10th International Workshop on Radiation Safety at Synchrotron Radiation Sources

-RadSynch19-

Book of Abstracts

Facility reports

Overview of the MAX IV facility

Authors: ROSBORG, Anders *(MAX IV)*; Radiation Safety Team *(MAX IV)*

The MAX IV Laboratory is the host of the 10th RadSynch workshop. An overview of the facility will be presented, giving a short description of several different aspects related to radiation safety. Topics include organization, site, accelerators and beamlines as well as designation of areas, radiation monitors, dosimetry and the personnel safety system.

Facility reports

Radiation measurement during operation of SESAME

Author: MOSA HAMAD, Adli *(SESAME)*

SESAME (Synchrotron-light for Experimental Science and Application in the Middle East) is Mid-dle East's first major international research centre, it is third generation light source located in Allan-Jordan using 2.5GeV, 400mA electron beam. 20MeV Microtron as pre-injector and 800MeV Booster synchrotron as an injector in the same tunnel have been successfully commissioned; this paper is tackling the radiation measurements during Storage Ring operation at 200mA, 2.5GeV. An intensive radiation measurement using online and passive radiation monitoring were taken places around foreseen hot spots and in general places around both tunnels. ALARA principle is applied by guaranteeing the radiation limits for non exposed workers to be 1mSv/y which corresponds to 0.5μSv/h, for 2000 working hours per year.

Facility reports

Radiation Dose Assessment and Monitor Practice at the Singapore Synchrotron Light Source (SSLS)

Authors: YANG, Ping *(Singapore Synchrotron Light Source (SSLS))*; FARUK, Sanjeev *(Diamond Light Source Ltd.);* BERKVENS, Paul *(ESRF);* CHEW, Eh Piew *(Singapore Synchrotron Light Source (SSLS));* WONG , Wai Kong Alaric *(Singapore Synchrotron Light Source (SSLS))*; DIAO, Chaozheng *(Singapore Synchrotron Light Source (SSLS));* BREESE, Mark B.H. *(Singapore Synchrotron Light Source (SSLS))*

A simulation using FLUKA is shown in the worst case of electron loss at the bend magnet T85 of the transfer line from the 100 MeV racetrack Microtron. The scenario shows that the simulated dose rate is about 5 times lower than that calculated using the empirical formulae (Daresbury model). This factor is coincident with the “conservative factor” of 5 for Daresbury model from previous experience.

Reviewing the dose assessment and dose surveys at SSLS, and considering together with some conservative absorption coefficients, we found this conservative factor can even be up to a factor of 10. In case of injection at 2 mA current and 2 Hz frequency, with 1.2 m thick concrete wall and an extra 10 cm thick lead belt, it should ensure the dose rate everywhere is less than 1.5 μSv/h, even in the worst case of electron loss. In normal operation, we have never found any significant dose above the background in the floor.

References:

1. Berkvens P., 14/02/2000, Shielding requirements for the Singapore Synchrotron Light Source, internal report.
2. Ryder R., Oct. 1998, Daresbury Laboratory Health Physics Report 98/208: Radiation Safety Assessment of the Helios II Accelerator at the National University of Singapore, internal report.
3. Yang P., Berkvens P. and Moser H.O., Radiation Safety at SSLS, JAERI Report, Spring-8 Document A 2005-002, pages 21-31, 17-19/11/2004.

Facility reports

Radiation levels around SOLARIS 1.5 GeV storage ring after the machine commissioning

Authors: WIKLACZ, Justyna *(National Synchrotron Radiation Centre SOLARIS)*; JAGLARZ, Magdalena *(National Synchrotron Radiation Centre Solaris)*, WAWRZYNIAK, Adriana *(MAX IV)*

The commissioning of the SOLARIS storage ring started in 2015 and since then radiation measure-ments has been performed using radiation monitoring stations and thermoluminescence dosime-ters (TLDs). In the meantime several improvements to the radiation shielding were done to fulfill the ALARA principle. To reduce electron losses and decrease radiation levels around the syn-chrotron, optimizations of the electron beam during injection into the storage ring, ramping and standard operation were carried out.

Radiation measurements results received before and after the chopper installation in the linac and additionally problems with radiation levels while the beam current is increasing to the designed 500mA value will be presented.

High Intensity Lasers

High-Intensity Laser Interactions with Solid Targets: Hot Electron Spectra and Bremsstrahlung Transmission Factors*

Authors: LIU, James *(SLAC National Accelerator Laboratory)*; LIANG, Taiee *(SLAC National Accelerator Laboratory)*; ROKNI, Sayed *(SLAC National Accelerator Laboratory);* BAUER, Johannes *(SLAC National Accelerator Laboratory)*

Interaction of a high-intensity optical laser beam with a solid target can generate 'hot' electrons, which generate radiation hazards (mainly bremsstrahlung photons and neutrons) from interaction of hot electrons with target and the surrounding materials. Studies at SLAC used the particle-in-cell code EPOCH for the generation of hot electron source terms and used the Monte Carlo trans-port code FLUKA for subsequent radiation transport and interaction. These studies characterized the hot electron yields and bremsstrahlung dose yields for laser intensities between 1017 and 1022 W cm-2.

In this presentation we summarize the characteristics of the hot electron source terms, such as the spectral shape, hot electron temperature, and yield. Estimates of the spectral shape were made for two laser intensities with stacks of Landauer nanoDot dosimeters (depth-dose approach). Com-parison to FLUKA calculations indicates that a Maxwellian instead of a relativistic Maxwellian distribution is more suitable for estimating the hot electrons' energy distribution.

Transmission factors of the resulting bremsstrahlung photons for common shielding materials were calculated with FLUKA, and the tenth value layer (TVL) thicknesses were derived. From about 1020 W cm-2 on, the second TVL values approach the asymptotic values corresponding to the 'Compton minimum' cross section of the shielding material, as expected.

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High Intensity Lasers

Safety challenges in terawatt laser-matter interaction experiments at the HED instrument at European XFEL

Authors: ANSARI, Zunaira *(European XFEL GmbH*); BOYD, Eric *(European XFEL GmbH);* HAAS, Tobias *(European XFEL GmbH);* ULF, Zastrau *(European XFEL GmbH);* NAKATSUTSUMI, Motoaki *(European XFEL GmbH);* BRAMBRINK, Erik *(European XFEL GmbH);* TOMA, Toncian *(Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany);* CLEMENT, Wolfgang *(Deutsches Elektronen-Synchrotron DESY);* TESCH, Norbert *(Deutsches Elek-tronen-Synchrotron DESY)*; LEUSCHNER, Albrecht *(Deutsches Elektronen-Synchrotron DESY)*

The Helmholtz International Beamline for Extreme Fields (HIBEF) is a user consortium contribut-ing and operating different experimental set-ups at European XFEL. At the heart of these set-ups are unique lasers consisting of a high intensity laser that can provide 100TW of power with a pulse duration as short as 25 femtoseconds. Combining XFEL X-ray pulses and ultra-high-energy, ultra-short optical laser pulses will allow femtosecond time scale and nano-scale phenomena to be probed for the first time. This unique combination of powerful optical laser and XFEL pulses will enable novel investigations of highly excited solids, high energy density states of matter, QED effects, ionization dynamics at high intensities and relativistic laser plasma interactions. The high intensity laser is installed at XFEL and is currently being commissioned. This talk describes the laser architecture, its properties and capabilities and touches briefly on the underlying physics leading to generation of ionizing radiation through laser-matter interaction. We describe the shielding concept for ionizing radiation and radiation monitoring during laser operation using specially developed detectors by DESY. In addition, passive dosimetry is also conducted and both will be explained.

References:

[1] M. Nakatsutsumi, K. Appel, G. Priebe, I. Thorpe, A. Pelka, B. Muller, Th. Tschentscher, Technical design report: Scientific instrument High Energy Density Physics (HED), XFEL:EU TR-2014-001, Germany, 196 p (2014). doi:10.3204/XFEL.EU/TR-2014-001. See also www.xfel.eu/research/instruments/hed

[2] www.hibef.de

High Intensity Lasers

Current status of the ELI Beamlines facility

Authors: HORVATH, David *(ELI Beamlines, Institute of Physics ASCR)*; OLSOVCOVA, Veronika *(ELI Beamlines, Institute of Physics ASCR)*; STRANSKY, Vojtech *(ELI Beamlines, Institute of Physics ASCR);* TRUNECEK, Roman *(ELI Beamlines, Institute of Physics ASCR);* TSINGANIS, Andrea *(ELI Beamlines, Institute of Physics ASCR);* Dr VERSACI, Roberto *(ELI Beamlines, Institute of Physics ASCR)*

ELI Beamlines is the Czech Republic based pillar of the Extreme Light Infrastructure (ELI), which benefits from the latest technical development in new generation laser technology to produce high intensity ultra-short laser pulses. ELI Beamlines aims at the development of ultra-short high brilliance X-rays sources and acceleration of particle beams.

