Status of Radiation Safety System at Taiwan Photon Source

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Abstract

Taiwan Photon Source (TPS), a third generation synchrotron accelerator operating 3GeV electrons in a orbit of 518 meters, is approaching the installation phase in 2013 after more than three years of civil construction. Radiation safety system, which is crucial to the safe operation of this powerful accelerator, includes shielding design, access control system, radiation monitoring and interlock system for accelerator and beamline. The design of all these elements has been completed after numerous times of discussions with staff from various subsystems and the procurements process is underway. This paper describes the current status of TPS project with focus mainly on the features of radiation safety system.

Introduction

The Taiwan Light Source (TLS), the first facility in Asia featuring a third generation synchrotron light source, has been operational for two decades. In recent years, thousands of scientists from Taiwan and around the world have been conducting scientific experiments in this 1.5 GeV storage ring with circumference of 120 meters. The performance of TLS is remarkably successful in terms of user number, proposals submitted, experiments performed and scientific achievements, although TLS is a relatively small accelerator. Inevitably, certain limitations have started to surface and some of them have little room to improve, such as the relatively high emittance of TLS that has limited the research capabilities of several experimental proposals, and most importantly, further expansion of new beamline will not be possible since all the beam ports have been occupied. With the increasing demands of X-ray users on the emerging research fields, National Synchrotron Radiation Research Center (NSRRC) has decided to build a new intermediate energy light source, the Taiwan Photon Source (TPS)[1], which will be a 3 GeV electron synchrotron with a circumference of 518 m and operating fully in top-up mode, aiming to provide synchrotron light with extremely high brilliance and low emittance. After the completion of the TPS project, there will be two complementary light source facilities TLS and TPS located in NSRRC campus to provide high quality synchrotron radiations covering wide range of photon spectrum to meet users' diversified needs.

The optimum goal of TPS radiation protection is to ensure the annual dose received by users or staff is compatible with the regulatory requirement set for general public that is 1 mSv in a year[2] and this is a widely adopted standard for new light sources[3]. However, this is not a trivial task given the fact that TPS has formidable shielding but radiation due to beam loss or gas bremsstrahlung from a storage ring of 518m operating at 3GeV and 500mA is a big challenge. To maintain accumulated radiation dose in TPS experimental floor or on the shielding wall below 1 mSv for 2000 working hours in a year requires very smooth accelerator operation under rigid safety envelope regulated by radiation safety system[4].

Shielding Design

The shielding design and dose assessment for TPS was summarized in the TPS Radiation Safety Analysis Report[5] which was reviewed by three prestigious experts from ESRF, SLAC and SPring8 in 2009. Methodology on safety analysis, tools for dose assessment and our preliminary results were discussed in this productive peer review, valuable experiences on safety control and helpful suggestions were adopted in the final report. The licensing process of TPS installation which was regulated as High Intensity Radiological Facility by Taiwan Atomic Energy Council was approved in 2010 and the civil construction was commenced.

Based on reasonable beam loss assumption about 70 % injection efficiency from booster to beam storage in the ring or equivalently 50% from LINAC to storage ring, the concrete shielding is 1 meter in thickness[6] and the cross sectional view of TPS shielding tunnel is shown in Fig.1. The injection section where beam loss is expected to be higher and ratchet walls where beamlines are extruded have thicker shielding of 1.2 meter. TPS adopts concentric shielding tunnel where booster is mounted on the inner wall and storage ring is located near the outer wall. The main access gateway for accelerator components is by way of moveable roof which has two layers of concrete blocks. All the air ducts and piping trenches are directing to the center of the ring where utilities and subsystem devices are located.

