Radiation Safety Training

Synchrotron Radiation Center

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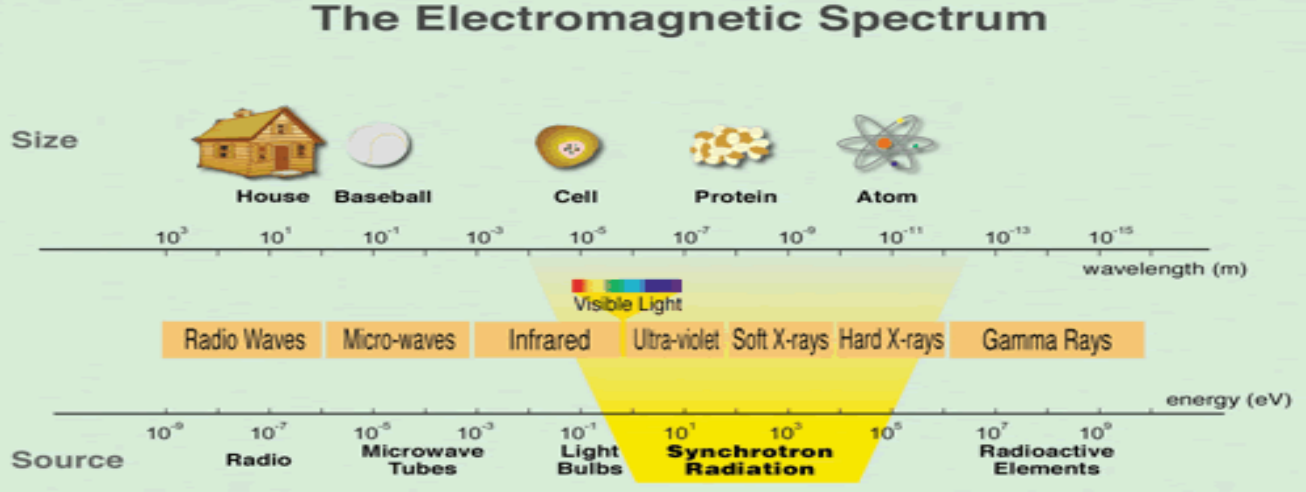
Course Objectives

Upon successful completion of this training course, you will understand the Synchrotron Radiation Center's Radiation Safety Program: including the radiation policy, radiological terminology, radiation sources, risks, hazards and controls, and your responsibilities. Successful completion of this course will allow you unescorted access to the SRC vault and CNTech Annex.

Introduction

The Synchrotron Radiation Center is a research laboratory operated as a national facility by the Graduate School of the University of Wisconsin - Madison with funding from the Division of Materials Research of the National Science Foundation. The SRC operates a 1 GeV electron storage ring (Aladdin) to produce synchrotron light, which is used by scientists from all over the world to conduct experiments.

Radiation at the Synchrotron Radiation Center (SRC) is both non-ionizing and ionizing radiation that is produced when electrons are lost either during injection, beam dumping, or during user beams. Because of this, safety measures are in place to ensure the safety of all personnel that enter the Aladdin vault. The SRC works with the University of Wisconsin-Madison Safety Department on radiation safety issues, and complies with all Nuclear Regulatory Commission (NRC) and Wisconsin Department of Health Services (DHS) regulations. Please contact the SRC Safety Officer for further information.



The Electromagnetic Spectrum
http://all-physics.net/

Terminology

Beam: A flow of electromagnetic or particulate radiation that is either colliminated and generally unidirectional, or divergent from a small source but restricted to a small solid angle.

Bremsstruhlung: Secondary (photon) electromagnetic radiation (x-rays) produced by deceleration of charged particles passing through matter.

Injection: Term used to describe the process of accelerating electrons and placing them into the electron storage ring at the SRC.

Interlock: A circuit or device constructed and installed to prevent operation of a device while safeguards are not in place. Interlocks work in combination with shielding and exclusion devices.

Ionizing radiation: Radiation with enough energy to remove electrons from atoms, leaving two electrically charged particles behind. Ionizing radiation has higher energy electromagnetic waves than non-ionizing radiation. Ionizing radiation can be either atomic particles like alpha (α), beta (β) and neutron or electromagnetic radiation like x-ray and gamma (γ) ray.