After many years of preparatory work, ELI Beamlines has entered its commissioning phase and the very first data are being collected. This presentation provides an update on the status of the facility with respect to the one presented at RadSynch2017, describing the current status of the installation and the expected operations for the next two years. Besides, some of the first results obtained so far during the commissioning phase will be shown.

Personnel Safety Systems

Radiation protection interlock systems at the KIT synchrotron

Authors: HAGELSTEIN, Michael *(KIT);* GIES, Albert *(KIT);* BRÜNDERMANN, Erik *(KIT);* KUBAT, Richard *(KIT);* MUELLER, Anke-Susanne *(KIT);* RUPRECHT, Robert *(KIT*); SCHUH, Marcel *(KIT);* STEINMANN, Johannes *(KIT);* WESOLOWSKI, Pawel *(KIT*); ZWERNEMANN, Olaf *(KIT)*

The KIT synchrotron, located in Karlsruhe, Germany, is in its 20th year of operation. The accelera-tor complex consists of a 50 MeV microtron, a 0.5 GeV booster synchrotron, and a 2.5 GeV storage ring called KARA (Karlsruhe Research Accelerator). The Institute for Beam Physics and Technol-ogy (IBPT) operates the KIT synchrotron and in additions commissions the accelerator test facility FLUTE, a 50 MeV linear accelerator and a source for coherent, high power THz radiation. IBPT delivers synchrotron radiation to 20 beamlines (an example see [1]), conducts accelerator research, and develops innovative technology (see i.e. [2, 3]). You may watch the video on YouTube [3] for current activities and strategies.

The radiation safety and protection system of the KIT synchrotron is composed of three interlinked systems: the personnel interlock system (PIS) of the machine and the Beamline Personnel Safety System (BPSS) of the beamlines [4], together with an independent system to control the status of all front-end shutters.

The PIS consists of hard-wired linked hardware (keys, doors, search switches, emergency stop switches, automatic audio system, warning lamps) controlled by a not inherently safe plc and is in operation since the start-up of the facility in 1998. The PIS design follows safety standards and the principle of good engineering practice.

The BPSS is a Safety Instrumented System (SIS) to control the exclusive access of ionizing radia-tion or persons to the beamline radiation hutches. The reliability for components and the overall system was defined in terms of safety categories and based on the risk analysis by the standard ISO 13849. The standard links the Safety Integrity Level (SIL) concept to Performance Levels (PL) defining an approach in terms of probabilistic failure rates for components and systems [5].

To achieve compliance with the regulations defined by the current machinery directive [6, 7], we plan to refurbish the PIS and adapt the new system to current standards and intend to still follow good engineering practice.

Personnel Safety Systems

References:

[1] Zimina, A. et al. (2017). “CAT-ACT - A new highly versatile x-ray spectroscopy beamline for catalysis and radionuclide science at the KIT synchrotron light facility ANKA”. Review of scientific instruments, 88 (11), Art. Nr.: 113113. doi:10.1063/1.4999928”

[2] N. Hiller, E. Huttel, A.-S. Müller, A. Plech, F. L. Müller, P. Peier, V. Schlott, “A SETUP FOR SIN-GLE SHOT ELECTRO OPTICAL BUNCH LENGTH MEASUREMENTS AT THE ANKA STORAGE RING”, Proceedings of IPAC2011, San Sebastián, Spain

[3] T. Boltz, M. Brosi, E. Bründermann, P. Schönfeldt, M. Schwarz†, M. Yan, and A.-S. Müller; “STUDIES OF LONGITUDINAL DYNAMICS IN THE MICRO-BUNCHING INSTABILITY USING MACHINE LEARNING”; IPAC2018, Vancouver, BC, Canada

[4] https://www.youtube.com/watch?v=BztxS8pbxcM

[5] K. Cerff, D. Jakel, R. Stricker, M. Hagelstein, I. Birkel; “EVALUATION OF THE BEAMLINE PERSONNEL SAFETY SYSTEM AT ANKA UNDER THE AEGIS OF THE ‘DESIGNATED ARCHI-TECTURE’ APPROACH”, Proceedings of ICALEPCS2013, San Francisco, CA, USA

[6] Machinery Directive; 2006/42/EG

[7] M. Hauke et al, “Funktional safety of machine controls“, BGIA Report 2/2008e

Personnel Safety Systems

Management of ALBA synchrotron Personal Safety System: maintenance and upgrades

Authors: DEVIENNE, Arnaud *(ALBA Spain Synchrotron);* GARCIA-FUSTE, Maria-Jose *(ALBA Spain Synchrotron)*; VILLANUEVA, J. *(ALBA Spain Synchrotron)*

ALBA is a Spanish synchrotron facility formed with a 3 GeV electron synchrotron accelerator generating bright beams of synchrotron radiation, located near Barcelona.

At ALBA, electrons are first accelerated in a 100 MeV linear accelerator LINAC, and then injected in a synchrotron accelerator named Booster which increases the energy up to 3GeV. Finally, the electron beam is stored in a synchrotron Storage Ring with a current up to 400 mA emitting a bright beam of synchrotron radiation. Both the Booster and the Storage Ring are located inside the same concrete shielding area called Tunnel, while the LINAC is located in a separated concrete shielding called Bunker. Outside the Tunnel shielding, and tangentially to the Storage Ring, are located the experimental research laboratories named Beamlines, where scientists receive synchrotron light by the mean of dipole magnets or insertion devices, for a wide variety of experiments. At present ALBA has 8 Beamlines installed, 3 Beamlines under construction, and 1 Beamline in the design stage.

ALBA Personal Safety System is an interlock system designed for the prevention of radiation haz-ard originated by the accelerators and its sub-systems. Based on PLCs and following international safety standards, the ALBA Personal Safety System originally included the accelerators, 7 Beam-lines, 1 radiation monitors network and a separate radiofrequency laboratory. However, the con-struction of new beamlines, the operative experience and some inconsistencies detected in the yearly verifications have required successive upgrades.

This paper aims to explain the general management of ALBA Personal Safety System from a radia-tion protection service point of view. First, it details the periodic maintenance and the functional verification methodology followed to guarantee its operational effectiveness. Then it focuses on the commissioning of the upgrades performed to incorporate new beamlines, correct bugs and improve functionalities. Finally it sets out the training procedures and authorizations to operate ALBA Personal Safety System.

Personnel Safety Systems

Design of the ThomX PSS – Use of a complete safety PLC system for complex facility

Authors: BZYL,,Harold BZYL *(CNRS-IN2P3-IPNO);* ROBERT, Pierre *(CNRS-iRSD);* HORODYNSKI, Jean-Michel *(CNRS-iRSD)*;

ThomX (1) is a facility producing high-flux and high-energy X-rays using Inverse Compton Scattering effect between an electron beam (energy: 50-70 MeV; charge by pulse: 1 nC; repetition rate: 50 Hz) and a highly amplified laser (Fabry-Perot cavity (2)) (Figure 1). This facility could be used as an intermediate light source between synchrotron facilities and conventional X-rays sources (Figure 2). The compacity of the accelerator (greater diagonal of about 7 m length) is a key feature in order to be used in sensitive areas, for instance hospitals, museums…

ThomX is located in the same building as another accelerator, Andromede (3) (Van der Graaf Generator accelerating protons, nanoparticles of gold or fullerenes up to 4 MeV) (Figure 3). Both facilities will be used independently while workers could go in the common area between the two hutches. Thus, the biological shielding is designed in order to comply with the radiation protection objectives (4) and the PSS is designed to comply with the exploitation constraints. In the same time, the use of a beamline for X-rays and the needs to operate on various critical sub-systems (like the Fabry-Perot cavity or the pulsed magnets) imply a complex safety design to cover the entire scope of maintenance and exploitation mode.

Use of safety PLC to design PSS for light source facilities is constantly rising. Flexibility and ease for upgrade is the main advantages of this kind of systems. Feedbacks showed the high robustness and availability of safety PLC. Thus, the ThomX and Andromede PSS design is completely based on the use of safety PLC and SIL-3/PLe safety relays. Interconnexion between the safety PLCs is based on an MRP ring. This system complies with the current French standard for accelerators PSS conception (NF M 62-105 (5)) but its innovative design will lead the incoming new version.

After a brief introduction of the ThomX facility as a compact light source for X-rays, the global architecture of the ThomX PSS will be described. Several highlights will be made on various critical sub-systems in order to show the advantages of the use of safety PLCs vs wired-logic systems.

Personnel Safety Systems

References:

[1] Variola, Alessandro, et al. *ThomX : Technical design report.* Orsay : LAL, 2013.

[2] Bonis, J., et al. Non-planar four-mirror optical cavity for high intensity gamma ray flux production by pulsed laser beam Compton scattering off GeV-electrons. *Journal of instrumentation.* Janvier 2012.

[3] Eller, Michael J., et al. Andromede Project : Surface analysis and nano-particle surface interactions in the keV to Mev Energy Range. *19th International Conference on Ion Beam Modification of Materials.* Leuven, Belgium : s.n., 14-19 September 2014.

