ONLINE MEASUREMENT OF ELECTRODE GAINS FOR STRIPLINE BEAM POSITION MONITOR IN THE HLS II STORAGE RING*

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Abstract

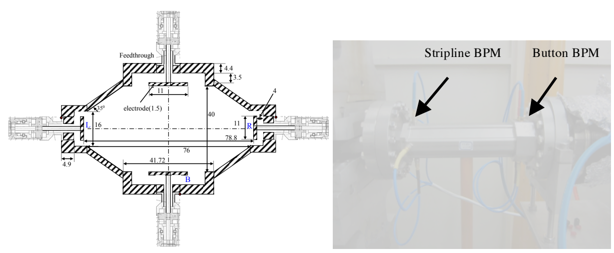
ßπThree axially symmetric stripline beam position monitors were installed in the HLS II storage ring and each stripline BPM was machined with button BPM together. Due to mechanical errors of stripline BPM, differences in electrode gains will lead to measurement error for beam position and mutual coupling between beam horizontal position and vertical position. So it is very important to calibrate electrode gains for axially symmetric BPM. A method was proposed to calibrate electrode gains of this kind of BPM. This method is suitable for all axially symmetric BPMs, whether stripline BPM or button BPM. The online calibrated gains were compared with offline calibrated gains and the results have shown that online and offline calibrated electrode gains were basically consistent.

INTRODUCTION

Hefei Light Source II (HLS II) is a second generation Light Source[1]. From the beginning of 2016, HLS II has entered normal operation stage. Some parameters for the HLS II storage ring are shown in Table 1. BPM usually used in the storage ring is button BPM, but in order to measure some parameters based on stripline BPM, three stripline BPMs were still installed in the HLS II storage ring. Each stripline BPM was machined with button BPM together to save space[2]. The cross section of the stripline BPM is shown in Fig. 1(a) and site installation map for one stripline BPM is shown in Fig. 1(b). In this paper, a method was proposed to calibrate electrode gains of axially symmetric stripline BPM and the results between online and offline calibrated gains were compared. Specific details will be described in the next section.

ONLINE MEASUREMENT OF ELECTRODE GAINS FOR AXIALLY SYMMETRIC STRIPLINE BPM

As mentioned in the abstract, differences in electrode gains of BPM can lead to many measurement errors for beam parameters, so measurement of electrode gains for BPM is very important. For mirroring symmetric BPM, electrode gains of BPM was measured online and offline by D. L. Rubin[3] et al. For axially symmetric BPM, electrode gains of BPM was measured offline in [4]. We proposed a method to online measure electrode gains of axially symmetric BPM. Specific method and calibrated results are described in detail.



(a) Cross section (b) Site installation map

Figure 1: Stripline BPM of the HLS II storage ring.

Table 1: Some Parameters of the HLS II Storage Ring

Circumference	66.13 m
Beam Energy	800 MeV
RF frequency	204 MHz
Harmonic number	45
Natural emittance	< 40 nm·rad
Injected beam current	360 mA

The most important step for calibrating electrode gains of BPM is to establish constraint relationship between induced signals of four electrodes. The constraint relationship between induced signals of four electrodes can be expressed as the following[4]:

$$Q_{\Delta/\Sigma} - Q_0 = S_Q\left[\left(\frac{P_x}{S_x}\right)^2 - \left(\frac{P_y}{S_y}\right)^2 + \sigma_x^2 - \sigma_y^2\right] \quad (1)$$

where $Q_{\Delta/\Sigma}$ is transverse quadrupole component with difference/sum method for stripline BPM, which is shown in Equation (1) in [4]. Q_0 is non-zero component of $Q_{\Delta/\Sigma}$ due to the distance between horizontal electrodes is different from that between vertical electrodes. S_Q is transverse quadrupole component sensitivity. P_x and P_y are electrical position calculated with difference/sum method, the formulas for P_x and P_y are shown in Equation (4) and (5) in [4]. S_x and S_y are horizontal and vertical position sensitivities respectively.

When electrode gains of axially symmetric stripline BPM were offline calibrated, tungsten wire of 0.2 mm diameter was used, so $\sigma_x=\sigma_y=0.2$ mm, where σ_x and σ_y are horizontal and vertical beam size respectively. In this

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situation, σx2-σy2 is equal to zero, so (σx, σy) have no contribution to equation(1). But when electrode gains of axially symmetric stripline BPM are online calibrated, contribution to equation(1) from (σx, σy) must be considered. SQ, Sx and Sy when electrode gains of axially symmetric stripline BPM are online calibrated are the same as those when electrode gains are offline calibrated. So SQ =0.0012mm-2, Sx=0.0773mm-1, Sy=0.0764mm-1, but (σx, σy) must be considered when Q0 is online calibrated.

When electrode gains of axially symmetric stripline BPM are online calibrated, beam need to be moved to pass central area of a certain range in the stripline BPM. Local bump method can be used to move beam in a grid of a certain range in the stripline BPM and four electrode induced signals at each grid point are obtained. When beam current was 25 mA, Beam positions in the stripline BPM(HLS II SR-BD-STLB1) produced with local bump are shown in Fig. 2.

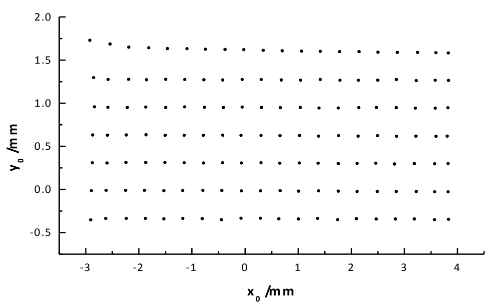

Figure 2: Beam positions produced with local bump.