The Lamp is lit: Announcement made over the public address system when the injection is completed, which serves to notify personnel that the vault doors are open and it is safe to enter the Aladdin vault.

Machine-produced radiation: Radiation produced by a machine or device, such as x-ray producing machines, particle accelerators, high voltage power supplies, electron microscopes, high voltage rectifiers, high voltage projection equipment, and other types of high voltage machines.

Non-ionizing radiation: Radiation that does not have sufficient energy to remove electrons from atoms within material. Non-ionizing radiation includes electromagnetic radiation (ER), radio waves, microwave, infrared light (IR), visible light, ultraviolet light (UV), laser light (IR, visible and UV) and non-ER like magnetic fields and ultrasound.

Operator on Duty (OOD): Person from the SRC Operations group that is designated on each shift to be in charge of the injection process and to respond to Staff and User issues.

Radiation: The emission and propagation of waves or particles through matter or space. Matter absorbs energy from radiation.

Radiation generating device: A machine that does not typically contain radioactive material or sources, but generates radioactive fields when operated. In general, when these devices are not operating, external radiation does not exist. Access to the radiation hazards during operation is restricted through the use of shielding, interlocks, yellow and magenta

colored chains and tape, and evacuation of all personnel from the exclusion zone before and during operation of the machine. Radiation generating devices at the SRC include the microtron, Aladdin storage ring, and Laue camera.

Rem: The basic unit of ionizing radiation dose equivalent which measures the estimated biological damage or health risk to the body. It is usually expressed in smaller units called millirem (mrem): 1000 mrem = 1 rem. The System International (SI) unit is the sievert (Sv). 1 Sv = 100 rem.

Synchrotron radiation: The name given to light radiated by charged particles following a curved trajectory and moving near the speed of light. For example, a charged particle under the influence of a magnetic field produces synchrotron radiation. Synchrotron radiation has a number of unique properties:

- High brightness: synchrotron radiation is extremely intense (hundreds of thousands times higher than conventional x-ray tubes) and highly collimated.
- Wide energy spectrum: synchrotron radiation is emitted with a wide range of energies, allowing a beam of any energy to be produced.
- Synchrotron radiation is highly polarized.
- It is emitted in very short pulses, typically less than a nano-second (a billionth of a second).

Radiation Sources

Non-Occupational

Non-occupational sources of radiation include: radon gas, cosmic radiation, internal sources (within our own bodies), and terrestrial sources (materials in the earth's crust) and medical radiation.

Occupational

Some examples of occupational sources of radiation include radionuclides (radioisotopes) and machine-produced radiation such as x-rays. Radionuclides are not currently used at SRC.

Ionizing radiation at the Synchrotron Radiation Center

At the SRC, radiation produced by electron interactions may cause ionizations within the body if exposed. The synchrotron radiation (IR, visible, UV, and x-ray) and Bremsstruhlung radiation that go down the beamlines are hazardous. In addition to the synchrotron radiation produced at the SRC, other radiation is created as electrons orbit the ring. As electrons orbit the ring, electrons are lost from interactions with stray gas molecules, ionized molecules (from previous electron-gas interactions), and from impacts with ring components. These interactions create the Bremsstruhlung radiation, x-ray radiation, and neutrons. Bremsstruhlung radiation is intense x-ray radiation that is aimed

forward in the direction of travel of the beam. Bremsstruhlung radiation is highest at the ends of the long straight sections. Soft and hard x-ray radiation is not directed along the path of the beam like Bremsstruhlung radiation, but is scattered, although most is forward directed. X-rays are generated in the microtron vault when electrons are accelerated during injection. Neutrons are created primarily during injection. When the beam of electrons is injected into the ring, the process is inefficient and many electrons are lost. When electrons strike the linac in the microtron or the inflector, photons are emitted. If the photons have sufficient energy and strike a nucleus, neutrons are ejected and scattered in all directions.

Ionizing Radiation Exposure to the Public

Members of the general public receive a total dose of about 360 millirems per year from natural sources, medical tests, consumer products, etc.

