CONCEPT OF RADIATION MONITORING AND SAFETY INTERLOCK SYSTEMS FOR XFEL/SPRING-8

N. Nariyama#, T. Matsushita, H. Aoyagi, M. Kago, C. Saji, R. Tanaka, JASRI, XFEL Joint Project/SPring-8, Hyogo 679-5198, Japan
T. Itoga, Y. Asano, RIKEN, XFEL Joint Project/SPring-8, Hyogo 679-5148, Japan

Abstract

XFEL/SPring-8 is an X-ray laser facility currently being constructed in Japan. The facility consists of an 8-GeV electron linac, in-vacuum undulators and experimental beamlines. The safety interlock system of XFEL, which controls personnel access and radiation containment for protection from prompt radiation hazard, was designed to match that of SPring-8. This paper describes the concept of the safety interlock and radiation monitoring system at XFEL/SPring-8.

INTRODUCTION

RIKEN is building an XFEL facility at the SPring-8 site in cooperation with JASRI. The compact XFEL is a linac-type 8-GeV electron accelerator with an injection cycle of up to 60 Hz. Its radiation protection features differ from those of a conventional electron linac in that the users of the X-ray laser stay on the extension of the electron beam because the laser is emitted within the co-axis of the beam. As a result, the electron beam must undergo deviation after laser oscillation in the accelerator tunnel and must be properly disposed of into the underground beam dump at all times.

The maximum beam loss was assumed to be 1% in the accelerator section. However, beam loss allowed at the undulator section was set to 0.1%; having more than one electron bunch hit the shield wall can induce an unacceptable rise in the dose level. To prevent such incidents, a beam termination response faster than the electron injection cycle was required.

Taking these constraints into account, the XFEL accelerator safety interlock system was designed to fulfill the requirement of matching the SPring-8 safety interlock system because both safety systems will be unified in the near future to deal with electron beam injection from XFEL to SPring-8. The safety interlock system of SPring-8 is scheduled to be changed from operation-mode dependence to area dependence this autumn.[1] The XFEL safety interlock system is expected to be adapted to this new system smoothly.

SAFETY INTERLOCK SYSTEM

Requirement

The distinctive design criteria of the XFEL accelerator safety interlock are as follows:

- It works independently.
- It treats the accelerator and undulator areas as one area.
- If an incident that can give overexposure to personnel occurs, it must terminate the operation of the electron gun within 16.6 ms, which corresponds to operation at a frequency of 60 Hz.

Functionally, the safety interlock system consists of access control (AC) and radiation control (RC) systems;[2] the former keeps personnel from prompt radiation in the accelerator tunnel and the latter prevents radiation hazards outside the tunnel.

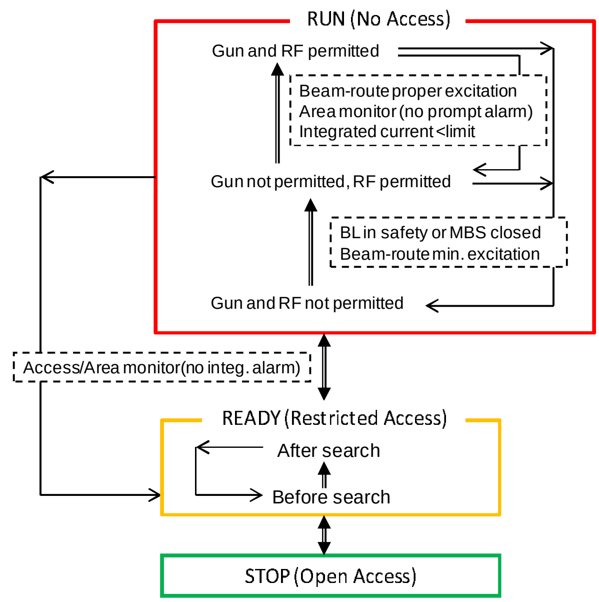

Figure 1: Status transition. The double-line arrow shows a normal transition, and the single-line arrow indicates an alarm trip to lower status. The dotted conditions are necessary for each higher status.

Access Control

Similar to SPring-8, there are three stages of access conditions for entry to the accelerator tunnel, as shown in Fig. 1: open access (Stop), restricted access (Ready) and no access status (Run). At restricted access, only authorized personnel can enter the tunnel with the system key through only the most upstream door in front of the control room. Before operation, a search procedure is conducted at this status by patrolling the inside and pushing the search buttons. Any door other than the entry door must be kept closed. When safety in the accelerator tunnel is confirmed and dose-integral alarm of the area monitors is not emitted, the operator can turn the system

#nariyama@spring8.or.jp

key to Run without any alarm activation. One minute after the status goes to Run, accelerator operation becomes permissible if the necessary safety conditions are satisfied. Any AC alarm shifts the status down to Ready and cancels the search confirmation, as shown in Fig. 1.

