# A Beam Position Feedback System for Beam Lines at the Photon Factory

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## Abstract

The beam position of the synchrotron radiation produced from the Storage Ring was stabilized by a twofold position feedback system. A digital feedback system was developed to suppress the diurnal beam movement (one cycle of sine-like drifting motion per day) which became a serious problem in low-emittance operation. The feedback was applied to the closed-orbit-distortion(COD) correction system in order to cancel the position variation at all the beam lines proportionately to the variation monitored at one beam line. An analog feedback system is also used to suppress frequency components faster than the slow diurnal movement.

## 1.Introduction

The synchrotron radiation from the Storage Ring must be supplied to users with its beam position highly stabilized. The vertical position of photon beam is defined by two coordinates (y: vertical position and y':angle) of the stored electron beam at the source point. The beam position at the experimenters' station is then given as $Y = y + y'\ell$ where $\ell$ is the distance from the source point.

At several beam lines, there were installed various kinds of beam position sensitive detectors. These detectors can measure the beam position with an accuracy of micrometer. Beam position was found both drifting in long term and oscillating with higher frequency components.

During the period when the Ring was operated under normal-emittance mode, beam position drift was not too serious. But, since it started being operated under low-emittance mode, the beam position drift became as large as 1 mm at 10 m of beam line BL 21. This diurnal drift of beam position (one-cycle of sine-like curve) was suppressed by a digital feedback method. A digital correction was added to reduce the deviation of a measured COD from a standard COD pattern taken at a fixed time of the day. This digital feedback method can reduce the global drifting of beam position but finer analog feedback must be added for certain beam lines which need to have higher frequecy components be smaller.

## 2. Beam position movement

The photon beam movement was monitored with detection means suitable for either X-ray or VUV beam lines.[1,2,3] For X-ray lines, two kinds of detectors are now in use: one which reads photoemission current from a pair of metal electrodes exposed to X-rays installed at BL 4C, 7C, 10B and the other which reads ion current from gas-filled chamber installed at BL 10A and 21A. For VUV lines, two-wire photoemission monitors are used at BL 12B and 21A.

### a. Diurnal beam movement

There used to be observed some diurnal drift of beam position but during normal-emittance operation, the beam height stayed within 100-200 μm being measured at BL 21. Most users were able to carry out their experiments under reasonably good conditions.

Since the low-emittance test operation started February this year, the diurnal beam movement, however, became a serious problem for most experimenters. Fig. 1 shows the diurnal drift of beam position

