DESIGN AND CALCULATION OF THE STRIPLINE BEAM POSITION MONITOR FOR HLS II STORAGE RING*

F. F. Wu, Z.R. Zhou, B.G. Sun#, P. Lu, Y. L. Yang, W.B. Li, T.J. Ma, C. C. Cheng, H.L. Xu
School of Nuclear Science and Technology & National Synchrotron Radiation Laboratory,
University of Science and Technology of China, Hefei, 230029, China

Abstract

According to the requirements of HLS II upgraded, in order to acquire the non-intercepting measurement of beam position and quadrupole component, a new stripline beam position monitor (BPM) was designed for storage ring. The BPM parameters were optimized to acquire impedence matching with characteristic impedance of the external transmission lines and the coupling coefficients between the electrodes were calculated. According to the difference/sum and log-ratio methods, the horizontal and vertical sensitivities, mapping figures and fitting polynomials wered acquired. The results showed that sensitivities using log-ratio method were bigger than those using difference/sum method. The sum signal was also simulated when beam displacement varied from (0 mm, 0 mm) to (5 mm, 5 mm), the result showed that the variation of normalized sum signal was no more than ± 6%. The gaussian weighted method of a two-dimensional grid structure was used to simulate the gaussian bunch and simulate the beam transverse quadrupole component changing with position (*x*, *y*), the result showed that the beam transverse quadrupole component changed linearly with position combination (x^2-y^2).

INTRODUCTION

The vacuum chamber of the HLS II storage ring is circular, but the vacuum chamber of the HLS II upgraded is octagonal, so a new octagonal stripline beam position monitor(BPM) was designed for the storage ring. Since the signal measured from BPM is filtered by Libera Brilliance, which has a bandwidth of 10MHz at center frequency of 408MHz, in order to make the induced signal amplitude largest, the stripline length was designed to be 183.8 mm.

ELECTRODE COUPLING ANALYSIS

To acquire impedance matching with characteristic impedance of the external transmission lines, the BPM parameters were optimized, the cross-section of BPM after optimization was shown in Fig. 1.

The energy of beam in the HLS II upgraded storage is 800 MeV, the electric field can be simplified to the two-dimensional electrostatic field in a plane perpendicular to the movement direction of beam. CST microwave studio program can analysis electrostatic field characteristic, coupling coefficients was calculated by it [1]. As was shown in Figure. 1, port PortA, PortB, PortC, PortD were set on left electrode, upper electrode, right electrode, lower electrode sequentially,.

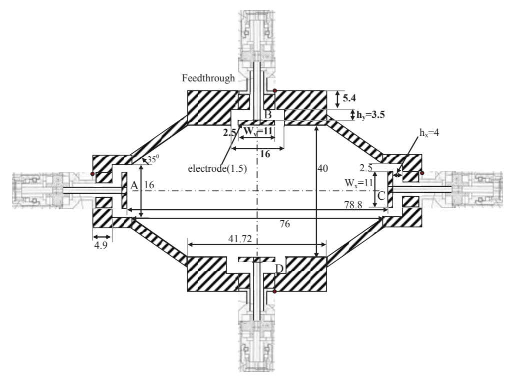

Figure 1: The cross-section of the stripline BPM.

The excitation current source set at PortA was shown in Fig. 2(a), and induced signals were shown in Fig. 2(b). The calculated coefficients were K_{AC}=0.01%, K_{AB}=K_{AD}=0.21%. As the distance between horizontal electrodes is different from that between vertical electrodes, coefficient K_{BD} also need to be calculated. The same excitation current source was set at PortB as shown in Fig. 2(a) and the calculated coefficient K_{BD} is 0.93%. The conclusion was that the coupling coefficients of the stripline BPM were very small.

