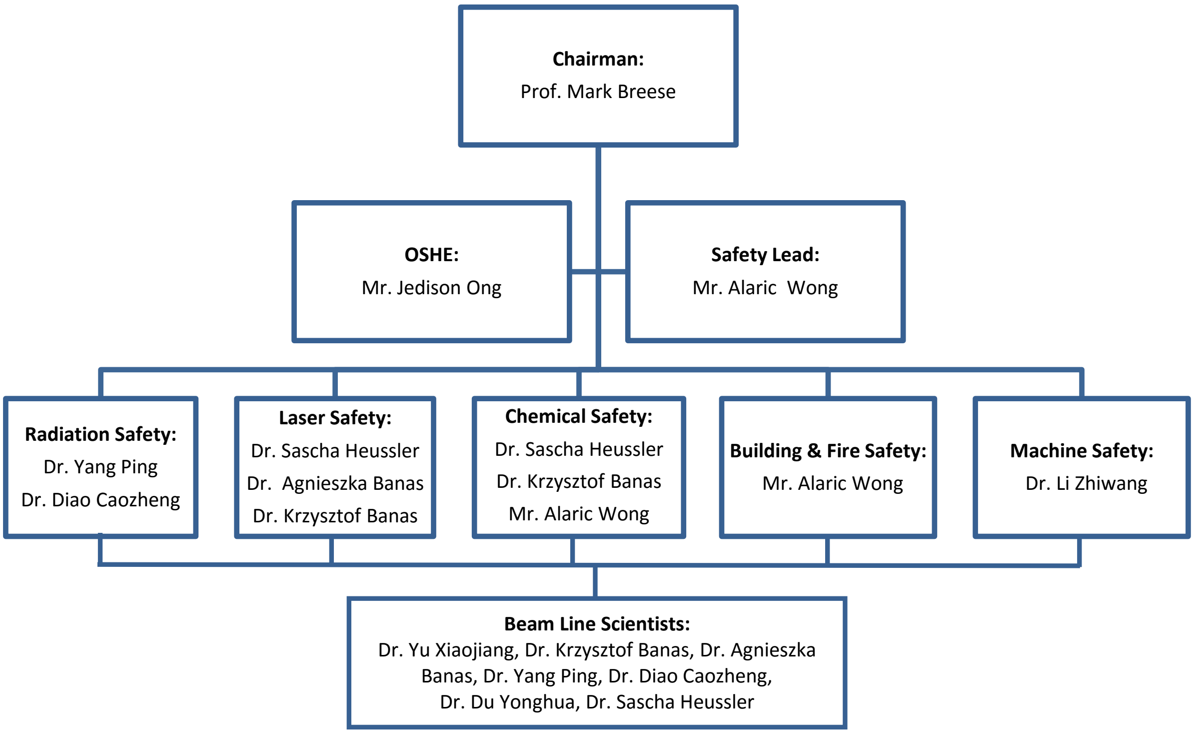
Singapore Synchrotron Light Source,
National University of Singapore

SAFETY MANAGEMENT MANUAL

Version 3.1

Revised by Krzysztof Banas, Alaric Wong and Jedison Ong
11/22/2016

SSLS Safety Committee



Safety committee Roles & Responsibilities:

Role	Name	Responsibility
Chairman	Prof. Mark Breese	Overall in charge of Safety Committee
OSHE Representative	Mr. Jedison Ong	OSHE rep/facilitator/advisor
Safety Coordinator/ Secretary	Mr. Alaric Wong	In charge of records (meeting minutes), building & fire safety. Overall support in safety matters
Member	Dr. Yang Ping	In charge of radiation safety. Beam Line scientist for XDD
Member	Dr. Diao Caozheng	In charge of radiation safety when Dr. Yang is not available. Beam Line scientist for RSXS
Member	Dr. Li Zhiwang	In charge of machine safety.
Member	Dr. Sascha Heussler	In charge of chemical & laser safety. Beam line scientist for LiMiNT
Member	Dr. Yu Xiaojiang	Beam line scientist for SINS
Member	Dr. Krzysztof Banas	In charge of chemical & laser safety. Beam Line scientist for PCIT
Member	Dr. Agnieszka Banas	In charge of laser safety. Beam Line scientist for ISMI
Member	Dr. Du Yonghua	Beam Line scientist for XAFCA

Glossary

AIMS	Accident Incident Management System
RPNSD	Radiation Protection and Nuclear Science Department
DRPNSD	Director of Radiation Protection and Nuclear Science Department
ISMI	Infrared Micro/Spectroscopy beamline
L5	L5 license holders to use an irradiating apparatus, usually also the radiation safety officers
LiMiNT	Lithography for Micro/Nanotechnology facility for micro/nanofabrication
NUS	National University of Singapore
OI	Oxford Instruments
OSHE	Office for Safety, Health & Environment
PCIT	Phase Contrast Imaging and Tomography beamline
PSS	Personnel Safety System
SINS	Surface, Interface and Nanostructure Science beamline
SSLS	Singapore Synchrotron Light Source
SL	Shift Leader
TLD	Thermo-luminescence dosimeter
XDD	X-ray Demonstration and Development beamline

1 Introduction

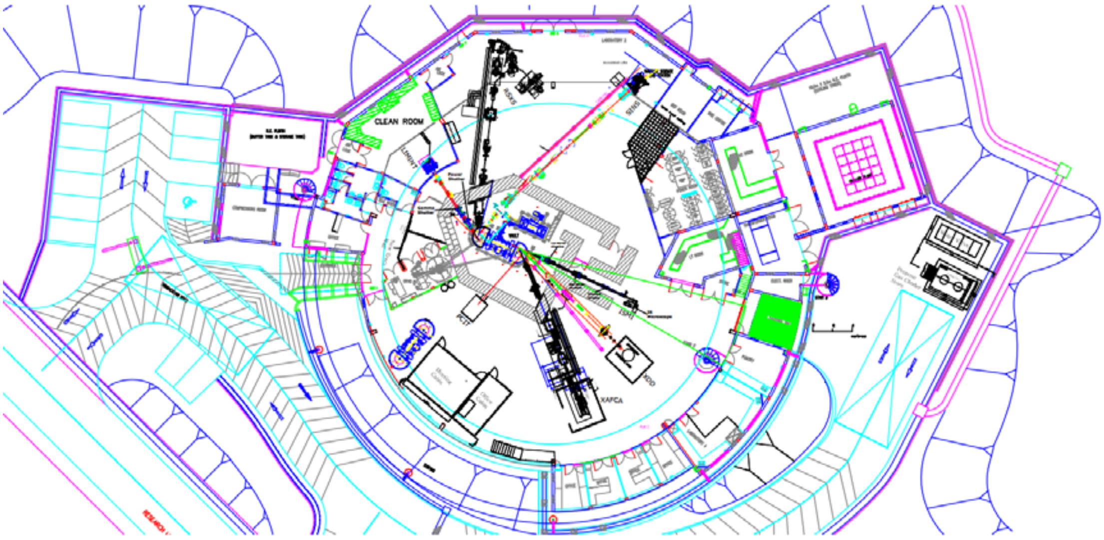
1.1 Singapore Synchrotron Light Source

The Singapore Synchrotron Light Source (SSLS) is a university-level research institute at the National University of Singapore. It is a user facility offering synchrotron radiation based services to a broad community of users from Singapore and abroad. Its mission is in detail

- To provide synchrotron radiation service for scientific and technological applications ranging from basic research up to advanced manufacturing
- To perform own R&D in synchrotron radiation applications
- To train manpower in synchrotron radiation science and technology
- To attract and enable industry to conduct advanced research and manufacturing in Singapore
- To provide synchrotron radiation service for commercial applications
- To develop advanced synchrotron radiation sources

SSLS is operating an electron storage ring featuring two superconducting bending magnets as its source of synchrotron radiation and five beamlines and experimental facilities that use the synchrotron radiation for their different specific purposes. A sixth beamline for diagnostic purposes is under construction.

The storage ring – dubbed Helios 2 by its builder Oxford Instruments - runs an electron beam of 700 MeV energy and, presently, up to 500 mA current. The current in the storage ring has a lifetime (1/e decay time) ranging from 11 to 17 h depending on current level. Therefore, the storage ring is injected once per day in the morning and is then running till the evening. Injection into the storage ring is performed using a 100 MeV microtron accelerator that is typically operated once a day in the morning. The whole accelerator facility comprises the storage ring, the microtron, the transfer line in between them, the plant room that houses all power supplies and controls, the LHe refrigerator system, and the water cooling systems. These are outlined in the “Plan view of the building with the accelerator system and its subsystems”.



Plan view of the building with the accelerator system and its subsystems

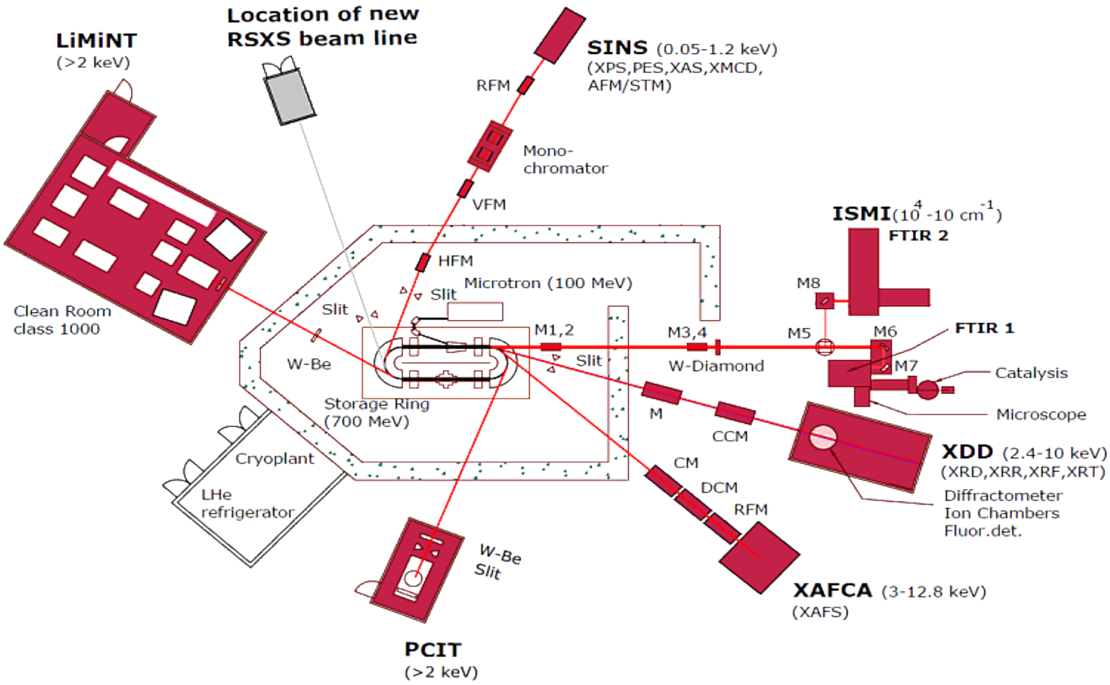
At the storage ring, 21 beam ports are available for attaching so-called beamlines that transport the light to the experimental stations where samples can be measured and micro/nanodevices produced. With electron energy of 700 MeV and a bending magnetic field of 4.5 T, the characteristic photon energy (wavelength) is 1.47 keV (0.845 nm). Helios 2 delivers up to 5x10^{14} photons per second in a 0.1% spectral bandwidth into each beam port simultaneously.

SSLS has been operating since 2000, starting with the commissioning of the accelerator facility and building beamline and experimental stations gradually up to the present status which is depicted schematically in “Schematic outline of SSLS showing beamlines and experimental facilities together with the accelerator system” .

Presently, six beamlines are in operation and seventh is under construction:

1. **XDD:** X-ray Development and Demonstration covering a spectral range from 2.4 to about 10 keV photon energy.
2. **ISMI:** Infrared Spectro-/Microscopy ranging from 10000 cm^{-1} in the near infrared to 10 cm^{-1} in the far infrared (1.3 eV to 1.3 meV photon energy).
3. **SINS:** Surface-, Interface- and Nanoscience operating at photon energies from 0.05 to 1.2 keV photon energy (soft X-rays).
4. **PCIT:** Phase Contrast Imaging and Tomography operating at photon energies from 2 to 12 keV.
5. **LiMiNT:** Lithography for Micro- and NanoTechnology operating at photon energies from 2 to 12 keV.
6. **XAFCA**: X-ray Absorption Fine structure for catalysis (3-12.8 keV photon energy).

7. **RSXS:** Resonant Soft X-ray Scattering designed for photon energies from 3.5 eV to 1.5 keV photon energy (soft X-rays) - under construction.



Schematic outline of SSLS showing beamlines and experimental facilities together with the accelerator system

Owing to the equipment installed and the use made of it, SSLS has to deal with the following risk areas:

- Ionizing radiation (dominant issue)
- Cryogenic (ca. 2 m^3 LHe and 23 m^3 inventory)
- Chemical (small inventory)
- Mechanical (conventional)
- Electric (conventional)
- Fire (conventional)

The population of SSLS’ building is composed of staff, users, and visitors.

1.2 Environmental, Health and Safety (EHS)

1.2.1 Safety is the responsibility of every Employee at SSLS.

1.2.2 The management of SSLS recognizes the importance of environmental protection, conservation, workplace safety and personal health within its research activities and strives to provide a healthy and safe environment for our staff, students, collaborators and visitors.

1.2.3 SSLS is committed to:

1. Conduct research activities in compliance with local laws and regulations related to occupational safety, health and environment.

2. Promote EHS awareness, through training and communication, to all staff, students and collaborators and motivate to be proactive and responsible for environmental protection, workplace health and safety.

3. Ensure all staff, users and visitors comply with the established policies and practices for environmental, health and safety.

4. Assess health and safety hazards to provide safe work practices, prevent occupational diseases and damage to property

5. Use materials and energy efficiently, minimize waste and improve waste handling.

2 Emergency Procedures

2.1 Emergency Contacts

Contact numbers of staff-in-charge of the SSLS, beamline scientists, key support staff (e.g. Incident Response Taskforce (IRT) and Security at NUS) and external agencies (e.g. Civil Defense Force, Ambulance Service) are prominently displayed at each beamline at SSLS.

For all **MINOR** incidents

a. such as small incipient fires, non-hazardous gas leakage, odour detection, minor spillage (< 20 l), minor injuries, equipment malfunction, etc.

For all **MAJOR** incidents

b. such as incipient fires/ explosion, hazardous/ toxic gas leakage, minor spillage (> 20 l), major injuries, etc.

Contact SSLS Help Line (Tel: 651 67931) to notify the Shift Leader (SL).

