J. Synchrotron Rad. (1998). **5**, 621–623

A synchrotron radiation beam-position monitor at the Taiwan Light Source

J.-R. Chen,[a,b]* T. S. Ueng,[a] G. Y. Hsiung,[a] T. F. Lin,[a] C. T. Lee,[b] S. L. Tsai[b] and S.-L. Chang[b]

[a]Synchrotron Radiation Research Center, No.1 R&D Road VI, Hsinchu Science-Based Industrial Park, Hsinchu 30077, Taiwan, and [b]Department of Nuclear Science, National Tsing-Hua University, Hsinchu 30043, Taiwan.
E-mail: jrchen@alpha1.srrc.gov.tw

(*Received 4 August 1997; accepted 28 November 1997*)

A prototype photon-beam-position monitor has been designed, fabricated and tested at the Taiwan Light Source of the Synchrotron Radiation Research Center. Aluminium was chosen as the material of the blade electrodes due to its low atomic number and high thermal conductivity. The resolution of this photon-beam-position monitor was $<\pm 1$ μm. The sensitivity of the blade electrode has been measured *in situ*. Results of measurements for bending-magnet light and undulator light with different gaps are described.

Keywords: beam-position monitors.

1. Introduction

Photon-beam-position monitors (PBPM) have been widely studied at many synchrotron radiation facilities (Aoyagi, 1996; Elleaume, 1987; Loyer, 1994; Mitsuhashi *et al.*, 1992; Mortazavi *et al.*, 1986; *Proceedings of the Workshop on X-ray Position Monitors*, 1993; Warwick *et al.*, 1995; Zhang *et al.*, 1995). The blade-type PBPM is the most promising one to meet the stringent performance requirements. However, several problems, such as contamination from the light emitted by bending magnets, different responses due to different undulator gaps, cross-talk effect among blade electrodes, thermal effects *etc.*, have to be considered when a blade-type PBPM is employed in an undulator beamline.

There are several undulators in commission or under construction at the Taiwan Light Source (TLS) (*SRRC Annual Report*, 1995; Wang *et al.*, 1996). To keep the electron beam orbit constant during the operation of undulators, good BPMs (either electron or photon BPMs) and an effective feedback system are necessary. Due to the limitation of the existing electron BPMs, a prototype photon BPM has been developed. Several tests have been carried out. The experiments and the results are described in the following sections.

2. Experiments

2.1. *PBPM design considerations*

Fig. 1 shows schematic diagrams of the PBPM structure. Two blades (A), each with a thickness of 0.5 mm, were used as the photoemissive elements. Aluminium was chosen as the blade material due to its low atomic number and high thermal conductivity. These two blades were separated by $\sim$8 cm and were able to be electrically biased in order to reduce the cross-talk effect or to increase the sensitivity. No deformation or melting was observed on the blades after the irradiation of undulator light.

In order to reduce contamination from the scattered photoelectrons, two mask plates (B and C) were added to form entrance and exit windows of the PBPM. A biased photoelectron-collector (D), located at one side of the PBPM, was used to collect the scattered photoelectrons.

The aluminium blades were fixed to a cooled aluminium block (E) with ceramic insulators (F) for electrical insulation. The aluminium block was mounted on an XY stage driven by stepping motors. The whole PBPM unit was installed in a chamber which could be adjusted in the yaw direction for alignment purposes.

2.2. *Experimental system*

Three PBPMs were installed in the front-end of the U-10 undulator beamline. These three PBPMs were located at about 7.5 m, 9.0 m and 10.3 m from the middle of the undulator. An aluminium plate with a slit opening of 1 mm (H) $\times$ 20 mm (W) was mounted on a motor-driven unit, which was installed in the PBPM1 chamber and located right in front of PBPM1. The slit was used to provide a defined photon beam of height 1 mm for *in situ* photoemission sensitivity measurements of the blades. In order to have a softer radiation irradiated on the blades during the measurement, the slit was installed about 3 mm above the central plane.