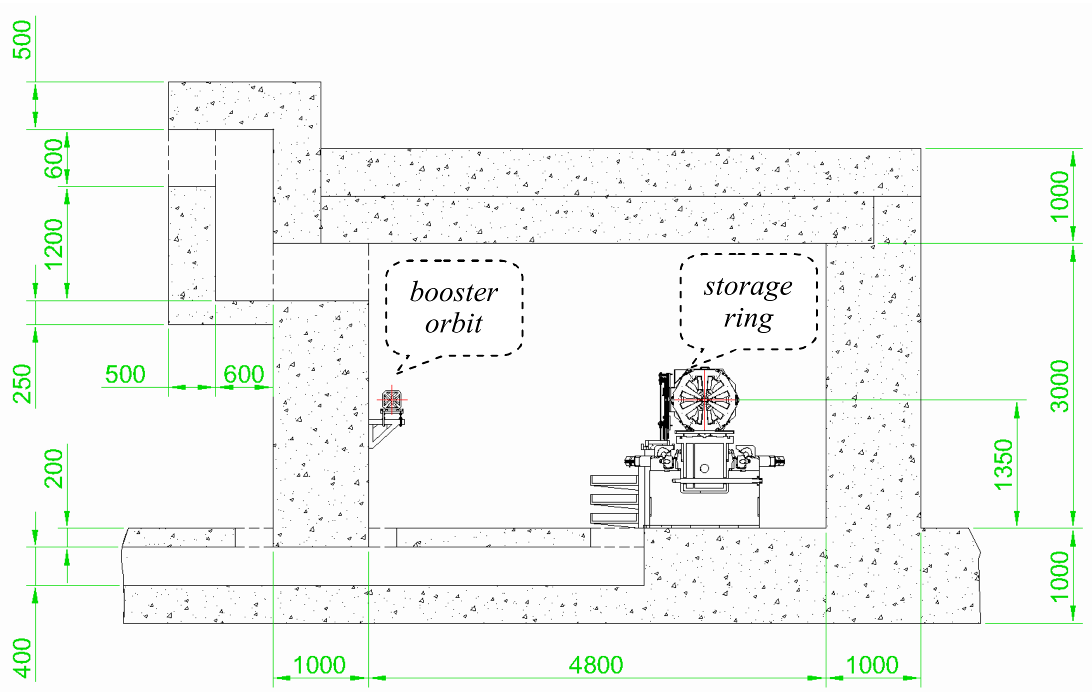

Fig. 1 Cross sectional view of TPS concentric shielding tunnel.

Radiation Monitoring

Radiation detectors, gamma and neutron included, with interlock capability will be the workhorse for TPS monitoring program both for accelerator and beamlines. At least twelve monitoring stations will be deployed on the shielding wall of TPS as shown in Fig. 2. Typical locations include high beam loss areas such as injection section and downstream of LINAC, the vicinity of long insertion device, maze entrances where people frequently access and some potential hot spots. We are planning to install one monitoring station in each beamline to make sure the radiation exposure to our users is within our design limit.

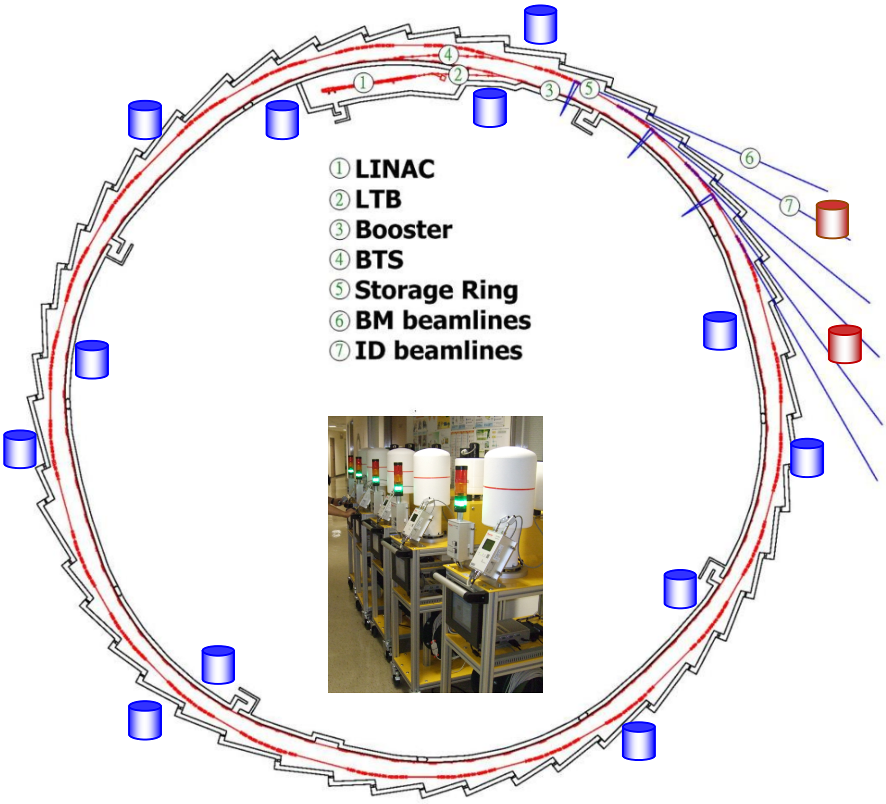

Fig.2 The proposed location of TPS interlocked radiation monitors.