2.2 Incident Response Taskforce (IRT) Contact List

Lab/Office Name	Name of representative	Office Telephone
Shift Leader		651 67931
Directors Office	Prof. Mark B. H. BREESE	651 67930
XDD Beamline	Dr YANG Ping	651 64749
ISMI Beamline	Dr Agnieszka BANAS	651 67005
SINS Beamline	Dr YU Xiaojiang	651 67951
PCIT Beamline	Dr Krzysztof BANAS	651 67837
LiMiNT Beamline	Dr Sascha P. HEUSSLER	651 63228
XAFCA	Dr Du Yonghua	651 61004
RSXS	Dr YU Xiaojiang	651 67951

2.3 Important Contact Numbers – EXTERNAL ASSISTANCE

Service Name	Telephone
Fire/ HAZMAT/ Ambulance	995
Police	999
Non-Emergency Ambulance Service	1777
NUH Enquiry Service	677 95555
Drug & Poison Information Centre	642 39119
Clementi Police Divisional HQ	677 25990
NUS Campus Security Post	687 41616
Fire Safety & Shelter Bureau, FSSB	673 44308
Ministry of Manpower, MOM (OS&H)	643 85122
National Environment Agency, NEA	673 27733
Health Sciences Authority, HAS	621 30838
Agri-Food & Veterinary Authority, AVA	632 57625
Singapore Red Cross Society	633 60269

2.4 Medical Support Procedures

- If an accident occurs, the injured person must be sent immediately to the Accident & Emergency (A&E) Department in National University Hospital (NUH).
- For ambulance service call 995 (for emergency) or 1777 (for non-emergency).

2.5 Fire Emergency and Evacuation Procedures

Procedures for Fire Alarm Activation

1. The fire alarm can be raised by:

   a. Breaking the “Emergency Fire Call Point”.

    b. Activation of automatic smoke or heat detector system.

2. When the alarm is activated at SSLS, the alarm bells shall ring continuously
3. An audio and visual signal will be registered at NUS Security Office
4. Upon hearing the fire alarm sounding, proceed to check and confirm the source of activation

Action taken by Informant in the event of Fire Alarm

1. Alert surrounding people to leave the scene
2. Stop all activities if possible
3. Retreat to a safe area
4. Call **6874 1616** and provide relevant information.
    a. Location of incident/ accident
    b. Type of incident/ accident
    c. Number and nature of injuries
    d. Name and contact number of informant

2.6 Chemical Emergency Procedures

2.6.1 Procedures for Spills of Volatile or Flammable Materials

1. Warn all persons nearby
2. Turn off any ignition sources such as burners, motors and other spark-producing equipment
3. Small spills can be absorbed with paper towels or other absorbents
4. Leave the room and close the door if possible
5. Contact the Incident Controller at SSLS

2.6.2 Procedures for Chemical Spill on a Person

1. Know where the nearest eyewash and safety shower are located and how they operate
2. For most of the chemicals that splash on the skin, remove any jewellery that may contain residue, flush immediately under running water for at least **15 minutes until no further pain**, or until emergency paramedics arrive and seek medical advice immediately.

3. When providing assistance to a victim of chemical contamination, use appropriate personal protective equipment, such as gloves.

4. Hold the eyelids open and move the eye up, down, sideways to ensure complete coverage.

5. For spill on clothing, immediately remove contaminated clothing, including shoes and jewellery, while standing under running water or the safety shower.

6. Consult the MSDS to see if any delayed effects should be expected, and keep the MSDS with the victim.

7. Call the ambulance (Tel: 995) to take the victim to the hospital for medical attention. Be certain that emergency paramedics are told exactly what the victim was contaminated with so they can treat the victim accordingly.

2.6.3 Procedure for Cryogenic Liquid Spill on a Person

1. Contact with cryogenic liquids may cause crystals to form in tissues under the spill area, either superficially or more deeply in the fluids and underlying soft tissues.

2. The first aid procedure for contact with cryogenic liquids is identical to that for frostbite.

3. Remove all protective clothing, gloves and shoes immediately. Check for affected area.

4. Re-warm the affected area as quickly as possible with warm water (between 39^{o} and 41^{o} C).

5. Do not rub the affected tissues

6. Do not apply heat lamps or hot water and do not break blisters.

7. Cover the affected area with a sterile covering/ bandages and seek assistance for burns at the hospital.

2.6.4 Incidental Spills (< 20 L) – Procedures for Small, Low-Toxicity Chemical Spills.

1. Be prepared. Keep appropriate spill-containment material on hand for emergencies. Consult with the Incident Controller to determine which materials are suitable in a particular case.

2. Laboratory staff is trained to distinguish between the types of spills they can handle on their own and those spills that are classified as “MAJOR”.

3. Only trained laboratory staff is qualified to clean-up spills that are “incidental”.

4. If the spill exceeds the scope of the laboratory staff's experience (training or willingness to respond) the staff must alert professional help.

2.7 Biological Emergency Procedures

Not applicable

2.8 Electrical and Mechanical Emergency Procedures

2.8.1 Emergency Electrical Safety Procedures

Electrical Shock Dynamics (3 important considerations)

- Path - entering the body and exiting the body
- Amount of current or energy flowing in the body
- Duration of exposure - degree of injury also depends on the duration and frequency of the current. Note: "Shock" injuries can resemble an "Iceberg" where most of the injuries are internal, with only an entry and exit wound visible. Prompt attention is required by individuals specifically trained to treat electrical injuries.

60 Hz AC Current	Response
0.5 – 3 mA	start to feel the energy, tingling sensation
3 – 10 mA	experience pain, muscle contraction
10 – 40 mA	grip paralysis threshold (brain says let go; but physically cannot do so)
30 – 75 mA	respiratory systems shut down
100 – 200 mA	experience heart fibrillation
200 – 500 mA	heart clamps tight
Over 1500 mA	tissue and organs burn

<u>Accident victims can also incur the following injuries from electrical shock:</u>

- Low-voltage contact wounds
- High-voltage contact wounds from entry and exit of electrical current
- Burns
- Respiratory difficulties (the tongue may swell and obstruct the airway; or vaporized metal or heated air may have been inhaled)
- Infectious complications
- Injury to bone through falls, heat necrosis (death of tissue) and muscle contraction (shoulder joint injuries and fracture of bones in the neck are common injuries caused by muscle contraction).
- Injury to the heart such as ventricular fibrillation, cardiac arrest or stoppage
- Internal and organ injuries

- Neurological (nerve) injury
- Injury to the eyes (cataracts from electrical injury have occurred up to three years after the accident)

Shock Rescue Procedures

In response to an electrical accident, follow these procedures immediately:

- Call for help (can't be handled by one person) and follow the emergency response system as set forth in the safety procedures of each organization.
- Get the approved first-aid supplies (these should be easily accessible when required).
- De-energize the circuit.
- Separate the person from the energy source.
    - Make sure you and the victim are in a safe zone - not in contact with any electrical source, away from downed or broken wires.
    - Never grab the person or pull the person off the current with your hands; you might become part of the circuit and become injured as well.
    - Use a dry wood broom, leather belt, plastic rope or something similar that is non-conductive such as wood or plastic cane with hook on the end to free the person from the energy source
    - Administer first aid2apply mouth-to-mouth resuscitation and/or CPR; know what to do
    - Keep the victim lying down, warm and comfortable to maintain body heat until help arrives. Do not move the person in case of injury to neck or back.
    - If the victim is unconscious, put him/her on side to let fluids drain.
    - Make sure the victim receives professional medical attention (person shocked could have heart failure hours later)

      Burn victim first-aid steps:

        - If the person's clothing is on fire, roll the person on the ground to smother the flames.
        - Cool the burn with water or saline for a few minutes or until the skin returns to normal temperature. Do not attempt to remove clothing that is stuck to a burn.
        - Remove constricting items from the victim, such as shoes, belts, jewellery and tight collars. They could continue to burn or cut off circulation if the victim experiences swelling.
        - Check the victim's breathing and heartbeat. Apply mouth-to-mouth resuscitation and/or CPR if necessary.
        - Keep victim warm and comfortable by covering him/her with clean, dry sheets or blankets.
        - Cover wounds with clean sheets and dry blankets.
        - Elevate burned areas to reduce swelling.

* Special thanks to Safe Electricity for providing material for these workplace electrical safety tips. For more information on Safe Electricity, visit their website at www.safeelectricity.org

2.8.2 Emergency Mechanical Safety Procedures

In response to a mechanical accident, follow these procedures immediately:

- Call for help and inform the trained First-Aid personal (sometime can't be handled by one person) and follow the emergency response system.
- Get the approved first-aid supplies (these should be easily accessible when required).
- Stop the machine immediately and switch off the machine.
- Guide the injured person to a safe place.
- Make sure you and the victim are in a safe zone.
- Use cotton to cover the body bleeding part for further loss of blood.
- Use water or solution to wash the injury body part and make sure there are no residues left in the wound.
- In case of a lot of blood is loss, keep the victim lying down, warm and comfortable to maintain body heat until help arrives. Do not move the person in case of injury to neck or back.
- If the bleeding would not stop, call the emergency ambulance at once and send the injury person to hospital immediately.
- If the victim is unconscious, put him/her on side to let fluids drain.
- Remove constricting items from the victim, such as shoes, belts, jewellery and tight collars.
- Keep victim warm and comfortable by covering him/her with clean, dry sheets or blankets.
- Cover wounds with clean sheets and dry blankets.
- Make sure the victim receives professional medical attention.

2.9 Radiation Emergency Procedures

2.9.1 Person within the Shield Vault

Any person who is accidentally within the Shield Vault after the Search has been completed should, on hearing the warning message or seeing the warning lights, immediately walk towards the labyrinth exit and press "EMERGENCY OFF" button, leave the Shield Vault via the Labyrinth door and report to the Control Room.

2.9.2 Person on Vault Roof

Any person who is accidentally on the Vault roof after the search has been completed should, on hearing the warning message, leave immediately and report to the Control Room.

2.9.3 Radiation Incident

In an unlikely event of a person being accidentally irradiated by being inside the Shield Vault while HELIOS 2 is operating, the Shift Leader should:

- Shut down HELIOS 2.
- Endeavour to ascertain the length of time that the person was irradiated and his location during irradiation.
- If the person has sustained physical injury that requires treatment, take him/her to Emergency Department at the National University Hospital, 5 Lower Kent Ridge Road, Singapore 119074, Tel. 6772 5000 (or 6779 5555 in general). This action should have priority over any longer term treatment for radiation exposure.
- Preferably in consultation with the Director and SSLS' Radiation Safety Officer holding L5 license, if practical, to make an estimation of the dose received.
- Contact the OSHE, Office of Safety, Health and Environment, NUS

Office of Safety, Health and Environment, NUS		
Telephone		651 66863
Fax		677 86031
WWW	http://www.nus.edu.sg/osh/	
Postal Address	8 Kent Ridge Drive, #03-02, Singapore 119246	
Director	Dr Peck Thian Guan oshhead@nus.edu.sg	651 65961
SSLS Liaison Officer Safety & Health Manager	Mr Jedison Ong oshoca@nus.edu.sg	651 65966

- Ask the Radiation Physicists for advice on how to proceed.
- Ensure that the person's film badge is kept safe and is processed as quickly as possible.
- Inform the Director if necessary, after assessing the situation.

2.9.4 Bursting Discs

If any cryostat bursting disc ruptures, personnel must leave the Shield Vault as quickly and as close to the floor as possible and inform the Incident Controller.

2.9.5 First Aid Boxes

First Aid boxes are located in the Cleanroom, SINS beamline, outside Chemistry Laboratory and in the Chemistry Laboratory.

2.10 Accident/Incident Reporting

- All **major incidents** (such as fire/explosion, hazardous gas leakage, major spillage (> 20 l) and major injuries, etc.) must be reported to OSHE.
- In the event of all minor incidents (such as small incipient fires, non-hazardous gas leakage, odour detection, minor spillage (< 20 l), minor injuries, equipment malfunction, etc.) contact SSLS Shift Leader (Tel: 65167931).
- A report can be done via **"AIMS (Accident and Incident Management System)"** at this link https://inetapps.nus.edu.sg/osh/portal/eServices/ehs360_aims.html
- Alternatively, if you are a staff: Go to Staff Portal > Safety, Security & Sustainability > eServices menu > Select AIMS
- Alternatively, if you are a student: Go to Student Portal > Quick Links > Select AIMS
- Input the required information into AIMS.
- The **"AIMS" report** could be downloaded from the SSLS web page or from OSHE web page at NUS (https://inetapps.nus.edu.sg/osh/portal/eServices/ehs360_aims.html).
- The **"AIMS" report** is used as a tool to determine the root cause and improve current practice.

3 First Aid Services

3.1 Safety shower and Eyewash Station

1. No chemistry work is allowed throughout SSLS except in the clean room and the chemistry lab. The latter has only restricted authorization to (describe allowed processes such as electroplating in beaker, titration)

2. A safety showers are installed in the clean room and the chemistry laboratory.

3. Every laboratory employee shall be instructed in the location(s) and use of a safety shower. Ideally, a person should be able to find the shower with his or her eyes closed.

4. A “safety Shower” sign shall be placed outside each room that has a shower. The floor shall be clear under the shower.

3.2 First Aid Kit

1. First Aid boxes are located in the Cleanroom, SINS beamline, outside Chemistry Laboratory and in the Chemistry Laboratory.

2. The kit should be easily accessible.

3. Each laboratory user shall be trained to know where the kit is located.

3.3 First Aid Manual

For detailed procedures on handling each injury case, consult the first aid manual, which is inside the first aid kit, or refer to the nearest first aide in each laboratory.

3.4 Sick Bay

Persons who are feeling unwell or need rest prior to seeking medical attention, should be escorted to the Sick Bay located in the Pantry room.

3.5 Personal Injury

3.5.1 Burn from fire

1. If your clothing catches fire, decide very quickly how to put the fire out and minimize burns. The following methods are in order of preference

    - Get under the safety shower or other water source if one is immediately at hand

    - If a safety shower is not immediately available, stop, drop, and roll to extinguish the fire, holding your hands over your face to shield your face and eyes.

    - Roll up in a fire blanket if one is nearby. If the fire blanket is used, remove it immediately after the flames are extinguished to prevent further injury from heat build-up.

2. Assess the condition of the skin burn area.

If skin is not broken, run water over the burn area to remove heat.

If skin is broken, apply a dry, sterile dressing over the wound. Seek medical attention as soon as possible.

3.5.2 Inhalation

1. A person exposed to smoke or fumes shall be removed to fresh air and seek medical advice immediately.
2. Any victim overcome by smoke or fumes shall be treated for shock.
3. If not breathing, give artificial breathing if a trained personnel is available.
4. If person needs to be rescued from a contaminated area, evaluate the possibility of harm to the rescuer before anyone enters or remains in the contaminated area without proper protective equipment.
5. If an MSDS is available for the material inhaled, it should accompany the victim to the medical treatment facility.

3.5.3 Shock

1. Shock is likely to develop in any serious illness or injury.
2. The following signals are indicators that the victim is suffered from shock:
   a. Restlessness or irritability
   b. Altered consciousness
   c. Pale, cool, moist skin
   d. Rapid breathing
   e. Rapid pulse
3. In caring for shock, have the victim lie down and rest as comfortable as possible and thereby slow the progression of shock.
4. Control any external bleeding. Help the victim maintain a normal body temperature and avoid chilling.
5. Do not give the victim anything to eat or drink.
6. Obtain medical assistance promptly since shock cannot be managed first aid alone.