3. Results and discussions

3.1. *Calibration*

The photon beam position, y, was calculated from the blade currents by using the formula

$$y = K_y(\alpha I_U - \beta I_L)/(\alpha I_U + \beta I_L) = K_y(I_U - \gamma I_L)/(I_U + \gamma I_L),$$

where K_y is the proportional constant, I_U and I_L are the photoemission currents of the upper (U) blade and the lower (L) blade, α and β are the photoemission sensitivities of the upper and the lower blades, and $\gamma = \beta/\alpha$. By changing the vertical position of the PBPM, the K_y value could be derived from the relationship of the blade currents (I_U and I_L) and the PBPM position (y).

The sensitivity test result was obtained by scanning the upper and lower blades of the PBPM across the photon beam (1 mm in height) which penetrated through the slit. Fig. 2 shows a typical

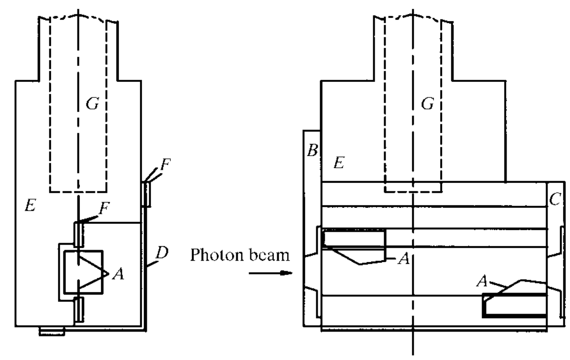

Figure 1
Schematic diagrams of the PBPM structure. A, blade; B and C, mask plate; D, photoelectron collector; E, aluminium block; F, ceramic insulator; G, cooling channel.

result of the sensitivity measurements. The ratio, γ, was defined as the ratio of the area under the two peaks. In Fig. 2 it was about 0.7.

3.2. *Effects of bias voltages on K_y and γ*

It was observed from the results that the effects of the bias voltages (of the blade and the collector) on K_y and γ were small if suitable bias voltages were chosen. It was also noted that the K_y value with a blade bias at 0 V is almost the same as the 'saturation' value as long as the collector bias voltage is large enough (*e.g.* $\geq$200 V). In this work, however, −24 V and +200 V were chosen as the bias voltages for the blade and the collector, respectively, due to a higher stability of K_y and γ at these voltages.

3.3. *Effects of the horizontal position and the angular misalignment on K_y and γ*

An experiment was carried out to study the effects of the misalignment in the yaw direction on the K_y and γ values. The results showed that the variation of both values was $\leq$1% within an angular (yaw) range of $\pm 0.5^\circ$.

Fig. 3 shows the effect of the PBPM horizontal position on the K_y value. It is shown that the K_y value increased as the horizontal position moved outwards from the storage ring. The increase of K_y might be due to the increase of the vertical beam size of the photon beam. The decrease in photon beam brilliance (increase beam size) could decrease the conversion sensitivity of the blade currents to the PBPM position (increase the proportional constant K_y). As the horizontal position moved outwards from the storage ring, the contamination from the upstream bending-magnet light increased. This effect could increase the total beam size. The variation of the effect of the horizontal position on the γ factor was about ±8%. Although this value is not large, it is still significant. The variations in the γ value might be due to the variations of the photon energy, the photon spatial distribution or some other factors.

From the experimental results it was observed that both the K_y and γ values were sensitive to the horizontal position of the PBPM. It seemed that there was a systematic factor governing this phenomenon.

3.4. *Effect of the undulator gap on K_y and γ*

It is shown in Fig. 3 that the K_y value increased as the undulator gap increased except for the case at a full open gap of 220 mm. The increase of K_y might be attributed to the larger beam size or other unknown reasons.

Fig. 4 shows the relationship of γ *versus* the undulator gap. The γ value increased from 0.67 at 25 mm gap to 0.81 at 220 mm full open gap. The increase of γ might be due to a systematic changing of the photon beam parameters, or some other unknown reasons.

3.5. *Index of uncertainty of the measurement*

There are many factors contributing to the uncertainty of the PBPM measurement results. In order to study the confidence level and to find out the factors that cause the uncertainty, three sets of PBPMs were used in this work.