[4] *Shielding Design and Radioprotection for Andromede and ThomX accelerators.* Horodynski, Jean-Michel and Wurth, Sebastien**.** EPJ Web of conferences, Paris : EPJ, 2016. eISSN: 2100-014X.

[5] AFNOR. Accélérateurs industriels - installations. *Norme française.* Paris : AFNOR, 12 1998. NF M62-105.

Beamlines

Beamline shielding design and safety protection at TPS

Authors: LIU, Joseph *(National Synchrotron Radiation Research Center, Taiwan)*; CHEN, Ang-Yu *(National Synchrotron Radiation Research Center, Taiwan);* WEN, Po-Jiun *(National Synchrotron Radiation Research Center, Taiwan)*

Beamline shielding at Taiwan Photon Source (TPS) is designed to protect against intensive bremsstrahlung and synchrotron radiation in a separate manner. With space constrain inside the hutch and cost of shielding taken into consideration, different calculation approaches and shielding arrangements are adopted to effectively attenuate these two intrinsically different radiation sources. This paper illustrates the shielding design at TPS that is aimed to provide a safe research environment out-side the beamline hutches. Other safety concerns at TPS beamlines, such as oxygen deficiency and ozone production, are also addressed.

Beamlines

Effect of Magnetic Fields on Bremsstrahlung radiation

Authors: ANSELL, Stuart *(MAX IV);* REFTLÉR, Josefin *(MAX IV)*; PAULSSON, Johanna *(MAX IV)*

The ability to build and run complex Monte Carlo models of synchrotron facilities has advanced rapidly in the last few years, due in part to advances in computational programs and algorithms to generate complex geometries and apply sophisticated variance reduction automatically. We have used and developed the CombLayer tool coupled with FLUKA to investigate at the effect of magnetic fields in the undulators at Max IV. A detailed beamline model (5000 components) was built from the start of the dipole to the end of the optics hutch for the MaxPEEM beamline. In addition to the physical materials the model included magnetic fields for the undulator, quadrupole-sexapole-quadrupole device after the undulator and the first dipole segment.

Bremsstrahlung radiation fields generated by electron interactions with the residual vacuum gas in the straight sections pointing down the beamline can contribute the the majority of the dose constribution at the beamline. Although, the electron path is often modeled as a straight line, it is not. It oscillates down the undulator and is often directed away from beamline centre axis and the resultant bremsstrahlung emission for electron-gas particle interactions is corresponding con-voluted. Since the bremsstrahlung process is highly forward going
in the laboratory frame, this convolution, results in a reduction in the direct bremsstrahlung radia-tion entering the optics hutch. Simultaneously, it is necessary to continue to track the bremsstrahlung photons which typcially hit the walls of the vacuum chambers. The electrons continue to be oscil-lated by the undulator and will either hit the undulator vacuum pipe, or be deflected into vacuum pipe by the quadrupole apperatures further down the beamline. These impact points produce sec-ondary particles which can be observed in the beamline optics hutch.

The resultant radiation field was calculated for three cases (a) undulator at full gap, (b) undulator fully closed and (c) undulator in helical configuration. In the helical configuration the path of the electron never points down the beamline within the undulator. These results were compared with experimentally measurements made at the same conditions.

Beamlines

Safety Concept of the Sacrificial Absorbers for secondary Beamshutters

Authors: WEFER, Anne *(Deutsches Elektronen-Synchrotron);* SCHULTE-SCHREPPING, Horst *(Deutsches Elektronen-Synchrotron*); HESSE, Math-ias *(Deutsches Elektronen-Synchrotron)*; DRESSEL, Michael *(Deutsches Elektronen-Synchrotron)*

The new insertion device beamlines in the PETRA III extension halls will be divided in 4 sectors with two undulator insertion devices in each sector, one straight section will be transformed in a side station sector with a 1mrad canting angle (P21) and the other straight section with a 40m long damping wiggler will be used as a single beamline with a hard X-source (P61).
The P61 beamline is using the powerful radiation from the array of damping wigglers. The 40m damping wiggler array provides energies beyond 100keV which must be shielded by heavy con-crete hutches.

To make the optics and experimental hutches accessible without switching off the storage ring, the photon beam and the bremsstrahlung has to be stopped inside the storage ring tunnel. This is realized by a combination of photon shutters (PS), a sacrificial absorber (SA) and a beamshutter (BS), which is controlled by the personnel safety interlock. The SA is a acting as a beam power detector (burn through monitor) in front of the beam shutter, and stops the beam in case of not fully closed PS1 and PS2. If a not fully closed PS persists over a longer time, the high power photon beam will burn a hole into the SA. This results in a venting of the beamline and a dump of the particle beam in the storage ring.

At P61 also the secondary beamshutters includes the sacrificial absorber, but in that case they are not connected to the vacuum of the storage ring. The safety function of venting the storage ring is invalid. This leads to a new concept of monitoring the temperature of the SA. In case that the BS is not closing completely, the SA is hidden by the photon beam which leads to an increase of the temperature. The warming of the SA will be detected with 2 PT100 thermocouples that are attached to the copper absorber block. This allows switching off the beam before melting the SA.

Beamlines

Save acquisition of sacrificial absorber temperature at PETRA beamline P61

Authors: DRESSEL, Michael *(Deutsches Elektronen-Synchrotron)*

The PETRA beamline P61 will be operated with a white X-ray beam. Power absorbers will be used to control the beam entering experimental areas. The position of the power absorbers can not be determined in a safety oriented way. Therefore the temperature increase of sacrificial ab-sorbers will be used to detect beam behind the power absorber. The concept for safely acquiring temperature will be presented.

Beamlines

Upgrade of the SYRMEP hard X-ray imaging beamline at Elettra: Radiation Protection and Radiation Safety issues

Authors: TROMBA , Giuliana *(Elettra - Sincrotrone Trieste);* CASARIN, Katia *(Elettra - Sincrotrone Trieste)*; VASCOTTO, Alessandro *(Elettra - Sincrotrone Trieste)*

The SYRMEP hard X-ray energy beamline of Elettra has been recently upgraded to allow a more flexible use of micro-tomography setups.
For this purpose the possibility to transport to the same experimental hutch either the mono or the white/pink beam has been accomplished by realizing a system capable to vertically translate the monochromator and the beamstopper.
The radiation protection implications have been evaluated by means of Monte Carlo simulations using FLUKA. A new design of experimental hutch including a new shielded roof and a new door has been enforced to take into account the high intensity scattering generated by the unfiltered white beam transported to the experimental hutch.
The safety system has also been upgraded considering the two working modalities and the possible use of monochromatic beam for clinical imaging (‘patient mode’).
All the considered aspects concerning radiation protection and personnel safety system will be illustrated and discussed.

Beamlines

Characteristics of Laser Compton Scattering photon beams and its application to radiation safety researches

Author: ASANO, Yoshihiro *(NewSUBARU/University of Hyogo)*

Laser Compton Scattering (LCS) photon beam has many characteristics such as a unique spectrum of the maximum intensity peak at the maximum energy. Besides the photon energy and the po-larity can be changed easily with changing the electron energy or laser polarization. Recently, many LCS beamlines have been constructed with constructing synchrotron radiation facilities to investigate nuclear science. Now some plans of small size LCS system are presented to get high energy photons with a table top size to use in industry or safety. At SPring-8 site, we have three LCS beamlines; two beamlines are at SPring-8, LEPS-I (1) and LEPS-II (2), another is BL-1 at New-SUBARU(2).
Characteristics of these LCS beamlines are presented including how to get quasi-mono energy photons and present status of the LCS beamlines in the word. In addition, the availability to use radiation safety investigation will be overviewed including our activity (3), (4) to measure photo-neutron distribution due to photo-nuclear reaction depending on photon polarization.

Reference:
(1)Yoshihiro Asano, Takao Nakano, Tomoaki Hotta and Yuji Ohashi," Shielding Design Calcula-tions for Laser Electron Photon Beamline of SPring-8". J. Nuclear Science & Technology supple-ment 1 p217-221 (2000)
(2).Yoshihiro Asano, Shuji Miyamoto and LEPS-II collaboration "Shielding Design of Laser Elec-tron Photon beamlines at SPRING-8", Progresses in Nuclear Science and technology 4 p252-256(2014)
(3)Toshiro Itoga, Hiroshi Nakashima, Toshiya Sanami, Yoshihito Namito, Yoichi Kirihara, Shuji Miyamoto, Akinori Takemoto, Masashi Yamaguchi, and Yoshihiro Asano, " Measurement of neu-tron energy spectra for Eg=23.1 and 26.6 MeV mono-energetic photon induced reaction on natC using laser electron photon beam at NewSUBARU", 13th International Conference on Radiation Shielding & 19th Topical meeting of the Radiation Protection and shielding Division of the ANS, ICRS-13 & RPSD-2016 Paris, France Oct.3-6 2016
(4)Yoichi Kirihara, Toshiro Itoga, Toshiya Sanami, Hiroshi Nakashima, Yoshihito Namito, Shuji Miyamoto, Akinori Takemoto, Masashi Yamaguchi, and Yoshihiro Asano, "Measurement of neu-tron spectra for photonuclear reaction with linearly polarized photon", 13th International Con-ference on Radiation Shielding & 19th Topical meeting of the Radiation Protection and shielding Division of the ANS, ICRS-13 & RPSD-2016 Paris, France Oct.3-6 2016

Beamlines

Radiation safety exercise in Beamline & some learning points

Authors: FARUK, Sanjeev *(Diamond Light Source Ltd.)*; DOULL, Richard *(Diamond Light Source Ltd.)*

Ionising Radiations Regulations 2017 (IRR17) and other health and safety legislation require a re-hearsal of the contingency plan at regular intervals. Diamond does this exercise to comply with the law and to encourage a positive safety culture. This give the beamline staff an awareness of the danger of accidental radiation exposure. So far, 19 beamlines have participated. The scenario is, someone has been accidentally locked in the hutch with the beam on, members of beamline staff are asked to respond to the incident and the actions taken are noted. At the end of the exercise we highlight the actions needed to save lives and reduce the exposure level are prioritised. We record the time taken to turn the beam off and estimate the dose that the casualty could have received. A series of recommendations and problems are raised from all these exercises, which will need to be debated before incorporating in future beamline and PSS design.

