Determination Of Photon-beam Axis At BL27SU

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1. Introduction

For many synchrotron radiation users, one of the most interesting matters in the use of an undulator as a light source is the fluctuation of the photon-beam axis while tuning the photon energy, *i.e.*, changing the gap. At SPring-8, steering coils located upstream and downstream at the insertion device (ID) correct the variation of closed orbit distortion (COD) caused by the error field of the ID. The policy of COD correction is that changing the gap of a specific ID does not affect the photon-beam axis of other beamlines. In other words, changing the ID gap may fluctuate the photon-beam axis of its own beamline. Therefore, it is necessary to estimate the quantity of such fluctuation.

At BL27SU of SPring-8, a novel ID called a figure-8 undulator is adopted as a light source to produce linearly-polarized soft X rays in the energy range between 100 eV and 5000 eV [1]. The power distribution from the figure-8 undulator has two outstanding features. One is that the on-axis power density is much lower compared to conventional linear undulators, being an important advantage for soft X-ray beamlines using undulators as light sources. The other is that it is asymmetric with respect to the vertical axis [2], which makes it difficult to determine the photon-beam axis by using conventional methods.

In this report, two new methods to determine the photon-beam axis are described and comparison between the two is made. In addition, results of estimation of fluctuation of photon-beam axis are shown.

2. Power-distribution Measurement

The relative intensity of radiated power emitted from the figure-8 undulator was measured by means of voltage-force current-measurement using the thin-foil I_0 monitor, which is the transmission type photo-cathode with 50 μm thick gold-foil, and its specific isolated I/V converter [3]. These equipment enable us to get information about spatial distribution of radiated power by scanning the front-end xy slits assembly (FEslit) in horizontal and vertical direction [4]. Figure 1 shows the measured spatial distribution of radiated power when the undulator gap was 50 mm. In order to clarify the power distribution, a filter was inserted into the beam axis so as to reduce the soft X-ray contribution. Characteristic V-shape of the power distribution was clearly observed. The photon-beam axis in the vertical direction can be easily determined from this measurement because the spatial distribution in the vertical direction is symmetric with respect to the horizontal plane.

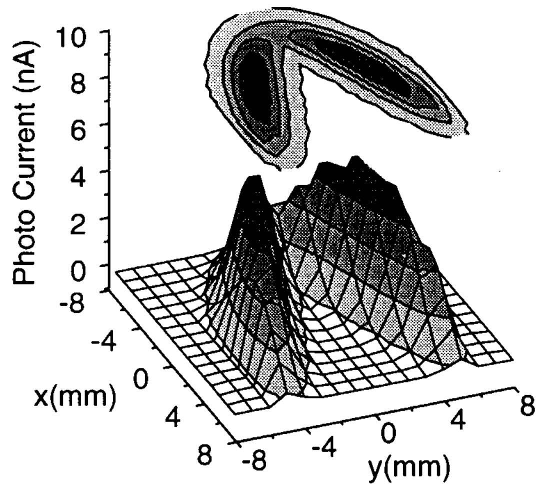

Fig. 1: Measured spatial distribution of power density.

Determination of the optimum position of the FEslit in the horizontal direction, on the other hand, is tricky because the power distribution in the horizontal direction is asymmetric and the axis of the fundamental radiation resides in the hollow of the characteristic V-shape. According to the radiation theory, the emission angle θ_y in the vertical direction, where the radiated power density is maximum, is well characterized by the horizontal magnetic field to be $\gamma K_x/\sqrt{2}$ in the vertical plane where $\theta_x = 0$. This fact means that we can determine the photon-beam axis in the horizontal direction by scanning the FEslit in vertical direction. We have measured the spatial distribution several times and get the optimum position of the FEslit to be (0.68 $\pm$ 0.2, -0.33 $\pm$ 0.07).

3. Spectral Measurement

The power distribution along the horizontal direction has its maximum at the point far from the axis, while the photon flux density at the peak energy of each harmonic has its maximum near the axis. Therefore, it is possible to determine the photon-beam axis by measuring the spectrum at various points of observation.

3-1 Principle

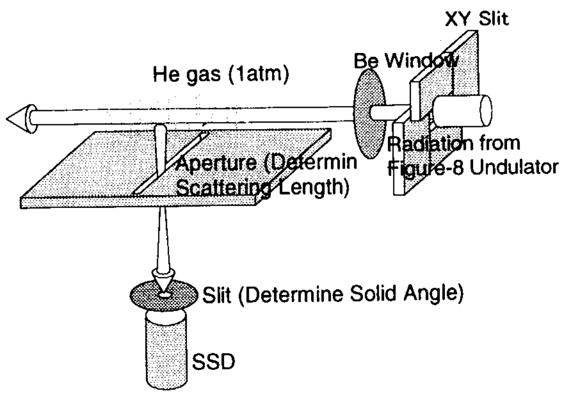

Fig. 2: Schematic illustration of instruments to measure spectra.

