

RADIATION MEASUREMENT AROUND A 10-T SUPERCONDUCTING WIGGLER AT SPring-8

M. Shoji, K. Soutome, N. Kumagai, J. Tada, T. Magome, M. Oishi, T. Ohshima,
S. Sasaki, M. Takao, T. Takagi, K. Tsumaki, T. Yorita, and H. Yonehara,
JASRI/SPring-8, Sayo-gun, Hyogo 679-5198, Japan
Y. Asano, The Japan Atomic Energy Research Institute,
Sayo-gun, Hyogo 679-5148, Japan

Abstract

In August 2002, a 10-T superconducting wiggler was installed in the 8-GeV electron storage ring at SPring-8. High-energy (~3MeV) and intense synchrotron radiation was produced from the wiggler, and scattered photons were generated by the interaction of synchrotron radiation with photon absorber materials. The intense radiation environment in the storage ring tunnel damages accelerator components, such as cable insulators and coils for electromagnets. To suppress such damage, it is necessary to understand the dose distribution and the spectrum of scattered photons near the wiggler.

The dose distribution and the spectrum of scattered photons from the photon absorber was measured by thermoluminescent dosimeters (LiF TLD) with lead filters (0, 0.5, 1, 3, 6 mm in thickness). At the same time, alanine dosimeters and GafChromic film (made of polyethylene) were used to measure the dose of photons which exceeded the dynamic range of TLD dosimeters.

The results of an experimental data analysis showed that, as expected, photons of energies of several hundred keV were scattered over a wide range.

INTRODUCTION

SPring-8 is a synchrotron light source composed of an 8-GeV electron storage ring, a booster synchrotron, and a 1-GeV injector linac. The storage ring has 44 normal Chasman-Green cells, each of which has a 6.5-m straight section for insertion devices. The main parameters of the storage ring are listed in Table 1.

Table 1: Parameters of SPring-8 storage ring [1]

Electron energy		8 (GeV)
Beam current		100 (mA)
Circumference		1436 (m)
Number of cells	Normal cell	44
	Straight cell	4
SR from B-magnet	Power density	1.5 (W/mrad/mA)
	Critical energy	30 (keV)

We installed a 10-T superconducting wiggler (SCW) in one of the normal cells in August 2002. The main parameters of the SCW are described in Table 2. We tested its performance in September 2002[2]. A beam was successfully stored in the storage ring at SCW magnetic fields of up to 9.5 T. The stored current was limited to

0.1mA to maintain radiation safety. The storage ring is always operated at a beam current of 100mA for beamline users. If we use the SCW on 100-mA operation, the radiation level in the storage ring tunnel increases by high-energy photons scattered at the photon absorber. To reduce radiation damage to the accelerator components, we need quantitative data on the scattered photons from the SCW and we have to shield them from the intense radiation environment, effectively.

Table 2: Parameters of the SCW

Construction	Three pole magnet
Magnetic field	9.5 (T) (Max. 10.3 (T))
SR Power density	22 (W/mrad/mA peak)
Total power	1.0 (kW/1mA)
Critical energy	400 (keV)
Radiation angle	25 (mrad)

In this paper, we describe an investigation in dose distribution and the spectrum of high-energy scattered photons near the SCW. We then use the data to design the radiation shields for accelerator components.

EXPERIMENTS

Experimental setup

Figure 1 shows a schematic layout of the experimental setup. The SCW was installed close to the center of the straight section. The vacuum chamber of the photon absorber was placed downstream of the SCW. As shown in Fig. 1, two lead blocks (100-mm wide, 50-mm deep, and 200-mm high) were attached on both sides of the chamber (only on the outside of the storage ring circumference). They shaded the accelerator components, such as the vacuum gauge head, etc. The photon absorber was made of copper, and had a rectangular aperture with 52-mm horizontal and 32-mm vertical axes. SR with a larger angular spread than 10 mrad in the horizontal plane is influenced by the absorber walls. One TLD stand (2-m wide and 2.3-m high) was placed upstream of the absorber, at a distance of 1m. Another TLD stand (2.5-m wide and 2.3-m high) was placed downstream of the absorber, without touching the vacuum pipe of the beamline.

