Simulation and Experimental Studies on Radiation Generation in an Electron Storage Ring

Runa Murayama[a], Miho Shimada[b,a], Hirohi Miyauchi[b,a], Katoh Masahiro[a]

[a]*Hiroshima University (HiSOR)*
2-313 Kagamiyama, Higashi-Hiroshima, Hiroshima 739-0046, Japan
[b]*High Energy Accelerator Research Organization (KEK)*
1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan

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The synchrotron radiation source at Hiroshima University, HiSOR which was constructed nearly 30 years ago, has been facing serious challenges, including a decline in competitiveness due to construction and commissioning of new generation light sources with higher-performance as well as a reduction in operational availability caused by aging of the facility. In response to these issues, the construction of a successor facility, HiSOR-2, is being planned.

In many electron storage rings used as synchrotron light sources have shielding walls surrounding them. However, the current machine, HiSOR, does not have such shielding wall. It has two huge bending magnets of 180 degrees. Their iron cores are H-shaped and the return yokes of outer sides play the role of shielding wall. However, its successor, HiSOR-2, will not employ such specially designed bending magnets but instead will use bending magnets of normal shape and standard size. As a result, the shielding effect provided by the yoke of the bending magnets will not be expected. Therefore, it is being considered to surround the accelerator with shielding walls. To save the construction cost, a rational scheme of radiation protection is required.

As the first step of our study on the radiation protection for HiSOR-2, we are investigating the shielding effects of accelerator components, particularly those of the magnets. We constructed a simple model of a part of a storage ring consisting of a straight section followed by a bending section, as shown in Figure 1. In this model, we consider collisions between stored high energy electrons and residual gas molecules in the vacuum chamber. The collision would result in changes in the momentum and energy of an electron and would significantly change its orbit. When this change is larger than some threshold, the electron finally hits the vacuum chamber wall and generate electromagnetic showers which contain gamma-rays, electrons and positrons. In addition, gamma rays are also produced via bremsstrahlung when the electron collides with the gas molecules. The gamma-rays produce neutrons when they hit some materials. The behavior of their propagation in air provides fundamental knowledge necessary for considerations of radiation protection.

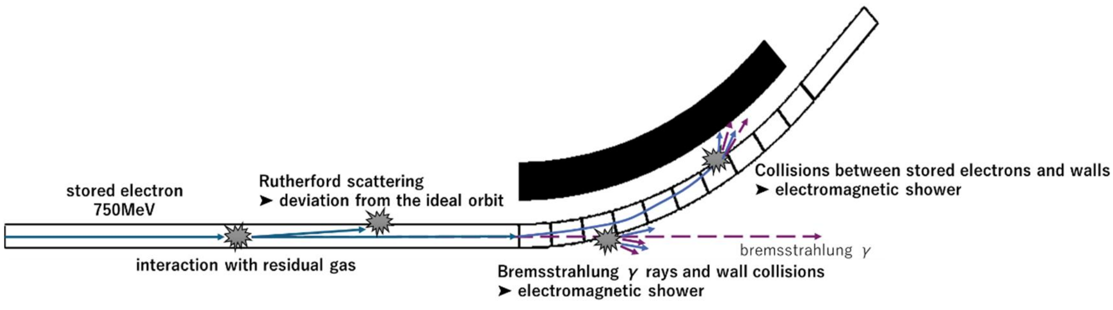

FIGURE 1. Beam loss mechanisms due to residual gas interactions

The simulations were performed using PHITS (Version 3.350) [1]. The simulation model consists of a C-shaped bending magnet with a yoke of iron and coils of copper and vacuum chamber (beam pipe) of SUS.

The model is based on the UVSOR electron storage ring, which is a typical low energy synchrotron light source [2]. In the model, the vacuum chamber is filled with monoxide (CO) gas of an appropriate pressure. Electrons running on the reference orbit come into the system. Some of them collide with residual gas at the straight section and deviate from their original orbit. The effect of the magnetic field is included in the simulation. Therefore, the electrons that lose energy are largely deflected in the bending magnet section. An example of the simulation result is shown in Figure 2, where the flux of the radiation is indicated by color. Generation and propagation of the radiation are clearly seen in the result.

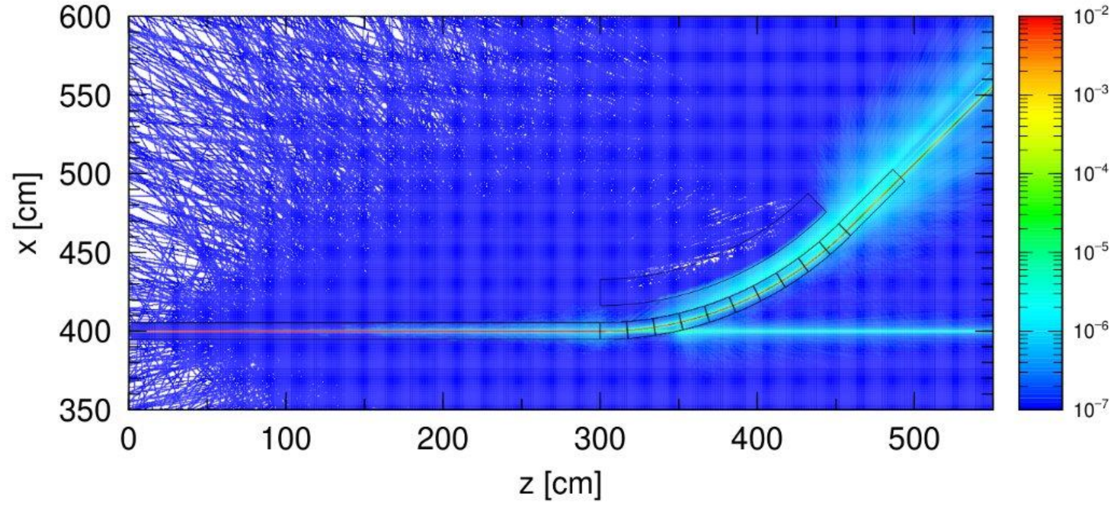

FIGURE 2. An example of simulation result. The flux of the radiation composed of mainly electrons and gamma-ray are indicated by color.

In parallel to the simulation study, a measurement study at the UVSOR storage ring is going on using Gafchromic films. Comparisons between the measurements and the simulation results are being conducted. The results will be reported in near future.

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REFERENCES

1. T. Sato *et al.*, ***J. Nucl. Sci. Technol***. 61, 127-135 (2024)
2. H. Ota *et al.*, ***J. Phys.: Conf. Ser***. 2380(1) 012003-012003 (2022)