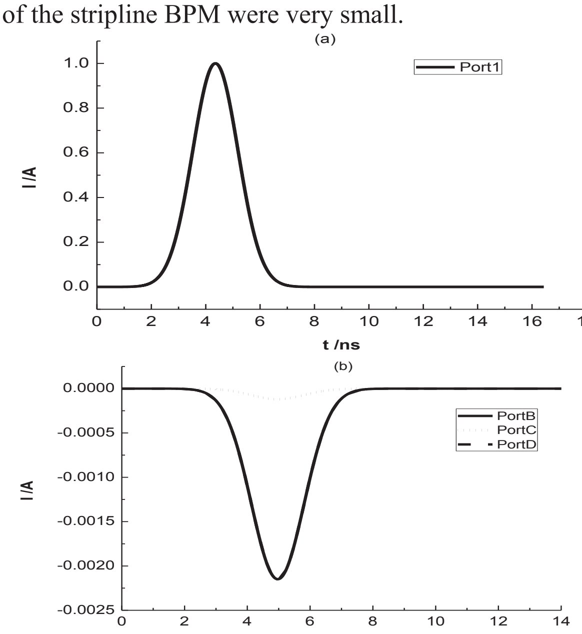

Figure 2. The excitation current source (above) and the induced signals (bottom).

SIMULATION AND ANALYSIS

Position Calibration

The matlab program was used to simulate and analysis beam calibration [2]. It was assumed that the beam moved from (-5 mm, -5 mm) to (5 mm, 5 mm), the step length was 0.5 mm. The induced signals were processed acording to the difference/sum and log-ratio methods and the normalized position (U, V) can be calculated, the equations (1) and (2) are the difference/sum and log-ratio equations. V_A, V_B, V_C, V_D are induced voltages on the left, top, right, bottom electrode. The mapping figures are shown in Fig. 3.

$$U_{\Delta/\Sigma} = \frac{V_A - V_C}{V_A + V_C}, V_{\Delta/\Sigma} = \frac{V_B - V_D}{V_B + V_D} \quad (1)$$

$$U_{\lg} = 20\lg\frac{V_A}{V_C}, V_{\lg} = 20\lg\frac{V_B}{V_D} \quad (2)$$

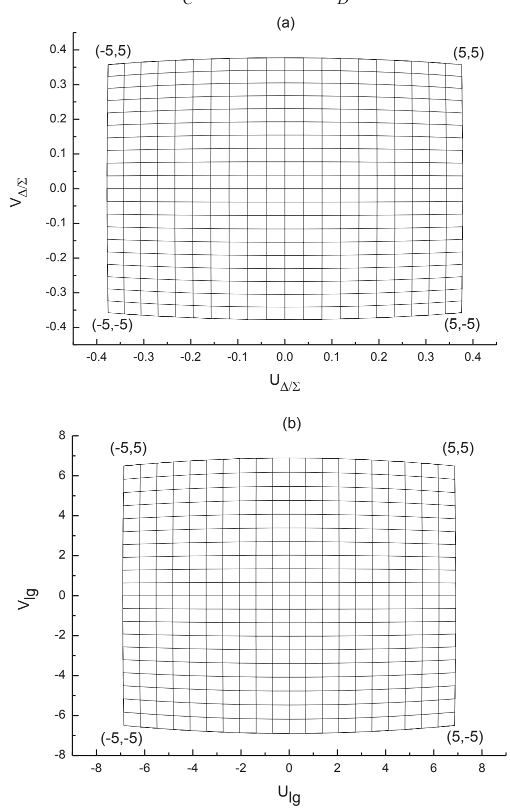

Figure 3. Mapping figure: difference/sum method (above) and log-ratio method (bottom).

As was shown in Fig. 3, the normalized position had a good linear relationship with the machnical position near the mechanical center, it had a good reference value for the following off-line calibration work.

Acording to the normalized position (U, V), By polynomial fitting the beam machnical position (x, y) fitting polynomials with normalized position (U, V) were got. The equations (3) and (4) corresponded to the difference/sum and log-ratio method.