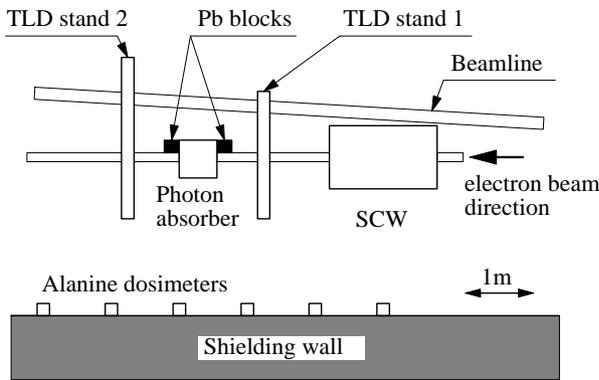


Figure 1: Schematic layout of the experimental setup. TLD dosimeters were attached on the TLD stands.

TLD dosimeters with lead filters were assembled on the holder made of paper. Eight TLD holders were attached on the upstream stand, and 7-holders were on the downstream stand. The arrangement of TLD holders on the upstream stand is shown in Fig. 2. The detection angle from the beam axis was from 45 to 50 degrees.

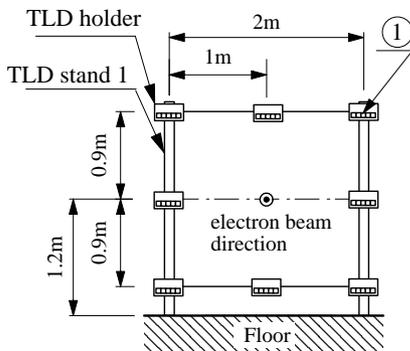


Figure 2: Arrangement of TLD holders.

On the shielding-wall, 1.2-m above the floor (the same height as the median plane of the electron orbit), twenty alanine dosimeters were mounted at intervals of 1m from just besides the SCW.

Measurements

We prepared two sets of TLD dosimeter assemblies. First, one set was mounted on the TLD-stands. Before dose measurement, we operated the storage ring at a very small current (0.1mA.10min) and fixed the electron orbit to hit the SR at the same place of the photon absorber. Dose measurement was carried out for one hour with the storage ring operated at a beam current of 1mA. The dose measured during the small current operation was about 2 percent of the dose measured at a 1-mA operation. Next, we dumped the stored beam, and changed the TLD assemblies for the other set. We then mounted twenty alanine dosimeters near the SCW to measure a dose that exceeds the dynamic range of a TLD dosimeter (more than 2 Gy). At the same time, we fitted a GafChromic

film around the vacuum chamber of the photon absorber to measure the dose distribution of the surface of the absorber.

All the dosimeters were irradiated for one hour at a beam current of 0.1mA. After irradiation, we analyzed them and got information on the dose of the scattered photons.

RESULT AND DISCUSSION

We found that the dose measured at the upper part of the median plane of the electron orbit is larger than the dose measured at the lower part. This result may be explained by the TLD assemblies being shaded with the accelerator components (such as Pb blocks, vacuum pumps, and girders of the vacuum chambers), which were installed near the photon absorber. We shall confine ourselves to analyzing the data which was obtained at the upper part of the median plane.

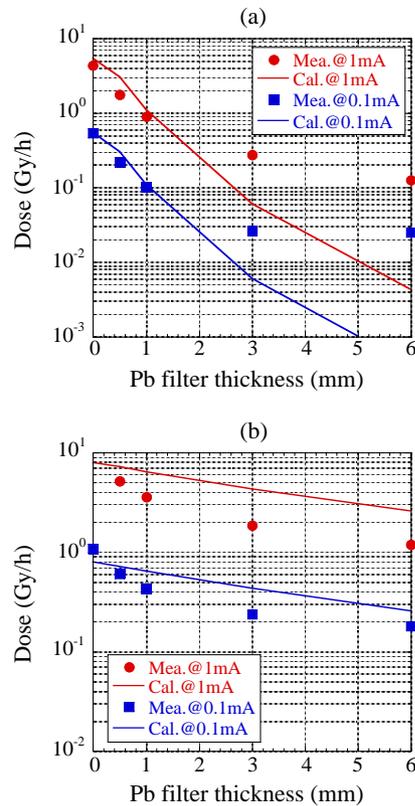


Figure 3: Dose measured and calculated on vertical plane of electron orbit. (a) is dose at upstream of the absorber, and (b) is at downstream. Dose is plotted as function of lead filter thickness.

Figure 3 shows a typical result of dose that was measured at the place pointed with 1 in Fig.2, and the result of dose calculation using STAC8 code. Data over 5 Gy was excluded because the TLD lost linearity with the dose sensitivity. The dose is in proportion to the stored beam current of the storage ring and the dose of the downstream is over an order of magnitude larger than the

dose of the upstream. They may be attributed to the angular dependence on the cross section of Compton scattering.