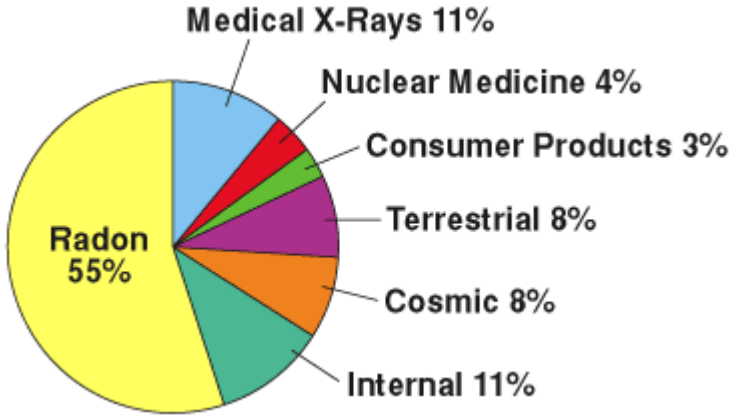


Chart: U.S. Nuclear Regulatory Commission
http://www.nrc.gov/reading-rm/basic-ref/glossary/exposure.html

This chart shows that of the total dose of about 360 millirems/year, natural sources of radiation account for about 82% of all public exposure, while man-made sources account for the remaining 18%. Natural and artificial radiations are not different in kind or effect. Above this background level of radiation exposure, the NRC requires that its licensees limit maximum radiation exposure to individual members of the public to 100 mrem (1 mSv) per year, and limit occupational radiation exposure to adults working with radioactive material to 5,000 mrem (50 mSv) per year. NRC regulations and radiation exposure limits are contained in Title 10 of the Code of Federal Regulations under Part 20, and the Wisconsin Administrative Code, Department of Health Services (DHS) 157.

Dose Limits & Monitoring Devices

Permissible Dose Limits and Occupational Dose

A **rad** (radiation absorbed dose) is defined as the unit of radiation absorbed in matter (SI unit is the gray (Gy) 1 Gy = 100 rad). A rad is equal to 100 ergs of energy deposited per gram of matter. Radiation can cause cellular damage; however, this cellular or biological damage varies between the different types of radiation, even for the same amount of absorbed dose. This difference in biological damage is called the quality factor (Q). For γ and x-rays, the quality factor is 1. The Q for α and neutrons can be 20.

For radiation safety, the **rem** (roentgen equivalent man) is defined as the unit of radiation dose equivalence which is used to normalize the biological effectiveness of the various types of radiation. The rem is derived by multiplying the radiation absorbed dose (rad) by the quality factor (Q) for the particular radiation. Equivalent dose is often expressed in terms of thousandths of a rem, or millirem (mrem). The maximum dosages, as established by the Nuclear Regulatory Commission (NRC) and the Wisconsin Department of Health Services (DHS), are listed in the following table:

Radiation Worker	mrem/yr	rem/yr
Whole body	5,000	5
Lens of eye	15,000	15
Skin	50,000	50
Hands, wrist, feet, ankles	50,000	50
Thyroid	50,000	50
Minor (under 18 years old)	500	0.5
Unborn child of radiation worker	500*	0.5*
Members of the general public	100	0.1

*over entire gestation period for declared pregnant worker

Table: Maximum Permissible Dose Limits

The permissible radiation exposure limits for radiation workers are set so there will be no somatic (skin burn, hair loss, etc.) effects, even if the worker is exposed to the maximum permissible exposure year after year. In addition, the University of Wisconsin Radiation Safety Department investigates all radiation exposures exceeding 200 mrem deep, 2250 mrem skin, 600 mrem lens and 1250 mrem extremity per month. Radiation workers at the SRC typically receive a radiation dose equivalence of less than 25 mrems per year.

Radiation Monitoring of Personnel

Radiation monitoring of SRC personnel working and performing research in the Aladdin vault and the CNTech Annex has been performed for over 20 years. The results of the

personnel radiation monitoring have always shown minimal to no exposure to radiation. In early 2009, radiation studies were conducted in the above areas to verify the historic minimal radiation levels.

