BEAM POSITION MONITOR FOR UNDULATOR BY USING SR MONITOR TECHNIQUE

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Abstract

A beam position monitor for the undulator by using the optical SR monitor technique has been tested in the Photon Factory. A visible SR in far tail of the undurater spectrum is extracted by a water-cooled beryllium mirror. The extraction mirror has a hole in the center for passing through the central peak of the undulator radiation. Extracted visible light in large opening angle has same optical axis of the undulator radiation, because of it is a far tail of the spectrum of same radiation. We applied focusing system to observe a beam position in the undulator through an optical image of beam. The results show us this method is applicable to monitor a position of beam in the undulator, and gap change of undulator has no effect for the beam position monitoring.

INTRODUCTION

Monitoring the undulator radiation is still one of important problem in the SR facilities. Many designs of photon beam position monitor based on photoemission type are developed for the monitoring undulator radiation. Since radiations from up-and down stream bending magnet edge are superimposed in the radiation from the undulator, it is difficult to monitor the undulator radiation independently [1]. This problem is very serious in the VUV undulator, because the spectrum range of the both radiation is almost in the same rang. To solve this problem, we apply the technique of optical SR monitor.

The low-energy tail (visible light range) in the spectrum of undulator radiation is emitted in large opening angle. Watching the undulator radiation, surrounding of central sharp cone of the radiation, we can observe visible radiation from the undulator. This radiation is no meaning for undulator radiation users, but still having a possibility to use monitoring the undulator radiation. We extracted this low-energy tail of the radiation by water-cooled beryllium mirror which has a hole in center to pass through the main power of undulator. In the same range of opening angle, we have bending radiation and undulator radiation together. To separate both rays, we applied focusing system as like as in the visible SR profile monitor. Because conjugation distances from the source points of the bending magnets and undulator are different each other, we cannot focus on the source points into the same focusing plane. Using this technique, we separate the undulate radiation from the bending radiation. The results of test of this system for monitoring a beam position are described in this paper.

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EXTRACTION OF UNDULATOR RADIATION

The optical system is installed in the BL-5 undulator beam line. The optical layout is shown in figure1. We insert a water-cooled Be-mirror with central hole to extract the low-energy tail (visible light range) in the spectrum of undulator radiation. The mirror is set at 7.9m downstream from the undulater.

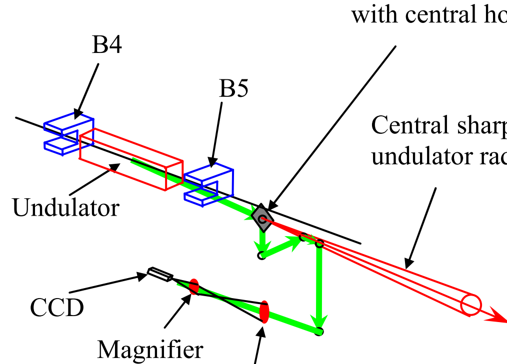

Figure 1: Layout of optics system of the monitor.

The diameter of central hole of the mirror is optimized to pass the sharp cone of radiation from the undulator. The result of a simulation of power distribution of BL5 undulater is shown in figure 2. The opening angle of sharp cone is about 1.2 mrad, therefore corresponding diameter of the radiation at 7.9m point is 9.48mm. To pass this central powerful cone of radiation, we decided the diameter of the hole by 10mm.

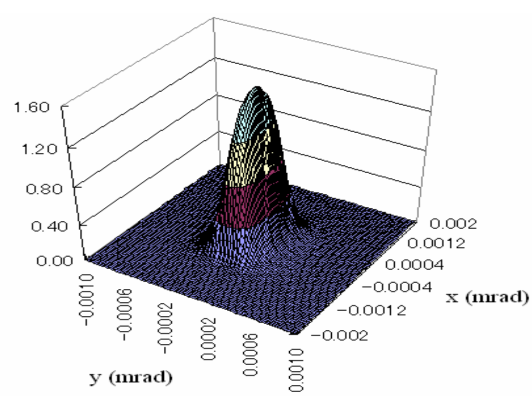

Figure 2: Power distribution of radiation from BL-5 undulator. The gap of undulator is 70mm.

