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REAL-TIME RADIATION MONITORING SYSTEM WITH INTERLOCK PROTECTION MECHANISM IN TAIWAN PHOTON SOURCE

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Abstract

To ensure radiation safety for personnel working in the facility, the Radiation and Operation Safety Division has installed a real-time radiation monitoring system in the working area to monitor gamma rays and neutrons, for which the annual dosage limit is designed to be less than 1 mSv/year. Considering 2000 working hours for users and staff members, we have derived a control dose rate limit 2 μSv/4h for interlock protection. If the accumulated radiation dose monitored with the system exceeds 2 μSv within a 4-h counting interval, the radiation monitoring station sends a signal to the interlock system to stop injection until the next counting period interval. This paper introduces the radiation monitoring system and its related design information in Taiwan Photon Source.

INTRODUCTION

Taiwan Photon Source (TPS) is a 3-GeV light source with a circumference more than 500 m and operating fully in top-up mode, aiming to provide synchrotron light with extremely great brilliance and low emittance (Fig. 1). For more detailed information about TPS, please refer to its design handbook [1].

Figure 1: Top view of the TPS facility.

The Occupational Safety and Health Management organization at National Synchrotron Radiation Research Center (NSRRC), also known as the Radiation and Operation Safety Division (ROSD), is responsible for drafting, planning, supervising and promoting the relevant affairs associated with safety, health and environmental protection, and giving implementation instructions to the related departments.

In a large facility such as TPS, the practical implementation of a radiation safety system (RSS) has two complementary sub-systems: access control system (ACS) and radiation control system (RCS) of the accelerators [2 - 4]. The RCS is to ensure that radiation in occupiable areas does not exceed design limits under all normal and even abnormal conditions of accelerator operation. It will include passive installations (such as shielding) and active systems (such as a radiation monitoring system). This article describes mainly the design framework and its interlock function of the radiation monitoring system designed by ROSD in TPS.

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RADIATION SOURCES

For the radiation safety system, radiation sources of four kinds originating from the operation of a synchrotron accelerator are considered – bremsstrahlung, neutrons, induced activation and synchrotron light. The design objective of radiation protection is to minimize the hazards arising from all these sources.

The former three forms of radiation sources result from interactions between lost electrons and accelerator components or walls. Bremsstrahlung originates from collisions between electrons and accelerator components during the generation, acceleration, injection and storage of an electron beam. Electrons of great energies penetrate into matter and cause an electromagnetic cascade [5]. The resultant copious gamma rays with a broad energy spectrum tend to be forward-peaked and are the primary target for shielding design (Fig. 2).

Neutrons are produced in photonuclear interactions from high-energy gamma rays. Although neutrons are much fewer and lack a strong directional dependence, shielding against them is also an important part of the shielding design because of their strong penetration of matter [6].

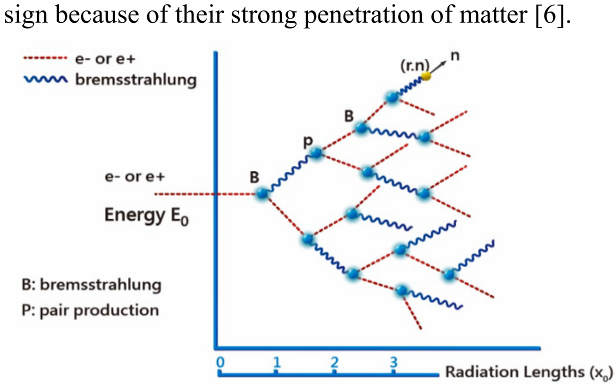

Figure 2: Electromagnetic cascade effect.

Induced activation is found in accelerator components when exposed to highly intense radiation. The susceptibility to activation depends on the energy and power of the incoming radiation as well as the target material. Radiation protection for induced activation in an electron accelerator is less significant than for bremsstrahlung or neutrons, as the half-life of a radio-nuclide is typically short and the activation decreases to a negligible level within a short time.

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Although having the greatest intensity, the energy of synchrotron light for low-energy facilities is much smaller than bremsstrahlung and neutrons. The penetrating ability of synchrotron light is so small that it is unable to escape from beamline shielding to induce a high dose for users.