3.5.4 Ingestion

1. If a person ingests a toxic chemical, determine, if possible, what was ingested.
2. Wash out mouth with plenty of water, provided person is conscious. Do not induce vomiting.

3. Seek medical advice immediately.

4. Inform the ambulance paramedics of the first aid treatment shown on the container label or the MSDS. The MSDS should accompany the victim to the medical treatment facility.

3.5.5 Puncture or cut

1. When treating a victim with a puncture wound or cut, wear personal protective equipment (e.g. gloves) to minimize exposure to human blood, body fluids, or other chemical or biological contamination.

2. Apply a pressure pad or clean cloth firmly to the wound. Raise the wounded area above the level of the heart to slow the bleeding

3. For severe bleeding or spurting, very firmly press the pressure pad directly on the wound. Keep the victim warm, calm, and oriented to prevent shock.

3.5.6 Dermal contact

1. If a chemical spill on a person, the first goal is to remove the chemical from the person’s skin as soon as possible, without spreading it onto you.

2. Remove contaminated clothing immediately (including shoes and jewellery), while standing under running water.

3. For all chemicals (with the exception of HF), flush the skin under a safety shower for **at least 15 minutes until no further pain or irritation**, or until paramedics arrive, and seek medical advice immediately.

4 Fire Safety Practices

4.1 Fires and Explosion

Three things must be present at the same time in order to produce fire:

1. Enough oxygen to sustain combustion
2. Enough heat to raise the material to its ignition temperature
3. Some sort of fuel or combustible material

4.2 Classes of Fire

Fire is classified according to the type of fuel:

- **Class A** Ordinary combustible materials (such as wood, paper, cloth, rubber and plastics, etc.)
- **Class B** Flammable liquids and gases (such as gasoline, oil, grease, acetone, etc.)
- **Class C** Energized electrical equipment (for electrical fires)
- **Class D** Combustible metals (such as lithium, sodium and magnesium) and organometallics (such as trimethylaluminium)

4.3 Portable Fire Extinguisher

Portable extinguishers are located along paths of travel, near the doorway or preferably on escapes routes. Class D materials are not allowed at SSLS.

Type of portable fire extinguisher	Class of Fire
Water	A
Carbon dioxide	B, C
Dry chemical powder	A, B, C
Metal-X powder	D

Hence does Metal-X powder extinguisher is not required. At SSLS:

- **Class A** fires will be fought using **water fire hoses**
- **Class B & C** fires will be fought using **carbon dioxide extinguisher**

4.4 General Fire Prevention

- Regular tidying and cleaning of workplaces and keeping the premises clear of combustible waste.
- Combustible materials and flammable liquids and gases, in current use, are to be kept a safe distance away from heat-generating equipment, such as hot plates, ovens and furnaces.
- Regular checking of all electrical equipment for proper connection and wiring.
- All exit doors should be easily opened from inside.
- Passageway leading to exit doors should be free from any obstacles.
- There should be clear access to fire-fighting equipment, fire alarm call-points, power and light switch boards and control valves.

4.5 Evacuation Drill

Evacuation drill shall be conducted at least once a year to familiarise all personnel with the plan.

All SSLS personnel should be aware of the following:

1. Emergency evacuation procedures
2. Location of designated assembly area (NUS Car Park 11) during evacuation
3. Location of all emergency exit doors at SSLS

Location and type of fire-fighting equipment and fire alarm call-points in offices/laboratories.

5 Accelerator systems and Beamlines

5.1 Accelerator System

Accelerator system is crucial to SSLS. Therefore, necessary roles have to be implemented to make sure its smooth and safe operation. **FAULTY ACTIONS MAY CAUSE DIPOLES' QUENCH OR DAMAGE OF THE SUBSYSTEM. ONLY TRAINED PERSONS ARE ALLOWED TO OPERATE THE MACHINE.** See Appendix A for details.

As shown in Figs. 1 and 2 in Chapter 1, the accelerator has two superconductor dipoles. The dipoles are the main bending magnets and have a field of 4.5 T. To keep the dipoles superconductive, they are cooled down to 4.2 K by liquid helium and liquid nitrogen system. Electrons from the Gun in Microtron are injected into the ring. The electrons circulate inside the ring and are ramped to full energy 700 MeV. When the electrons are bent by dipoles, they give off radiation and lose energy. Their energy loss is compensated by RF system. Therefore, the potential hazards regarding the accelerator system are mainly:

- X-ray radiation during injection from Microtron (10 mA, at 2 Hz and 100 MeV),
- X-ray radiation during ramping and stored beam (115 W each of 21 ports),
- Magnet field, very large attractive forces, up to 22 N,
- Extremely low temperature of the cryogens (-269 °C),
- High voltage hazards from the accelerator electrical power supply (120 kV),
- Heating and burns risk in RF system (50 kW).

The detail descriptions of these hazards are presented in Safety Management Manual Appendix A. For machine and human safety, the following general roles must be followed by staff, users and visitors. Please consult the duty shift leader if there is any doubt about the roles.

- Do not enter the Vault, Plant Room, Cryogenics room, and Control Room without permission, please inform the shift leader if you wish to do so,
- Do not apply any force/load on the cooling water pipes and compressed air pipes, and liquid nitrogen/helium lines,
- Do not stand close the safety valves and burst discs,
- Do not touch ice balls by hand in cryogenic plant or Vault,
- Do not standing or apply pressure on the any part of the accelerator, such as vacuum pipes, kickers, septum, RF cavity, RF wave guides helium transfer lines, etc.,
- Keep away from the Vault wall when beam is stored,
- Do not enter the vault immediately after beam dump, please consult the duty shift leaders for vault entry, the radiation monitor came with the machine should be carried when entering into the vault; please consult the duty shift leaders for vault entry,
- Keep away from the RF and Microtron HV power supply,
- Do not use the compressed air whenever dipoles are full of liquid helium.

5.2 XDD (X-ray Development and Demonstration) beamline operates with X-rays with energies from 2.4 keV to 10 keV.

Beamline Scientist

Dr YANG Ping (Tel.: 651 64749 e-mail: slsyangp@nus.edu.sg)

XDD beam line covers single crystal and powder diffractometry, reflectometry, fluorescence detection and absorption spectroscopy. As it is a hard X-ray beamline, ionizing radiation safety is a crucial issue to this beamline.

Radiation safety at XDD

- To ensure safe operation and a safe work site for personnel, the beamline is controlled by its beamline control system, which consists of the Beamline Safety System (BSS) and the Personnel Safety System (PSS), the control panel as shown in Fig. 5 of Appendix D. Beamline components such as vacuum shutters, crystals and mirror are protected by interlocks and cooling water.
- Gamma-shutter, a 70 mm Ta equivalent, acts as a shutter to shield gamma ray and synchrotron radiation, to ensure that there is no dose inside the experimental hutch and hence to let users prepare the experiment safely inside the hutch.
- Extra shielding for the beamline after the mirror will be installed or respective area is controlled.
- No-one must be present inside the hutch while beam is ON and the interlock is in operation. To evacuate the hutch, search procedure is provided in the control system and should be abided every time before new experiment runs. The procedure is shown in separate Figures of Appendix D.
- The hutch is built for protecting the personnel to conduct the experiment outside.
- Do not operate the beamline during the electron beam injection.
- No visitors are allowed to operate the XDD beamline without supervision from the beamline scientist or staff member. Only trained users can operate the beamline and conduct the experiment. After training they must sign a form as attached in Appendix D, i.e. “Authorized users at XDD experimental station”.

Chemical samples handling

For staff and users, who have approved by SSLS to handle chemicals, should note that

- All samples storage and preparations must be done in chemistry room.
- Clean and/or sample disposal practices must be done in the Chemistry room.
- Wear gloves and goggles prior handling samples.

- Use the Hood located in the chemistry room when manipulating liquid or gas samples.
- Toxic gases are purchased and stored in smallest quantities as possible.
- During use and storage, highly toxic gases are located in continuously ventilated gas cabinets.
- A continuous gas monitoring should be used for signalling releases of toxic gases.
- When not in use toxic gases should be removed and placed in safe area.
- When toxic gases are in use do not keep regulators and pipes pressurized after samples transfer.
- Never let valves of toxic gases open. Immediately close them after use.
- Purge the pipes with inert gases (He, Ar).
- Gas cylinder should be transported on a wheeled cylinder trolley.
- Never slid or roll a cylinder, even practiced handlers can easily lose control of them.

In case necessary, SSLS chemical safety officer or OSHE safety officer should be called in.

Radioactive samples

Radioactive sample has to be approved by the Director before bringing to SSLS.

Electrical connection

There are special electrical connectors to XDD beamline and its equipment.

- Do not disable or disconnect them. Consult with the beam managers.
- XDD provides users with wall socket.
- Do not overload the electrical circuit.
- Check with the electrical personnel Miao Hua (Tel.: 651 64750 e-mail: slsmh@nus.edu.sg) for powering particular equipment.

Vacuum pump safety

There are some general safety considerations in using a rotary pump that should be followed for user safety and extending the usable life of the pump. These and other safety issues are covered in more detail in the documentation provided by the pump manufacturer. The vacuum pump manual supplied by the manufacturer should be completely read and understood before the user attempts to operate, repair, or perform maintenance procedures.

Vacuum pumps (rotary, turbo pumps and ionic pumps) belonging to XDD beamline are specifically designed for the beamline.

- Do not disconnect or use them. XDD vacuum pumps are used to evacuate clean air only.
- Do not obstruct the ventilation around the pumps to prevent the units from overheating.
- Check with beamline managers and with qualified personnel CHEW Eh Piew (Tel.: 651 64748 e-mail: slscep@nus.edu.sg)

5.3 ISMI (Infrared Spectro-/Microscopy) beamline ranging from 10000 cm^{-1} in the near infrared to 10 cm^{-1} in the far infrared (1.3 eV to 1.3 meV).

Beamline Scientist

Dr Agnieszka BANAS, (Tel.: 651 67005 e-mail: slsba@nus.edu.sg)

Radiation safety

a) Radiation safety (X-rays and VUV radiation safety at ISMI)

Infrared SpectroMicroscopy (ISMI) beamline is a very low energy delivering beamline. The light is emitted in the infrared range and extends to the visible. The spectral range is within 1.3 meV to 1.3 eV. The vertical extraction beamline design of the emitted light from Helios2 machine excludes automatically all higher energy photons (x-rays and soft x-rays) from reaching the end station. Vacuum ultra violet (VUV) light and ultra violet light (UV) are filtered out with a diamond window. Moreover, the Gold coated mirrors used to transport the light to the end station greatly attenuate both VUV and UV light.

There is no specific protection needed from X-rays and VUV light at ISMI end station. The beamline end station is constructed in open area and there is no hutch at the working place. However, the user should fully comply with the radiation safety procedures at SSLS institute. X-ray radiation safety personnel is Dr YANG Ping (Tel.: 651 64749 e-mail: slsyangp@nus.edu.sg)

Do not operate the beamline during the electron beam injection. However, you still can work, independently, with the FTIR equipment at the end station.

b) Radiation safety (Infrared and visible light radiation safety)

To operate ISMI beamline please check first with the beamline scientist. (Dr Agnieszka BANAS (Tel.: 651 67005 e-mail: slsba@nus.edu.sg)).

Also “ISMI Beamline Operating Instruction” manual is available for trained users who are familiar with the beamline equipment.

The equipment of ISMI end station are two Fourier transform spectrometers and one infrared microscope. They operate under seal and in the vacuum. No infrared scattered light is emitted from these equipment. Sample chambers of the spectrometers are manufactured and designed in isolation from the rest of the optics. However, for alignment purposes or particular experiments, venting optics and opening of covers might be required. In this particular case, consult with the beamline managers at first. IR light or He-Ne laser (class II bellow 5 mW) light might reflect or scatter out from the instruments.

- Although weak in energy and intensity, never expose yourself or your eyes directly to these light sources.
- Warning: Do not operate the microscope if the covers are removed or appear damaged. Never look or use optical instruments to look into the laser beam or its reflection of any surface. Directly looking into the laser light can cause permanent eye damage.
- Do not use highly reflecting surfaces to watch and align the spot light.
- Do not wear a watch in your hands. Uncontrolled reflected light might harm other nearby person.
- Incorporated He-Ne Laser component inside the spectrometer is of class II, delivering intensity bellow 1 mW. However, do not remove any filters or beam dump within the laser path. Consult with the beamline managers and with the company engineers.
- Wear a safety goggles.
- Infrared optics are hygroscopic, easily damaged and in general poisonous. Wear gloves.
- Each instrument has “instruction manual” read it carefully.

Cryogenic liquid handling

a) Liquid Nitrogen

ISMI beamline uses small quantities of liquid nitrogen to cool down a (250 ml Dewar) MCT infrared detector. To these purpose ISMI provides a 2 l Dewar for Nitrogen handling as well as a reservoir tank (vessel) of 60 l.

Operation with liquid nitrogen can cause serious frostbites.

- Protect your face with a visor or goggles.
- Protect your hands with cryogenic gloves.
- Do not touch any frozen or unprotected part of the cryogenic pipes when transferring the liquid.
- Do not obstruct the relief valve of the vessel.
- Use the 2 l Dewar to collect the liquid nitrogen from the vessel.
- If no liquid nitrogen in the 60 l vessel do not shake it or tilt it.
- Vent (using venting valve) the vessel prior you open it.

The beamline scientist or trained personnel are the only responsible to fill up the liquid nitrogen in the mobile 60 l vessel when empty. They should comply with the regulation and safety transfer of liquid nitrogen from the main reservoir tank located outside the storage ring.

- Check for registration and inform the personnel (room 004) LI Zhiwang (Tel.: 651 67931 e-mail: slslizw@nus.edu.sg) and CHEW Eh Piew (Tel.: 651 64748 e-mail: slscep@nus.edu.sg)
- Follow the procedure provided by LI Zhiwang (Tel.: 651 67931 e-mail: slslizw@nus.edu.sg) instructions pages.

Warning: Stand clear of boiling and splashing liquid and its issuing gas. Boiling and splashing always occur when charging a warm container. Always fill in liquid nitrogen slowly to minimize boiling and splashing.

b) Liquid Helium

At ISMI beamline the use of liquid Helium is required only when performing experiments with the Bolometer detector. Several operations need to be coordinated at a time for successful experiments performing.

- Check your beam time availability.
- Make sure your experimental set up is operational.
- Make sure you have a pumping unit at your disposal. Bolometer detector need to be pumped every time before cooling.
- Coordinate your beam time and the liquid helium delivery.
- For Liquid Helium vessel handling check the procedure provided by LI Zhiwang (Tel.: 651 67931 e-mail: slslizw@nus.edu.sg) instructions pages.
- Read carefully and follow the instruction manual for cooling the Bolometer detector. It is a must.
- Never operate or transfer Helium when you are alone.
- Use safety goggles and gloves when handling cryogenic equipment.
- Operate in an open area.

Warning: Stand clear of boiling and splashing liquid and its issuing gas. Boiling and splashing always occur when charging a warm container.