For AC, the following status signals are monitored: door switch (double), personal key, search buttons and emergency buttons.[3] Emergency buttons are available at all times including general safety.

Signs and sirens are also important tools for AC. For XFEL, the access condition is indicated above each entrance, and a siren starts to sound after the confirmation of safety in the accelerator tunnel.

Radiation Control

Under both normal and abnormal conditions, RC has to ensure that the dose outside the accelerator enclosure remain under acceptable levels. XFEL operation consists of electron gun and RF operations. Any RC alarm terminates the electron gun. In addition, radiation from straying electrons needs to be considered during RF operation. If this occurs, the safety interlock system terminates RF as well.

The system has three types of components for RC: shielding, beam containment and radiation monitoring. Beam containment devices confine the beam to its intended path and operational parameters.[2] Active devices are electromagnets and current monitors, and the passive devices are collimators, stoppers, dumps and permanent magnets. The safety interlock system watches the signal status of the active devices and movable passive devices.

The XFEL will initially have two beamlines, BL1 and BL3, for the beam route, as shown in Fig. 2. The beam routes are switched by the electromagnet at the bottom of the accelerator section, and at BL1, the beam is kicked back to the original direction. At the end of the undulator section, all of the electrons are diverted down and injected into the dumps. By monitoring the combination of excitation status for these four electromagnets, beam containment is assured; this interlock is named the "beam-route interlock."

For gun permission, the electron beam must be incident into the dump core, i.e., proper excitation of the electromagnets is necessary. Because the proper current of electromagnet depends on the accelerated energy, a table of energies and the proper currents is prepared. For RF permission, the straying electrons such as dark currents only need to be contained, which requires minimum excitation. Thus, the beam-route interlock works at two levels, and for all routes, the BL3 dump magnet is always excited during operation because the electrons come straight to it when a trouble occurs with the switching magnet.

As a further contingency, permanent magnets are set just downstream of the 8-GeV dump magnets; even if any trouble happens, the electrons are never incident into the optics hutches through the beam pipe.

Current monitors (CT) are installed just before the 50-MeV dump and kicker magnet, which impose limits on the accelerated electron numbers. When the current exceeds the preset level, permission for gun operation is cancelled.

Radiation monitoring is the last resort of RC. The functions and system are described in the next section.

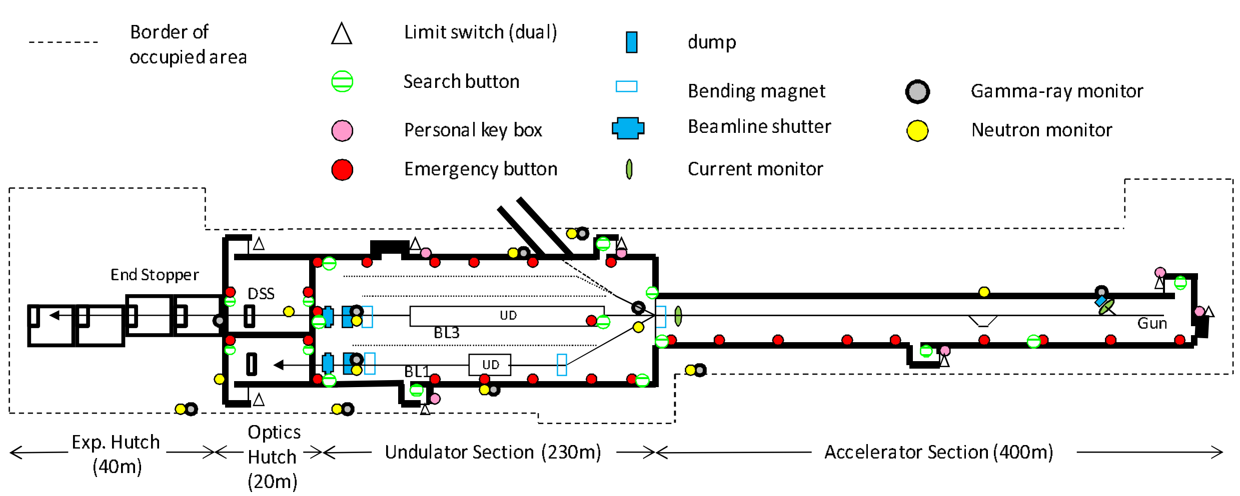

Figure 2: AC and RC components at XFEL. Gamma and neutron monitors are set on the roof above the switching magnet and 8-GeV dumps. Permanent magnets are set just downstream of the 8-GeV dump magnets.