Figure 2 shows the schematic illustration of instruments to measure the spectrum. After transmitting the Be window, the photon beam is introduced into the chamber filled with He gas with the pressure of the atmosphere. The photons scattered to the right angle with respect to the photon beam by He atoms are detected by the solid state detector (SSD). Spectra at various observation points are measured by scanning the FEslit. After that, the counts at specific energy are plotted vs. the observation points and the photon-beam axis is determined by comparing the results with the calculation.

3-2 Result

Table 1 shows the conditions of measurement. At each gap, the FEslit is moved by 0.3 mm (horizontal) and 0.1 mm (vertical) step. Figure 3 shows an example of the dependence of the measured spectra on the change of the FEslit horizontal position (= x). The gap value is 77 mm and the FEslit vertical position -0.3 mm. The photons below 3 keV were not observed due to absorption by the Be window. From this figure, sharp peak correspondent to each harmonic is found in lower energy, while it disappears in higher energy. The photon counts at the peak energy (*e.g.* 3.3 keV, indicated by an arrow in the figure) has its maximum at x = 0.72, meaning that the photon-beam axis is around there. What is interesting is that the photon counts in higher

Table. 1 Measurement conditions

Gap (mm)	160, 100, 77, 61, 50, 45, 40
FEslit vertical position (mm)	-0.18~2.82
FEslit horizontal position (mm)	-0.8~0.2
FEslit Width (mm)	0.5
FEslit Height (mm)	0.2

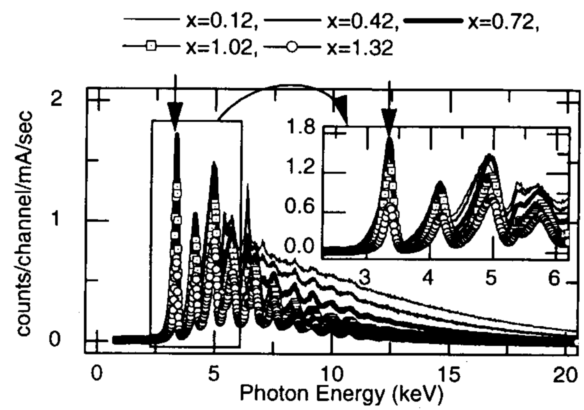

Fig. 3: Dependence of spectra on the FEslit horizontal position.

energy (*e.g.*, more than 10 keV) degrade as the increase of x. This is similar to the dependence of the power density on x. Figure 4 shows the relation between photon counts at 3.3 keV and x. In the same figure, calculation results including the

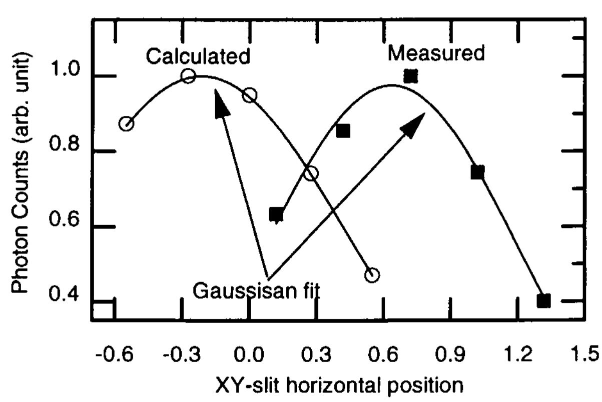

Fig. 4: Photon counts as a function of FEslit horizontal position. Both measured and calculated are shown.

detector's resolution, electron-beam emittance and FEslit width and height is also shown. The calculated photon-count peak is found at x = -0.2 mm, while that of the measured data is found at x = 0.64 mm, therefore we determine the photon-beam axis to be at x = 0.84 mm.

Using the methods above, the photon-beam axis at each gap is determined. Table 2 shows the result. The fluctuations of vertical and horizontal axis are within ± 0.1 mm and ± 0.03 correspondent to ± 3 μrad and ± 1 μrad deflection, respectively.

When the energy of the 1st harmonic is set at 1000 eV, the horizontal and vertical photon-beam divergence is calculated as 25 μrad and 17 μrad, respectively. Therefore, the photon-beam fluctuation due to the change of the gap is within 10 % of the photon-beam divergence.

Table. 2 Determined photon-beam axis

Gap (mm)	x axis (mm)	y axis (mm)
40	0.78	-0.46
45	0.74	-0.47
50	0.72	-0.47
61	0.71	-0.45
77	0.84	-0.44
100	0.86	-0.43
160	0.95	-0.50

4. Conclusion

The results of determination of photon-beam axis using two different methods agree well with each other. Using the spectral-measurement method, the quantity of fluctuation of photon-beam axis due to the gap change is estimated and found that it is small enough compared to the photon-beam divergence.

As the figure-8 undulator is a novel ID, other characteristics such as polarization, spatial distribution and complete flux should be investigated. The experiments for such investigation are now in progress.

References

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