Chemical samples handling

All samples storage and preparations must be done in chemistry lab. However, samples storage and usage must be within the risk level permitted in the chemistry lab.

- For staff and users who have been approved by SSLS to handle chemicals.
- Cleaning and/or sample disposal practices must be done in the Chemistry lab.
- Wear gloves and goggles prior handling samples.
- Use the Hood located in the chemistry lab when manipulating liquid or gas samples.
- Toxic gases are purchased and stored in smallest quantities as possible.
- During use and storage, highly toxic gases are located in continuously ventilated gas cabinets.
- A continuous gas monitoring should be used for signalling releases of toxic gases.
- When not in use toxic gases should be removed and placed in safe area.
- When toxic gases are in use do not keep regulators and pipes pressurized after samples transfer.
- Never let valves of toxic gases open. Immediately close them after use.
- Purge the pipes with inert gases (He, Ar).
- Nitrogen and Helium cylinder should be transported on a wheeled cylinder cart.
- Never slid or roll a cylinder, even practiced handlers can easily lose control of them.

Electrical connections

There are special electrical connectors to ISMI beamline and its equipment.

- Do not disable or disconnect them. Consult with the beam managers.
- ISMI provides users with wall socket.
- Do not overload the electrical circuit.
- Check with the electrical personnel Miao Hua (Tel.: 651 64750 e-mail: slsmh@nus.edu.sg) for powering particular equipment.

5.4 SINS (Surface-, Interface- and Nanoscience) beamline operates with X-rays with energies from 50 eV to 1.2 keV.

Beamline Scientist

Dr. YU Xiaojiang (Tel.: 651 67951, e-mail: slsyxj@nus.edu.sg)

SINS comprises a soft X-ray beamline and an end-station, is a research facility equipped with soft X-ray photoemission spectroscopy (PES) and X-ray absorption spectroscopy (XAS). The SINS beamline inside the vault has a 6° horizontal deflection angle, so high energy radiation is shielded by the thick wall of the vault, the low energy radiation soft X-ray transportation in the beamline is isolated by the wall of beamline pipes, there should be no hazard radiation existing in the SINS working place. It also has a twin anode X-ray gun in end-station, the produced Soft X-ray (with energy 1486.6 eV or wavelength 0.834 nm) is encapsulated inside the stainless steel analysis chamber only, no dose can be leakage.

Before the personnel begin their research at SINS beamline, they must read completely **SINS User Manual** which can be requested at the beamline scientist and experimental coordinator. And they must comply following description:

- Do not operate the beamline without supervision under SINS beamline scientist, except for those who has been trained by beamline scientist.
- At least two persons are required on the site when doing experiment.
- After hour visitors should be reported.

Other Safety concern

- General laboratory safety please refer to chapter 9 Safety Management Manual
- Ionizing and Non-Ionizing radiation concern refer to chapter 6 Safety Management Manual
- Chemical hazard safety refers to chapter 7 Safety Management Manual

5.5 PCIT (Phase Contrast Imaging and Tomography) beamline operates with X-rays with energies from 2 keV to 12 keV.

Beamline Scientist

Dr Krzysztof BANAS, (Tel : 651 67837, e-mail: slskb@nus.edu.sg)

PCIT Beamline Safety

The PCIT beamline at SSLS is connected to a radiation protection hutch. The PCIT beamline provides X-rays for imaging. The PCIT beamline comprises of 4 groups:

Group 1: Power Shutter:

The Power Shutter is directly connected to Dipole 2 of Helios 2.

Group 2: Collimator, Gamma Shutter and 1st Beryllium Window (500-µm thickness):

The collimator selects small part of a beam and hence reduces the amount of radiation downstream. The gamma-shutter, in closed position, absorbs the gamma-radiation from Helios 2. The Beryllium is located in the experimental hutch and separates the high vacuum from the atmospheric pressure outside the beam tube. The X-rays are travelling about 2 m in atmosphere before reaching sample and detector.

Group 3: Gamma-STOP is constructed from the thick lead brick and allows stopping all gamma radiation inside the experimental hutch.

Group 4: The experimental hutch eliminates radiation hazard almost completely. The door to experimental hutch is interconnected with the operation of the gamma-shutter. If the door to experimental hutch will be opened by mistake the gamma-shutter will automatically be activated and shut down the beam.

General Safety

In normal operation, PCIT beamline users can operate the beamline without any radiation hazard. Users must, however, be aware of the potential hazard in and around equipment to avoid possible injury and equipment damage.

Radiation Safety

The PCIT beamline poses no potential radiation hazard to its users. However, users must understand and fully comply with the radiation safety procedures at SSLS. No alteration of the radiation safety equipment is allowed without prior knowledge of Beamline Scientist and Radiation Safety Officer. Please refer to the Radiation Safety Manual.

Electrical Safety

Users are protected from potential hazards associated with voltage, current and power levels. Any attempt to modify, rectify or dismantle the equipment must be done by trained or qualified personnel.

Mechanical Safety

There are a number of moving parts in the system which are powered by electrical motors. In normal use, users are not required to undertake mechanical work. Any servicing or repair work must be done by trained or qualified personnel.

Vacuum Safety

Vacuum components can fail and cause explosion which can result in injury and equipment damage. Please report any malfunction of the vacuum system to Beamline Scientist.

Hazardous/Toxic Material

Beryllium is used in the Beryllium windows in the PCIT beamline. Beryllium may oxidize to highly toxic Beryllium Oxide powder when expose to fire. Do not attempt to clear up the remains of any fire. Inform relevant personnel if an accident involves possible Beryllium or Beryllium Oxide contamination. The windows must be protected from oxidation.

Vacuum Control System

Users should **NOT TURN OFF** the vacuum without prior knowledge of Beamline Scientist and SSLS' operating team.

5.6 LiMiNT (Lithography for Micro- and NanoTechnology) beamline operating with X-ray energies above 2 keV.

Beamline Scientist

Dr Sascha Pierre Heussler (Tel.: 651 63228, e-mail: slshsp@nus.edu.sg)

LiMiNT Beamline Safety

The LiMiNT Beamline in SSLS is connected to an X-ray scanner in the cleanroom. The LiMiNT Beamline provides a photon flux for (deep) X-ray Lithography. The LiMiNT beamline comprises of 4 groups:

Group 1: Power Shutter, Filter Unit and collimator:

The Power shutter and filter unit is directly connected to Dipole 2 of Helios 2 and the collimator blocks radiation from reaching the scanner and reduces the heat load on all downstream components

Group 2: 1st Beryllium Window (200-µm thickness) and gamma-shutter:

The Beryllium separates the UHV in Group 1 from the HV in Group 2. The gamma-shutter, in closed position, absorbs the gamma-radiation from Helios 2. This allows users to work on the X-ray scanner without any radiation hazards.

Group 3: Beam Position Monitor.

Group 4: 2nd Beryllium Window (200-µm thickness) and X-ray Scanner

The 2nd Beryllium window separates the HV in Group 3 from the scanner section. Between the 2nd Beryllium window and the scanner, a gate valve which is interlocked by the control system such that the 2nd beryllium window cannot be set under atmospheric pressure even when the scanner is being vented.

General Safety

In normal operation, LiMiNT beamline users can operate the X-Ray scanner without any radiation hazard when the scanner lid is in open position. Users must, however, be aware of the potential hazard in and around equipment to avoid possible injury and equipment damage.

Radiation Safety

The LiMiNT Beamline poses no potential radiation hazard to its Users. The power shutter (in Group 1) and the gamma-shutter (in Group 2) is actuated simultaneously, thus absorbing all synchrotron and gamma-radiation from Helios 2. These shutters are closed by an interlock whenever the scanner lid is in the open position. However, users must understand and fully comply with the radiation safety procedures at SSLS. Refer to the Radiation Safety Manual.

Electrical Safety

Users are protected from potential hazards associated with voltage, current and power levels. Any attempt to modify, rectify or dismantle the equipment must be done by trained or qualified personnel.

Mechanical Safety

There are a number of moving parts in the system which are powered by electrical motors or compressed air. In normal use, users are not required or undertake mechanical work. Any servicing or repair work must be done by trained or qualified personnel

Vacuum Safety

Vacuum components can fail and cause explosion which can result in injury and equipment damage. Never exceed an overpressure of 0.1 bar gauge inside the vacuum system.

Hazardous/Toxic Material

Beryllium is used in the beryllium windows in the LiMiNT beamline. Beryllium may oxidize to highly toxic beryllium oxide powder when expose to fire. Do not attempt to clear up the remains of any fire. Inform relevant personnel if an accident involves possible beryllium or beryllium oxide contamination. The windows must be protected from oxidation during bake out by having vacuum/ inert gas on both sides of the window.

Computer Control System

There are 2 Ion Pumps in the LiMiNT beamline to control the pressure in each of the groups mentioned above. They are controlled by a computer control system. As such, users should **NOT TURN OFF** the computer system, especially when the synchrotron is running.

5.7 Clean Room at the LiMiNT beamline

This training is undertaken to assure that individuals of differing backgrounds receive a uniform experience for working in the SSLS cleanroom. Most users of the SSLS cleanroom have had minimal exposure to a working chemical laboratory setting.

In addition to the special concerns of cleanrooms, this training targets the chemical hazards associated with processing of silicon wafers as well as thermal, electrical and other hazards of particular equipment.

In this session we will cover:

- Identify the various chemical hazards and how to deal with them
- What to do in an emergency situation
- How to conduct experiments
- Some basic guidelines for general chemical use, storage and hazards.

This training serves as an active portion of the SSLS right-to-know communication program. Right-to-know laws were implemented by OSHE and although, universities are strictly exempt from such laws, it has always been SSLS policy to adhere to these regulations. The right-to-know gives workers access to information on the hazards to which they can reasonably be expected to be exposed at SSLS. This information is contained in the MSDS.

Emergency Plan:

When an alarm is sounded, secure equipment / process and evacuate the clean room.

When an accident occurs, report it immediately.

When there is a spill

- Use pH paper to test
- Clean-up
- Always use Neoprene gloves, especially in fume hood
- Always rinse well with water

Clean room carries Special Hazards

Chemical use – processing and etching with strong oxidizers. **Always check the MSDS** sheet whenever using a new material.

Always have a mentor when using a piece of equipment for the first few times, until you are confident of using the equipment on your own.

If unsure about a procedure – **Stop and ask for help** from someone who knows.

Safety Consciousness

Reduce worry by going the extra mile

- Always leave equipment in at least as good condition as you found it
- Last person out – check all machinery is left in a safe (off) position and that all water is being turned off
- Mentor responsibility. Always show the best example even if in a hurry.
- Careless activities can result in lowered expectations both for you and others using the cleanroom
- For multi-use equipment such as the microscope, carelessness in the use of equipment may carry over to other processes and may endanger personnel and/or equipment.

<u>Remember</u>

1. Good housekeeping is integral to a safe environment.

2. Cleanroom rules are set up for your protection and the safety of equipment. Disregarding these rules can have long-term consequences.

3. Carelessness and/or blatant disregard of such rules may lead to the suspension of cleanroom access.

5.8 XAFCA (XAFS beamline for catalysis research) beamline operates with X-rays with energies from 1.2 keV to 12.8 keV

Beamline Scientist Dr. DU Yonghua (Tel.: 651 61004, e-mail: du_yonghua@nus.edu.sg)

XAFCA is a new X-ray absorption fine-structure (XAFS) spectroscopy beamline for fundamental and applied catalysis research, built by the Institute of Chemical and Engineering Sciences, and the Singapore Synchrotron Light Source. XAFCA covers the photon energy range from 1.2 to 12.8 keV, making use of two sets of monochromatic crystals, an Si (111) crystal for the range from 2.1 to 12.8 keV and a $KTiOPO_4$ crystal [KTP (011)] for the range between 1.2 and 2.8 keV. Experiments can be carried out in the temperature range from 4.2 to 1000 K and pressures up to 30 bar for catalysis research. A safety system has been incorporated, allowing the use of flammable and toxic gases such as H_2 and CO.

Before the personnel begin their research at XAFCA beamline, they must read completely XAFCA User Manual which can be requested at the beamline scientist and experimental coordinator. And they must comply following description:

- Do not operate the beamline without supervision under XAFCA beamline scientist
- At least two persons are required on the site when preparing experiment.
- After hour visitors should be reported.

Other Safety concern

- General laboratory safety please refer to chapter 9 Safety Management Manual
- Ionizing and Non-Ionizing radiation concern refer to chapter 6 Safety Management Manual
- Chemical hazard safety refers to chapter 7 Safety Management Manual

5.9 RSXS (Resonant Soft X-ray Scattering and VUV magneto-optical ellipsometry) beamline operates with X-rays with energies from 3.5 eV to 1.5 keV

Beamline Scientists

Dr. YU Xiaojiang (Tel.: 651 67951, e-mail: slsyxj@nus.edu.sg)

Dr. DIAO Caozheng (Tel.: 651 67965, e-mail: slsdcz@nus.edu.sg)

RSXS beamline is designed for resonant x-ray scattering, absorption and reflectivity measurements at energies from 3.5 eV to 1.5 keV.

Before the personnel begin their research at RSXS beamline, they must read completely **RSXS User Manual** which can be requested at the beamline scientist and experimental coordinator. And they must comply following description:

- Do not operate the beamline without supervision under RSXS beamline scientist, except for those who has been trained by beamline scientist.
- At least two persons are required on the site when doing experiment.
- After hour visitors should be reported.

Radiation safety

There is no specific protection needed at RSXS end station. The beamline end station is constructed in open area and there is no hutch at the working place. However, the user should fully comply with the radiation safety procedures at SSLS institute.

No visitors are allowed to operate the beamline without supervision from the beamline scientist or staff member. Only trained users can operate the beamline and conduct the experiment. After training they must sign a form.

Chemical samples handling

For staff and users, who have approved by SSLS to handle chemicals, should note that

- All samples storage and preparations must be done in chemistry room.
- Clean and/or sample disposal practices must be done in the Chemistry room.
- Wear gloves and goggles prior handling samples.

- Use the Hood located in the chemistry room when manipulating liquid or gas samples.
- Toxic gases are purchased and stored in smallest quantities as possible.
- During use and storage, highly toxic gases are located in continuously ventilated gas cabinets.
- A continuous gas monitoring should be used for signalling releases of toxic gases.
- When not in use toxic gases should be removed and placed in safe area.
- When toxic gases are in use do not keep regulators and pipes pressurized after samples transfer.
- Never let valves of toxic gases open. Immediately close them after use.
- Purge the pipes with inert gases (He, Ar).
- Gas cylinder should be transported on a wheeled cylinder trolley.
- Never slid or roll a cylinder, even practiced handlers can easily lose control of them.

In case necessary, SSLS chemical safety officer or OSHE safety officer should be called in.

Electrical connection

There are special electrical connectors to RSXS beamline and its equipment.

- Do not disable or disconnect them. Consult with the beam managers.
- RSXS provides users with wall socket.
- Do not overload the electrical circuit.
- Check with the electrical personnel for powering particular equipment.

Vacuum Safety

Vacuum components can fail and cause explosion which can result in injury and equipment damage. Please report any malfunction of the vacuum system to Beamline Scientist.