TPS area monitors feature FHT191N ion chamber, FHT762 neutron detector and FHT6020 alarm and display module capable of providing audio and visible warming and these devices are integrated in a cart to facilitate transportation. Intensive functional tests were performed for the first batch of detectors before full scale purchase, and the specifications of these detectors is shown in Table 1. We have compared new detectors manufactured by Thermo Scientific with our existed area monitors, environmental High Pressure Ion Chamber (GE RSS-131ER), pressured ion-chamber type survey meters (Fluke 451P) and long He-3 neutron detectors in various radiation environments such as 150 MeV LINAC, 1.5GeV TLS and inside beamline hutches. We are satisfied with the performance of new detectors in our pulsed radiation fields, in terms of timing response and the precision deviation with other detectors[7].

Table 1 The specifications of TPS area monitoring stations

FHT 191 N	**Ionization chamber**
Measurement Ranges	Gamma dose rate from 10nSv/h up to 10Sv/h
Energy Range	35 keV to 7 MeV
Data Memory	256 periods of selectable length (history)
FHT 762 Wendi-2	**Wide-Energy Neutron Detector**
Measurement Ranges	1μSv to 100mSv/h Cf-252
Energy Range	25meV to 5 GeV according to ICRP 74 (1996)
Sensitivity	Sensitivity: 0.84 cps/(μSv/h) Cf-252 Gamma sensitivity: 1 to 5μSv/h at 100 mSv/h, 662keV

To ensure TPS annual dose will not exceed 1 mSv, we will continue our approach in TLS to accumulate radiation dose within a time period of 4 hours and the integral dose, gamma and neutron combined, must not exceed 2 micro Sv. In case of high dose situation, the accelerator interlock for those detectors on the shielding wall will inhibit LINAC from producing new electrons and the booster RF system will be turned off redundantly. For beamline interlock, the local heavy metal shutter will be closed until new time duration begins. The interlock capability is realized by the analog output of FHT6020 processor and hardwired to radiation safety control system and subsequently to interlock devices. An industrial computer is supplemented to the monitoring cart to process and display the dose information locally, then relay the data for further applications. As shown in Fig.3, the dose information will be displayed graphically in an integrated browser and the alarm message will be sent to safety officer in case of high dose situation.

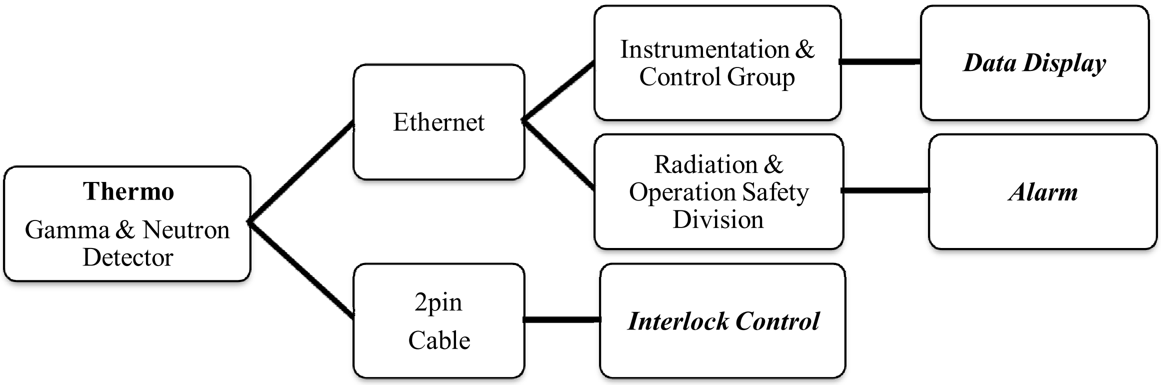

Fig. 3 The configuration of data process for dose information from TPS area monitors.

Commissioning of SRF

The operation of superconducting Radio Frequency (SRF) cavity can produce high dose due to the acceleration of dark current generated by the impurities on the inner surface of cavity. This radiation generation process during RF operation is similar to X ray tube that the energy of radiation is dependent on the RF accelerating voltage and the intensity of radiation dose relates to the RF power. The acceptance test and high power commissioning of three SRF cavities for TPS are arranged inside a concrete bunker with shielding ability equivalent to 60cm of concrete in Utility Building II as shown in Fig.4. Three radiation detectors are arranged to monitor the dose distribution and they are inside the test bunker using Fluke 451P survey meter, on the surface of shielding wall using 451P and the working area where staff constantly occupied using HPIC. Interlock limit of 4μSv for 4 hours is set for the monitoring result of HPIC and the ready check of RF electronics will be terminated in case of high radiation situation to stop further RF operation.