SEPARATION OF UNDULATOR RADIATION FROM BENDING RADIATION

We applied an ordinal focusing system to produce an image of the beam in the undulator. The function of central hole of the Be-mirror is not only to pass the powerful radiation cone, but also having an important optical function. When we focus the light onto the undulator source point, the defocused light from bending magnet is simultaneously overlapped in the same focus plane. When the mirror has a convenient hole at the centre, the defocused bending light becomes ring pattern surrounding from an image of undulater light as shown in figure 3.

Figure 3: image of undulator light (central bright spot) with defocused bending light from the downstream bending magnet.

We can separate the undulator light from the bending light by masking defocused ring pattern. Since in our case, the intensity of defocused light from upstream bending magnet was negligible small, we did not care the light from upstream bending magnet.

IMAGING SYSTEM FOR THE OBSERVATION OF ELECTRON BEAM IN THE UNDULATOR

A conventional focusing system as is the optical profile monitor [2] is installed to observe the beam image in the undulator. The focal length of the objective lens is one of the key point to realize good separation between two focusing points on the optical axis those are conjugated to the undulator source point and bending source point. In general, longer focusing length of the objective lens gives larger separation, but practically, to make focal length longer, the total length of optical system becomes too long. We applied 1000mm focusing length doublet lens. This lens gives a separation of 17 mm between two focusing points in our condition, and it gives enough separation of the undulator light from bending light as shown in figure. 3. The spectrum of the input light is limited by 10nm at 550nm by a band-pass filter. The σ component is chosen by dichroic sheet polarizer.

The results for separated beam images of the beam in the undulator and in the downstream bending magnet are shown in figures 4 and 5 respectively.

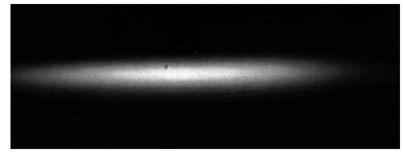

Figure 4: Separated beam image in the BL-5 undulator. The gap of undulator is 140mm.

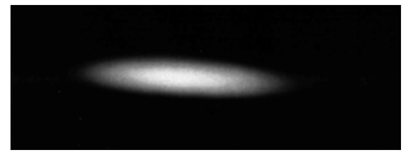

Figure 5: Separated beam image in the BL-5 bending

According to the values of β-function in the undulator source point βx=10.25m, βy=8.64m, and in the bending source point βx=2.69m, βy=8.48m, the beam profile in the undulator has a large beam size in the horizontal compare with the beam size in the bending magnet. The spatial resolution of this focusing system is no longer enough to measure the vertical beam size due to diffraction. Since our point in this work is not to measure the beam sizes, but to measure the beam position. This image is enough for the position detection of the beam in the undulator.

CALIBRATION OF BEAM POSITION BY OPTICAL BEAM SIFTER

The calibration of system is necessary to know the absolute quantity for the position movement of the beam. We can use several methods to calibrate the beam position, for example, to apply local bump to move the beam by known quantity, to move whole focusing system, to move optical axis by optical beam shifter, etc. The first one, to apply a local bump, has not accurate enough due to ambiguities in the lattice parameters of the source point. To move the whole focussing system is possible, but it is not easy. To compare with these methods, using a optical beam shifter which is usually used in surveyor's level is very simple and accurate. The optical beam shifter shifts the optical axis in parallel manner as shown in figure 6 by rotate optical flat set in front of the objective lens. The optical shifter makes shifted virtual image on the focal plane.

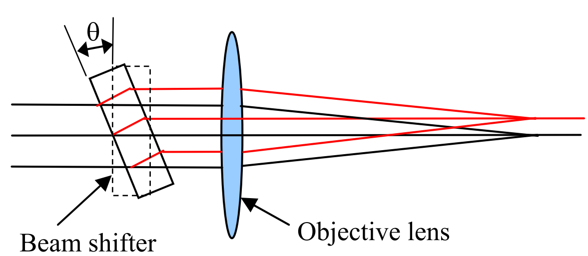

Figure 6: Function of beam shifter for the calibration of beam position by sifting the input optical axis.