Beamlines

First Experiment on a radioactive spent fuel sample on the MARS beam line at Synchrotron SOLEIL

Authors: PRUVOST, Jean-Baptiste *(Synchrotron SOLEIL)*

The MARS beam line is a specially dedicated beam line for radioactive material analysis at Syn-chrotron SOLEIL.
This paper describes briefly the MARS beam line and the radiation safety aspects involved by the first experiment realized on a PWR UO2 spent fuel sample on the high resolution diffraction sta-tion in November 2018.
Containment, shielding, non-contamination controls, area delimitation and dosimetry issues are presented.

New projects/Upgrades

Radiation Protection Status of Sirius Project

Authors: BACCHIM, Fernando *(Brazilian Synchrotron Light Laboratory)*

Sirius, the second synchrotron light source of Brazilian Synchrotron Light Laboratory (LNLS), is a fourth-generation light source, using a 3 GeV electron beam with a very low natural emittance. Sir-ius is composed by a 150 MeV LINAC, a full energy booster (150 MeV to 3 GeV) and a 3 GeV storage ring (518 metres of circumference). The storage and the booster rings are concentric and shares the same concrete tunnel while the LINAC is housed in a separate one. The experimental hall can accommodate up to 40 beamlines. There are 20 straight sections to receive insertions devices and 20 super bending magnets with a permanent 3.2 T magnetic field. The LINAC was purchased from SINAP (Shanghai Institute of Applied Physics, China) and it has already been installed and com-missioned. The booster ring is completely installed and is being commissioned. The storage ring is almost completely installed, and its commissioning is expected to start in June 2019. The accelerators shielding, including local shielding and passages chicanes, were defined using the FLUKA software and considering normal and abnormal electrons losses with conservative geometries.

For the LINAC commissioning three radiation monitors, for photons and neutrons, were used. The value of the integrated dose in 4 hours was connected with the personal protection system and interlocked the electron gun if it exceeded 2 uSv in one of them. Passive dosimeters were used in three dozen of points in strategical positions inside and outside of the concrete tunnel. During the booster low energy commissioning, eight radiation monitors were used. Again, at this commissioning stage, more than 100 points were monitored with passive dosimeters. To the booster high energy commissioning, eighteen radiation monitors were used, all of them for photons and neutrons. During all the commissioning process already made, the experimental data shows that the radiation doses respected the Brazilian annual public limit of radiation in all accessible zones. The dose rate due to the activation process was measured along all the accelerators components before people access liberation after operation periods. Eventually, dose rates bigger than 0.5 uSv/h were found and the access was not liberated to these areas.

During the Sirius two first operation phases, eighteen beamlines are being planned. The installation of the frontends for the first six beamlines is already started, and first photon beams are foreseen for the last months of this year. All the

New projects/Upgrades

bremsstrahlung and photoneutrons simulations for the hutches design and specification were performed using the FLUKA software. The calcu-lations of synchrotron radiation were performed using STAC8. Dr. Paul Berkvens was officially consulted for several calculations of different beamlines, performing an extremely complete and helpful analysis. As the first phase of the storage ring operation will be performed with an expected 50 mA of maximum current, due to radiofrequency suppling limitations, the commissioning of the firsts beamlines will occur with currents 10 times lower than the specified value.

New projects/Upgrades

Radiation Monitoring for the ESRF EBS storage ring

Authors: BERKVENS, Paul *(ESRF);* COLOMP, Patrick *(ESRF)*

The original ESRF Chasmann Green type storage ring was definitely stopped on 10 December 2018. A new, hybrid multi-bend, storage ring is presently being installed and commissioning will start beginning of December 2019.
ESRF will maintain its present radiation protection policy, stating that nobody working the ESRF should be considered as radiation workers. The non-exposure of the people is guaranteed by a number of interlocked radiation monitors.
For the old storage ring, 64 superheated drop neutron detectors, installed on the roof of the stor-age ring, combined with ionization chambers next to the beamline optics hutches guarantee the derived dose limits (2 micoSv per 4 hours).
Detailed shielding calculations have been carried out for the new storage ring. The results show that the number of radiation monitors on the storage ring tunnel roof must be increased from 64 to 128, and a number of extra ionization chambers along the ratchet wall must be foreseen.
Taking into account the predominance of neutrons in the residual radiation fields outside the stor-age ring tunnel, and taking into account the energy spectra of these neutrons and the pulsed nature of this radiation, superheated drop neutron detectors were identified as the most suitable monitors. A contract with the Hungarian company Radosys has been set up for the delivery of the new mon-itors, in close collaboration with the University of Pisa (F. D'Errico). The latter will also develop a special superheated drop detector, using optical readout, that will be used around the beam loss collimators, where the expected integrated doses in case of a total beam loss are too high for the standard acoustical readout detectors.
The present paper describes how the number of radiation monitors was defined, using the results of the detailed radiation safety assessment and explains how the measured neutron doses are in-terpreted to obtain conservative values for the total doses, used for the 4-hours dose interlocks.

New projects/Upgrades

Radiation Protection Issues of BESSY VSR

Authors: OTT, Klaus *(Helmholtz-Zentrum Berlin, BESSYII);* BERGMANN, Yvonne *(Helmholtz-Zentrum Berlin, BESSYII);* BUNDELS, *Anne (Helmholtz-Zentrum Berlin, BESSYII);* HUCK, Holger *(Helmholtz-Zentrum Berlin, BESSYII);* PICHL, Lutz *(Helmholtz-Zentrum Berlin, BESSYII)*

Depending on the experiment, the focus of the users of synchrotron light sources is on different parameters. Some experiments require high flux X-rays while the pulse length is of no concern. On the other hand a large and growing fraction of BESSY's user community focuses on functional materials where dynamics on the picosecond and sub picosecond range are essential. To fulfill both requirements BESSY plans a major upgrade to provide high-flux and picosecond-pulse beams simultaneously [1,2]. The unique feature of the BESSY Variable pulse-length Storage Ring (BESSY VSR) will be the simultaneous operation of long (15 ps rms) and short (1.7 ps rms) pulses. This approach is complementary to the concept of Diffraction Limited Storage Rings (DLSR). DLSRs reduce the emittance by two orders of magnitude, but require to lengthen the bunches up to the 100 ps range to reach acceptable life times.

The impact this project has on the overall radiation safety at BESSY is discussed. The major aspect is that the number of electrons injected into the storage ring per year will not be increased, thus keeping the annual radiation level through the shielding walls the same. We present the way this number will be controlled by our top-up interlock. The inclusion of super conducting cavities in the storage ring will require additional safety measures, because of possible field emissions whose radiation level we calculated with Fluka [3,4]. Finally, we present Fluka calculations for the shielding design of a new facility to test the super conducting cavities of the VSR modules.

References

[1] A. Jankowiak et al, "The BESSY VSR Project for Short X-Ray Pulse Production", Proceedings IPAC (2016)

[2] A. Jankowiak, J. Knobloch et al., "Technical Design Study BESSY VSR ", Helmholtz-Zentrum Berlin, 2015, http://dx.doi.org/10.5442/R0001

[3] G. Battistoni, S. Muraro, P.R. Sala, F. Cerutti, A. Ferrari, S. Roesler, A. Fassò, J. Ranft, "The FLUKA Code: Description and Benchmarking", Proc. of Hadronic Shower Simulation Workshop 2006, Fermilab 6-8 September 2006, M. Albrow, R. Raja eds., AIP conference Proceeding 896, 31-49 (2007)

[4] A. Fassò, A. Ferrari, J. Ranft, P.R. Sala, "FLUKA: A Multi-Particle Transport Code", CERN-2005-10 (2005),INFN/TC_05/11,SLAC-R-773

New projects/Upgrades

SLS 2.0: Upgrade of the Swiss Light Source and radiation safety challenges

Authors: PEDRAZZI, Lisa *(PSI);* MAYER, Sabine *(PSI);* KELLER, Maya *(PSI)*

The Swiss Light Source (SLS) at PSI is a third-generation synchrotron light source, which is in operation since 2001. With an energy of 2.4 GeV, it provides photon beams of high brightness for research in materials science, biology and chemistry.