Scattered photon spectrum on the surface of the TLD was calculated by assuming the geometrical arrangement of the photon absorber and the TLD. From the calculation, we found that photons of energies mainly from 100 to 300 keV will be observed upstream the absorber and 100 to 1000 keV will be observed downstream. Using the spectra, we estimated the dose on the TLD. The calculated dose was drawn in Fig.3. The calculated dose agrees with the measured values except for a few points measured upstream using the thick filters. This discrepancy may be interpreted on the assumption that the TLD dosimeters placed upstream of the absorber were influenced by high-energy-photons such as secondary-scattered-photons from the SCW chamber. In order to support this explanation, it is necessary to calculate the dose taking account of the effect of secondary-scattered-photons.

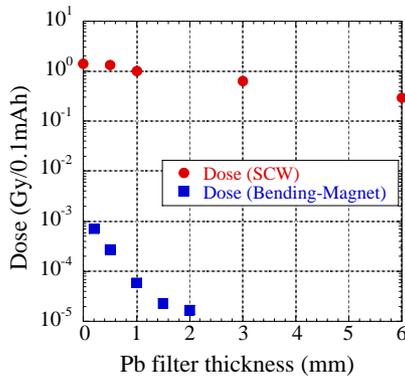


Figure 4: Comparison with dose from SCW and bending magnet.

We compared the dose of scattered photon from SCW with the dose from the bending magnet of the storage ring [3]. The result is shown in Fig. 4. Data was normalized by the stored current and the distance from the absorber. The difference between two slopes of the plots may be attributed to a difference in the critical energy of the incident photons. The total power of SR from SCW, that was absorbed by the photon absorber, is two orders of magnitude larger than the total power from the bending magnet at the same current operation. The order of magnitude between the dose from SCW and the dose from bending magnet cannot be interpreted from the difference in total power. The dose difference may be explained by the assumption that high-energy-scattered-photons from SCW escaped from the absorber chamber and increase the radiation level at the TLD dosimeters. To prove this assumption, it is necessary to carry out a detailed study on the energy of scattered photons from the bending magnet.

The measured values of alanine dosimeters were less than the search limit (less than 2 Gy). The reason for this

result is that all dosimeters were placed more than 3m from the photon absorber.

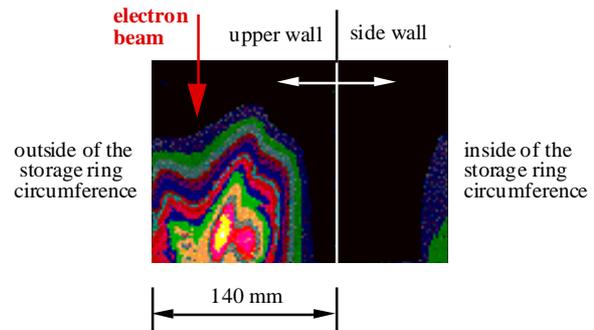


Figure 5: Dose distribution measured using GafChromic film on the photon absorber.

Figure 5 shows the dose distribution on the photon absorber. Maximum value of the dose is 1500 Gy. As shown in Fig. 5, GafChromic film that was put on the upper wall, was much exposed than the film put on the side wall. This fact is supported by several ways:

1. Thickness of the upper wall is a one-third of the side wall,
 2. Dose distribution is influenced by the angular dependence on the cross section of Compton scattering,
 3. SR from SCW is linearly polarized in a median plane of the electron orbit, and scattered photons have a maximum strength in a vertical direction of polarization.
- Further analysis is necessary.

CONCLUSION

The dose distribution and the energy spectrum of scattered photons from the photon absorber were measured near the SCW. The dose from the SCW is three orders of magnitude larger than the dose from the bending magnet. The dose distribution is predicted from the principle of Compton Scattering.

If we design the radiation shields for accelerator components it is necessary to investigate dose distribution and the energy spectrum of penetrated photons in future.

ACKNOWLEDGEMENTS

The authors wish to thank the staff of the facilities and SPring-8 service Co., Ltd. for their kind help.

REFERENCES

- [1] H. Ohkuma, et al., Proc. of the PAC 2001, Chicago, Illinois, June 18-22, 2001, p. 2824.
- [2] K. Soutome, et al., "Generation of high-energy synchrotron radiation with a 10T superconducting wiggler installed in the Spring-8 storage ring", published at this conference.
- [3] A. Imai, Master's Thesis to Kyoto university.