Fig. 5 shows the results of measurements with three PBPMs. In Fig. 5(*a*) there are three curves corresponding to beam positions measured by the related PBPMs. It can be seen that the values of the three curves are in good coincidence in both the trend and the microfluctuation. This implies good reliability of the measurement system. In Fig. 5(*b*) the three curves show the angles derived from the beam positions of the three PBPMs. Since there was no optical element in the PBPM region, the three measured angles should in principle be exactly the same. In our measurements, although the trends of the three angle curves were similar, the values of these three angle curves were different from each other. The variations in the PBPM structure, the K_y factor, the γ factor, the electron beam quality or other factors might induce the differences in the values of these three angle curves.

Although there were discrepancies among the values of the three angles, the differences were not large (*e.g.* $\leq$4 µrad in Fig. 5). Furthermore, it was observed that the drifts in the angle curves were small. A result of $\leq\pm$1 µrad h^{-1} drift was obtained (this value depended on the stability of the electron beam orbit).

The results of this work showed that the position resolution of the PBPM was better than ±1 µm and the drift was better than ±1 µm h^{-1}. The index of uncertainty, evaluated from the deviations of the three angles, was estimated to be <±3 µrad without

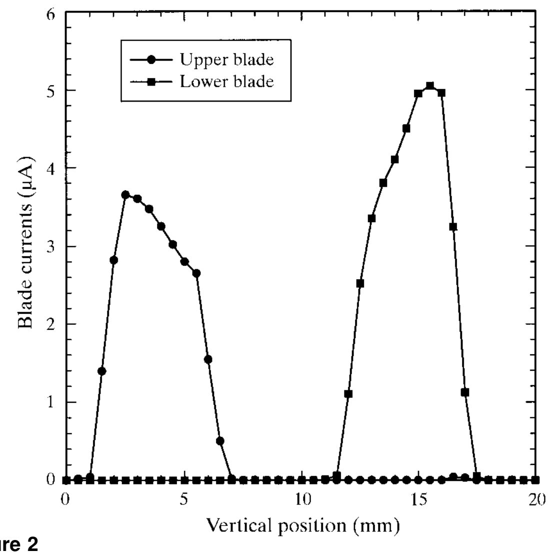

Figure 2
Result of the sensitivity measurement scan.

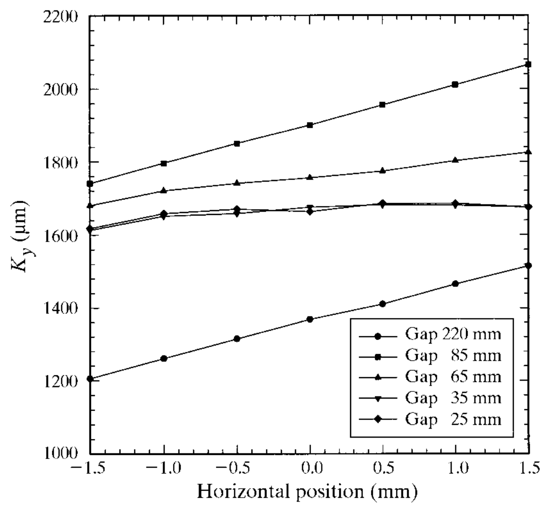

Figure 3
Curves of K_y *versus* PBPM horizontal position at different undulator gaps. Positive values are for the PBPM moving outwards from the ring.

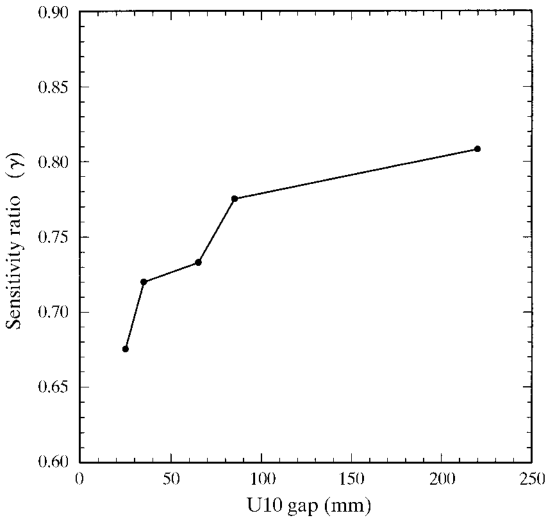

Figure 4
Results of the relationship between γ and the undulator gap.

changing the undulator gap. The index of uncertainty increased to about $\pm$70 μrad as the undulator gap changed from 25 mm to 65 mm. More studies are necessary for further improvements.