Users should NOT TURN OFF the vacuum pumps, open/close valves without prior knowledge of Beamline Scientist and SSLS' operating team.

5.10 Ellipsometry Laboratories

Ellipsometry laboratories consist of two systems: Sentech Ellipsometry System and Woollam Ellipsometry System

Ellipsometry Systems Persons in Charge

Dr. Pranjal Kumar Gogoi (Tel.: 6516 7695, e-mail: nnipkg@nus.edu.sg)

Dr. Teguh Citra Asmara (Tel.: 651 67965, e-mail: slstca@nus.edu.sg)

Ellipsometry is a technique whereby the change in the polarization of light reflecting off a surface is analysed to determine the optical and dielectric properties of a thin firm. Ellipsometry generally is a safe instrument to operate however safety precaution should still be observed when handling the equipment. The personnel should undergo extensive training by the experience end user in order to run the system independently. User manual and risk assessment are available in the laboratory and end user is encouraged to read the information

Sentech Ellipsometer

- Do not operate the equipment, except for those who has been trained
- Wear safety goggles when handing chemicals in work bench and use transport tray when moving chemical bottle
- Before turning on the ellipsometer, always check the operation state of the equipment
- Stay clear from the ellipsometer during operation, to avoid the injury caused by the movement of the equipment
- Beware of hand injury when matching the ellipsometer table with the cryo table, work should be carried out with at least two person
- During baking of metal bellow, please stay clear of the equipment to avoid injury to skin

Woollam Ellipsometer

- Do not operate the equipment, except for those who has been trained
- Before turning on the ellipsometer, always check the operation state of the equipment
- Wear safety goggles and cryogenic gloves when handling transfer line tubing between Dewar and equipment end to prevent frost bite to the skin

Other Safety concern

- General laboratory safety please refer to chapter 9 Safety Management Manual
- Cryogenic Liquid Handling & Transfer refer to chapter 10.5.2 Safety Management Manual
- Chemical hazard safety refers to chapter 7 Safety Management Manual

6. Ionizing and Non-Ionizing Radiation Hazards

SSLS is operating an electron synchrotron facility, which includes Helios 2 storage ring with energy of 700 MeV, a microtron injector with energy of 100 MeV and other supporting facilities. Only machine related radiation is existing.

In accordance with local regulations on radiation protection stated in this chapter, SSLS has taken and adopted stricter measures over-shielding to bulk shields and activated radio-activity. Such measures reduce the radiation dose level to less than 1 mSv/year and make SSLS site as a PUBLIC site. Ten years of operation show that the dose is mostly from construction concrete, i.e. the enhanced background. Contribution from Helios 2 storage ring is negligible (ref: Appendix C).

In general, SSLS does not concern radio-active substances. Once radio-active sample is encountered, corresponding clauses below will be abided and OSHE officer will be called in if necessary.

Details of the measures of radiation shielding and protection can be found and referred to Appendix C.

6.1 Introduction

6.1.1 The Radiation Protection Act (Chapter 262) regulates the use, control, import, export, licence, disposal, documentation and inspection of radioactive materials, ionising and non-ionising irradiating apparatus, and nuclear materials.

6.1.2 Under this Act, the Regulations that are applicable to NUS are:

1. Radiation Protection (Ionizing Radiation) Regulations;
2. Radiation Protection (Non-Ionizing Radiation) Regulations;
3. Radiation Protection (Transport of Radioactive Materials) Regulations

Note: The maximum penalty for infringements of the Act is S$ 100,000/- and 5 years jail.

6.1.3 All employers, equipment owners and users who possess and/or operate any of the irradiating apparatus (such as beamline, experimental stations and LASERS, etc.) or use any of the radioactive materials (samples, etc.) must be trained or call in the radiation safety officer (L5 at SSLS) before they are allowed to do so.

6.1.4 Ionizing radiation is radiation that is capable of causing atoms and molecules on its path to split into positive and negative ions:

- Alpha rays, Beta rays, neutrons and Gamma rays
- Decay of radioactive substances
- X-rays – electromagnetic radiation ($3x10^{15}$ Hz to 10^{19} Hz, or 0.03 nm to 100 nm)
- Produced electronically by synchrotron or other equipment.

6.1.5 Non-ionizing radiation is radiation that is not capable in causing ionization but is capable in causing other injuries to the body. The biological effect is mainly the thermal effect:

- Electromagnetic radiation and fields with wavelength greater than 100 nm.
- Radiowave (> 1 m), Microwave (1 mm to 1 m), Infrared (700 nm to 1 mm), Visible (400 nm to 700 nm) and Ultraviolet (100 nm to 400 nm).
- LASERS
- Acoustic radiation and fields with frequencies above 16 Hz.
- Ultrasound

LASER is an acronym for Light Amplification by Simulated Emission of Radiation

- Laser radiation may be released either as a pulse or a continuous wave radiation, which can be designed over a wide range of frequencies, from infrared to ultraviolet regions.

1. Class I Laser
    - No-risk lasers, safe by the virtue of their power output or engineering design
    - Accessible laser output < 0.39 µW
2. Class II Laser
    - Visible laser radiation (400 nm to 700 nm) in pulse or continuous wave
    - Power emitted < 1 mW
    - Not capable of causing any eye injury within 0.25 sec
    - E.g. barcode scanner and laser pointer.
3. Class IIIA Laser

- Emit visible and/or invisible laser radiation
- For visible Class IIIA Laser devices power range 1-5 mW
- Not capable of damaging the eye unless starred for a long time or optical instruments are used
- E.g. construction alignment lasers and lower power entertainment lasers.

4. Class IIIB Laser (**License to possess laser and/or license to use laser**)
    - Medium-power and moderate-risk laser
    - Power output < 500 mW for emission duration > 0.25 sec.
    - Capable of causing potential serious eye injury
    - E.g. therapeutic, acupuncture, bio-stimulation, military laser range finders.
5. Class IV Laser (**License to possess laser and/or license to use laser**)
    - High-power and high-risk laser
    - Power output > 500 mW for emission duration > 0.25 sec.
    - Capable of causing potential fire and skin burn hazard
    - E.g. industrial cutting, communication field, research

6.2 Radiation Protection (Ionizing Radiation, IR) Regulations

6.2.1 General Requirements

1. No individual below the age of 18 years shall be engaged in radiation work.
2. Any one engaged in radiation work shall have a license or be registered as a radiation worker and shall wear a personal monitoring device to monitor the amount of radiation received in the course of this work. At SSLS, the L5 is registered and others are also under the monitoring to/by RPNSD.

6.2.2 Licensing

1. Licenses are issued by RPNSD (Radiation Protection Nuclear Science Department, part of National Environment Agency) for the import, export, sale, dealing in, possession and use of radioactive materials and irradiating apparatus and the transport of radioactive materials.

2. Several types of licenses (R1, L3 and L5) are being issued, depending on the requirement and situation.

3. Application for the licenses can be found on the following web page: http://www.nea.gov.sg/services-forms/licences-permits-building-plan-clearances/radiation.

6.2.3 Control of Radiation Exposure

1. Any individual who is in possession of or uses irradiating apparatus or radioactive materials may not cause another individual to receive a radiation dose greater than can be justified in the circumstances and not more than the specified annual dose limit.

2. The license holder (the employer or equipment owner) shall ensure that radiation work is performed in a safe manner

3. Responsibilities of license holder (the employer or equipment owner):

- Maintaining a current inventory for all ionizing radiation irradiating apparatus and conducting regular survey on regular basis.
- Putting up labels for all ionizing radiation irradiating apparatus
- Sending authorized users of the ionizing radiation irradiating apparatus for medical examination and applying licenses for their operations.
- Sending authorized users of the ionizing radiation irradiating apparatus for training and maintains records.

4. Training staff shall be provided, by the employer or equipment owner, to all staff encountering ionizing radiation sources

6.2.4 Dose Limits, Medical and Radiological Supervision

1. Radiation workers (L5 and R1 licenses)

   - Effective dose limit (whole body) is 20 mSv/year (average over 5 years).
   - Further provision: Effective dose < 50 mSv in any one year.

2. Non-radiation workers/ public members

   - Effective dose limit (whole body) is 1 mSv/year (average over 5 years).

3. If the dose report indicates that the staff has received a dose in excess of three-tenths of the dose limit, his supervisor shall send him for a medical examination

4. Investigations shall be made by the licensee and RPNSD to ascertain the cause of excessive dose.

5. The occupational dose limit for women who are not pregnant is the same as that for man, but once pregnancy is declared, the equivalent dose limit to the surface of woman's abdomen is 2 mSv for the remainder of the pregnancy.

6.2.5 Labelling of Radiation Sources and Radiation Areas

1. The license shall ensure that each irradiating apparatus and each container of radioactive material is properly labelled with the radiation hazard logo.

2. The area containing ionizing radiation sources must be restricted to only the authorized user with license.

6.2.6 Storage of Radioactive Materials (in case needed, OSHE should be enquired)

1. Radioactive materials shall be stored in a safe and secured place.

2. Only the license and the radiation workers under his charge shall have access to the radioactive materials.

3. Outside the defined area where the radioactive materials are stored, the radiation levels shall be < 0.5 µSv/hour.

4. Precautions for the safe storage and keeping of radioactive materials are also specified, including specifications for storage containers, fire and chemical safety etc.

6.2.7 Accounting of Radiation Materials

1. Licensees shall keep proper records of radioactive materials used by them.

2. If the radioactive material is missing and is not accounted for within 24 hours, the licensee shall notify RPNSD immediately.

6.2.8 Checking of Leakage of Sealed Source

1. Once every 12 months, overall annual review shall be performed on Helios, beam lines and each sealed radioactive source to ensure that is not leaking.

2. If it is found to be leaking, RPNSD shall be immediately informed and the source shall be removed and stored in a proper manner.

3. The areas affected by the leakage shall be decontaminated under the supervision of RPNSD.

6.2.9 Use of Sealed Sources and Irradiating Apparatus in Teaching, Research and Some Industrial Process

1. The irradiating apparatus shall be adequately shielded. For a radiation source in a walled enclosure or a cabinet, the radiation level anywhere outside the walled enclosure or cabinet, accessible to any individual < 10 µSv/hour.
2. Effective arrangements shall be provided, maintained and used to prevent insertion of any part of the body into a useful beam.

3. Effective interlocks shall be provided so that the charged particle accelerator has to be switched off before any door of the enclosure in which the charged particle accelerator is installed is opened and cannot be switched on as long as the door is open.
4. Adequate warning to every individual in the vicinity shall be given by both appropriate light & sound signals, arranged to operate automatically:

    - While the apparatus is about to be energized
    - While the apparatus is energized
    - When the shutter used for the purpose of attenuation the useful beam is about to be opened, and
    - While the shutter is open

5. Declare and display prominently the safety features for the irradiating apparatus.
6. For radiation work in a field site, a boundary shall be set and clearly defined by ropes, fences etc. and radiation hazard logo and warning notices.
7. There shall be continuous and competent supervision of the site whenever a sealed source is exposed or irradiating apparatus is energized within the site.
8. Any radiation area monitor, survey meter or direct reading personal dosimeter used for any purpose in connection with the Regulations, shall be calibrated once in every 12 months.

6.2.10 Radiation Accidents

1. Radiation accidents in medical and non-medical applications of ionizing radiation of radioactive materials are defined in the Regulations.
2. If an accident should occur, the actions to be taken by the licensees or safety officers.
3. The licensee has to notify the appropriate authorities and in all cases, the licensee shall notify RPNSD within 24 hours and in writing within 48 hours. A written report shall be provided within 10 days.
4. Details of measure of radiation shielding and protection can be found and referred to "Local Rules for the Safe Operation of HELIOS 2 at SSLS, SSLS internal reports, safety-2c and 21".

6.2.11 Radiation Protection (Non-Ionizing Radiation, NIR) Regulations

General requirements

1. In the eighties, there were concerns over the safety of microwave ovens, laser and ultrasonic devices.

2. On the February 1st, 1992, the following NIR irradiating apparatus were brought under legislative control:

- Ultraviolet lamps
- Microwave ovens
- Ultrasound apparatus
- Magnetic Resonance Imaging (MRI) apparatus
- Lasers

6.2.12 Licensing

1. A separate license is required to keep or possess each irradiating apparatus.
2. Application for license could be lodged under http://www.nea.gov.sg/services-forms/licences-permits-building-plan-clearances/radiation

7 Chemical Hazards

7.1 Exposure to chemicals

A thorough discussion of toxicity is beyond the scope of any single publication.

Individuals who handle chemicals should supplement the information in this document with specific details applicable to their laboratories.

Such information is available in Safety Data Sheets (SDSs) and other reference materials that are available.

The complex relationship between a material and its biological effect in humans involves considerations of dose, duration and frequency of the exposure, route of exposure, and many other factors, including sex, allergic factors, age, previous sensitization, and lifestyle.

7.2 Exposure routes

Chemicals enter the body through the following routes:

1. Inhalation: absorption through the respiratory tract.

2. Ingestion: absorption through the digestive tract by eating or smoking with contaminated hands or in contaminated work area.

3. Dermal: absorption through the skin or eyes.

4. Injection: percutaneous injection through the skin.

Toxic effects can be immediate or delayed, reversible or irreversible, local or systemic**.**

7.3 Acute and Chronic Toxicity

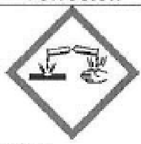
1. Toxicity is a measure of poisonous material's adverse effect on the human body.
2. Generally, toxicity is divided into two types, acute and chronic.
    a. Acute toxicity is an adverse effect with symptoms of high severity coming quickly to a crisis.
    b. Chronic toxicity is an adverse effect with symptoms that develop slowly over a long period of time as a result of frequent exposure.
3. Do not underestimate the risk of toxicity. All substances with unknown toxicity should be handled as if they are toxic.

7.4 Safety Data Sheet (SDS)

1. SDS are the most basic source of chemical hazard information.
2. All laboratory personnel must be familiar with the recommended precautions associated with the chemicals they handle.
3. SDS should be filed in a central location in the laboratory, for immediate reference and assessment. At SSLS these locations are clean room and chemistry room.
4. SDSs (in accordance to SS586 Part 3: Specification for hazard communication for hazardous chemicals and dangerous goods - Preparation of safety data sheets (SDS)) would provide the user with the following information
    a. Identification
    b. Hazards identification
    c. Composition/Information on ingredients
    d. First aid measures
    e. Fire-fighting measures
    f. Accidental release measures
    g. Handling and storage
    h. Exposure controls/personal protection
    i. Physical and chemical properties
    j. Stability and reactivity
    k. Toxicological information
    l. Ecological information
    m. Disposal considerations
    n. Transport information
    o. Regulatory information
    p. Other information including information on preparation and revision of the SDS

7.5 GHS chemical labelling

Chemicals shall be labelled in accordance to the United Nations Globally Harmonised System of classification and labelling of chemicals (GHS). The adaptations of both international guidelines in local context are summarized in Singapore Standard SS586 Specification for Hazard Communication for Hazardous Chemicals and Dangerous Goods. The GHS pictograms convey physical, health or environmental hazard that is assigned to a GHS hazard class and category. The nine GHS pictograms in accordance to the standard is shown below:

Flame	Flame over circle	Exploding bomb
 • Emits flammable gas • Flammables • Self-heating • Self-reactives • Organic peroxide • Pyrophorics	 • Oxidisers	 • Explosives • Organic peroxide • Self-reactives
Corrosion	Skull and crossbones	Gas cylinder
 • Corrosives	 • Acute toxicity (severe)	 • Gases under pressure
Health	Environment	Exclamation mark
 • Aspiration toxicity • Carcinogenicity • Germ cell mutagenicity • Target organ toxicity • Respiratory sensitiser • Reproductive toxicity	 • Environmental toxicity	 • Acute toxicity (harmful) • Irritant • Narcotic effects • Respiratory tract irritation • Skin sensitiser

Source: SS 586 Part 2

All chemicals in use at SSLS should be tagged with the proper GHS Pictogram(s) label. The appropriate GHS pictogram(s) of the chemical to be labelled can be found in the SDS. It is also a good idea to write in both the manufacturer's name and date of receipt. This helps to keep track of old or expired chemicals. Almost all chemicals degrade over time, especially in warm weather.