The beam position data when beam was moved on the horizontal center axis were used to fit the relationship between the corresponding transverse quadrupole signal QΔ/Σ and horizontal position x0, the result of fitted relationship is shown in Fig. 3.

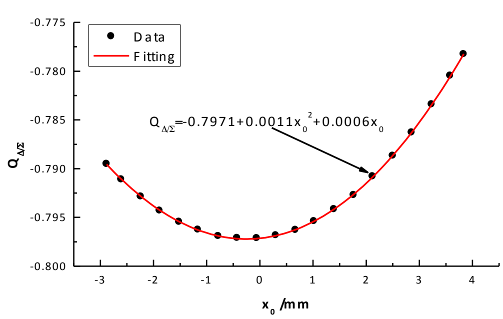

Figure 3: Relationship between $Q_{\Delta/\Sigma}$ and x_0 when beam was moved on the horizontal center axis.

As is shown in the Fig. 3, the constant term of the fitted result is -0.7971. This constant term includes contributions from beam transverse size (σ_x, σ_y). Since beam current was very low during the measurement, so (σ_x, σ_y) were approximately equal to theoretical values. Theoretical values of (σ_x, σ_y) in the position of this stripline BPM(HLS II SR-BD-STLB1) are (0.827mm, 0.036mm). The contribution from beam transverse size (σ_x, σ_y) is $S_Q(\sigma_x^2-\sigma_y^2)=8.192\times10^{-4}$ to the constant term of the fitted result, so Q_0 in the equation (1) can be calculated in the following:

$$Q_0 = -0.7971 - S_Q\left(\sigma_x^2 - \sigma_y^2\right) = -0.7979 \qquad (2)$$

Refer to the equation(8) in [4], Least squares fitting function which can be used to online calibrate four electrode gains of axially symmetric stripline BPM can be expressed in the following:

$$\chi^2 = \sum_{i=1}^{n}\left[\begin{array}{l}\left[\left(\dfrac{g_R V_R^i + g_L V_L^i - g_T V_T^i - g_B V_B^i}{g_R V_R^i + g_L V_L^i + g_T V_T^i + g_B V_B^i} - Q_0\right) - c\cdot S_Q\cdot\right. \\ \left.\left[\left(\dfrac{1}{S_{xn\,\Delta/\Sigma}}\dfrac{g_R V_R^i - g_L V_L^i}{g_R V_R^i + g_L V_L^i}\right)^2 - \left(\dfrac{1}{S_{yn\,\Delta/\Sigma}}\dfrac{g_T V_T^i - g_B V_B^i}{g_T V_T^i + g_B V_B^i}\right)^2 + \sigma_x^2 - \sigma_y^2\right]\right]\end{array}\right]$$

where g_R~g_B are four electrode gains of axially symmetric stripline BPM, c is a coefficient that finely correct S_Q, V_{Ri}~V_{Bi} are the i-th measured electrode induced signals of the stripline BPM(HLS II SR-BD-STLB1).

χ^2 has a minimum value when the best gains are obtained [4]. In order to acquire more accurate electrode gains, we adopt the method used by D. L. Rubin[1] et al to calculate electrode gains of axially symmetric stripline BPM. One of the four electrode gains is set to 1 at every time and final four electrode gains can be calculated by averaging four results. The results of electrode gains of axially symmetric stripline BPM(HLS II SR-BD-STLB1) are shown in Table 2.

Table 2: The Results of Electrode Gains of Axially Symmetric Stripline BPM(HLS II SR-BD-STLB1)

	g_R	g_L	g_T	g_B
First time	1	0.92	0.94	0.98
Second time	1.08	1	1.02	1.06
Third time	1.06	0.98	1	1.04
Fourth time	1.02	0.94	0.96	1
Averaged result	1.04	0.96	0.98	1.02

The fitting results for raw data and corrected data based on calculated electrode gains are shown in Fig. 4.

As is shown in the Fig. 4, the data corrected by online fitted gains is linear and passes through zero, so the online calculated gains of the axially symmetric stripline BPM based on the above method are correct. The online fitted gains were compared with offline calculated gains and are shown in Table 3. As is shown in the Table 3, the results between online and offline calculated gains are basically consistent.

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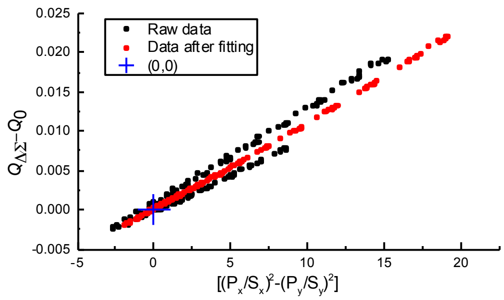

Figure 4: The fitting results for raw data and corrected data based on calculated electrode gains.

Table 3: Results Between Online and Offline Fitted Gains

	g_R	g_L	g_T	g_B
Online fitted gains	1.04	0.96	0.98	1.02
Offline fitted gains result	1.07	0.96	0.96	1.02

CONCLUSION

We have introduced a method for online calibrating electrode gains of axially symmetric stripline BPM. The result shows that the data corrected by online fitted gains is linear and passes through zero. Online and offline calibrated electrode gains are compared and the results are basically consistent.

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