4. Summary

A two-blade PBPM was designed and tested at the TLS. Aluminium was chosen as the blade material due to its high thermal conductivity and low atomic number.

A slit located upstream of the beamline was installed. With such a design, the photoemission sensitivity of the blades could be measured *in situ*.

The effects of several factors, such as bias voltage, transverse and angular misalignment, and different undulator gaps on the K_y and γ factors, were studied. No significant effect (<2%) was found due to small bias voltage variation or angular misalignment. However, the change in both horizontal position and undulator gap had a significant effect on the K_y and γ parameters. The deviation was about $\pm$10% in the undulator gaps of interest and the PBPM horizontal positions.

A system with three PBPMs was set up in this work. With such a design, data on three beam positions and three beam angles were obtained. The uncertainties of the measurements were evaluated by comparing these data. A position resolution of $\pm$1 μm and a drift in angle of $\pm$1 μrad h^{-1} were obtained. The index of uncertainty of the measurements in this work was estimated to be <$\pm$3 μrad without changing the undulator gap. In the case of the undulator gap varying from 25 mm to 65 mm, the index of uncertainty degraded to about $\pm$70 μrad.

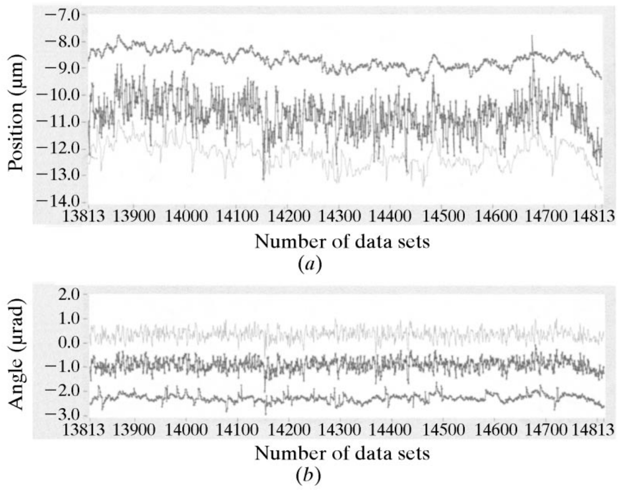

Figure 5
Position (*a*) and angle (*b*) results of the measurements with three PBPMs. The number of data sets taken, shown on the horizontal axis, is about two sets per second. (*a*) Top curve: BPM1; middle: BPM2; bottom: BPM3. (*b*) Top: BPM1 − BPM2; middle: BPM2 − BPM3; bottom: BPM − BPM3.

References

Aoyagi, H. (1996). Third Joint APS-ESRF-Spring-8 Workshop, April 16. Himej, Japan.
Elleaume, P. (1987). ESRF Report, ESRF-Synchrotron Radiation/ID-87–11. ESRF, Grenoble, France.
Loyer, F. (1994). ESRF Report, ESRF/Mach DIAG 94/22. ESRF, Grenoble, France.
Mitsuhashi, T., Ueda, A. & Katsura, T. (1992). *Rev. Sci. Instrum.* **63**, 534–537.
Mortazavi, P., Woodle, M., Rarback, H., Shu, D. & Howells, M. (1986). *Nucl. Instrum. Methods*, A**246**, 389–393.
Proceedings of the Workshop on X-ray Position Monitors (1993). ESRF, Grenoble, 22–23 November.
SRRC Annual Report (1995). SRRC, Hsinchu, Japan.
Wang, Ch., Chang, L. H., Chang, C. H., Chen, H. H., Fan, T. C., Hsu, K. T., Hsu, J. Y., Hwang, C. S., Lin, M. C. & Pan, K. T. (1996). *Proceedings of the European Particle Accelerator Conference, EPAC96*, Barcelona, June 10–14. Bristol: Institute of Physics.
Warwick, T., Andresen, N., Portmann, G. & Jackson, A. (1995). *Rev. Sci. Instrum.* **66**, 1984–1986.
Zhang, X., Sugiyama, H., Ando, M. & Shiwaku, H. (1995). *Rev. Sci. Instrum.* **66**, 1990–1992.