Typical results of radiation measurements during RF commissioning on January 14~15 2013 are shown in Fig.5 and Fig. 6 in which blue lines denote the results from 451P at the downstream of RF cavity inside the bunker, red lines indicate the dose intensities on the outer shielding wall measured by 451P and green lines show the dose levels at the staff working area by HPIC. When SRF started operation at 110kW of RF power with TPS routine gap voltage of 1.6 MV, the radiation inside the bunker increased to 550 μSv/h and maximunly to 1000 μSv/h as shown in Fig.5 . Those detectors outside the shielding wall had no distinguishable changes from background level. As commissioning condition increased to acceptance test parameters of 300kW of RF power and gap voltage of 2.4MV on 15:50 of January 15 as shown in Fig.6, the radiation inside the bunker surged to a staggering hieght of 50000 μSv/h or about 50 mSv/h, the dose on the wall and in staff working area was 1.0 μSv/h and 0.5 μSv/h respectively. When commissioning proceeded to continuous wave (CW) mode on 16:00~16:20 of January 15, three detectors reported stablized readings without further increase. The radiation levels outside the bunker are reasonablely acceptable and the shieling is sufficient to provide radiation protection against SRF commissioning.

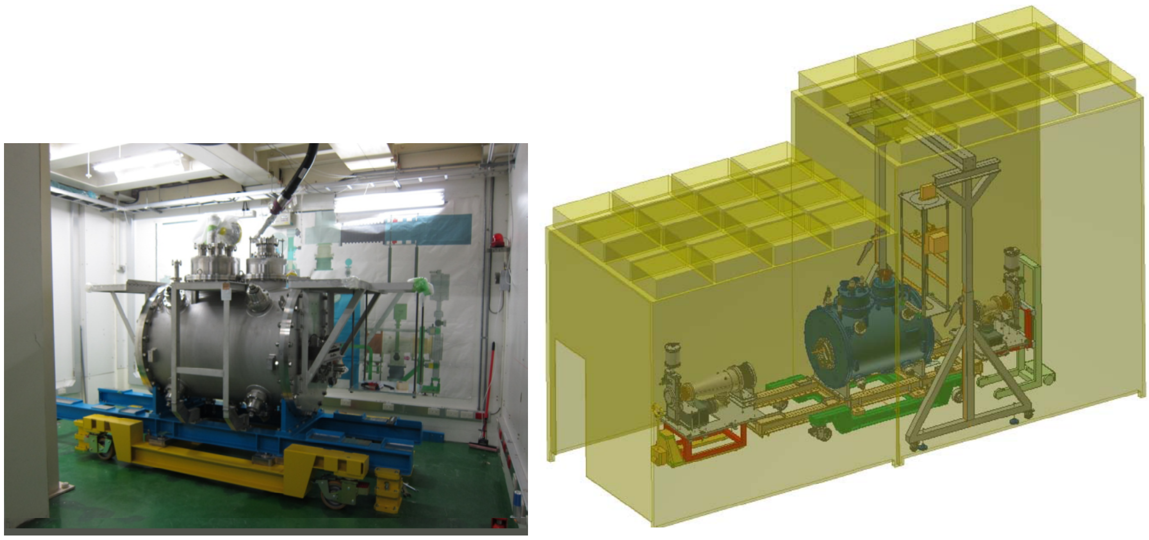

Fig. 4 The commissioning of three SRF cavities are arranged in a test bunker made of 60cm concrete in thickness with interlocked radiation monitor.