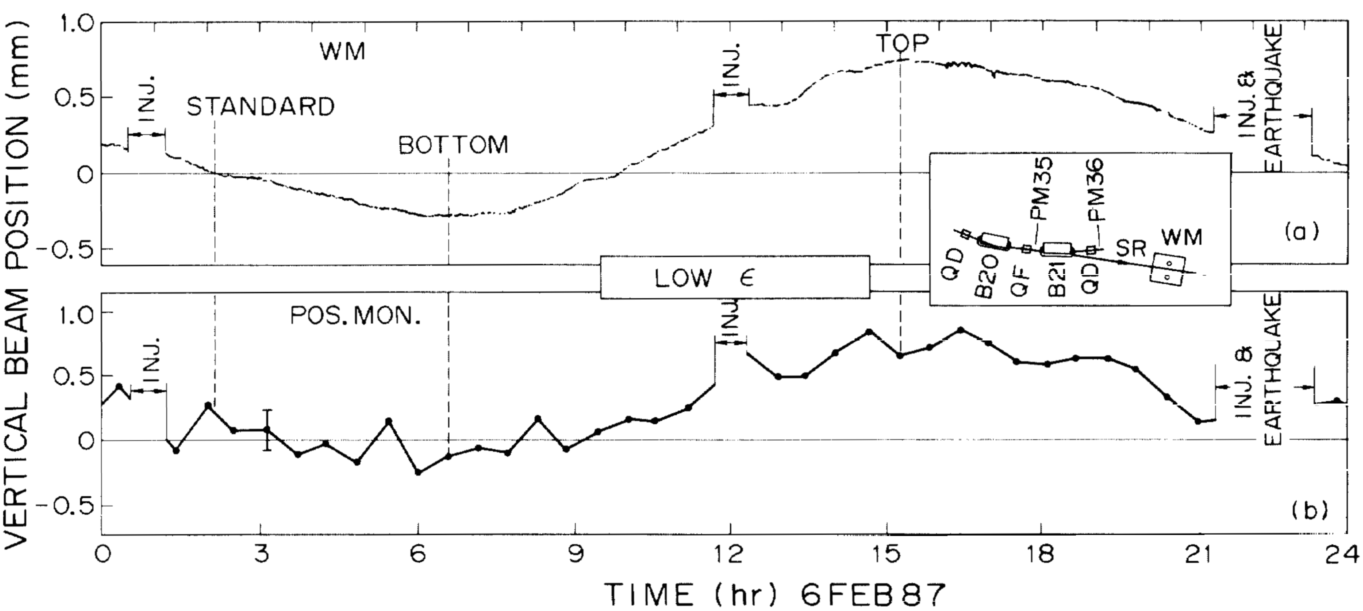


Fig. 1 Diurnal beam movement taken with (a) a photoemission wire monitor placed at $\ell$=10.6 m from the source point of BL 21. The accuracy of this detector is order of a few micrometer and (b) a set of two position monitors (PM35 and PM36) in the Storage Ring. The data of the two position monitors give the vertical position of the stored electron beam y and the angle y' at the source point. The vertical beam height of photon beam at the wire monitor is then computed from these values as $Y = y + y'\ell$.

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measured at BL 21 with two independent detection systems: (a) a wire monitor and (b) with a set of position monitors in the Ring . The total variation of beam position in a day is given as the difference in position measured at the lowest(BOTTOM) and the highest(TOP) points on the drift curve and it was too big to be tolerated. The whole tendency of the diurnal movement is apparently due to the climatic environment around the Light Source building although the mechanism is not yet fully understood. The pattern of descending from midnight to dawn and ascending from daybreak to midday repeats everyday and has a first-order linear correlation to the outdoor temperature(low -2 °C to high 12 °C). More detailed analysis of the mechanism is now being undertaken.

The beam positions at other beam lines also varied by almost the same amount and experimenters were irritated with the low-emittance operation. A method is being tested to suppress the diurnal variation and is described in Section 3.

b. Position noise spectrum

Position noise spectra were measured at several beam lines by using position sensitive detectors and an FFT analyzer.[1,2] A typical noise spectrum is shown in Fig. 2. The noise level for low-emittance mode was about twice as high as that for normal-emittance mode. Most of the spectral components were identified for their sources. Identification of noise sources was made by laying vibrometers in the Storage Ring tunnel and its basement, and the results were reported in a separate paper.[4] Noise sources were mainly four airconditioners above the ring tunnel and the liquid-helium refrigerator placed in the basement.

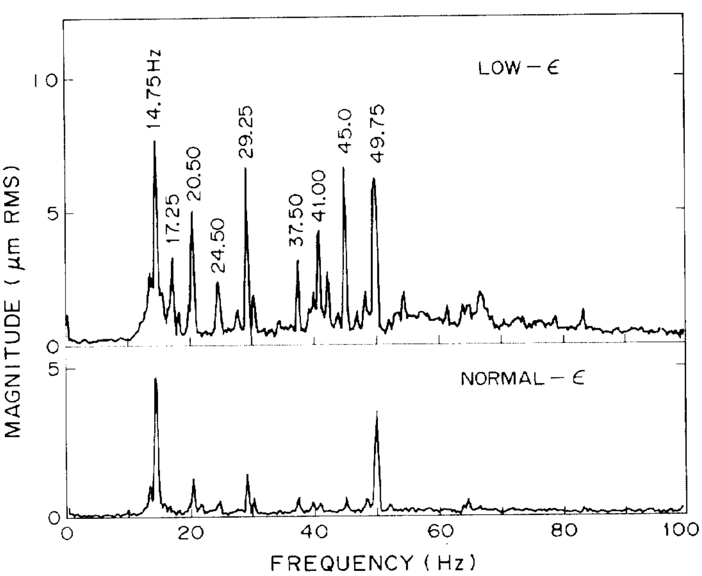


Fig. 2 Beam noise spectra taken at BL 21 with a wire monitor for normal- and low-emittance modes.

3. Beam Position Feedback Systems

Two kinds of feedback methods were employed to reduce the beam position variations mentioned above.

a. Analog Feedback for the suppression of beam position noise.

To suppress beam position noise, an analog feedback system was devised and tested at three beam lines; BL 10A, 12 and 21A.[1] As a part of the work was already reported, a brief description is given here. The analog feedback system was comprised of three components: a beam position monitor for either X-rays or VUV radiation, a servo controller with frequency compensation circuits, and steering magnets. Figure 3 shows some results taken at BL 12 using a wire monitor as position detector. Noise spectra were compared for both cases with the feedback loop open and with that closed. The 14.5 Hz noise peak was suppressed by a factor of 100. In the lower half of the figure, a set of chart recorder traces is shown for the loop closed and opened.