Materials ready for disposal must be properly labelled with the appropriate GHS pictogram(s) and the contents of the container clearly identified. All chemicals must be labelled when used at the SSLS facility.

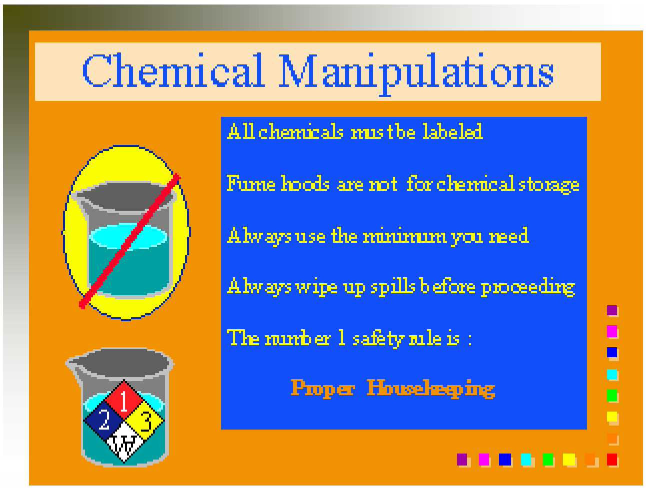
7.6 General Guidelines for Handling Chemicals

7.6.1 The chemical handling guidelines in this document are founded on several basic principles:

1. Substitute less hazardous chemical whenever possible
2. Minimize chemical exposure
3. Avoid underestimating risk
4. Provide adequate ventilation

7.6.2 Avoid skin contact with chemicals as much as possible.

7.6.3 Prepare yourself, and then protect yourself.

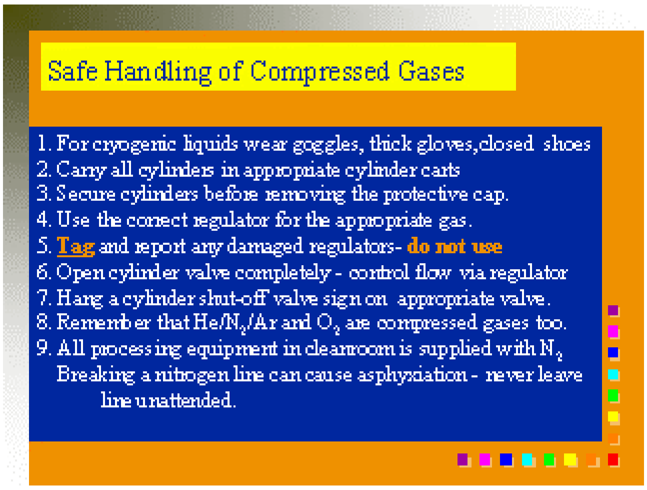


- Labelling of chemicals is always essential. Labels prevent accidents by insuring that proper conditions are always met and that there are no incompatibilities.
- Use only the amount required. Large quantities are cumbersome. This handling difficulty significantly increases the risk for spills.
- Remember that fume hoods are for working with opened chemicals. They are not for storage.
- Store all chemicals in the appropriate container.
- Store acids and caustic separately and flammable solvents in still another cabinet.
- Flammable liquids, acid and caustic cabinets are available just outside of the LiMiNT clean room.

- Never hands carry chemicals. Use appropriate bucket carriers and / or carts.
- Eye protection SHALL be worn when handling or working with chemicals
- Always use face shields or safety glasses and an apron when working with acids.
- Be aware of hot plates and ovens in areas adjacent to where you are working with solvents. These can be potential fire or explosion hazards.
- Always leave your work area clean, pick up spills immediately. Poor housekeeping practices increase the risk for injury or damage!

- **Cryogenic hazards** pose several potential risks.
- Remember that cryogenic liquids are under pressure.
- Eye protection and insulated gloves SHALL be worn when working with cryogenic liquids.
- Always wear closed, preferably leather shoes when handling cryogens.
- Sandals are inappropriate footwear in any laboratory setting.
- If a cryogenic liquid spills on the floor **do not move:** flexing a frozen limb may cause permanent tissue damage. Call for help. This is why we have a buddy system. The buddy system is based on the observation that we have visual contact between two persons.
- It is probably a good idea to wear a water-proof apron as well, if there is danger of spilling the cryogenic material.
- Remember that all nitrogen supplied to the clean room for operation of almost all the equipment is transported to the clean room as a cryogenic liquid first. This is because, this nitrogen is much purer (i.e. cleaner) than nitrogen from a compressed gas cylinder.

- Shorts and sandals are not appropriate for wearing when your duties include the use of cryogenic liquids.



- The above diagram summarizes compressed gas cylinder handling. Wear gloves and goggles when handling cryogenic liquids. Never attempt to handle a compressed gas cylinder by hand. Carts are available for the safe transport of these cylinders. It is most important to ascertain that the correct regulator is used for the correct gas. Note that these regulators are not interchangeable. For instance, hydrogen has a back-flow valve to prevent back flow of contaminated gas into the cylinder. Hydrogen and acetylene have the lowest lower limits for explosion of any gases (4% and 1%, respectively). Do not use a damaged regulator. Tag the regulator immediately and bring it to the attention of your supervisor.

- Use the regulator to control the gas flow by opening the cylinder valve completely. Hang a shut-off valve tag on the appropriate valve for emergency shut-offs.

- Care should be taken with noble gases - such as helium and argon as these are potent asphyxiants in an enclosed environment. In the cleanroom, nitrogen gas is routinely used and can also act as an asphyxiant. Therefore, never leave a nitrogen line open, broken or unattended. Since almost all cleanroom equipment is supplied by nitrogen, there is a very real potential for this area to become a confined space area, where any gas can displace the available oxygen.

7.7 Chemical Storage: Labels, Dating and Compatibility

7.7.1 Container of chemicals (including self-prepared chemicals) should be clearly labelled of its contents (identify) and hazards (warning in words or symbols).

7.7.2 Chemicals shall be dated on receipt in the laboratory and on opening. This information provides a history of the chemicals in each container and guides future researchers as to potential quality of the chemicals stored in the laboratory

7.7.3 Care should be taken to segregate incompatible chemicals (for example corrosives and flammables should not be stored together) according to the information from the SDS or Singapore Standard SS286.

7.7.4 All safety cabinets must be kept locked at all times other than during depositing or withdrawal of chemicals.

7.7.5 Opened bottles of toxic/ carcinogenic chemicals should be kept tightly capped, sealed and placed in safety chemical cabinets.

7.7.6 Fume hoods should be kept clear of chemical bottles so as to prevent the chances of chemicals mixing in the event of a spill or fire.

7.7.7 Chemical bottles/containers in constant use, should be placed in chemical-resistant non-absorbent, easy cleaning trays.

7.7.8 Sources of ignition and other combustible materials should be removed from chemical storage area. Chemical storage areas must be well ventilated.

7.7.9 Ordinary domestic refrigerator should not be used to store temperature-sensitive flammable solids and corrosive. “Explosion-safe” refrigerator must be used instead.

7.8 Transport of Chemicals

7.8.1 When chemicals are carried by hand, they must be placed in carrier baskets or an acid-carrying bucket to prevent breakage and spillage.

7.8.2 Appropriate gloves, eye protection, aprons must be worn when transporting hazardous materials.

7.8.3 No personnel (staff/student/visitor) from SSLS is allowed to transport/bring in or out chemicals/gases from/in outside of SSLS. Only chemical suppliers are licenced to transport the chemicals/gases with accompanying delivery orders and SDS.

7.8.4 All movement of chemicals/gases must be tracked with proper record at all times.

7.9 Chemical Fume Hood and Glove Box

7.9.1 Perform experiments that involve the use of chemicals that release gases, vapours or aerosols in a chemical fume hood.

7.9.2 Weighting of powdered chemicals that are harmful when inhaled should be carried out using special weighting accessories (e.g. special glass container) and weigh inside a chemical fume hood.

7.9.3 Chemical fume hood must be clear of chemical bottles to prevent the chances of chemicals mixing in an event of spill or fire.

7.9.4 Do not place electrical receptacles or other spark sources inside the hood when flammable liquids or gases are present.

7.9.5 The sash of chemical fume hood must always be lowered to a minimum level when not in use or when experiments are still in operation.

7.9.6 Check that the exhaust is working before conducting the experiment.

7.9.7 Do not place your head inside to hood when contaminants are being generated.

7.9.8 In case of fire, lower the sash of the fume hood immediately. Retreat to a safe area and call for help.

7.10 Waste Management

7.10.1 Reduce the amount of raw materials (such as solvents, acids, etc.) to reduce the quantity of chemical waste being generated.

7.10.2 Do not pour any chemicals into the sink/sewer.

7.10.3 All chemical wastes must be collected in preferably 5L plastic carboys.

7.10.4 A 60% filled container is ideal for safe disposal.

7.10.5 Mixing of chemical waste in waste storage containers is strictly prohibited.

7.10.6 General lab waste (gloves, wipes, paper, bottles, etc.) should never be mixed with either chemical or biohazard material.

7.10.7 All contaminated lab wastes (gloves, wipes, bottles, etc.) are collected by designated lab cleaner for disposal to Toxic Waste Container Store.

7.10.8 Sharps (such as needles) are collected in small plastic containers or snap-cap bottles and labelled clearly.

7.10.9 Empty boxes/containers/glass reagent boxes – bearing hazardous materials labels – must be defaced prior disposal to Toxic Waste Containers.

7.10.10 Waste chemicals should be segregated according to their compatible groups and collected in separate labelled containers.

7.10.11 Chemical waste containers should always be tagged with information on the chemical names, description, generator's name and date of generation.

8 Biological Hazards

No biological hazards have been identified at SSLS so far. In case SSLS will be requested to enable experiments with hazardous biological materials adequate safety regulations will be introduced.

9 Electrical and Mechanical Hazards

9.1 Electrical Safety Practices

9.1.1 Examine all electrical cords periodically for signs of wear and damage.

9.1.2 Properly ground all electrical equipment.

9.1.3 Do not run electrical cords along the floor where they will be a tripping hazard and be subjected to wear.

9.1.4 Do not plug too many items into a single outlet. Be aware of not trying to drain more than the rated power out of an outlet.

9.1.5 All new electrical and electronic laboratory equipment must be inspected for electrical hazards before using.

9.1.6 Wiring must not be overloaded, otherwise it will overheat and the insulation will be damaged.

9.1.7 When work is to be performed on electrical equipment, make sure that the electrical source is turned off, power cord pulled, rendered inoperative, tagged and locked.

9.1.8 In the event that equipment becomes wet, power should be disconnected at the circuit breaker.

9.2 Mechanical Safety Practices

9.2.1 Crane at SSLS shall only be operated by trained staff member. Please ensure operator is proficient in handling the equipment, the appropriate PPE is worn and the necessary safety measures are taken to prevent injury to operator as well as public.

9.2.2 Walkways will be introduced on demand.

9.2.3 The floor area should be free of loose materials or slippery substances.

9.2.5 All walkways, workstations, access to emergency equipment and exits should be freed from obstruction at all times.

9.2.6 Flammable and combustible materials can be stored only in the designated area with a permission from the Safety Committee.

9.2.7 Appropriate eye protectors should be used in operations that result in projecting loose particles, e.g. hammering, chiselling, grinding and welding.

9.2.8 Gloves with sufficient thermal insulation capacity should be worn when handling hot and cold objects.

10 General Laboratory Safety

10.1 General Laboratory Practice

10.1.1 Visitors to Laboratory

1. All visitors (except consultants, auditors, contractors, maintenance personnel) shall be accompanied at all times.
2. Do not allow visitors, including children and pets be in laboratories where hazardous substances are stored.

10.1.2 Laboratory doors

1. Fire and building safety codes require that laboratory doors (which are classified as “fire doors”) be kept closed/secured at all times.
2. Keeping doors closed also help to ensure that ventilation systems work properly.

10.1.3 Housekeeping

1. Keeping things clean and organized helps provide a safer laboratory.
2. Avoid slipping hazards by cleaning up spilled liquids promptly.
3. Never block or even partially block the path to exits or to safety equipment.

10.1.4 Equipment maintenance

1. Equipment should be inspected regularly.
2. Equipment awaiting repair or due for maintenance should be removed from service and clear sign should be put in place to inform other users.

10.1.5 Cleaning Glassware

1. When cleaning laboratory glassware, wear appropriate gloves.
2. Do not clean food containers in a sink that is used for cleaning contaminated glassware and vice versa.

3. Flammable solvents such as acetone should be used in minimum quantities for cleaning and with appropriate precautions (by checking MSDS).

10.1.6 Uncertainties and Familiarization

1. Be familiar with the potential hazards of the materials and equipment being used and the appropriate response.
2. Be alert to unsafe conditions and unsafe acts.
3. A new user of equipment must be sufficiently trained before using it.

10.1.7 Unattended or Overnight Operations

1. If experiments run while researcher is not present, an "Unattended Experiment in Progress", containing information about experiment and the contact information of the user, shall be posted.
2. Experiments that are left unattended for long periods of time or overnight are prime sources of fires, floods, and explosions.

10.1.8 Working Alone

1. Staff is requested to work in a presence of another staff member at all times in the building.
2. For Cat 1/ PG Students (Postgraduates):
    - They are allowed to access laboratory during office hours after EHS training.
    - They are allowed to work with minimum supervision, in the presence of working staff. They must not work alone.
3. For Cat 2/ (Trainees with > 2 months attachment) and Cat 3/ (Ad-hoc Students with < 2 months attachment)
    - They are allowed to access laboratory during office hours after EHS training.
    - They are allowed to work with supervision at all times. They must not work alone.

10.1.9 Personal Hygiene

- Personal hygiene is extremely important to persons working in a laboratory

- Contamination of food, beverages, or smoking materials is potential route exposure to toxic chemicals or biological agents through ingestion.
- Eating, drinking, smoking, gum chewing, applying lip balm or cosmetics, handling contact lenses, pipetting by mouth are prohibited in the work area.
- Glassware and utensils that have been used for laboratory operations should not be used to prepare food or beverages.
- Laboratory refrigerators should not be used for food storage.

