PHOTON BEAM POSITION MONITOR BASED ON POSITION-SENSITIVE DETECTOR FOR HLS *

Y. Y. Xiao, B. G. Sun[#], L. M. Gu, P. Lu, J. G. Wang, L. L. Tang
NSRL, School of Nuclear Science and Technology, University of Science and Technology of China, Hefei 230029, P. R. China

Abstract

In order to overcome the limitation that the existing photon beam position monitors (PBPM) cannot measure the beam position in vertical and horizontal at the same time, a new photon beam position monitor based on position-sensitive detector (PSD) has developed at HLS (Hefei Light Source). The new PBPM based on the PSD has very fast response speed, high sensitivity and wide dynamic range. This PBPM system also includes the C4674 signal processing circuit, NI USB-9215 data acquisition device and the LABVIEW data acquisition program. This PBPM system has been calibrated vertically and horizontally on-line, then has been applied in the beam line B3EA of HLS to measure the position of the synchrotron light. Some results are given.

INTRODUCTION

The Hefei Light Source (HLS) consists of an 800MeV electron storage ring and a 200MeV Linac injector. Beam stability of the synchrotron radiation source beam lines is very interested by the light source users. One of the most sensitive diagnostic tools for the observation of beam stability is the PBPM. For this reason, many countries attach great importance to developing different types of PBPM [1-4]. We developed a new PBPM system based on PSD，which can measure the horizontal and vertical beam position in both directions. Compared with the existing PBPM system [3, 4], the new one should have a higher dynamic range, higher sensitivity and the enough linear range. Finally, we used the developed measurement system in HLS, help to acquire higher quality and higher stability of the light source.

PBPM SYSTEM DECRIPTION

The PBPM system based on PSD is shown in Fig. 1. It consists of two parts, in front is the optical imaging module, followed by photoelectric conversion module.

In HLS B3EA, the synchrotron light reflected by the mirror and then focused by the lens, we can add and subtract filters and attenuators to adjust the light intensity and wavelength. We can install the PSD in the focusing position to monitor the position of synchrotron light. The PSD choose the pincushion type PSD S1880 from Hamamatsu [5]. In order to ensure there is enough light into the PSD active area, we used the 2:1 imaging lens.

After the PSD detects the beam position, the signal processor C4674[6] will amplify the signal and compute to get the photon position information, then use the data acquisition module NI USB-9215[7] to converse the analog signal to digital signal. Finally, the digital signal is read and display by the software LAVIEW.

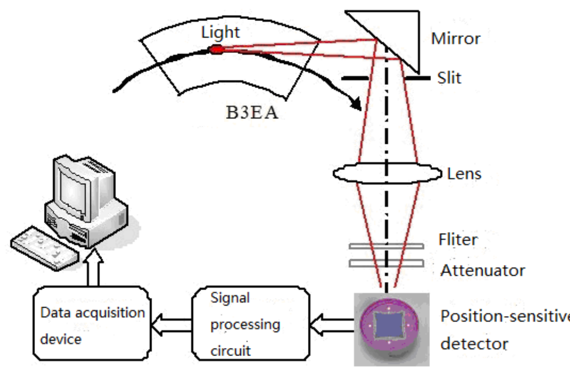

Figure 1: Block diagram of PBPM system.

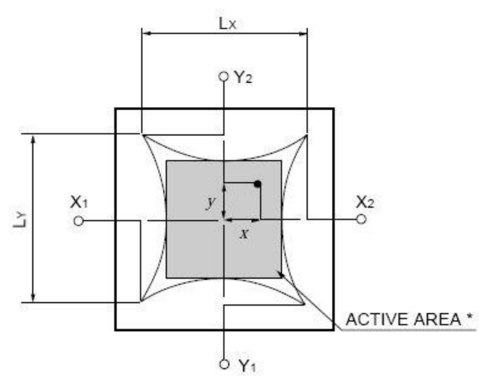

Figure 2: S1880 active area.

As shown in Fig.2: such a conductivity panel of S1880 is surrounded by four arcs. When the synchrotron light shines in the active area, there come out four photon currents from the intersection of the arcs. Suppose the currents of X1、X2、Y1、Y2 are I_{X1}、I_{X2}、I_{Y1}、I_{Y2} , as relative to the center, the position conversion formula is :

$$\begin{cases} X = \dfrac{L_X}{2}\dfrac{(I_{X2}+I_{Y1})-(I_{X1}+I_{Y2})}{I_{X1}+I_{X2}+I_{Y1}+I_{Y2}} \\ Y = \dfrac{L_X}{2}\dfrac{(I_{X2}+I_{Y2})-(I_{X1}+I_{X2})}{I_{X1}+I_{X2}+I_{Y1}+I_{Y2}} \end{cases} \quad (1)$$

Where, L_X=14mm, L_Y=14mm.