We used an optical flat made of optical glass SF11. The thickness is 20mm. The refractive index of SF11 for 550nm is 1.78. The quantity of the parallel shift δ of optical axis is given by;

$$\delta = d \cdot \left[\sin\theta - \frac{\cos\theta \cdot \sin\theta}{n \cdot \sqrt{1 - (\sin^2\theta)/n^2}} \right]$$

Where d is the thickness of the optical flat, n is the refractive index of glass, and θ is rotation angle of optical flat. With two-dimensional rotation of the optical flat in the vertical and the horizontal plane, we can calibrate the vertical and the horizontal scale independently. The results of two times of calibration are shown in figure. 7.

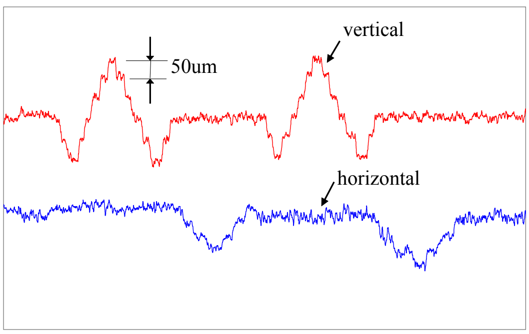

Figure 7: Result of calibration for beam positions. One step of the calibration corresponds to 50μm.

We use a simple position analysis via centroid calculation to obtain the vertical and the horizontal beam positions. According to fast beam position feedback system [3] for vertical direction, the vertical beam position is stable during the calibration, and we obtained a good result of calibration for the vertical beam position. We only have RF frequency feedback to stabilize the horizontal beam position in the PF. The horizontal beam position was not stable enough to obtain good result for calibration for horizontal in this time. One step in the vertical beam position is corresponding 50μm in figure 7, and spatial resolution of this monitor is better than few microns.

OBSERVATION OF BEAM POSITION IN THE UNDULAOR DURING MOVING OF THE GAP

After the calibration of the monitor system, we observe the vertical and the horizontal beam position in the undulator during moving the gap. We change the undulator gap form 140mm to 70mm. Corresponding K values are 0.56 and 4.13 respectively. The intensity of beam image changed four times during the change of gap. The profile of observed beam image is not change during the gap movement. A result of measurements for beam positions in the vertical and the horizontal during moving the gap is shown in figure 8. When we change the gap of undulator, from 140mm to 70mm, the beam positions in the undulator were moved about 10μm in vertical. We cannot found any systematic movement in the horizontal beam position. The vertical and horizontal beam positions are measured every 1sec.

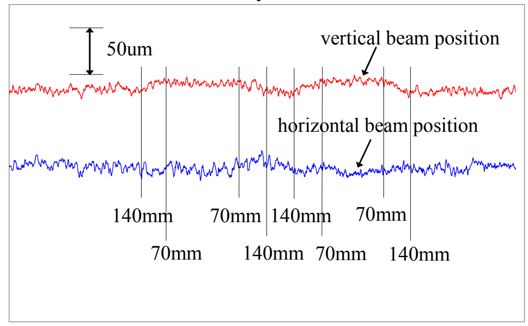

Figure 8: A result of measurements beam positions during moving the gap from 140mm to 70mm.

ANGULAR DETECTION OF BEAM

To obtain the complete information of beam position in the phase space, we mast measure the angular deviation of the beam. To measure an angular deviation of the beam in undulator is just same problem to measure an angular deviation of optical axis of SR from the undulator. Since the afocal system like a Kepler type telescope [4] converts the angular deviation of optical axis of input ray into position deviation, we can measure an angular deviation through a position deviation on CCD. This afocal system will be installed in the monitor in coming autumn to test angular deviation detection of the beam.

CONCLUSIONS

A beam position monitor for the undulator by using the optical SR monitor technique has been tested in the Photon Factory. We separate undulator light from downstream bending light by optical way. We obtain spatial resolution of the monitor better than few microns and measure the vertical and the horizontal beam positions during the change of undulator gap. The change of the undulator gap has no effect for position detection in this monitor.

ACKNOWLEDGEMENT

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