It is foreseen to upgrade the facility in 2023-2024 (project SLS 2.0) to increase the brightness. For this scope, the whole storage ring (288 m circumference with 36 dipole magnets of 1.4 tesla mag-netic field, 177 quadrupole magnets, 120 sextupole magnets, 73 horizontal and vertical beam steer-ers, 24 skew quadrupole magnets and 12 straight sections with undulator magnets) have to be replaced as well as part of the concrete shielding.

A short overview of the project SLS 2.0 and the main challenges for the radiation safety are dis-cussed.

New projects/Upgrades

Initial experience for 3.5 GeV Diamond II shielding calculations

Authors: FARUK, Sanjeev *(Diamond Light Source Ltd.)*; DOULL, Richard *(Diamond Light Source Ltd.)*

Diamond is planning to replace its current storage ring with a new Double-Triple Bend Achromat (DTBA) known as Diamond II. With a plan to build this within the existing shielding this study calculates if the current shielding is sufficient and if any increases are required.
The current Diamond storage ring and beamlines are shielded to run at an energy of 3.0 GeV and 500mA current. The plan for Diamond II is to increase the energy to 3.5 GeV and reduce the maximum current to 300 mA. Currently, Diamond has two different lengths (15.6m and 18.6m) Di-amond II, will have three different ID straight sections of 3.9m, 6.5m and 9.5m. Health Physics did the initial shielding calculation for the storage ring using Shield 11 (electron loss), semi-empirical formula and FLUKA for Gas bremsstrahlung (GB) in the stage ring and optics hutches and STAC 8 for synchrotron radiation on the beamlines. The initial calculation indicates the shutter thickness could decrease in Booster to storage (BTS) and the front end shutters. However, there will be an increase in shutter thickness in place of all current bending magnet beamlines. Most of the optics hutch lead wall thickness will not need any modification except those with superconducting wig-glers and all current bending magnet beamline hutches (which will be ID beamlines on Diamond II). For the assessment, we used a dose constraint of 1mSv/year.

New projects/Upgrades

Comparison and Expansion of Semi-Empirical Shielding Formulas with FLUKA Calculations

Authors: HUCK, *Holger (Helmholtz-Zentrum Berlin, BESSYII);* OTT, Klaus *(Helmholtz-Zentrum Berlin, BESSYII)*

In the advent of diffraction-limited storage rings (DLSR) [1], long-term plans for a possible succes-sor of the BESSY II storage ring are under investigation. Such a facility would have a significantly reduced beam lifetime compared to a standard third-generation light source, placing stringent re-quirements on radiation protection, especially on controlling the annual number of injected elec-trons per year and on shielding design.

A complex facility like this cannot be simulated in total and in necessary detail in a reasonable time frame. Therefore, semi-empirical shielding formulas [2-6] can be an essential tool for designing an overall shielding concept. Existing formulas had been mostly derived for and fitted to different parameter regimes than those common to next-generation light sources. In this paper, we present recent FLUKA [7, 8] simulations tailored to adapt the existing formulas to the specific needs of a possible BESSY II successor. For example, source terms for Niobium, and the giant resonance neutron yield as function of target length for different materials are derived.

References:

[1] P. F. Tavares et al, “Commissioning and first-year operational results of the MAX IV 3 GeV ring”, J. Synchrotron Rad. 25, 1291-1316 (2018)

[2] H. Dinter, J. Pang, K. Tesch, ”Calculations of Doses due to Electron-Photon Stray Radiation from a High Energy Electron Beam behind Lateral Shielding“, Radiat. Prot. Dosim. 25, 107 (1988)

[3] K. Tesch, “Shielding against High Energy Neutrons from Electron Accelerators – A Review”, Radiat. Prot. Dosim. 22 No.1, 27-32 (1988)

[4] K. Tesch, “Data for Simple Estimates of Shielding against Neutrons at Electron Accelerators”, Part. Accel. 9, 201-206 (1979)

[5] M. Sakano et al., “Calculations of Dose Equivalents due to Stray Radiation from a High Energy Electron Beam in a Forward Direction”, Radiat. Prot. Dosim. 37 No.3, 165-173 (1991)

[6] A. Fassò et al., “Shielding against electrons”, Landolt Börnstein – Group 1, Vol. 11, 309 (1990)

[7] G. Battistoni, S. Muraro, P.R. Sala, F. Cerutti, A. Ferrari, S. Roesler, A. Fassò, J. Ranft, “The FLUKA Code: Description and Benchmarking”, Proc. of Hadronic Shower Simulation Workshop 2006, Fermilab 6-8 September 2006, M. Albrow, R. Raja eds., AIP conference Proceeding 896, 31-49 (2007)

[8] A. Fassò, A. Ferrari, J. Ranft, P.R. Sala, “FLUKA: A Multi-Particle Transport Code”, CERN-2005-10 (2005), INFN/TC_05/11, SLAC-R-773

Activation/Decommissioning

Investigation for activation of accelerators at various synchrotron radiation facilities in Japan

Authors: YOSHIDA, Go *(High Energy Accelerator Research Organization (KEK));* MATSUMURA, Hiroshi *(High Energy Accelerator Research Organization (KEK));* MASUMOTO, Kazuyoshi *(High Energy Accelerator Research Organization (KEK));* NAKAMURA, Hajime *(High Energy Accelerator Research Organization (KEK));* TOYODA, Akihiro *(High En-ergy Accelerator Research Organization (KEK));* NISHIKAWA, Kouichi *(High Energy Accelerator Research Organization (KEK));* MIURA, Taichi *(High Energy Accelerator Research Organizatio (KEK));* HAYASHI, Kenji *(Institute for Molecular Science, National Institutes of Natural Sciences);* ISHIOKA, Jun *(SPring-8, RIKEN);* HANAKI, Hirofumi *(Japan Synchrotron Radiation Research Institute)*

We are working on the research for establishment of more reasonable decommissioning process of accelerator facilities with the aid of Japan Nuclear Regulation Authority. In this research, there are three important issues: (1) clarification of the target facilities and accelerators for assessment of activation, (2) development of novel technique for assessment of activation, and (3) provide a guideline for decommissioning as a manual book. This research has been progressed since September 2017.
To achieve the aim of theme (1) and (2), we have investigated various type of facilities such as synchrotron, cyclotrons, and electrostatic accelerators. In this presentation, we will discuss the result of radiation measurement experiment at some typical synchrotron radiation facilities in Japan. The investigated facilities and maximum acceleration energy are follows: Spring-8 (8 GeV), KEK PF (2.5 GeV), UVSOR (750 MeV), HiSOR (700 MeV), and SR-center (575 MeV). These accelerators not only differ in the maximum energy but also differ in the type of pre-accelerator up to the storage ring.
First, we set the solid track detectors (CR-39) and the thermo-luminescent dosimeters (TLD) at principal places that were expected the beam-loss level was high, and mapped the thermal and epithermal neutron flux for the whole facility. And, after the accelerator operation was stopped, con-tact dose-rate measurement with a NaI survey meter and gamma-ray spectrometry with a LaBr3 scintillation detector was conducted for the beam line components such as magnets, beam profile-monitors, gate-valves and beam-pipes.
In all facilities, activation level was quite low. Whole beam-line tunnels made of concrete were not activated and no radionuclides were detected except natural nuclides. Also, almost beam-line components were not and/or low activated. Especially, no places exceeded the background level with dose-rate measurement in SR-center. Whereas, some components such as RF-cavity, beam-profile monitor, and flexible tube joint were strongly activated, and nuclides made by (γ, n)

Activation/Decommissioning

reaction such as 51Cr, 54Mn, and 57Ni were identified. 57Co which is a daughter nuclide of 57Ni was also detected in the same place.

57Ni could be considered to reflect the beam-loss during the just previous operation, due to short life of 36 h. Actually, we found the count rate (cps) of 57Ni and the contact dose rate of an accelerator component showed good correlation in all facilities. This result indicates the beam losses in the synchrotron radiation facilities could be normalized regardless of the acceleration energy. Details and other results will be discussed in the presentation.