Due to the documented history of minimal to no radiation exposure to individuals working and performing research in the SRC Aladdin vault, the University of Wisconsin-Madison Office of Radiation Safety has decided to discontinue issuing radiation dosimeters to all visiting researchers and SRC staff that do not work primarily in the Aladdin vault and CNTech Annex. This change in policy is affirmed by the radiation codes found in Wisconsin DHS 157.25(2)(a), which requires radiation monitoring of adults who are likely to receive, in one year, a dose in excess of 10% of the occupational dose limit. Ten percent of the adult occupational dose limit is 500 mrem per year, and personnel working in the Aladdin vault and CNTech Annex at the SRC typically receive a radiation dose equivalence of less than 25 mrem per year.

Therefore, beginning October 1, 2009, radiation dosimeters will no longer issued to SRC users, SRC staff members who spend minimal time in the Aladdin vault, and visitors.

Pregnancy

Pregnant persons are allowed in the Aladdin vault. Pregnant workers have the option to declare their pregnancy to the SRC Safety Officer or to the UW Radiation Safety Department. Due to the documented history of minimal to no radiation exposure to individuals working and conducting research in the Aladdin vault and CNTech Annex, pregnant workers will not be exposed to any levels of radiation which may pose a hazard to the fetus. The SRC Safety Officer or the UW Radiation Safety Department can provide answers to any questions personnel may have.

ALARA Program

The SRC goal is to control radiation doses as low as reasonably achievable in accordance with the Nuclear Regulatory Commission (NRC) regulations as adopted by the Wisconsin Department of Health Services (DHS). SRC follows the ALARA (As Low as Reasonably Achievable) radiation exposure philosophy in the Aladdin vault. Radiation exposure is lowered by reducing the duration of exposure, limiting access to areas where radiation exposure may result, and creating effective radiation shielding (time, distance, and shielding). In addition, warning devices to alert personnel to the potential for radiation exposure, interlocks, and exclusion devices serve to reduce radiation exposure.

Persons with Pacemakers and other Magnetically Controlled Medical Devices

Magnetic fields can cause pacemakers and other magnetically controlled medical devices to malfunction, and strong magnetic fields can be present in the Aladdin vault with or without beam in the ring. Therefore, people with pacemakers and other magnetically controlled medical devices are not allowed in the vault at any time.

Health Effects from Radiation

Exposure to radiation can be classified as acute or chronic.

Acute radiation exposure is the result of receiving a large dose of ionizing radiation over a short period of time. The bodily effects from an acute exposure are dependent on the amount of radiation received:

Below 10,000 mrem (100mSv): no observable effects. Effects that are not immediately observable may appear over time.

Above 10,000 mrem (100 mSv): observable effects include changes to blood count.

Exposure mSv	Exposure mrem	Bodily Effect
< 100	< 10, 000	No clinically detectable effects
500	50,000	Slight blood changes
1,000	100,000	Detectable blood changes
2,000	200,000	Blood changes; some nausea, vomiting, fatigue
4,000	400,000	Blood changes, nausea, vomiting, fatigue, anorexia, diarrhea, some deaths in 2 - 6 weeks
7,000	700,000	Death likely within 2 months for 100% exposed

Table: Physical Effects from Whole Body Acute Exposure

Chronic radiation exposure is the result of receiving usually repeatedly, small increment dosages of radiation over a long period of time. Natural radiation and most occupational radiation are examples of chronic radiation. Biological effects from chronic radiation exposure may occur in the individual or in the future children of the exposed individual. Chronic radiation doses may cause an increased risk of cancer. The risk of cancer from occupational exposure is small as compared to the natural occurrence of cancer.

Shielding, Exclusion Devices, Interlocks, and Controlled Areas

Shielding

Radiation shielding absorbs radiation. The density and thickness of shielding is dependent upon the type and energy of the radiation present. Shielding for x-ray and gamma radiation needs to be a thick, dense material. Shielding at SRC includes concrete, lead, and borated poly.

Exclusion Devices

An exclusion device is a construction or device that is used as a physical barrier to prevent accidental exposure while radiation is present. An exclusion device can sometimes act or be part of radiation shielding. Plexiglass is commonly used as an exclusion device at SRC. Yellow-magenta chain, tape, and ribbon is used to indicate areas that may have radiation and are therefore off limits (exclusion zones). Never proceed past these defined barriers.

Interlocks

An interlock is a circuit or device constructed and installed to prevent operation of a device while safeguards are not in place. Interlocks work in combination with shielding and exclusion devices.

