V-coupling-blades beam position monitor for NSRL undulator source

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Abstract. In order to measure the vertical and horizontal position of the centroid of the radiation, a nondestructive V-coupling-blades beam position monitor (V-BPM) was designed, constructed, and tested for NSRL undulator source. The monitor is comprised with two pairs of water-cooled symmetrical triangle electrodes made of molybdenum. To increase the photoemission currents, both V-coupling-blades were inserted in the beam edges at an angle of 10° in horizontal and offset each other along the beam direction. A bias of 300V was adapted to collect the photon-electronics more effective. This paper describes the principles and structure features of the V-BPM and discusses the results of performance tests.

1. Introduction

Stability of photon beam position is reemphasized in recent operation of high brightness synchrotron radiation facilities. Efforts have been made to improve the schemes of beam position monitoring which become more complicated for insertion devices[1]. The high-flux photon beam from the insertion device casts higher power radiation (heat load) onto a beam monitor. The electron storage ring of the NSRL will normally operate at 0.8 GeV with a maximum design current of 300 mA[2]. A new undulator is installed at a straight section to produce high flux radiation with the photon energy of 7.6 to 58.3eV by changing the magnetic gap. Based on the characteristics of the VUV light source, a V-coupling-blades beam position monitor has been developed to detect the stability of the photon beam from the undulator. The monitor is comprised with two pairs of V-coupling-blades made of molybdenum. The blades were inserted in the horizontal beam edges. To increase the photoemission currents, both of them were angled at 10 degrees between the blade surface and the photon beam direction. And they were longitudinally offset against each other along beam direction. To collect the photon electrons more effectively, a bias of 300V was adapted to draw the liberated photoelectrons away from the surface of the V-coupling-blades. This paper describes the principles and structure features of the V-BPM which has been tested at the ARPES beamline. The test results show that the V-BPM will meet the requirements to detect the photon beam stability for the new undulator source of NSRL storage ring which will be constructed.

2. The BPM structure

Several types of monitors have been developed to observe the beam position. They are split ion chambers, photoemission devices, pickup electrodes, fluorescence detectors and position sensitive detectors. We developed the monitor for high-flux photon beam from insertion devices based on photoemission effect. It is more stable and easier to insert into the vacuum chamber of the beamline. A
schematic drawing of the monitor is shown in figure 1. And figure 2 shows the arrangement of the four electrodes.

![Figure 1. Outline of the V-BPM.](image1)

**Figure 1.** Outline of the V-BPM.

**Figure 2.** Arrangement of the electrodes: front view from beam direction.

The monitor comprised two pairs of symmetrical triangle blades as the electrodes at both horizontal edges of the photon beam. The blade shape was designed to make a balance of both input heat power and output photoemission between the right-hand and left-hand electrodes. Each pair of blades with water-cooled frame was individually housed in the vacuum chamber and was made adjustable in the horizontal position against the photon beam. The blades were wire-cut with a molybdenum sheet of 1 mm thickness and face the photon beam at an angle of 10 degrees. To reduce the cross-talk of electrodes, the left pair of electrodes was set downstream of the right pair. The photo emissive molybdenum was chosen as blades for its suitable photo emissive energy of 4.1eV and it is easy to fabricate. A schematic drawing of the V-BPM assembly is shown in figure 3.

![Figure 3. Schematic diagram of the V-BPM assembly.](image3)