10.2 Personal Protective Clothing and Equipment

10.2.1 Protective Clothing

1. Ordinary clothing and eyeglasses offer some protection. Laboratory staff shall have responsibility to dress sensibly for laboratory work.
2. Laboratory personnel are responsible for using special protective clothing and equipment when they are required by safety.

10.2.2 Skin Protection

1. Cover unprotected skin whenever possible.
2. Wear sturdy shoes to protect against chemical splashes or broken glass.
3. Aprons, laboratory coats, gloves and other protective clothing shall be readily available and used.

10.2.3 Hand Protection

1. Gloves are worn to prevent contact with toxic or biological agents and to protect from burns by hot, extremely cold surfaces or corrosives as well as cuts from sharp objects.
2. Proper protective gloves must be worn at all times when necessary.

10.2.4 Eye Protection

1. Eye protection is mandatory in laboratories because of obvious hazards of flying objects, splashing chemicals, and corrosive vapours.
2. Mandatory and proper eye protection is required for all personnel working in or visiting research laboratories and workshops where hazardous materials are handled.
3. This mandatory rule applies to staff members, students, contractors and visitors.

10.3 Compressed Gas Cylinders

10.3.1 Storage Practices

1. Only cylinders that are in use shall be kept in the laboratory.
2. Cylinders are secured in accordance with local fire codes. They must be kept in a stand or be attached safely otherwise.
3. Cylinders are maintained in an environment at near-room temperatures.
4. When the cylinder is not in use, close the main cylinder valve tightly.

10.3.2 Transportation

1. If applicable, large cylinders are transported only on a wheeled cylinder cart.
2. Cylinders shall be protected from potential damage from falling or striking objects.

10.3.3 Use of Cylinders

1. Laboratory personnel must wear eye protection when changing regulators or manipulating tubing or equipment potentially under pressure.
2. Cylinders are situated away from heat and ignition sources.
3. Cylinders are situated away from major traffic flow.
4. Cylinder leaks are attended immediately.

10.3.4 Empty Cylinders

1. Full and empty cylinders are not manifold together.
2. Promptly remove the regulator from empty cylinder and replace the protective cap.
3. Empty cylinders are labelled as “Empty” or “MT”.

10.4 Cryogenic fluids

Cryogenic fluids, such as liquid nitrogen, have the potential to cause an oxygen deficiency environment. Do store and use cryogenic fluids with adequate ventilation.

Never allow any unprotected part of the body to come with contact with uninsulated pipes or equipment that contains cryogenic fluids.

Use suitable hand truck for container movement.

Personnel must be thoroughly familiar with properties and safety considerations before being allowed to handle cryogenic fluids and/or its associated equipment.

Eyes are most sensitive to the extreme cold of cryogenic fluids and their vapours.

10.5 Cryogenic liquids at Helios 2

SSLS used liquid helium and liquid nitrogen mainly for cooling down the dipole magnets. The liquid temperature is extremely low. Faulty action may cause not only low temperature human injury but also compressor trip, lose liquid helium, and burst the pressure vessel. Please handle carefully to prevent the cryogenics accidents.

10.5.1 Liquid Nitrogen

Liquid nitrogen is stored in the nitrogen tank outside the building and the tank is connected to the fridge and dipoles. The tank supply liquid nitrogen to the cryogenics system 24 hours.

The nitrogen tank has a liquid supply valve for our beam line users. **ONLY TRAINED PERSONS ARE ALLOWED TO COLLECT LIQUID NITROGEN FROM THE TANK**. Before collect the liquid, the person must sign on the log book at OFFICE 4, stating the person’s name, the department, and how many litres are going to be collected. To collect the liquid nitrogen from the tank,

- wear cryogenics gloves;

- wear goggles;
- use a proper container, say a mobile liquid nitrogen Dewar;
- move the mobile Dewar close to the tank;
- take out the siphon on the mobile Dewar;
- put the black insulated pipe which connected to the tank into the mobile Dewar;
- close the valve next to the safety valve between the tank and the black pipe;
- slowly open the manual supply valves between the tank and the black pipes
- when liquid collection is completed, closed the liquid supply valves, and open the valve next to safety valve;
- put back the black pipe under the tank.

10.5.2 Liquid Helium

ONLY TRAINED PERSONS ARE ALLOWED TO TRANSFER LIQUID HELIUM FROM SUPPLIER'S DEWAR TO SSLS STORAGE DEWAR.

Before transfer liquid helium, weight the supplier Dewar and record it first. Cryogenics gloves must be used when handing the siphon. 5 grade helium gases should be used to pressurize the supplier Dewar. To transfer liquid helium, two persons are required to complete the job, and the following procedures have been shown to be adequate to do the helium transfer at SSLS.

- Bring down the buffer pressure first to accept the liquid easily and ecumenically;
- Wear cryogenics gloves
- Move the supplier Dewar to the floor scale;
- The person downstairs open the supplier's Dewar valve first, a ladder may be necessary to reach the valve;
- Two persons work together to insert slowly the lower side of siphon to the supplier's Dewar, once the gas comes out from the upper side with a weak sound that can be heard, stop insertion and tighten the nut to fix the siphon position.
- Close the safety valve on the supplier's Dewar to increase it pressure;
- Hold the upper siphon and point the opening outward;

- Once white frog is seen from the upper side of the Dewar, insert the upper side of the siphon into the tube on the top of the storage Dewar and tighten the nut quickly.
- Open the valve on the top of the storage Dewar and start the liquid transfer.
- Open the Dewar neck flow to decrease the Dewar pressure to safe level, 350 mbar gauges.
- When the pressure in the supplier's Dewar is less than 5 psi, connect an 8 mm OD hose to a 5 grade helium gas cylinder regulator and purge for 1 minute, and open the purge valve on the supplier's Dewar to purge for 1 minute at the same time, and then connect the hose to the supplier's Dewar. Control the pressure from the regulator at 1 bar gauge, and flow rate at 25 l/min.
- The helium level inside the Storage Dewar will increase. Once the liquid level in the storage Dewar stops increasing, do the flowing
- Stop the gas supply to the supplier's Dewar immediately,
- Lift the lower part of the siphon 0.5 m up and fix it;
- Lift the upper part of the siphon slowly until the valve on the top of the Dewar can be closed.
- Open the supplier's Dewar safety valve to decrease is pressure;
- When the pressure in the supplier's Dewar is at atmosphere pressure, take out the lower part of the siphon;
- Take out the upper part of the siphon;
- Move down the supplier's Dewar from the floor scale and close its liquid port valve.

10.5.3 Cryogenics Emergency

Whenever there is an emergency, say a loud noise from cryogenics room, compressor trip, large amount of ice appears, or liquid nitrogen overflow, water flooding, if you are not sure, please don't try to rescue the machine, please call **9030 3023** or **9030 3237.**

10.5.4 HELIOS EMERENCY

In case of **Dipole Quench and Power Failure**, please call **9030 3023** or **9030 3237**

11. Training at SSLS

11.1 Training for staffs and students at SSLS

1. All new staffs and students are required to attend a Safety Orientation and pass all relevant Online Safety training before they are allowed to enter laboratories and beamlines to begin their research at SSLS.

2. Prior to the training, new staffs and students are allowed to enter SSLS and participate in experiments under the supervision of qualified staff.

3. The Safety Orientation conducted by the Safety Lead shall cover emergency procedures, hazardous areas and good lab practices.

4. The Online Safety trainings are as listed below. The online trainings can be done at https://ivle.nus.edu.sg/

    - Chemical safety training (OSHCHM01)
    - Ionizing Radiation safety training (OSHRAD01)
    - Laser safety training (OSHRAD02)
    - Laboratory Safety Induction Training (OSHGEN01)

It is mandatory that everyone working in SSL must attend Ionizing Radiation safety training. As for Laboratory Safety Induction Training, it is mandatory for staffs.

11.2 Training for users and collaborators at SSLS

1. All above (11.1) criteria will be also applied to users and collaborators actively participating in research activities at SSLS.

11.3 Visitors at SSLS

1. Visitors will be allowed to visit research facilities at SSLS under the supervision of staff member only.

APPENDIX A ACCELERATOR SYSTEM SAFETY

A.1 Introduction

As described in Chapter 1, HELIOS 2 is a powerful storage ring X-ray source which uses superconducting magnets to achieve a much more compact size than would otherwise be the case. With a total X-ray output of 12 kW, it is an extremely powerful source $\approx 10^4$ stronger than a conventional electron bombardment source. Furthermore, the fact that synchrotron radiation is tightly collimated in the vertical direction means that the intensity of illumination on a target can be much higher than for an isotropic source of the same power. The ring has 21 beam ports with an electron energy of 700 MeV and a bending magnetic field of 4.5 T, the characteristic photon energy (wavelength) is 1.47 keV (0.845 nm).

HELIOS is crucial equipment to SSLS. Therefore, necessary safety roles have to be implemented to make sure its smooth and safe operation. **FAULTY ACTIONS MAY CAUSE DIPOLES' QUENCH OR DAMAGE OF THE SUBSYSTEM. ONLY TRAINED AND SKILLED PERSONS ARE ALLOWED TO OPERATE THE MACHINE.** In addition, the general roles listed below must be followed.

- Do not enter the Vault, Plant Room, Cryogenics room, and Control Room without permission, please inform the shift leader if you wish to do so;
- Do not apply any force/load on the cooling water pipes and compressed air pipes, and liquid nitrogen/helium lines;
- Do not stand close the safety valves and burst discs;
- Do not touch ice balls by hand in cryogenic plant or Vault;
- Do not standing or apply pressure on the any part of the accelerator, such as vacuum pipes, kickers, septum, RF cavity, RF wave guides helium transfer lines, etc;
- Keep away from the Vault wall when beam is stored;
- Do not enter the vault immediately after beam dump, please consult the duty shift leaders for vault entry, the radiation monitor came with the machine should be carried when entering into the vault; please consult the duty shift leaders for vault entry;
- Keep away from the RF and Microtron HV power supply;
- Do not use the compressed air whenever dipoles are full of liquid helium.

A.2 Cryogenics

ONLY TRAINED AND SKILLED PERSONS ARE ALLOWED TO HANDLE CRYOGENICS SUSTEM.

Cryogenics system provides cooling of the dipole magnets. There are a number of potential safety risks. The following list of hazards and recommended procedures provides general guidelines for safe cryogenic practice.

Liquid cryogens, namely helium and nitrogen have boiling points of 4.2 K (-269°C) and 77.3 K(-196°C) respectively. Even when kept in insulated storage vessels (Dewar), the liquids will remain at their boiling temperature and boil off gas with the gas increasing in volume to approximately 700 times its original volume as it warms to room temperature.

A.2.1 Handling Cryogens

When handling cryogens the following hazards may be encountered.

a. Extreme cold.

Exposed skin will stick and subsequently be torn on removal from contact with cold surfaces. Cold burns can result from contact with a jet of cold gas or liquid.

b. Mechanical Strength

Flexible or soft materials become hard and brittle, and may break easily if they are strained. Polythene tubing is more suitable than rubber tubing for transferring liquid nitrogen but is still likely to fracture if moved. All metal transfer lines are preferred, except for temporary installations where experienced persons are responsible. Cryogens spilt on vacuum equipment may freeze O-rings and thus cause loss of insulating vacuum.

Do not force open the frozen valves, use hot air gun to warm up the frozen valve. Do not leave siphon insert into the Dewar after use, this may cause liquid drop on the floor, as a result, it may damage floor and injury people.

c. Asphyxiation.

Most common cryogens are not poisonous, but there is a risk of asphyxiation if a large amount of gas is released into a confined space displacing atmospheric oxygen. There is no sensation of breathlessness to warn the victim of the danger. It is dangerous to store or transport Dewar in confined spaces.

d. Precautions

As a precaution, when handling liquid cryogens:

(i)Wear loose fitting protective gloves (impervious to liquid) which you can remove quickly if cryogens are spilt inside the gloves.

(ii)Wear eye protecting goggles.

(iii)Wear sensible shoes with trousers over the top of them so that spilt fluids do not collect inside them.

(iv)Keep cryogens away from areas where they may spill on cables. Cryogens spilt on electrical cables may freeze and fracture the insulating layer. Moisture from the atmosphere may cause short circuiting or electrical hazards to personnel.

(v) Two persons are required when handling liquid cryogens.

e. First Aid

If any cryogen comes into contact with the eyes or skin, flood the area with large quantities of cold or tepid water immediately. Apply a cold compress. Never use hot water or dry heat. MEDICAL ADVICE SHOULD BE SOUGHT IMMEDIATELY.

A.2.2 Storage Dewar and Cryostat Hazards

a. Condensation of contaminates

The cryogens or cold surfaces in a cryostat may condense contaminates from the atmosphere. Frozen water or air may block up narrow tubes preventing the venting of natural boil off from the system and leading to a build-up of pressure in the vessel. When attempting to clear a blockage wear thick gloves as there is a danger that a jet of cold gas or liquid may result.

b. Fire hazards.

Most commonly used cryogens are not themselves flammable however liquid oxygen may condense onto cold surfaces. The presence of any oil or grease in this oxygen rich environment will result in a severe fire hazard.

c. Risk of explosion.

In general cryostats are fitted with pressure relief valves to prevent the risk of damage if a high pressure accidentally occurs. High pressure might occur where a cryogenic liquid is trapped in a pipeline. The liquid can boil which may cause a dangerously high pressure. In the event of a vacuum failure cryogenic fluids will boil vigorously and lead to pressure build ups.

d. Warming up of a system.

When warming up a system take care that no enclosed volumes are trapped. Open all valves to allow the gas boiled off to escape. Frozen air can exist in vacuum spaces, so take care to avoid pressure build up due to this air vaporising.

A.3 SAFETY ASPECTS OF MAGNETIC FIELDS

The superconducting dipole magnets produce a strong fringe field which extends well beyond the boundary of the containment vessel. While there is no conclusive evidence that magnetic fields can directly affect health, VERY LARGE attractive forces on magnetic materials may cause equipment to move suddenly and uncontrollably towards a dipole. It is quite possible for someone to become trapped between a large magnetic item (for example a compressed gas cylinder or pumping trolley) and either dipole cryostat, resulting in severe injury or death. Because forces vary so rapidly with distance, by the time an operator is aware of a disturbance to some equipment, very often it is too late to prevent it moving uncontrollably!

Iron objects experience the greatest force along the machine axis which passes through the dipole centres of curvature. The highest field gradient outside the OVC occurs at the centre of the arc. Table A.1 shows the force on 1kg of iron at various distances from the OVC.

Table A.1 Force on 1 kg of iron

Distance from OVC [cm]	Maximum force [N]
0	21.6
10	8.0
20	3.2
50	0.4
100	0.03

The operation of medical electronic implants (e.g. pacemakers) may be affected by a magnetic field. Five gauss is considered to be a safe working field level for pacemakers. The stray field outside the vault area is less than 5 gausses, so precautions against stray magnetic fields are only necessary within the vault itself.