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# bgsun@ustc.edu.cn

CALIBRATION OF PHOTON BEAM POSITION MONITOR

Calibration

Although the sensitivity of the PBPM can been calculated, but the sensitivity must been accurately measured so to advance the measurement precision. So, the monitor has been calibrated in the beam-line BE3A of HLS.

During calibration process, the PSD was installed on 2 dimensions precision translation stages with 2μm resolution.

In the vertical direction, to move the PSD gradually in steps of 0.05mm, we can acquire the output voltage P of each step, and then we can draw out the plots (Fig.3) between the P and the moving distance. We can calculate the sensitivity and linear range.

The fitting linear line formula for the vertical direction:

$$P_y = -0.078 + 0.944\delta_y \tag{2}$$

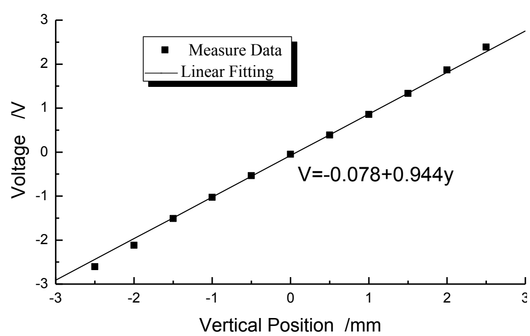


Figure 3: The vertical fitting linear.

When P=0, the slope of the line is the PSD vertical sensitivity. Thinking of the 2:1 imaging lens (C=0.5), the actual PBPM system photon position sensitivity of the vertical direction is:

$$S_y = 0.944C = 0.472mm^{-1} \tag{3}$$

In Fig.3, range from ±1.5mm in the center, the voltage P and the moving distance are in good linear. Thinking of the 2:1 imaging lens (C=0.5), the linear range of the PBPM system is ±3mm. So, the photon position expression of the PBPM system in the vertical direction within the ±3mm linear range is:

$$y = 2.118P_y \tag{4}$$

In the horizontal direction, we can draw the plots and fitting linear line as shown in Fig. 4.

The fitting linear line formula:

$$P_x = 0.0139 + 0.0.828\delta_x \tag{5}$$

We can also calculate the horizontal sensitivity:

$$S_x = 0.828C = 0.414mm^{-1} \tag{6}$$

As the horizontal linear rang is ±4.0mm, we can get the horizontal position formula within linear range:

$$x = 2.415P_x \tag{7}$$

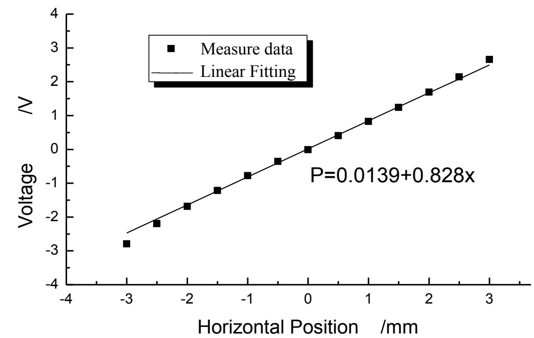


Figure 4: The horizontal fitting linear.

Analysis

Through the calibration experiments, we can get a table (Table 1) with the performance parameters of the PBPM system in both vertical and horizontal directions.

Table 1: Performance of the PBPM System

	Linear range(mm)	Sensitivity (mm^{-1})
Vertical direction	±3	0.472
Horizontal direction	±4	0.414

According to Table 1, we can get the following conclusions: In HLS, the linear range and sensitivity is a contradiction: when the linear range is wide, the sensitivity is low; when the linear range is narrow, the sensitivity comes out high. The reason why the parameters appear different is mainly due to synchrotron light for the elliptical Gaussian distribution. According to the beam profile measurement system of HLS [8], the bunch sizes of horizontal and vertical dimensions are 0.45mm and 0.32mm at 100mA. As the horizontal size is larger than the size in vertical, it comes out wider linear range and lower sensitivity in the horizontal direction.

MEASUREMENT RESULTS

Measurement Results of Resolution

In order to get the resolution of the PBPM system, we carried out short-term measurements.

