Development of a Photon Beam Position Feedback System Based on Two PBPMs at HLS (Postprint)

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Abstract

In this paper, in order to stabilize the position and angle of the light source point, a new photon beam position feedback system based on the Photon Beam Position Monitors was developed on Hefei Light Source, and used to correct the position drift and angle variation of the light source at the same time. On introducing the feedback principle, the transfer function matrix is calibrated, indicating that the new system is workable and effective.

Full Text

Preamble

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Abstract: In order to stabilize the position and angle of the light source point, a new photon beam position feedback system based on Photon Beam Position Monitors was developed at the Hefei Light Source. This system simultaneously corrects both the position drift and angle variation of the light source. By introducing the feedback principle and calibrating the transfer function matrix, the results demonstrate that the new system is workable and effective.

Key words: Photon beam position monitor, Position drift, Angle, Local feedback

2. Local Bump of Beam Closed Orbit at HLS

Stable beam orbit performance is critically important for synchrotron radiation light sources as it directly determines experimental quality. Users of the light source require precise measurement and stabilization of beam position and angle. Consequently, laboratories worldwide have devoted significant attention to photon beam position stabilization technologies [1–3].

The slow beam orbit feedback system at the Hefei Light Source (HLS) [4] can only correct the beam position at 24 Beam Position Monitor (BPM) locations in the storage ring. However, substantial position drift occurs at other locations during extended operation [5]. Furthermore, the existing photon beam position feedback system at HLS based on Photon Beam Position Monitors (PBPM) [6] can only correct the position at the PBPM itself, not along the entire beamline. Since stabilization of the complete beamline requires control of both the position and angle of the light source, a local feedback system based on two PBPMs is necessary.

To eliminate closed orbit distortion, the strength of corrector magnets is typically adjusted to create a local bump in the closed orbit. This allows the beam orbit between these magnets to be modified while other sections remain unchanged. The local bump system for the beam closed orbit at HLS [7] can adjust the light source position to meet experimental requirements by automatically generating a local bump that changes the photon beam position at a specific location without affecting other beam positions. This same principle enables photon beam position feedback.

3. Principle of Photon Beam Position Feedback System Using Two PBPMs

The light source consists of B3A_{20} and two BPMs, BPM-Q6E and BPM-Q8E. The new photon beam position feedback system incorporates two PBPMs in the beamline. PBPM1 is a staggered blade-type monitor [8] with a linear range of \$$\pm 2.5 mmandsensitivityof 1.429 mm$^{-1}\$, while PBPM2 is a wire-type monitor [9] with a linear range of \$$\pm 2 mmandsensitivityof 0.1979 mm^{-1}.Here, \Delta y${1}\$ *and* Δy_2 *represent the position drift between actual and reference orbits at PBPM1 and PBPM2, respectively, while* Δy{offset} and Δ denote the position drift and angle variation at the light source. The local feedback was implemented in the Machine Diagnostic Beamline (MDBL) at HLS, as illustrated in [Figure 1: see original paper]. The condition $[\Delta y_1\ \Delta y_2] = [0\ 0]$ indicates that the actual and reference orbits coincide throughout the beamline.

When the photon beam position feedback system is activated, the height of the local bump at BPMQ6E and BPMQ8E is determined from Eq.(4).

4.1 Calculation of K(s)

[Figure 2: see original paper] shows the schematic diagram of the MDBL at HLS. Eq.(5) can be derived using similar triangles, where $L_1 = 3.833$ m is the distance from the light source to PBPM1, and $L_2 = 6.333$ m is the distance to PBPM2.

K(s) serves as the transfer function matrix relating Δy_{offset}, Δ , Δy_1, and Δy_2, as expressed by Eq.(1). Similarly, T(s) is the transfer function matrix connecting Δy_{offset}, Δ , Δy_{BQ6E}, and Δy_{BQ8E}, as given by Eq.(2). Eq.(3) is derived from Eqs.(1) and (2), where N(s) = K(s)T(s).

During operation, deviation between actual and reference orbits means [Δy_{BQ6E} Δy_{BQ8E}] $\neq$ [0 0] at the two BPMs, and [Δy_{offset} Δ] $\neq$ [0 0] affects [Δy_1 Δy_2] $\neq$ [0 0] along the beamline. The photon beam position feedback system maintains [Δy_{BQ6E} Δy_{BQ8E}] = [0 0] by creating a local bump to achieve [Δy_1 Δy_2] = [0 0] .

Since photon beams propagate rectilinearly, the position drift and angle variation can be calculated from Eq.(7) as follows.

4.2 Calibration of N(s)

From Eq.(3), varying the beam position at BPMQ6E while keeping BPMQ8E constant yields Eq.(9). Conversely, varying the beam position at BPMQ8E while keeping BPMQ6E constant yields Eq.(10). The local bump is generated using Eq.(4), thereby correcting real-time position drift and angle variation.

5. Application of Feedback System Using Two PBPMs

N(s) is calibrated by manually creating local bumps, with the relationship between position and time shown in [Figure 3: see original paper]. [Figure 5: see original paper] displays the positions of the two PBPMs during three time intervals. Over a one-hour period, both the slow beam orbit feedback system and photon beam position feedback system were initially turned off, then sequentially activated at the beginning of the second and third hours.

The relationship between beam position and photon beam position data from [Figure 3: see original paper] is fitted using Eqs.(9) and (10), as shown in [Figure 4: see original paper]. From [Figure 4: see original paper], N(s) can be expressed by Eq.(11).

When both systems are turned off, the position drift is 15 m at PBPM1 and 30 m at PBPM2. When only the slow beam orbit feedback system is activated, the drift reduces to 10 m at PBPM1 and 17 m at PBPM2. When both systems are active, the drift is significantly suppressed, with statistical results shown in [Figure 6: see original paper], achieving drifts of approximately 0.67 m at PBPM1 and 0.81 m at PBPM2.

The position drift and angle variation at HLS under these three conditions can be calculated using Eq.(8), as shown in [Figure 7: see original paper]. With both systems off, the position and angle at HLS fluctuate by up to 18 m and 6 rad within one hour, and the beamline position changes due to the combined effect of position drift and angle variation. With only the slow beam orbit feedback system active during the second hour, the position drift becomes very small while angle variation remains at about 4 rad, making beamline position changes dominated by angle variation. With both systems active during the third hour, both position drift and angle variation are suppressed, resulting in stable photon beam position throughout the beamline.

6. Conclusions

The local feedback system for photon beams developed using two PBPMs can effectively correct both position drift and angle variation at HLS, thereby stabilizing the photon beam position along the beamline. In the future, this technology may be applied to undulator beamlines to correct photon beam position in both horizontal and vertical directions.

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