Figure 4 shows the effect of noise suppression measured at other beam lines when the DC noise levels around 0.1 Hz were reduced by a factor of 2 at BL 10A. The local bump used for the feedback loop covered from BL 8 to BL 11. Some effect of suppression was also observed at several beam lines beyond the bump.

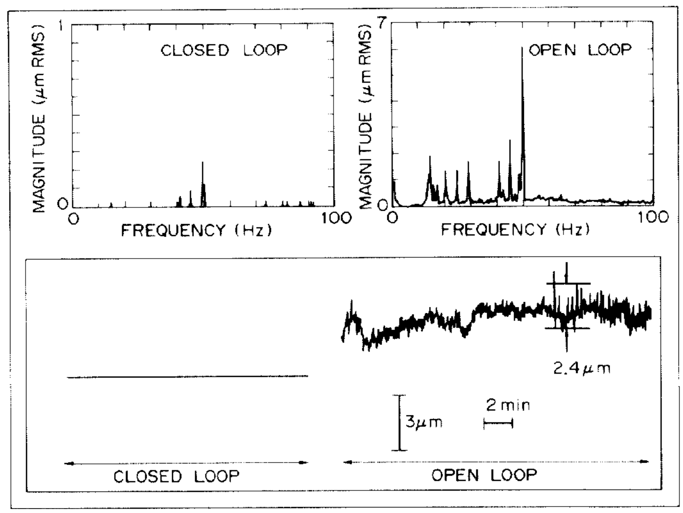


Fig. 3 Beam noise levels taken when the analog feedback loop was either closed or opened. The upper histograms were obtained by using an FFT analyzer and the lower traces were recorded by a chart recorder. The left trace is very a straight line.

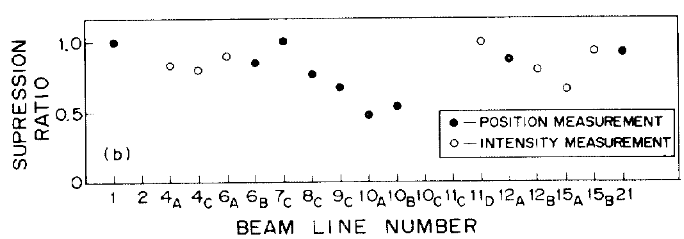


Fig. 4 Suppression ratio of the noise amplitude taken with closed feedback loop to that taken with open loop. Solid circles for beam lines where beam position was measured; open circles for lines where only intesity ratio was measured.

b. Digital Feedback for the suppression of diurnal beam movement

For large diurnal beam drifting, it is necessary to apply a global, real time COD correction. First, a standard point on the diurnal drift curve was chosen to start applying the feedback and at the same time, the photon beam must be visible through the center of each beam line. Second, the closed orbit distortion was measured for both points corresponding to the standard and the highest point on the drift curve. The difference between the two measurements is the amount of correction which should be applied to cancel the total drift in order to keep the photon beam staying where it was. Figure 5a shows the COD for the standard point and Fig. 5b gives the difference between two COD measuremts, one for the standard point and the other for either the highest-(TOP) or the lowest (BOTTOM) point of the diurnal drift curve. Third, when the position variation of photon beam exceeds a preset value of window, e.g., ±10 μm of position variation monitored at BL 21A, a

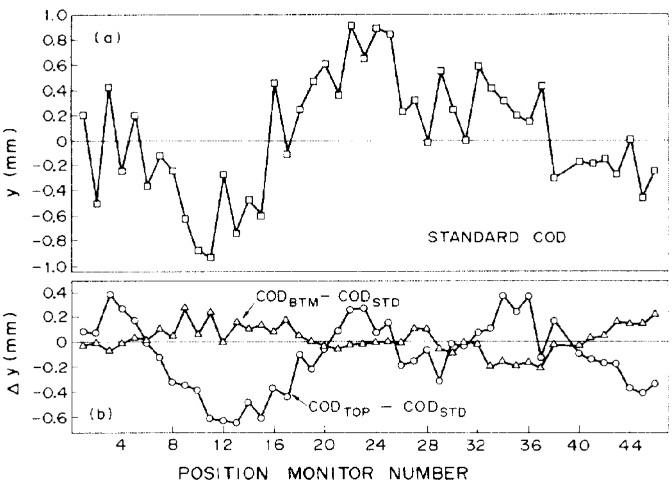


Fig. 5 (a) COD measured at the standard point indicated in Fig. 1. (b) Difference of COD between TOP (BOTTOM) and STANDARD points defined in Fig. 1.

factor of 4 compared to the diurnal variation observed when the low-emittance photon beam was supplied without the digital feedback. The finer sawtoothed structures appearing in the stabilized beam were not much disturbing the experimenters (the amount of shift at the sawtoothed edge was less than 100 μm for all beam lines).