Activation/Decommissioning

Risk Considerations of Synchrotron Radiation Facility

Authors: LEE, Hee-Seock *(Pohang Accelerator Laboratory, POSTECH)*; JUNG, Nam-Suk *(Pohang Accelerator Laboratory, POSTECH)*; LEE, Arim *(Pohang Accelerator Laboratory, POSTECH);* MOKHTARI ORANJ, Leila *(Pohang Accelerator Laboratory, POSTECH);* BAKHTIARI, Mahdi *(DANE, POSTECH)*

In last several years, IAEA have prepared a technical report of decommissioning of particle accelerator and may be published soon. In the report, the classification of accelerator type was discussed based on its severity related decommissioning issue. According to the draft, the synchrotron radiation facility was classified as one of the most dangerous facilities. However, our studies of activation issues of large-scale accelerator showed big difference between electron accelerator and heavy ion accelerator including proton. The risk level depending on type of particles were introduce a little at NCRP Report No. 144. Each country includes a little similar classification in its national regulation. We have studied radiation safety issues related to large-scale particle accelerator for last a few years. Several Monte Carlo codes like FLUKA, PHITS, and MCNPX were used to estimate the production of secondary radiation and residual activities. The trend of radiation severity was studied for different type of particles and those energies. The consideration of risk level of particle accelerator, especially synchrotron radiation facility, is introduced based on the radiation yields and activities, and discussed in the view of shielding design and decommissioning.

Activation/Decommissioning

Decommissioning of the ESRF storage ring

Authors: BERKVENS, Paul *(ESRF);* COLOMP, Patrick *(ESRF)*

The original ESRF Chasmann Green type storage ring was definitely stopped on 10 December 2018, to be replaced by a new hybrid multi-bend storage ring.
The removal and decommissioning of the old storage ring are governed by a specific authorisation delivered by the French Nuclear Safety Authority (ASN). This authorisation allows ESRF to dis-pose of the quasi-totality of the storage ring components as non-radioactive waste, applying strict measurement protocols, verifying the absence of measurable residual activation.
The present paper gives the status of the dismantling and the decommissioning of the storage ring. So far, a large quantity of cables, cable trays and smaller items has been successfully measured and disposed of.

Activation/Decommissioning

Radiation Protection Instrumentation of bERLinPro

Authors: PICHL, Lutz *(Helmholtz-Zentrum Berlin, BESSYII*); BERGMANN, Yvonne *(Helmholtz-Zentrum Berlin, BESSYII)*; BUNDELS, Anne *(Helmholtz-Zentrum Berlin, BESSYII)*; OTT, Klaus *(Helmholtz-Zentrum Berlin, BESSYII)*

The Energy Recovery Linac project bERLinPro is a test facility to study the possible usage of an ERL as synchrotron light source [1]. It is currently under construction and will be operated with the maximum beam parameters of 50 MeV and 100 mA cw current. Even if the electron losses within the recirculator are limited to 0.6 % due to the available rf power supply, (at higher losses an immediate beam break up occurs because of the ERL principle) the beam loss power is by orders of magnitude higher than in electron storage rings used for synchrotron radiation (e.g. the injection beam power of BESSYII is 17 W during 10 Hz injections). The Fluka [2,3] calculations of the resulting activations of machine components and air activations have been discussed in earlier papers [4,5].
We present in this work the components of the ambient dosimetry, the measurement system of air activations and their inclusion in the personal safety system. Additionally we present recent calculations of the activation of cooling water and the method of storing and measuring it in case of a leakage.

References:

[1] M. Abo-Bakr et al., “bERLinPro: a Prototype ERL for Future Light Sources”, SRF’09, Berlin, Germany, TUPPO017 (2009) http://accelconf.web.cern.ch/AccelConf/srf2009.

[2] G. Battistoni, S. Muraro, P.R. Sala, F. Cerutti, A.. Ferrari, S. Roesler, A. Fasso, J. Ranft, “The FLUKA code: Description and benchmarking” Proceedings of the Hadronic Shower Simulation Workshop 2006, Fermilab 6–8 September 2006, M. Albrow, R. Raja eds., AIP Conference Proceeding 896, 31-49, (2007)

[3] A. Fasso, A. Ferrari, J. Ranft, and P.R. Sala, “FLUKA: a multi-particle transport code” CERN-2005-10 (2005), INFN/TC_05/11, SLAC-R-773

[4] M. Helmecke, K. Ott “Activation Calculations for the bERLinPro Vacuum System”, RADSYNCH2013, BNL, USA (2013) https://www.bnl.gov/radsynch13/papers.php

[5] K. Ott, Y. Bergmann,”Radiation Protection Issues of bERLinPro”, RADSYNCH2015, DESY, Ham-burg, Germany (2015)

Activation/Decommissioning

Radiation Safety at FLUTE with Special Emphasis on Activation Issues

Authors: WESOLOWSKI, Pawel *(KIT);* BÖHM, Andreas *(KIT);* BRÜNDERMANN, Erik *(KIT);* HAGELSTEIN, Michael *(KIT);* MALYGIN, Anton *(KIT);* MARSCHING, Sebastian *(KIT);* MÜLLER, Anke-Susanne *(KIT);* NASSE, Michael J. *(KIT);* RUPRECHT, Robert *(KIT);* SMALE, Nigel *(KIT);* SCHMELZER, Thiemo *(KIT);* SCHUH, Marcel *(KIT);* ZWERNEMANN, Olaf *(KIT)*

The accelerator FLUTE (Ferninfrarot Linac- und Test-Experiment) has been set up in cooperation with DESY and PSI [1]. The Phase 1 (electron gun and diagnostics) has commenced operation and the extension into full energy of 42 MeV (Phase 2) is scheduled for the late 2019.
General safety issues of FLUTE are covered in this paper. The activation of the accelerator and vacuum parts are predicted. Special attention is given to the activation of aluminum and impurities in the electron absorber of the beam dump. Potential air activation in the experimental hall will be also discussed.

[1] A. Malygin, A. Bernhard, A. Böhm, E. Bründermann, S. Funkner, I. Kriznar, S. Marsching, W. Mexner, A. Mochihashi, M. J. Nasse, G. Niehues, R. Ruprecht, T. Schmelzer, M. Schuh, N. Smale, P. Wesolowski, M. Yan, A.-S. Müller, Commissioning Status of FLUTE, Proceedings of 9th Interna-tional Particle Accelerator Conference, IPAC2018, Vancouver, BC, Canada

Activation/Decommissioning

Activation Assessment of Fluorescent Lamps at Hard X-ray Main Beam Dump Bunker of PAL-XFEL

Authors: JUNG, Nam-Suk *(Pohang Accelerator Laboratory*); BAE, Oryun *(Pohang Accelerator Laboratory); KIM*, Hee Hoon *(Pohang Accelerator Laboratory*); LEE, Hyeon Jae *(Pohang Accelerator Laboratory*); LEE, Hee-Seock *(Pohang Accelerator Laboratory, POSTECH)*

Tri-wavelength fluorescent lamps had been used in a PAL-XFEL (Pohang Accelerator Laboratory X-ray Free Electron Laser) [1] tunnel, including an underground bunker for the main beam dump (MBD). Eu, Tb, Sb, Ce, etc. are used as an activator of a phosphor coated on the inner surface of a tri-wavelength fluorescent lamp glass [2]. Although these elements are contained in small amounts in fluorescent lamps, it is necessary to evaluate the activity concentration of spent fluo-rescent lamps used in the accelerator tunnel from the viewpoint of the radioactive waste disposal, because these elements have large thermal neutron capture cross-section.

In this study, the specific activity of induced radionuclides in fluorescent lamps installed in the HX MBD bunker and the HX undulator tunnel was analyzed by gamma-ray spectroscopy using a HPGe detector, and compared with their clearance level. The model of fluorescent lamps in the MBD bunker was FPL36EX-D (OSRAM, made in Italy). For fluorescent lamps with the FHF32SSEX-D (OSRAM, made in Korea) model used in the undulator tunnel, we considered the frequent e-beam loss position and selected lamps above the main dump magnet and the tune-up dump. The gamma dose rate and the surface contamination of irradiated fluorescent lamps were not distinguishable from the background level, but the interested radionuclides such as Eu-152, Eu-154, Sb-124, Tb-160, Ce-144 and Ce-141 were measured well by HPGe detector. No artificial radionuclide were measured in unused fluorescent lamp of the same model. In cases of fluorescent lamps in HX MBD bunker, the specific activity of Eu-152 is slightly larger than the clearance level in Republic of Korea (same as the IAEA level, 0.1 Bq/g). However, considering the long half-life of Eu-152 (13.5 year), a long storage time is required for the clearance. For fluorescent lamps in the undulator tun-nel, the activity concentration of Eu-152 was analyzed to be 100 times lower than the clearance level even though the installation period in the tunnel was long.

The result implies that it is necessary to manage the radioactive waste of the tri-wavelength flu-orescent lamps installed in the area where the beam loss frequently occurs even though it is an electron accelerator. After confirming this result, we removed the fluorescent lamp installed inside the MBD bunker and instructed the radiation worker to carry the lights in if necessary.

