A Portable Absolute-Intensity Monitor for High-Energy Synchrotron Radiation

An attractive advantage of SPring-8 is that a monoenergetic photon beam up to 100 keV energy region is available at bending-magnet beamlines. High-energy X-rays with an excellent energy resolution are not available by conventional X-ray machine and non-large-scale synchrotron radiation facilities. For applications of a unique photon beam, an absolute intensity monitor becomes an important tool; however, this type of monitor had not been realized.

In SPring-8, several parallel-plate free-air ionization chambers of different sizes are used as monitors, which has the advantage of robustness, easy handling and suffering no radiation damage even under long irradiation. The mechanism is simple; electrons emitted at photon interaction ionize the air and parallel electrodes collect the ions and electrons produced. The photon intensity can be calculated from the output current, which corresponds to the dose in the sensitive volume. For the measurement of the absolute intensity, electrons have to lose all the energy in the collecting volume because in the condition of no electron loss the conversion formula from dose to intensity is available. To attain the condition, the electrode separation has to be larger than the twofold of the maximum distance of electron traveling in principle. That is, the separation has to increase with the energy and so the necessary value reaches 27-cm at 100 keV. On the other hand, if the wide plate separation were used for high-intensity photons in SPring-8, a tremendously high voltage would be required to suppress the recombination.

Here, it should be noted that electrons are emitted by two kinds of interactions: photoelectric and Compton effect. While the energy of photoelectrons is almost the same as that of photons, the Compton recoil electrons have much lower energies; the maximum energies for 50 and 100 keV photons are only 8.2 and 28 keV, respectively. Conveniently enough, with increasing photon energy, the proportion of the ionization by photoelectrons decreases rapidly.

Furthermore, synchrotron radiation from bending magnets is linearly polarized on the horizontal plane; thus, photoelectrons are preferentially emitted on the horizontal plane as shown in Fig. 1. Therefore, most photoelectrons do not hit electrodes if they are placed horizontally. On the other hand, Compton electrons are emitted forward on the vertical plane; however, the energies are low enough. Thus, in high-energy region, the reduced photoelectric effect and linear polarization can be expected to decrease electron loss remarkably even not using such a wide plate separation. The narrow separation will increase the electric field, which will make the chamber applicable to high-intensity synchrotron radiation [1].

For detailed physical simulation, a Monte-Carlo electron/photon transport code, EGS4 [2], was used.

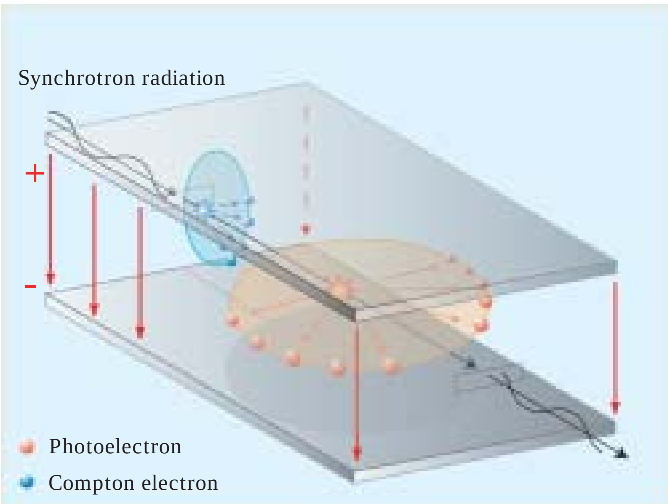

Fig. 1 Schematic of the electron motion produced in air of the monitor. Photoelectrons have almost the same energy as incident photons and some are emitted at a large angle with respect to the beam axis. Linear polarization, however, increase the magnitude of emission on the horizontal plane. By contrast, Compton electrons have a much lower energy when emitted on the vertical plane.

In the Monte-Carlo method, a random sampling method is used to determine the interaction probability, the particle direction, the energy after the interaction, and so forth. Linear polarization was considered in the calculations. For the electron loss, absorbed energies in the air at the plate separations of 8.5 cm and infinity were calculated, and the ratio of these two values was used as the collection efficiency: The difference between the ratio and unity equals the proportion of electron loss. Figure 2 shows the calculated result. The electron loss became within 3.3% even at 80 - 190 keV and beam size dependence was not observed between the 1- and 10-mm square beams. Without linear polarization, the electron loss increased to 4 - 5% between 70 and 150 keV. The reason for the decrease in electron loss at 150 keV is the decreased occurrence of the photoelectric effect.

For experimental confirmation, the photon intensity measured with the ionization chamber with an 8.5 cm plate separation was compared with that measured with a Si-PIN photodiode at **BL20B2** and **BL38B1** beamlines. The photodiode has been calibrated with a total absorption calorimeter [3]. The result is also shown in Fig. 2 as the ratio of both values. The ratio equaled unity within 3% and the dependence of the collection efficiency on the photon energy agreed with the EGS4 result. That is, the deviation from unity at 80 - 150 keV is due to the electron loss from electrodes.

In conclusion, a portable photon intensity monitor with an uncertainty of 3% for high-energy synchrotron radiation has been developed. While the interelectrode distance of 8.5 cm is much shorter than the twofold electron range at 150 keV, that is, 53 cm, sufficiently low electron loss was confirmed. The ionization chamber can be carried easily from one beamline to another to monitor the photon intensity.

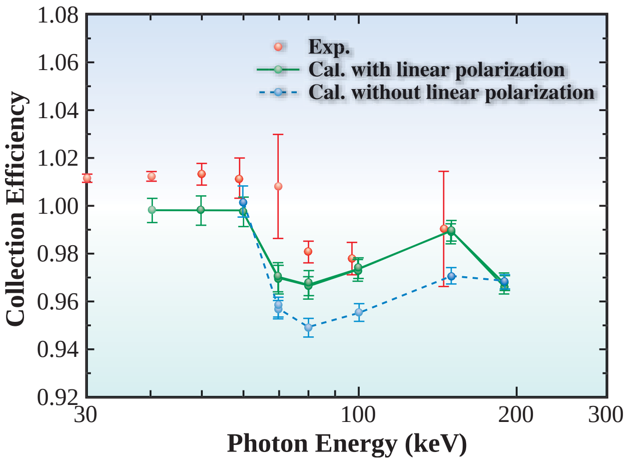

Fig. 2 Collection efficiency measured and calculated by considering linear polarization. Both values almost agreed with each other: the decrease between 80 and 150 keV is due to the electron loss. Without linear polarization, collection efficiency became clearly smaller between 70 and 150 keV.

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References

[1] N. Nariyama, N. Kishi and S. Ohnishi: Nucl. Instrum. Meth. A **524** (2004) 324.
[2] W.R. Nelson *et al.*: SLAC-265 (1985).
[3] H. Nakashima *et al.*: Nucl. Instrum. Meth. A **310** (1991) 696.