Strict Permit System for Removal of Shielding and Exclusion Devices

SRC radiation shielding and exclusion devices shall not be removed by Users. Do not tamper with radiation shielding, interlocks, exclusion devices or signs. SRC employs a strict permit system for the removal of any shielding and/or exclusion devices. Only authorized SRC Staff following the appropriate permit procedures may remove shielding and/or exclusion devices.

Controlled Areas

A one meter exclusion zone is fixed around the Aladdin ring. This exclusion zone is established to prevent personnel from entering an area where radiation, magnetic, and electrical hazards exist. This exclusion zone also prevents any interference with Aladdin ring components or the beam. A yellow-magenta chain marks the outer perimeter, while the ring cable tray marks the inner perimeter. Yellow and magenta ribbon/tape is also used to define boundaries of the radiation exclusion zones. When beam is present in the ring, personnel shall not enter the exclusion zone unless a permit for working in a radiation exclusion zone is obtained from the Operator on Duty.

The entire Aladdin vault is a controlled area during injection. Large numbers of electrons are lost during injection, resulting in high radiation levels around the microtron and storage ring. For this reason, the Aladdin vault shall be evacuated during injection.

Vault Lockout

Vault Lockout and Evacuation Procedure for Injection

Ten minutes prior to injection, an announcement is made to evacuate the Aladdin vault and the north vault access door is closed. Warning sirens begin a few minutes after the north door closes. All Staff and Users should begin to leave the vault when the sirens begin.

The Operator on Duty (OOD) shall make a sweep of the entire vault to search for personnel, and will require all personnel to leave the vault. While the OOD is conducting the sweep, a series of interlocks will be activated. After the sweep is completed, the OOD will complete the interlock activation, shut off the vault lights, and close the south vault door. When the lights are turned off, emergency lights located along each outer wall of the vault will automatically illuminate. If an individual becomes locked in the vault they should depress one of the red Emergency Stop buttons, located below each emergency light along the outer walls of the vault, or open one of the gates. This will immediately trip the interlock system and stop the injection process.

Responsibilities

SRC Management

- Conduct radiation safety training.
- Establishing and maintaining an effective ALARA program and annual goals.
- Conducting monthly radiation surveys to ensure that the exclusion zones are adequately defined.
- Radiation policy implementation.
- Holding Staff and Users accountable for following radiation safety rules.

SRC Staff and Users

- Obey all signs and postings and comply with all radiological safety rules and procedures.
- Never enter radiation exclusion zones.
- Never move or remove any shielding.
- Never tamper with interlock devices.
- Notify the SRC Safety Manager if anything unusual occurs.

Emergency Procedures

Emergency procedures are posted throughout the SRC and primarily next to every telephone in the Aladdin vault and SRC lower level. If there is a fire, pull a fire alarm, exit the building and meet in the designated meeting area in the northeast corner of the PSL parking lot just west of the SRC driveway. If there is a medical emergency or if the police must be notified, dial 911 from any telephone. When the dispatcher answers be certain to explain the emergency and provide the dispatcher with the building number where the emergency exists. Every telephone has a red and white 911 decal that lists the building number for that particular building.

The telephone system has an emergency backup (UPS) in the event that electrical power is lost. This system provides phone service for a minimum of four hours. There is also a stationery cellular phone (which only has service for 911 calls) located between the main

entrance doors to the SRC building.

The SRC also has an emergency two-way radio system that is available to all Staff and Users. This system must be used whenever a Staff member of User is working alone. In the event of an emergency, the person carrying the two-way radio should activate the unit by depressing the talk and either of the red buttons next to the talk button. This places a telephone call to the emergency dispatcher. The person activating this system should provide all relevant information to the dispatcher. To speak to the dispatcher, depress the talk button. To listen, release the talk button. If the system is activated accidentally, stay on the line and explain this to the dispatcher.

Laue Camera

Use of the Laue Camera

The Laue camera produces x-ray radiation. Radiation shielding and exclusion devices are used to protect personnel from exposure to radiation. Only those personnel who have received operational and safety training may use the Laue camera. For training, contact the SRC Safety Manager. Upon completion of the training, users may check out the Laue camera HT Lock key, which enables operation of the device.

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