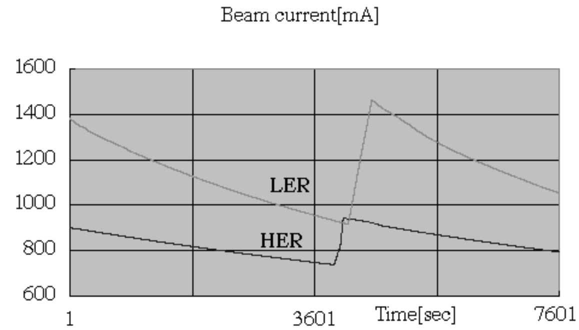

Figure 4: Beam currents history at physics run.

First, the gain coefficients were set to 1.0 for every electrode, that is the gains were not corrected. The position error changes with the ratio of electron and positron beam currents as shown in Figure 5-a. The horizontal position of the electron beam increased remarkably. The beam positions were calculated again by the same process after making a correction with the gain coefficients in Table 1.

Table 1: Gain coefficients for each electrode

Electrode #	OCTPOS-L	OCTPOS-R
1	1.0000	1.0000
2	1.0387	0.9912
3	1.4870	1.0343
4	0.9701	0.8836
5	1.0484	1.0057
6	1.0599	1.0673
7	0.9838	0.9582
8	0.9636	0.9798

The beam current dependence of the electron beam position has decreased considerably as shown in Figure 5-b. The position error is 100 μm(X) and -20μm(Y) when the ratio changed from –1.02 to –0.64. We have assumed the phase difference to be a constant value, such as π/4, calculated from the designed position of the BPM. But the actual phase difference may differ from the constant value, because the OCTOPOS has been installed within a tolerance of a few mm, and also due to the synchronized phase fluctuation by parasitic loss in the RF cavity. Since this finite-orbit separation method is sensitive to the phase difference, simulation studies of the phase error show that the major effect is to cause movement of the position reading in the horizontal direction, which is more harmful in the HER than in the LER. For this reason, we tried to calculate the positions again to correct for this phase difference. The phase difference due to longitudinal setting error of OCTOPOS was found through trial and error the values were –2 degree (OCTOPOS-R) and +2 degree (OCTOPOS-L), and RF synchronized phase shifts were given by an approximate equation. The result obtained in the way described above is shown in Figure 5-c. The slope of the X-position has become almost zero but the slope of the Y-position is the same as in Figure 5-b.

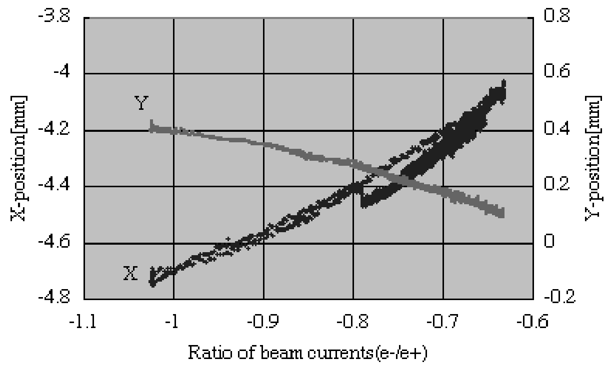

Figure 5-a: Variation of electron beam positions without gain correction at OCTOPOS-L

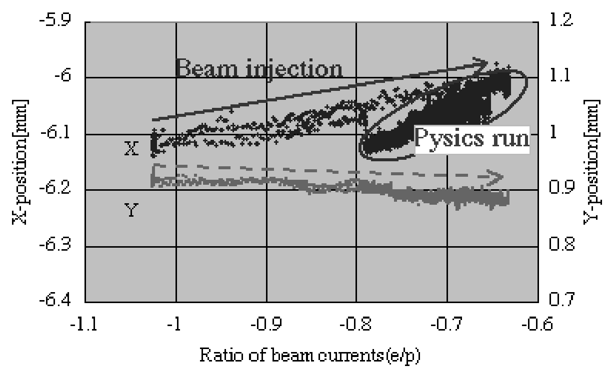

Figure 5-b: Variation of electron beam positions after correction of gain at OCTOPOS-L