Beamline Interlock

The experimental beamlines will initially consist of two optics hutches and four experimental hutches, as shown in Fig. 2. Because one optics hutch will include two or three beamlines in the future, the beamline safety interlock is comprised of optics hutch 1 and 2 safety interlocks and BL1 and BL3 safety interlocks. Each interlock monitors the door switches, search buttons, shutter operation keys and emergency buttons of each hutch for AC. For beam containment, beamline shutters, DSS (down stream shutter) and end stoppers are employed, and radiation monitors are set around the optics hutches. When both beamline shutters are closed, the beamline interlock is disconnected from the accelerator interlock.

Interlock for Gun Aging

With gun aging, the dose in the vicinity of the injection gun becomes considerably high, and personnel are prohibited from staying there. However, access to the undulator area is necessary even during aging for efficient maintenance because XFEL is a facility that will routinely be operated for X-ray users. Therefore, a safety interlock system for gun aging that differs from the accelerator safety interlock system was built.

The system provides three stages of status: Stop, Gun Aging Ready and Gun Aging Run. These statuses are selected by the operator with the system key (Fig. 3). At the status Gun Aging Ready and Gun Aging Run, access to only the accelerator area in the tunnel is restricted and prohibited, respectively; the undulator area is kept open to access. At the status Gun Aging Ready, a search is carried out, and after the confirmation transition to Gun Aging Run status becomes permissible.

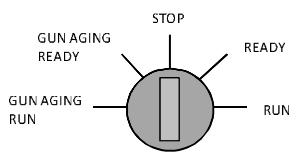

Figure 3: Key switch for operation, which never transits from Run to Gun Aging Run without passing Stop.

RADIATION MONITORING SYSTEM

The radiation monitoring system functions measure the dose accurately at points where it can rise due to operation and raise an alarm when the dose exceeds the preset level. At XFEL, gamma and neutron area monitors, which are air-filled ionization chambers and ^{3}He proportional counters, are set near the loss points on the outside wall of the tunnel and border of the occupied area (Fig. 2). The presumed loss points for the accelerator and undulator sections are the 50-MeV dump, bunch compressor, C-band accelerator, switching magnet, bending magnets and 8-GeV beam dumps.

The radiation monitoring system emits two types of alarm: prompt and dose-integral. For the prompt alarm, low and high trip levels are preset. The low-level alarm is a warning, and high-level alarm activation leads to gun termination. The alarm is latched until authorized personnel cancel it. Moreover, the dose of the monitors is integrated for a week and three months, which are periods for determining the dose limit according to law. When the dose in the period exceeds the preset value, an alarm is issued from the data collection PLC to stop the gun and RF (Fig. 4).

The signal network is illustrated in Fig. 4. An electric signal is converted into a light pulse to avoid interference from RF power. The alarm monitoring and data collection PLCs were developed to integrate the dose during these periods and transmit necessary alarm information. Redundancy is also improved by these additions. All of the electric power is backed up by UPS and MLP. The dose and alarm signals are sent to the SPring-8 data collection server for observation.

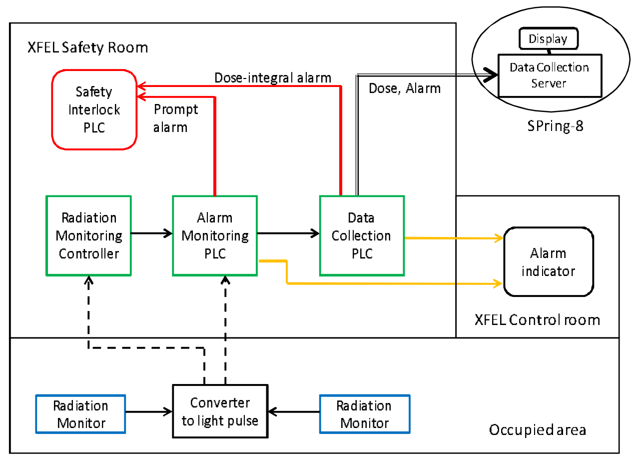

Figure 4: Signal network of the radiation monitoring system. The dotted arrow indicates the light signal.

SUMMARY

The safety interlock system of XFEL/SPring-8 is based on that of SPring-8, the reliability of which has been demonstrated through ten years of safe operation; the requirements for radiation control differ in such aspects as gun termination speed because of differences in configuration and shield. An interlock at gun aging, which was not installed at SPring-8, was designed for efficient maintenance. A radiation monitoring system was built by reinforcing redundancy in the signal and alarm network.

REFERENCES

[1] C. Saji, et al. "Construction of the new safety interlock system for SPring-8 accelerator", WAO2010, Daejeon, April 2010.
[2] V. Vylet, J.C. Liu and L.S. Walker, Radiat. Prot. Dosim. 137 (2009) 100.
[3] M. Kago, T. Matsushita, N. Nariyama, Y. Asano, T. Fukui, T. Itoga, C. Saji and R. Tanaka, "Design of the accelerator safety interlock system for XFEL in SPring-8", ICALEPCS'09, Kobe, July 2009 (2009); http://www.JACoW.org.