## 4. Summary

The beam-position stabilizing system described above meets well with users' present requirements. It is now optimized for the frequency of turning on the feedback and the amount of minimum position shift being added at one time. To reduce further the amount of shift, it is necessary to remodel the whole system of steering magnets. The value of minimum current sent to magnets is limited by the minimum current possible to set through the system of computer and digital circuits, i.e., 1 bit equivalent to magnet current is about 0.7 mA for 3A max. Several schemes are proposed to solve this problem. It would be acceptable if additional smaller magnets be able to adjust the amount of deflection finer than the present ones do. As new coils being added for the analog feedback system, the analog feedback signal must also be added in parallel to the digital feedback.

To apply the digital feedback effectively, it is more convenient to monitor the beam position near the area where the largest diurnal variation of the COD exists so that propagation of errors be minimized. As low-emittance mode (0.13 nmrad) became of practice,[5] it will soon be required to reduce the beam position variation to the same order of the beam dimension (much less than 100 μm) at certain critical beam lines.

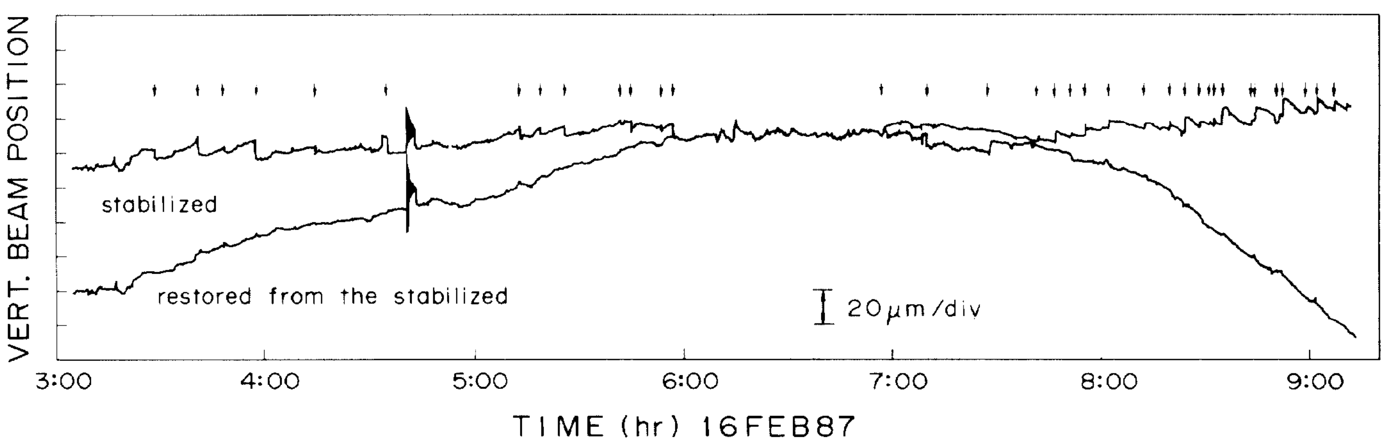


Fig. 6 Suppression effect of the digital feedback system. The upper trace is the stabilized beam position signal and the arrows indicate where a command "up" or "down" was given to the COD correction system. The lower curved trace is restored from the stabilized one. The joggle at 4:40 was due to earthquake.

command of either "up" or "down" is transmitted to the COD correction system which gives a correction of 100th of the total difference measured above.

The effect of the digital feedback system is shown in Fig. 6. The stabilized beam position signal stayed flat within the preset window of ±10 μm. The arrows point where the command of "up" or "down" was issued to the COD correction system from the position monitor located at BL 21. The lower curved trace shows the beam position restored from the stabilized one to show the beam position would have moved if the feedback was not applied.

The largest variation of beam position were seen between BL 4 and 12 (corresponding to PM 8 and PM18) as it is shown in Fig. 5b and were reduced by a

References


1. T. Katsura, Y. Kamiya, K. Haga and T. Mitsuhashi, Proceedings of the 13th Int. Conf. on High Energy Acc., U.S.S.; KEK Preprint 86-46(1986)
2. T. Mitsuhashi, K. Haga and T. Katsura, "Construction of a synchrotron radiation position monitor by means of X-ray photoemission", submitted to this conference.
3. Photon Factory Activity Report 86/87.
4. K. Huke, Jpn. J. Appl. Phys., Vol. 26, No.2(1987)
5. Y. Kamiya, M. Katoh, I. Honjo, A. Araki and M. Kihara, "Low emittance optics of Photon Factory Storage Ring at KEK", submitted to this conference.