REGULATORY REQUIREMENTS AND DESIGN DOSE LIMITS

The radiation safety program of NSRRC conforms to both Taiwan's regulations and international standards of radiation protection, control and monitoring; the principle As Low As Reasonably Achievable (ALARA) is applied.

A new safety standard on ionizing radiation issued by Taiwan AEC in 2002 recommended that the dose limit for a radiation worker should not exceed 100 mSv in five years. Implicit in this recommended dose, the optimized dose should not exceed 20 mSv in one year. In the community of synchrotron facilities, the annual dose limit ranges from 1 to 20 mSv. New facilities have generally adopted 1 mSv per year as an upper limit, which is equivalent to the regulatory requirement for the general public. This tendency strongly indicates that the experimental hall of a synchrotron facility is no longer a radiation-controlled area. To comply with the ALARA principle and recommendations from similar facilities, we have hence decided to accept a more challenging dose limit for TPS, 1 mSv/y, for all staff and users who are working 2000 hours in a year.

Considering 2000 working hours in a year as the maximum duration of occupancy for a typical user or staff member at the TPS experimental area, the allowable dose rate limit for any accessible area of the beamline is 0.5 μSv in one hour. Interlocked radiation monitors will be installed around the accelerator shielding wall and the beamline area. The interlock limit will be set to 2 μSv in 4 h. Such a design ensures that no user will receive a radiation dose larger than the TPS annual design limit, so that personal monitoring and access control is not mandatory.

When the cumulative radiation dose of the radiation detection station of an accelerator attains an excessively large value, greater than 2 μSv, the interlock system will stop the linear accelerator from generating new electrons, which decreases radiation in the experimental floor to the same level as the natural environment. When the radiation detection station of a beamline accumulates an excess dose of radiation, the heavy metal shutter in the front end will be triggered to close, which will terminate abnormal radiation.

POSITIONING OF TPS MONITORS

For each beamline we installed monitoring stations (Fig. 3) according to the distribution of radiation in the accelerator operation and the user occupancy in experimental areas (Fig. 4, update to 2021). The locations of monitoring stations around the accelerator are some possible hot spots or areas of high beam loss including position1 ~ position 16 in Table 1 (Fig. 5, update to 2021).

Figure 3: Real-time radiation monitoring stations with interlock.

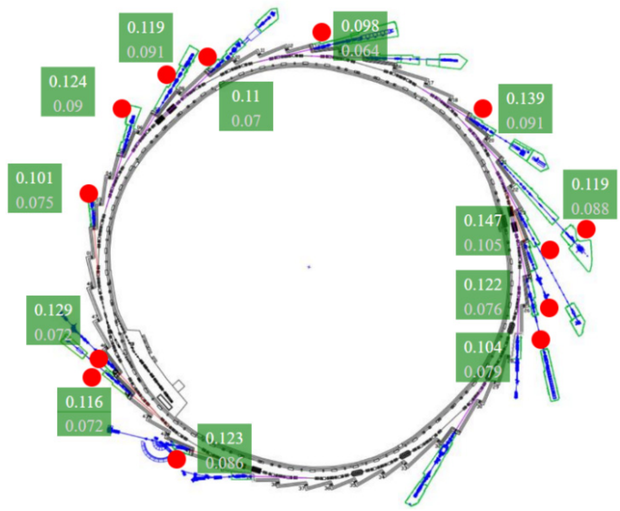

Figure 4: Positioning of monitors for TPS beamlines.