Activation/Decommissioning

References:
[1] I.S. Ko et.al., Applied Sciences, Vol. 7, 479 (2017)
[2] K. Binnemans, P.T. Jones, Journal of Rare Earths, Vol. 32, No. 3, 195 (2014)

Neutron detectors

A virtual detector for real-time neutron monitoring at European XFEL located in Hamburg Germany

Authors: MUKHERJEE, Bhaskar *(Resaerch Fellow*); HOFFMANN, Markus *(Wissenschaftlicher Mitarbeiter, DESY MSK*); FENNER, Michael *(Wissenschaftlicher Mitarbeiter DESY MSK);* SCHLARB, Holger *(Gruppenleiter DESY MSK)*

The European X-ray Free Electron Laser (XFEL) situated in Hansaetic city of Hamburg is driven by a 1.7 km long 17.5 GeV electron linear accelerator (Linac). The Linac is based on a long chain of accelerator modules accommodating high-performance superconducting Niobium-cavities devel-

oped at DESY (Deutsches Elektronen-Synchrotron) under the TESLA (Terra-Electron volt-Superconducting-Linear-Accelerator) Technology Collaboration (TTC). Intense fields of bremsstrahlung gamma rays

and Giant Dipole Resonance (GDR) photo-neutrons are produced when the accelerated field emis-sion electrons interact with the cavity walls, resulting in radiation exposure to electronic instru-mentation and control systems located in the vicinity of accelerator modules housing those cavi-ties.

Ionizing radiations, in particular energetic neutrons are detrimental to modern solid-state micro-electronics. Hence, in-situ radiation monitoring at the electronic-racks located close to accelerator modules in XFEL tunnel becomes imperative. Presently integrated gamma ray doses at 36 selected locations are evaluated every 3-calendar month (90 days) using thermoluminescent dosimeters (TLD-700). The implementation of a real-time dose monitoring system using the PIN-Diode based gamma-detector (PDGD) developed at DESY is in progress. On the other hand, a sensor suitable for low-level neutron detection in real-time within restricted spaces as described above is not avail-able. This shortcoming was circumvented using a novel experimental technique as summarized below:

(a) Dedicated stand-alone neutron-gamma dose measurements were carried out at FLASH (Free Electron Laser in Hamburg), the predecessor of XFEL based on the same type of TESLA cavities.
(b) Neutron dose equivalent (H) and gamma dose (D) rates were evaluated in close proximity of the cavities using super heated emulsion (bubble) detector and TLD-700 chips respectively.
(c) The cavities were activated at gradients of 17.5 MV/m. Thereafter the experiment was repeated for gradients of 22.5, 25.0 and 29.0 MV/m.
(d) The ratio of neutron dose equivalent and gamma dose rates (H/D) was found to be an explicit function “f(Eacc, D)”of gamma dose rate (D) and gradient (Eacc) set across the cavity of interest.
(e) Subsequently, an approximation formula was developed in order to estimate the neutron dose equivalent rate in the vicinity of the cavity of interest requiring the gradient (MV/m) set across the cavity and gamma dose rate evaluated with TLD. The 1MeV equivalent neutron fluence rate “1MeV (neutrons.cm-2h-1)” was

Neutron detectors

calculated by implementing relevant neutron dose equivalent to fluence conversion (kF) and 1 MeV equivalent fluence conversion (kE) factors.

At European XFEL real-time gamma dose rate monitoring at the locations of critical electronic instruments (racks) installed near the accelerator modules using the PDGD gamma dosimeters will commence shortly. Hence, by implementing the novel approximation formula presented in this paper the 1 MeV equivalent neutron fluence rate could be simultaneously evaluated from the PDGD readings in real-time. This makes a conventional gamma dosimeter a virtual neutron detector for European XFEL.

Neutron detectors

Calculation of Correction Factors for Albedo Dosimeters at BESSY II

Authors: BUNDELS, Anne *(Helmholtz-Zentrum Berlin, BESSY);* OTT, Klaus *(Helmholtz-Zentrum Berlin, BESSY)*

At synchrotron light sources like BESSY II a considerable part of the exposure to ionizing radiation consists of high energy neutrons with E > 10 MeV. The detection of neutrons with common Leake or Anderson-Braun monitors requires the thermalization of neutrons resulting in a high energy limit of 10 – 20 MeV. We calculated the resulting correction factors (between 2 and 3 depending on shielding) for our neutron monitors [1,2] and developed lead moderators which increase the upper detection limit of our neutron monitors to several GeV [3].
At BESSY II we use Albedo-Dosimeters for personal dosimetry which also require thermal energies for neutron detection thus making an underestimation of personal doses due to the high energy part of our neutron spectrum possible.
As a preliminary part of the determination of correction factors we calculate the response function of the Albedo-Dosimeters [7] from relative to absolute units using neutron reference spectra for neutron sources of the Physikalisch-Technische Bundesanstalt (PTB) [7].
In contrast to ambient dosimetry, where the fluence to dose conversion coefficients H*(10) [4] have been calculated up to the TeV range [5], the conversion coefficients Hp(10) for the personal dosimetry have been tabulated only up to 20 MeV [4] and more recently by Olsher et al [6] up to 250 MeV.
Finally, we present our approach to calculate the correction factors for Albedo-Dosimeters using Fluka [8,9] calculations of the neutron spectra in the experimental hall at BESSY II.

References:

[1] K. Ott, “FLUKA Calculations of Neutron Spectra at BESSY”, Proceedings EPAC (2006)
[2] K. Ott, Y. Bergmann, M. Martin, L. Pichl, “Upgrade of the Neutron Measurement System at BESSY”, Proceedings IPAC (2017)
[3] M. Caresana, M. Helmecke, J. Kubanak, G.P. Manessi, K. Ott, R. Scherpelz, M. Silari, “Instrument Intercomparison in the High Energy Mixed Field at the CERN-EU Reference Field (CERF) Facility”, Rad. Prot. Dos. 161, 67-72 (2014)
[4] ICRP publication 74, (New York: Pergamon Press 1996);
[5] A. Ferrari, M. Pelliccioni Rad. Prot. Dos. 77, p.159 (1998)
[6] R. H. Olsher, T. D. McLean, A. L. Justus, R. T. Devine and M. S. Gadd,” Personal Dose Equivalent Conversion Coefficients for Neutron Fluence over the Energy Range of 20 – 250 MeV”, Rad. Prot. Dos. 138, 199-204 (2010)
[7] IAEA Techn. Rep. Series 403, IAEA Vienna (2001)

Neutron detectors

[8] G. Battistoni, S. Muraro, P.R. Sala, F. Cerutti, A. Ferrari, S. Roesler, A. Fassò, J. Ranft, “The FLUKA Code: Description and Benchmarking”, Proc. of Hadronic Shower Simulation Workshop 2006, Fermilab 6-8 September 2006, M. Albrow, R. Raja eds., AIP conference Proceeding 896, 31-49 (2007)

[9] Fassò, A. Ferrari, J. Ranft, P.R. Sala, “FLUKA: A Multi-Particle Transport Code”, CERN-2005-10 (2005),INFN/TC_05/11,SLAC-R-773

Neutron detectors

Measurement of the neutron spectra at Taiwan photon source

Authors: LIN, Yu-Chi *(National Synchrotron Radiation Research Center)*; CHEN, Ang-Yu *(National Synchrotron Radiation Research Center)*; SHEU, Rong-Jiun (Department of Engineering and System Science, National Tsing Hua University)

In this study, we showed the results of the neutron spectra measurement outside the shielding wall at the injection region of the Taiwan Photon Source. The accelerator systems of Taiwan Photon Source at NSRRC comprise a 150-MeV injector and a 3.0-GeV storage ring. The energy distribution of the neutron at the TPS radiation field is of special interest. To reveal this, a set of homemade bonner cylinder spectrometers was adopted in the measurements. The spectrometer is a long-tube 3He proportional counter surrounded by cylindrical PE or heavy metal in different thickness as moderators. The tests were performed before and after the local shielding installation at the injection region. After the measurement and unfolding, the neutron spectrum at TPS was revealed and it’s clear that the neutrons with energy higher than 10 MeV dominate and contribute more after the shielding installation.

Neutron detectors

Neutron spectrometry at the ALBA Synchrotron Light

Authors: GARCIA-FUSTE, Maria-Jose *(ALBA Spain Synchrotron*); DOMINGO, Carles *(UAB Departament de Física);* DEVIENNE, Arnaud *(ALBA Spain Synchrotron,);* ROMERO--EXPÓSITO, M. (*UAB Department de Fisica);* VENTURA, Ana *(ALBA Spain Synchrotron);* CABALLERO, M.A. *(UAB Department de Fisica*)

Synchrotron light is produced at ALBA from electrons at 3 GeV in a storage ring of about 270 m circumference. Electrons are initially accelerated by a LINAC up to 110 MeV, and then transferred to the booster where they are accelerated to 3 GeV, finally they are transferred to the storage ring where they produce the synchrotron radiation used at the experimental stations. Transfer lines between LINAC and booster and between booster and storage are the most likely places where electrons may interact with beam elements. Although cross sections for neutron production from electrons are small, a considerable amount of neutrons may result from these interactions given the relatively high beam intensity. In the case of neutron dosimetry, given the strong dependence with energy of the radiation weighting factor and of the fluence to ambient dose equivalent conversion coefficient, it is necessary to have some spectrometric information to correctly assess dose. As to date no calibration facility provides neutron fields similar to those found at ALBA, so ambient dose equivalent has been originally evaluated with conversion factors obtained from calibration at an Am-Be neutron source.