**Figure 3.** Schematic diagram of the V-BPM assembly.

Plastic sheets were inserted between each electrode and the rest of the structure for electrically isolating. The signal currents were measured with a multi-accesses Keithley 6517 amplifier (contact wires fixed at the hole position of each blade and the other side to ground). Be window was arranged in front of the BPM to absorb noise photons from the upstream bending magnet. Position data were recorded by amplifying the photocurrent from four electrodes and taking the ratio of difference to sum of photocurrents from upper and lower electrodes[3]. In order to normalize incident beam flux, the following relationship was used:
\[ y = K_y P_y = K_y \left( \frac{I_{up\text{-left}} + I_{up\text{-right}}}{I_{up\text{-left}} + I_{up\text{-right}}} - \frac{I_{low\text{-left}} + I_{low\text{-right}}}{I_{low\text{-left}} + I_{low\text{-right}}} \right) \]
\[ x = K_x P_x = K_x \left( \frac{I_{up\text{-left}} + I_{up\text{-right}}}{I_{up\text{-left}} + I_{up\text{-right}}} + \frac{I_{low\text{-left}} + I_{low\text{-right}}}{I_{low\text{-left}} + I_{low\text{-right}}} \right) \] (1)

Where \( I_i \) is the photon current from each blade; \( y, x \) is the vertical and horizontal centroid position of the spot; \( P_v, P_h \) are detecting functions; \( K_v, K_h \) are response parameters decided by the experimental results.

### 3. Performance test

To test the performance of the V-BPM, the monitor has been installed at the ARPES beamline of NSRL and placed at 13.6m from the light source, exposed to the white beam directly. By use of the SPECTRA software of RIKEN Spring-8[4], the flux density of the undulator radiation with 16.6eV (corresponding GAP size 50mm) was calculated. As shown in figure 3 and figure 4 (unit: mm), the flux density made a Gaussian distribution in both directions and with the FWHM of 2.4mm in horizontal direction. Due to the offset of 5mm between two pairs of blades, it was a little bigger than two times FWHM to monitor the photon beam position properly and to make no influence for the downstream experiment[5].

![Figure 4. Flux density distribution by space at 16.6eV and 13.6m from light source.](image)

![Figure 5. Flux density distribution along x (black), y (red) directions at 16.6eV.](image)

A Labview program was developed for the scanning control and data read. The photocurrents changing with the position of blades were shown in figure 6 and figure 7. After collimating, the monitor read the same data of 0.25mA from each blade, the variation in signal current relative to photon beam position was 27.3nA/µm, and outputs were linear over 5mm in the horizontal and 10mm in the vertical, which were limited by the nonlinearity distributions of the photon beam.

![Figure 6. Photocurrents of blades change with vertical position.](image)

![Figure 7. Photocurrents of blades change with horizontal position.](image)
With a linear fit, as shown in figure 8 and figure 9 the slope of the curves were calculated as $Y=9.9P_v$ ($K_v=9.9$) and $X=6.1P_h$ ($K_h=6.1$). The resolutions were 2.83$\mu$m and 4.02$\mu$m in the horizontal and vertical respectively (rms with 60 points, integration time less than 1s).

![Figure 8](image1.png)  
**Figure 8.** The monitor function curves along vertical direction.

![Figure 9](image2.png)  
**Figure 9.** The monitor function curves along horizontal direction.

The vertical position of the light spot was measured over one injection period, which is 10 hours. The results were shown in figure 10. The beam spot drifted about 150$\mu$m in the vertical direction for the first 60min. And as the beam current decreased from 198mA to 116mA, the photon beam drifted about 200$\mu$m totally. The storage ring electron beam current was also listed in figure 10.

![Figure 10](image3.png)  
**Figure 10.** Long term beam stability measurement: vertical beam position (black) and storage ring beam current (red) change with time.

4. Conclusion
According to the characteristics of the undulator light source at NSRL, a nondestructive V-coupling-blades type beam position monitor was developed and tested. The results show that the resolutions for detecting the beam position are less than 3$\mu$m in the horizontal direction and less than 4$\mu$m in the vertical direction respectively, which will meet the requirement of monitoring photon beam stability for the new undulator beamline of NSRL storage ring reconstruction. The long term X-ray beam stability was also measured over an injection period. With two V-BPMs installed on a beamline, not only the position of the centroid but also the angle of the beam direction can be detected at the same time.

References
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