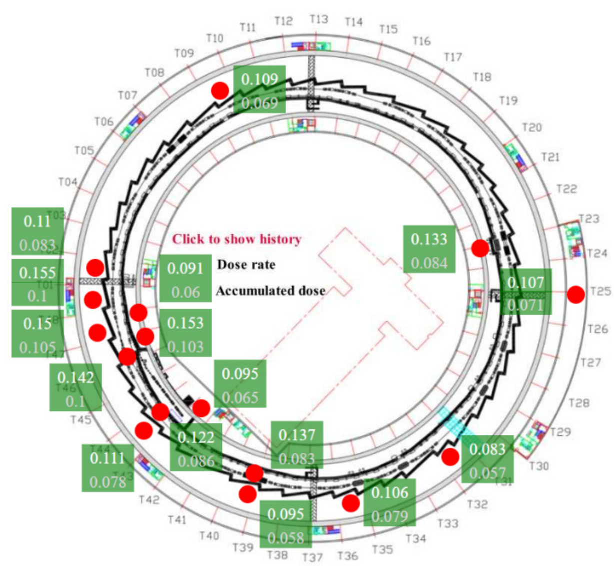

Figure 5: Positioning of monitors for TPS accelerator.

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Table 1: Positioning of Monitors

Number	Positions
NO.1	TPS control room
NO.2	Downstream of LINAC dump
NO.3	Downstream of LTB
NO.4	Entrance of LINAC maze
NO.5	Roof of BTS
NO.6	Inboard of BTS
NO.7	Outboard of LTB
NO.8	Downstream of BTS
NO.9	Beam port 09
NO.10	Booster RF
NO.11	Downstream of RF#2
NO.12	Downstream of RF#3
NO.13	Outboard of EPU46
NO.14	Roof of EPU46
NO.15	Outboard of EPU48
NO.16	Roof of EPU48

LOCAL DISPLAY INTERFACE OF A RADIATION MONITORING STATION

There are two major sources of radiation in the synchrotron accelerator. Besides synchrotron light provided in each beamline, bremsstrahlung is the major radiation source originating from electron depletion in every step of accelerator operation including generating, ramping, storing and dumping. The energy of electrons due to beam loss is released completely in the form of radiation; the high-energy radiation is generally blocked with the concrete walls of the accelerator shielding. Only a small amount of gamma-ray radiation and neutrons can be detected outside the shielding; the radiation exposure to staff is comparable with the radiation level of the natural environment in Taiwan. Considering the special pulse-time structure of the radiation field in the accelerator, we adopt mainly ionization chambers to measure gamma rays, and a moderated ^{3}He rem counter to measure neutron. We chose Thermo FHT192 as gamma-ray detector and Thermo FHT 762 as neutron detector. Both real-time data of gamma-ray and neutrons are collected with controller Thermo FHT6020 (Fig. 6).

Besides local display on a computer near the detector showing instantaneous monitoring results for the on-site staff (Fig. 7), the ROSD has also developed an online display interface so that staff can promptly obtain information anytime and anywhere (Figs. 4 and 5).

Figure 6: Display of Thermo FHT 6020 controller.

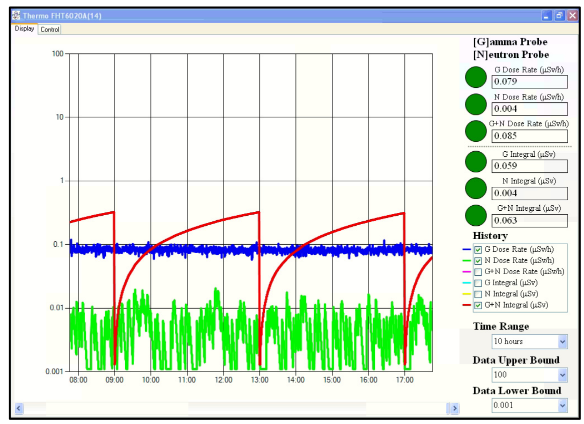

Figure 7: Local display interface of radiation data.

CONCLUSION

ROSD has set up a real-time radiation monitoring system including gamma-ray and neutron detectors with interlock in TPS. Monitoring stations exist in 16 sets for the accelerator and 13 sets for beamlines in 2021. For all detectors, the dose limit is the same, 2 µSv in 4 h, to comply with the ALARA principle and recommendations from similar facilities.

Each station has its local display showing instantaneous monitoring results. The gamma-ray and neutron doses can be accumulated and recorded in 24 h uninterrupted. The ROSD has also developed an online display interface; the staff can promptly obtain information anytime, anywhere.

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