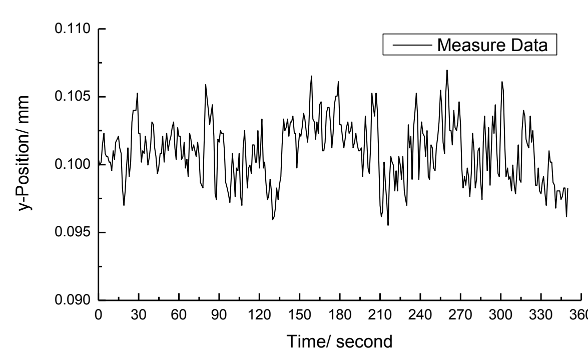


Figure 5: vertical direction.

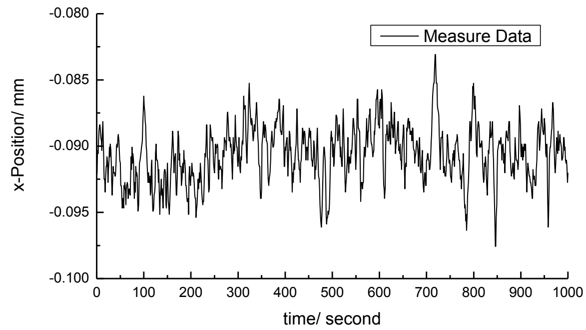
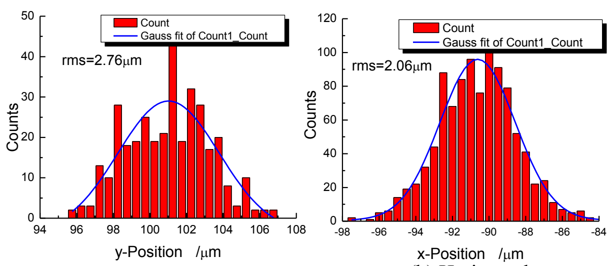


Figure 6: horizontal direction.

As shown in Fig.5 and Fig. 6, during the HLS normal operation, in 6 to 16 minutes, the photon position changes in the μm level.

With the measurement data, we can get the statistical results as shown in Fig.7. As it shows, the measurement results include its short time position jitter, the resolution of the PSD PBPM system should be better. So the PBPM system based on PSD is better than 3μm.



(a) Vertical (b) Horizontal

Figure 7: Resolutions of PBPM system.

Application of PBPM

We apply PBPM system based on the PSD in the beam line BE3A of HLS, measure the actual position of synchrotron light, and compare the result with measurement of BPM_BQ6E near the BE3A.

During injection process, the measurement results been shown in Fig.8 and Fig.9. Comparing the photon beam position curves of PSD and the beam position curves of BQ6E, we can find the trend of both in vertical and horizontal directions are almost the same.

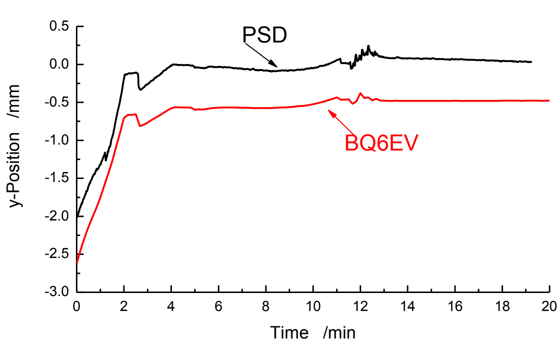


Figure 8: Vertical photon beam position curve of injection process compared with BQ6EV position curve.

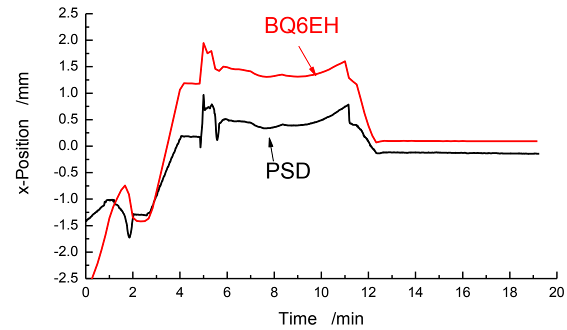


Figure 9: Horizontal photon beam position curve of injection process compared with BQ6EH position curve.

CONCLUSION

We developed a flexibility and high cost-effective PBPM system based on the PSD. From the calibration experiments, we can see the linear range is ±3mm, the sensitivity is 0.472mm^{-1} in the vertical direction; the linear range is ±4mm, the sensitivity is 0.414mm^{-1} in the horizontal direction. In the HLS, these parameters fully meet the requirements, and the better than the previous system. Based on actual measurements, the resolution of the system is better than 3μm.

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