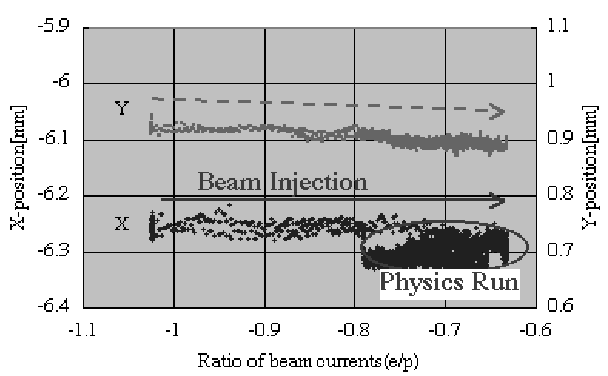

Figure 5-c: Variation of electron beam positions after correction of gains and phase difference between electron and positron bunch at OCTOPOS-L.

6 RELIABILITY

We have tested the correlation among these separated positions of OCTOPOS with some neighbouring BPMs (QCSRe, QCSLe, QCSRp, QCSLp, etc.). For the analysis of the correlation by actual beam positions, we measured all beam positions under single-kick orbits at different source points. A three-BPM correlation analysis based on the lattice model of the KEKB ring estimated that a difference of about 10 μm exists in the positions of the OCTPOS between the single-beam case and the two-beam case, as shown in the upper and lower parts of Figure 6. Incidentally, the other correlation errors of the IR are very large (about 0.1mm), perhaps related to the uncertainties of the values of the model optics.

The global optical function was corrected by using OCTOPOS under two-beam operation this summer [4]. There is no notable difference in the result of the correction between two-beam and single-beam operation.

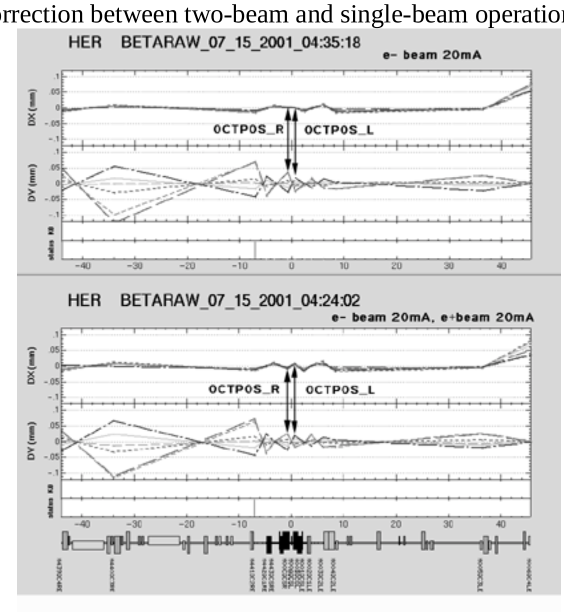

Figure 6: Correlation error at IR was calculated from the difference in the single-kick orbits in HER by the three-BPM correlation method (upper: electron beam; lower: both beams)

7 SUMMARY

The OCTOPOS system for the IR has been used for the first time to optimize the collisions under two-beam operation for physics experiments since last November. There is a disagreement in the results of the measurement between the OCTOPOS BPM and the four normal back-up BPMs during two-beam operation in the case of high-current beam, because of beam current dependence of their position. But the reliability of positions measured by OCTOPOS has been improved after corrections for gains and phase difference.

8 REFERENCES

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[4] H.Koiso, et al., “CORRECTION OF OPTICAL FUNCTIONS IN THE KEKB", Proc. Factories99