An experimental campaign was performed to measure the spectrum of the neutrons resulting from the interaction of beam electrons with different accelerator components in dedicated runs. Measurements were done with the UAB Extended Range Bonner Sphere Spectrometer (BSS), able to detect neutrons from the thermal energy region up to 1 GeV. Measurements took place inside the shielding tunnel, inside the LINAC bunker, and in the experimental hall. In addition, neutron production was simulated using FLUKA.

Spectra obtained in the measurement points, as well as global dosimetric quantities (neutron flu-ence and ambient dose equivalent, fluence fractions in different energy ranges and energy averaged in fluence and in dose) will be presented. Results at the points inside the tunnel and bunker are rep-resentative of the neutron “source” term in the unlikely situation of a beam loss during operation, while results at the point in the experimental hall are useful for radioprotection purposes.

Results from this campaign will allow extending the operational range of our BSS up to 3 GeV and obtaining particular calibration factors for each measuring place.

Neutron detectors

Characterization and test of DIAMON: a new, portable, real-time and direction-aware neutron spectrometer system

Authors: TRECCANI, Matteo *(Raylab);* RASTELLI, Dario *(Raylab)*; POLA, Andrea *(Politecnico di Milano. Diparti-mento di Energia);* PASQUATO, Stefano *(Raylab);* BANFI, Paolo *(Raylab)*; GARCIA-FUSTE, Maria-Jose *(ALBA Spain Synchrotron);* DEVIENNE, Arnaud *(ALBA Spain Synchrotron)*; DOMINGO, Carles *(UAB Departament de Física)*

Raylab, an italian startup company, spin off of Politecnico di Milano, has recently developed an innovative device named DIAMON: Direction-aware Isotropic and Active neutron MONitor with spectrometric capabilities. This single-exposure neutron monitor, based on multidetector system, performs neutron spectrometry to properly derive field and operational quantities in real time. The patent pending design provides a quasi-ideal isotropic response and an optimized spectrometric performance from thermal to high energies.

The presentation will introduce DIAMON and its potentialities in neutron field direction recon-struction and its capabilities for an accurate and efficient radiation protection for synchrotron workers and users.

DIAMON was deeply tested and characterized with fast and thermal neutrons at the calibration facility of Politecnico di Milano. Neutron spectra, dosimetric quantities assessment and related fluence fractions for different experimental conditions will be shown.

During the shielding stress test at ALBA synchrotron, a measurement campaign was performed with DIAMON in order to test and to characterize the capabilities of this new detection system. The results from the measurements taken at ALBA will be shown as preliminary results of a next elaboration for an intercomparison with the UAB Extended Range Bonner Sphere Spectrometer (BSS).

Free Electron Lasers

Development of a Safety Related Burn Through Detector for the European XFEL

Authors: CLEMENT, Wolfgang *(DESY);* LEUSCHNER, Albrecht *(DESY)*; TESCH, Norbert *(DESY);* RATHJEN, Andreas *(DESY)*; SINN, Harald *(European XFEL GmbH);* GERDT, Simon-Lando *(DESY)*

Material tests carried out at the European XFEL have confirmed that passive beam confinement of the FEL beam is not possible. To ensure safety behind beam shutters and safety beam stops, an active safety system is needed to detect and to shut down the FEL beam in case of a burn through of the beam. The upcoming operation of the European XFEL with full beam power without operation limits requires a reliable safety-related detector system which is currently being developed. This new detector system is based on the measurement of fluorescence in air induced by the FEL beam. First measurements at the European XFEL have successfully been performed. A description of the detector system and results of the test measurements are presented.

Containment of Bremsstrahlung Photons and X-ray Beams for the LCLS-II Project at SLAC

Authors: ROKNI, Sayed *(SLAC);* BAUER, Johannes *(SLAC);* LIANG, Taiee *(SLAC);* LIU, James *(SLAC);* XIAO, Shanjie *(SLAC)*

The Linac Coherent Light Source II (LCLS-II) project at SLAC will add a Super-Conducting (SC) RF Linac capable of delivering electron beam up to 4 GeV, 1 MHz and 1.2 MW, to the existing LCLS accelerator facility, which is a normal-conducting copper Linac.

The fixed gap undulator of LCLS is being replaced with two new adjustable gap undulators. When driven by the SC RF Linac, LCLS-II will produce tunable, fully coherent, high-brightness, soft X-rays (0.2-1.3 keV) and hard X-rays (1-5 keV). X-rays from the undulators are transported to the Front End Enclosure (FEE) where they can be directed to Free Electron Laser instruments housed in hutches in the Near Experimental Hall and the Far Experimental Hall.

While destructive capabilities of both electron and FEL beams will be significantly increased, reuse of most of the existing LCLS infrastructure (e.g. shielding of the accelerator tunnel, FEE and exper-imental halls) and many of the beamline components is an important factor in the efficient design of the project.

This presentation discusses the challenges to contain the LCLS-II higher intensity beams of forward-angle bremsstrahlung photons and X-rays in FEE and experimental hutches as well as the radiation safety system designed to mitigate the radiation hazards.

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Free Electron Laser

Electron Beam Containment System for LCLS-II*

Authors: BAUER, Johannes *(SLAC National Accelerator Laboratory);* LIU, James C. *(SLAC National Accelerator Laboratory);* SANTANA-LEITNER, Mario *(SLAC National Accelerator Laboratory);* ROKNI, Sayed H. *(SLAC National Accelerator Laboratory)*

The Linac Coherent Light Source II (LCLS-II) project currently under construction at SLAC will install a superconducting RF Linac for delivery of electron beam up to 4 GeV, 1 MHz and 1.2 MW inside accelerator housing that had been built for SLAC's warm Cu-based Linac.

This accelerator housing has lots of existing penetrations with near line-of-sight from the surface to the new accelerator. Beam with a normal power of 120 kW will pass through a 200-m-long, above-ground concrete housing that had originally been designed for just 5 kW beam. Since only limited shielding could be added, a robust Beam Containment System will be needed for safe operation of the new accelerator.

The talk will present the design of the Beam Containment System for electrons, from the devices that detect abnormal conditions (*e.g.*, from beam losses or beam mis-steering), over the logic to the shutoff systems. It will especially discuss two new BCS Radiation Monitor devices, one using small diamonds, another making use of Cherenkov radiation in glass fibers. To understand the response of these devices to various beam losses, and to determine the best location of these detectors along the beam line, special simulation routines were developed in FLUKA and experiments performed. The challenges to test and calibrate the devices will also be presented.

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Free Electron Laser

Radiation Safety Considerations for the FEL Beams from LCLS-II Normal-Conducting Linac

Authors: XIAO, Shanjie *(SLAC National Accelerator Laboratory)*; ROKNI, Sayed *(SLAC National Accelerator Laboratory);* LIU, James *(SLAC National Accelerator Laboratory)*

The Linac Coherent Light Source II (LCLS-II) at SLAC will first start operations with the existing LCLS normal-conducting Linac (17 GeV, 120 Hz) in early 2020 and the superconducting Linac (4 GeV, 1 MHz) will start later. The fixed undulator of LCLS will be replaced by two new adjustable gap undulators: one for soft X-rays and one for hard.

The electron beams from the normal conducting Linac are expected to generate stronger Free Electron Laser (FEL) beams than LCLS-I at extended X-ray energy ranges: 0.2-8 keV to soft X-ray lines and 0.2-30 keV to hard X-ray lines. In addition, a special operation mode combining multiple electron bunches into one pulse is proposed.

Altogether the FEL beams from the normal-conducting Linac may challenge collimators and stop-pers in the manners that are different with FEL beams from either LCLS-II superconducting Linac or previous LCLS-I. This presentation shows the different challenges and the radiation safety sys-tem to mitigate the hazard.

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Free Electron Laser

Radiation safety issues at SwissFEL

Authors: PEDRAZZI, Lisa *(Department of Radiation Safety and Security);* Dr HOHMANN, Eike *(Department of Radiation Safety and Security*); KARCHER, Albert *(Department of Radiation Safety and Security);* FUCHS, Albert *(Department of Radiation Safety and Security)*; MAYER, Sabine *(Department of Radiation Safety and Security)*

The Swiss Free Electron Laser (SwissFEL) at PSI is a new large-scale facility currently under com-missioning at the Paul Scherrer Institute (PSI). It is foreseen to accelerate electrons up to an energy of 7 GeV with a pulsed time structure. The accelerator can be operated with a maximum charge of 800 pC per pulse and a maximum repetition rate of 100 Hz. With a total length of 720 m, the accelerator consists, in its final layout, of an injector area (gun and booster), three linear accelerating sections, two parallel undulator lines, and several experimental areas. The facility is integrated in a regional recreation area.

Accessible areas surrounding the accelerator tunnel together with the pulsed time structure of the primary beam, lead to new challenges to ensure that the radiation level in these areas remains in compliance with legal constraints defined by the Swiss radiation protection ordinance.

The experiences related to radiation safety gained during the commissioning phase and first results of radiation measurements are presented.