From equations (3) and (4), we can get horizontal and vertical sensitivity coefficients, which are represented by S_x and S_y. For the difference/sum method S_x is 0.0795 mm^{-1} and S_y is 0.0778 mm^{-1}, for the log-ratio method S_x is 1.3799 mm^{-1} and S_y is 1.3492 mm^{-1}.

$$\begin{aligned} x &= 12.5719U_{\Delta/\Sigma} + 4.5479U_{\Delta/\Sigma}^3 + 0.6515U_{\Delta/\Sigma}V_{\Delta/\Sigma}^2 \\ y &= 12.8554V_{\Delta/\Sigma} + 5.3299U_{\Delta/\Sigma}^2V_{\Delta/\Sigma} + 2.7553V_{\Delta/\Sigma}^3 \end{aligned} \quad (3)$$

$$\begin{aligned} x &= 0.7247U_{\lg} + 0.0001U_{\lg}V_{\lg}^2 \\ y &= 0.7412V_{\lg} + 0.0009U_{\lg}^2V_{\lg} - 0.0003U_{\lg}^3 \end{aligned} \quad (4)$$

Sum Signal Calibration

The beam current can be acquired from the BPM sum signal, and thus beam current can be measured[3]. In order to analysis the influence of the beam position to the sum signal, It was assumed that the beam moved from (0 mm, 0 mm) to (5 mm, 5 mm), the step length was 0.5 mm. The result was shown in Fig. 4.

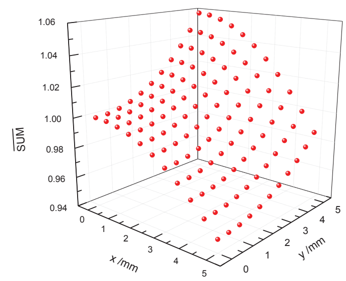

Figure 4: The variation graph of the normalized sum signal with the beam position.

Transverse Quadrupole Component Calibration

The gaussian weighted method of a two-dimensional grid structure [4] was used to simulate the gaussian bunch and the transverse quadrupole component was calculated by the difference/sum method , equation (5) corresponds to the difference/sum method, $Q_{\Delta/\Sigma}$ is the beam transverse quadrupole component acquired by the difference/sum method. The beam transverse size (σ_x, σ_y) was assumed to be (1.2 mm, 0.8mm) and it was simulated that the beam moved from (-3 mm, -3 mm) to (3 mm, 3 mm), the step length was 0.2 mm. Fig. 5 showed the beam transverse quadrupole component varied with beam position combination (x^2-y^2) and linearly fitting of it was done.

$$Q_{\Delta/\Sigma} = \frac{V_A + V_C - V_B - V_D}{V_A + V_B + V_C + V_D} \quad (5)$$

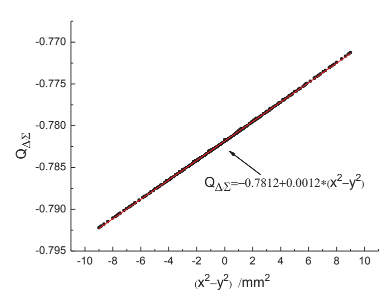

Figure 5: Simulation and linear fitting results of transverse quadrupole component varying with (x^2-y^2).

ISBN 978-3-95450-122-9

CONCLUSION

The electrode coupling coefficients were calculated, acording to them, it was known that coupling effect can be neglected. The position calibrating simulation results showed that sensitivities using log-ratio method were bigger than those using difference/sum method, so the log-ratio method will be used in the following off-line position calibrating work. The normalized sum signal varied no more than ±6%, so it can be used to measure beam current. The transverse quadrupole component changed linearly with beam position combination (x^2-y^2).

REFERENCES

[1] FANG Jia，SUN Bao-gen，LU Ping, et al. “Design and calculation for stripline monitor of HLS injector”. Atomic Energy Science and Technology, September 2011, Vol. 44, Suppl. (in Chinese).

[2] A. Olmos, F. Pérez, et al. “Matlab code for BPM button geometry computation”. Proceedings of DIPAC 2007, Venice, 2007, pp186-188.

[3] ZHANG Baichun，LENG Yongbin. “Simulation of beam bunch charge measurement using BPM pickup”. Nuclear Techniques, 2009, 32(4):256-259 (in Chinese).

[4] Russell J S, Gilpatrick D J, et al. “Characterization of beam position monitors for measurement of second moment”. Proceedings of PAC1995, Texas, 1995, pp2577-2579.