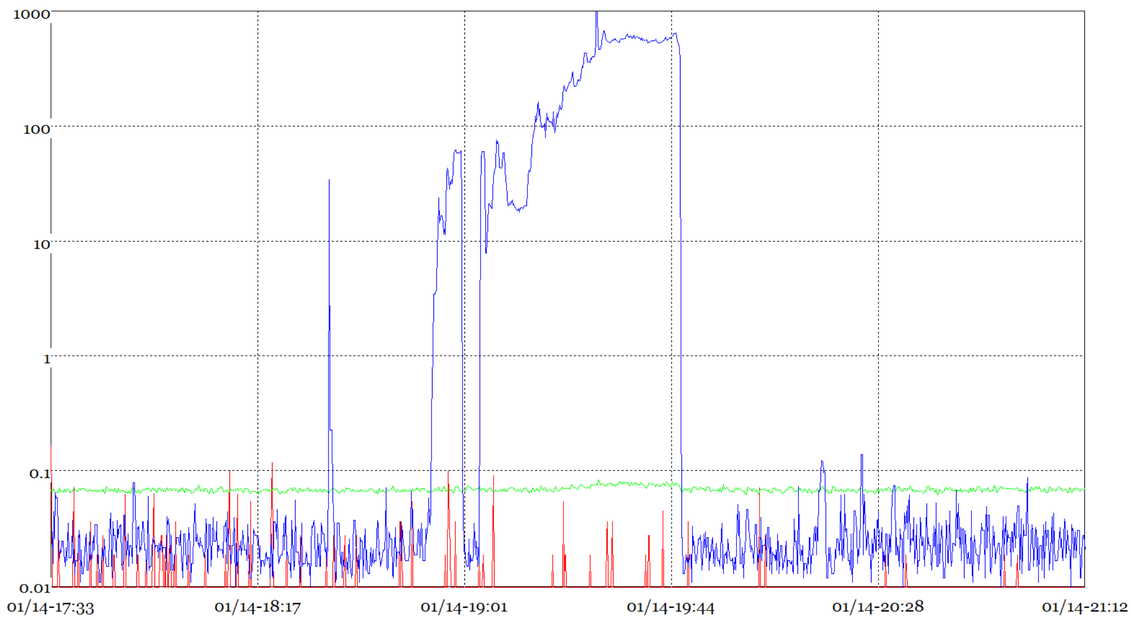

Fig. 5 Radiation intensities during RF commissioning at RF power of 110kW and gap voltage of 1.6MV.

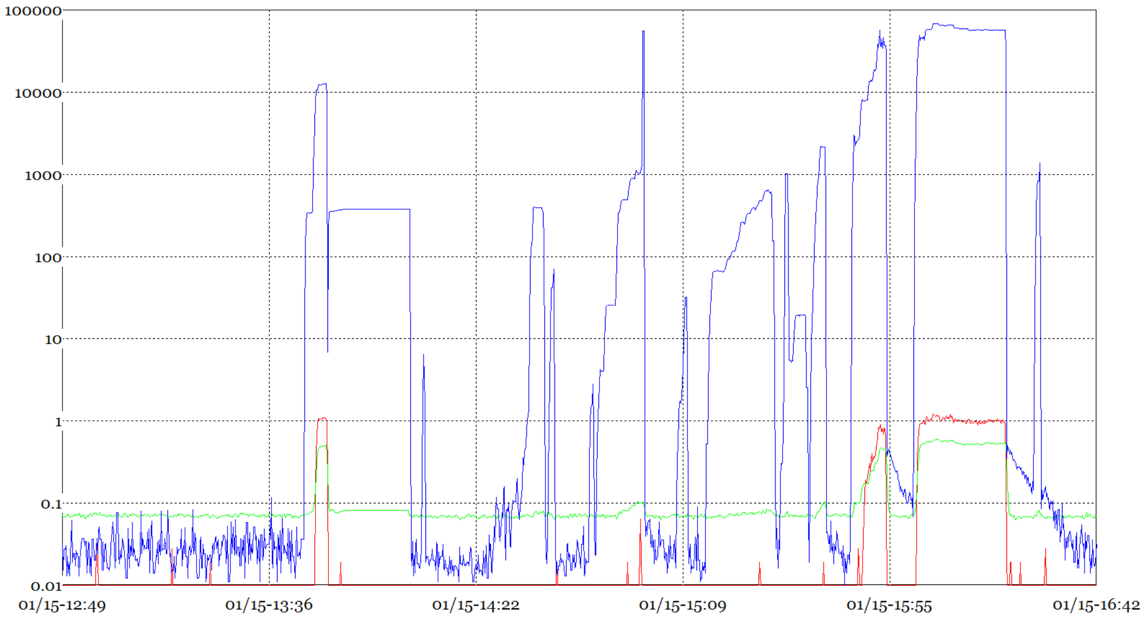

Fig. 6 Radiation intensities during RF commissioning at RF power of 300kW and gap voltage of 2.4MV.

Conclusions

The TPS project is at the final phase of civil construction and the installation of accelerator subsystems will begin in the second half of year 2013. Based on the experiences of TLS operation for twenty years, the radiation safety system for TPS including shielding design, radiation monitoring, access control and interlock protection should provide reasonable safety protection for normal operation when TPS begins routine user application. The challenge in the near future is to minimize the radiation exposure during TPS commissioning that unexpected beam loss may occur and hot spots are not identified yet. Organized commissioning plan, rigid operation discipline and systematical radiation survey will be crucial to eliminate possible radiation incident, especially we have a high occupancy area, the Research Building, encircled by the TPS accelerator. Commissioning of SRF cavity is able to produce intensive radiation in the range of several tenths mSv/h that requires proper shielding and radiation monitoring with interlock capability. Special attention must be paid to the zone clearance and radiation survey during SRF conditioning inside the TPS tunnel which is separated by fences without shielding ability into four access control sections.

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