Under normal operating conditions the superconducting dipole magnets will only be run with the vault evacuated and locked for HELIOS operations. However, during periods of maintenance or particularly after an excursion to elevated temperatures, it may be necessary to energise the dipoles when access to the vault has been routine. Under these circumstances, the following check list should be used and the shift leader (where applicable) consulted.

Check that the vault is clear of personnel and locked.

Anyone who MUST be in the vault should be made aware of the potential hazards from strong magnetic fields, and the sudden evolution of large quantities of cold helium gas in the event of a quench with coincident quench valve failure.

Check that the vault is clear of ferromagnetic objects.

These could move suddenly as the dipole field is raised causing damage to equipment or people. A special search should be made for hand tools left on or close to the dipoles.

Check that the vault is clear of field sensitive equipment?

This includes:

- Electric Motors - move at least 2 m from the dipoles.
- RGA Controllers - remove from the vault.
- Personal Computers - remove from the vault.
- Video Monitors (especially colour ones) - remove from the vault.
- Ion gauges - Those on the dipoles may not work while the field is on, others will have their calibrations changed.
- Credit cards etc. - Keep away from energised magnets.
- Floppy Disks - Keep away from energised magnets.
- Medical electronic implants (E.g. pace-makers) - Individuals with such aids should be excluded.

A.4 SAFE GAS HANDLING

HELIOS typically uses three gases:

- Nitrogen
- Helium
- Sulphur hexafluoride

All are used at relatively low pressure. In normal use the gases are used with equipment designed to protect the user from their potential hazards. Only suitably qualified personnel should attempt to disconnect, dismantle or modify equipment containing them.

A.4.1 Potential Hazards

The following list is not intended as a complete guide to all gas hazards on HELIOS, but serves to illustrate the range of potential hazards that exist.

- Microtron SF6 Waveguide insulation
- HELIOS vacuum system N2 Venting
- HELIOS vacuum system He Leak testing

A.4.2 Health Hazards

Refer to safety data sheets supplied by the gas supplier.

A.4.3 Essential Precautions

- Avoid rough handling of cylinders and overheating.
- Avoid flames or welding in vicinity.
- Treat every cylinder as full, handle carefully, always use a carrier.
- Use cylinders in an upright position and fixed so that they cannot fall.
- Avoid cylinders coming into contact with oil or grease. Regulators and valves must NEVER come in contact with oil or grease.
- Do not use cylinders as work supports.
- Store compressed gas cylinders in designated areas
- Take great care when removing compressed gas lines. Ensure that they are vented or may be vented without risk to personnel.
- When dealing with cryogenic vessels or lines refer to section on safe cryogenic practice.
- Fuel gas and oxygen gas leaks are highly dangerous.

A.5 POTENTIAL ELECTRICAL HAZARDS ON HELIOS2

PLEASE REFER TO THE ELECTRICAL AND MECHANICAL HAZARDS FOR GENERAL ELECTRICAL SAFETY, THINGS LISTED HERE ARE CLOSELY RELATED TO HELIOS2 ONLY.

HELIOS typically uses 300 to 400 kW of electric power from the mains supply. In normal use the user is protected from the dangers associated with the high voltage, current and power levels used by the equipment. Only suitably qualified personnel should attempt to disconnect, dismantle or modify the equipment.

A.5.1 Potential Electrical Hazards

Table A.2 illustrates the wide range of potential electrical hazards on HELIOS 2, it is not intended as a complete guide.

Table A.2 Potential Electrical Hazards

HIGH VOLTAGES	
RF transmitter	25 kV DC at 6 A
Ion pumps	7 kV at up to 750 mA
Ion clearing PSU	5 kV at up to 10 mA
Most VDU displays	up to 25 kV
Ion Gauges / RGAs	600 V
Superconducting magnet power supply, quench switch and quench detector	500 V (during a quench)
HIGH CURRENTS	
Superconducting magnet power supply and quench switch	1125 A at 30 V
Ring quadrupole PSU and magnets	275 A at 80 V
RADIO FREQUENCY POWER	
RF transmitter	50 kW at 55.558 MHz

Injuries caused by electricity may take any of the following forms:

- Electric shock
- Electric burn
- Fire of electrical origin
- Electric arcing
- Explosion initiated or caused by electricity

a. Electric shock

One effect of electrical current flowing through the human body is shock. When a shock is received, the electric current may take multiple paths through the body and its intensity at any one point is difficult or impossible to predict. The passage of electric current may cause muscular contractions, respiratory failure, fibrillation of the heart, cardiac arrest or injury from internal burns. Any of these can be fatal.

The nature and severity of injury depends upon the magnitude, duration and path of the current through the body and, in the case of alternating current, on its frequency. It is not possible to identify precise thresholds for the existence of hazard because a judgement has to be made in each case taking all the circumstances into account such as body weight, physical condition of the victim and so forth. A guide to the current magnitudes which mark the occurrence of various dangerous effects is given in the International Electrotechnical Commissions publication IEC 479. Quite low currents, of the order of only a few milliamperes, can cause fatal electric shock.

Factors influencing the likely effect of shock current are its voltage, frequency and duration and any impedance in the current path. The effects of electric shock are most acute at about the public electricity supply frequency of 60 Hertz. Susceptibility to electric shock is increased if a person is in good electrical contact with earth, such as in damp or wet conditions or in conducting locations such as inside a metal tank. Hot environments where people may become damp due to perspiration or humidity, thus reducing the insulation protection offered by clothing, may present an increased risk from electric shock.

The different conditions make it impossible to specify a voltage which is safe in all situations. The risk of injury from electric shock in any situation must be considered against the background of the various national and international standards and technical publications giving guidance as to the voltages and other factors which have been found by extensive experience to be safe. These documents must be interpreted carefully and with a view to the limitation of their various scopes and assumptions. The conventional public electricity supply voltage should always be considered as potentially fatally dangerous, particularly at the industrial supply voltage levels used in HELIOS. The most dangerous situation is where contact is made with conductors by each hand, current then flowing 'hand to hand' across the heart region.

b. Electric burn

Electric burns are due to the heating effect caused by the passage of electric current through body tissues. They are most commonly associated with electric shock and often occur in and on the skin layers at the point of contact with the electrical conductors which gave rise to the electric shock.

At high frequencies e.g. radio frequencies (RF) which include microwaves, it may not be necessary for contact to be made with live conductors for an electric burn to be received. In the case of RF the heating is by absorption of the electromagnetic wave energy by a dielectric loss process in the body of the victim. RF burns can thus be extremely deep within the body. RF burning can occur without the sensation of shock, particularly if no contact is made with the RF conductors, and can therefore cause severe injury before the victim is aware of their occurrence. Electric burns are usually painful and very slow to heal. Permanent scarring is common.

c. Fires of an electrical origin

Fires may be started by electricity in a number of ways, for example:

- Overheating of cables and electrical equipment due to overloading of conductors
- Leakage currents due to poor or inadequate insulation

- Overheating of flammable materials placed too close to electrical equipment which is otherwise operating normally and
- The ignition of flammable materials by arcing or sparking of electrical equipment

The injuries caused by fire include burns and smoke inhalation injuries.

d. Arcing

Arcing causes a unique type of burn injury. Arcing generates ultra violet radiation which causes damage akin to severe sunburn. Molten metal particles from the arc can penetrate, burn and lodge in the flesh. Additionally, there may be radiated heat damage caused by the arc.

Ultra violet radiation can cause damage; sensitive skin and eyes are especially vulnerable to arc flash. (Arc eye is commonly encountered with electric arc welding if the proper precautions are not taken.)

Arcing faults can occur if the energy available at a piece of electrical equipment is sufficient to maintain a conductive path through the air or insulation between two conductors which are at different potentials. The HELIOS magnet power supplies and magnet terminals are potential sources of arc injury. Most of these operate at low voltage, but the currents available are equivalent to those from an electric arc welder.

Under fault flashover conditions, currents many times the nominal rating or setting of a protective device may flow before those devices operate to clear the fault. The arc may dissipate a lot of energy and continue long enough to inflict very serious arcing burns or to initiate a fire, for example within 0.25 second (which is not an untypical minimum time for fault clearance). Arc flashovers caused during work on live circuit conductors are particularly hazardous as the worker may be very near to or even enveloped by the arc. Such cases often lead to very serious, sometimes fatal, burn injuries.

e. Explosion

This section includes injuries caused by explosions either of an electrical nature or those whose source of ignition is electrical.

Electrical explosions include the violent and catastrophic rupture of any electrical equipment. Switch gear, motors and power cables are liable to explode if they are subjected to excessive currents, which release violent electromagnetic forces and dissipate heat energy, or if they suffer prolonged internal arcing faults.

Explosions whose source of ignition is electrical include ignition of flammable vapours, gases, liquids and dusts by electric sparks, arcs or the high surface temperature of electrical equipment.

f. Essential Precautions

All the electrical equipment supplied as part of HELIOS 2 is provided with a protective ground. Do not remove protective grounds as this may cause an electrical safety hazard.

Do not disconnect equipment, open covers, dismantle or modify it unless you are

- Qualified to do so
- Authorised to do so
- Fully understand its operation and potential hazards or have total assurance through your local electrical permit to work the system that the equipment has been made safe.

g. First Aid

Do not attempt to administer first aid to someone who may have suffered electric shock until the source of the shock has been isolated.

A course in first aid to include methods of artificial respiration is recommended for those whose work involves equipment which may produce a high voltage.

A.6 HELIOS 2 RADIATION SAFETY

PLEASE REFER TO THE RADIATION CHAPTER FOR GENERAL INFORMATION ON RADIATION SAFETY. THE MATERIAL PRESENTED HERE IS FOR HELIOS 2 ONLY.

HELIOS is a powerful source of soft X-rays. These soft X-rays cannot get out through the vacuum vessel walls of HELIOS or the X-ray beamlines. A very thin beryllium window allows them to pass into the lithography tool. Soft X-rays are easily screened from any contact with personnel.

HELIOS also produces harder radiation - gamma rays - which are much more penetrating and consequently more dangerous. This radiation is an unwanted, but inevitable, part of the electron beam acceleration process. The resulting gamma rays interact with matter producing neutrons, which are even more penetrating. HELIOS is enclosed within a concrete shield to protect personnel from the hazard caused by these neutrons and gamma rays. Special interlocks and operating procedures ensure that HELIOS can never be switched on while personnel are within the enclosure.

A thick concrete shield reduces radiation exposure of personnel to a very low level. The radiation outside the shield coming from HELIOS is a small fraction of the natural background radiation level.

Radiation can be dangerous if not used properly but is safe when used properly. Shift leaders must rigorously follow the operating procedures at all times. The following sections present more detail on radiation hazards and the means of controlling them.

A.6.1. Injection

When the electron beam is injected into the storage ring, only a small proportion is captured into stable orbit; the rest is lost at various locations around the ring. The consequent impact of electrons against the ring vacuum vessel wall produces gamma rays which are sufficiently penetrating to pass straight through the vessel. These gamma rays come off in all directions, but are most intense in the 'straight ahead' direction. To provide a primary shield against these 'straight ahead' gamma rays, lead shielding is placed at suitable locations close to the ring. On interacting with the lead shielding and other material around the ring, some of the gamma rays produce neutrons. The thick concrete enclosure shields against these neutrons and also against any gamma rays which have got past the lead.

Microtron operation is the most dangerous time for radiation, because the microtron beam is intense. The personnel safety system and operating procedures have been designed to ensure that a person cannot receive a dangerous dose of radiation. It is the clear duty of all shift leaders to follow these procedures.

A.6.2. Ramping and Stored Beam

When the required circulating beam has been accumulated at injection energy, the microtron injector is switched off and HELIOS is ramped to full energy, where it remains with stored beam for several hours. From a radiation point of view, these two phases of ramping and storing are rather similar. In each phase the ring is emitting soft X-rays. Soft X-rays are totally screened by the beam vessels or lithography tool and are thus not normally a personnel hazard. In certain set-up or research situations however, there may be occasions when the lithography tool is removed. Shift leaders should therefore be aware that soft X-rays emerging directly from the beryllium window are dangerous; under no circumstances should personnel be exposed to them.

A more serious hazard during ramping or stored beam is that the electron beam may disrupt for some reason and collide with the vacuum vessel wall. If this happens, a pulse of penetrating gamma radiation will be created, very much like the case of beam loss at injection. Unlike injection however, the burst of radiation is very short; it lasts only for the time needed to lose the circulating beam. As noted below, the effect of radiation is cumulative, so that short bursts are much less damaging than the continuous linac output. Nevertheless, there is some radiation hazard and for this reason, personnel are excluded from the shielded enclosure during ramping and stored beam.

A.6.3 Induced Activation

If the injector has been running for a long time and the electron beam has been impacting a certain component of HELIOS - most likely the septum, energy slits or a beam stop - that component will become slightly radioactive. This effect is known as induced activation. The component itself then becomes a source of radiation and will continue to be active for several hours or days (depending on the material it is made of) after the electron beam has been switched off. The radiation emitted is relatively mild and does not prohibit radiation qualified personnel from entering the shield enclosure. To avoid unnecessary exposure, always survey the potential loss points (slits, septum, beam stops etc) for radiation after extended running. Place barriers around areas of induced activation to prevent anyone approaching too closely.

A.6.4 RF Cavity

In normal operation, the cavity emits no radiation. However, under conditions of poor vacuum or after the cavity has been exposed to air, it may occasionally suffer internal voltage breakdown. This breakdown produces X-rays which are sufficiently hard to penetrate the cavity wall and thereby cause a personnel hazard. Under normal circumstances therefore personnel should always be excluded from the shielded enclosure when the cavity is running.

The klystron amplifier operation is associated with many hazards, notably microwave radiation and X-ray radiation. The thyratrons in the high voltage pulse generator of the KMOD produce X-ray radiation. High voltage must not be applied to the thyratrons unless adequate X-ray shielding is correctly located, this is normally provided by the metal enclosure formed by the klystron modulator cabinet. Shift leaders should be aware that, if the lead shields are removed to carry out maintenance work, this raises a potential radiation hazard. Whenever the lead shielding has been disturbed in any way, a radiation survey must be carried out, to ensure that the shielding has been replaced properly.

A.6.6 Shielding

Ideally, any shield should enclose the radiation source entirely and should be thick enough to attenuate the radiation flux down to a low level. In practice, it is always necessary to make holes in a shield so the personnel may enter and utilities may pass through the shield. Radiation travels in straight lines, so long narrow holes are permissible if they do not 'look' directly at the source. Where large holes are needed for personnel access, a labyrinth with two or more bends is made, so that the radiation cannot escape.

A.6.7 Personal Dosimeters

The effect of radiation is cumulative, i.e. the damage done depends on the integrated dose received. A short exposure to intense radiation may produce the same effect as a long exposure to weak radiation. For radiation workers who may occasionally be exposed to some radiation, e.g. from induced activation, it is necessary to keep a running total of cumulative radiation does receive. This total is checked, at regular intervals and is recorded over the individuals working life to ensure that they never receive a cumulative radiation dose in excess of the safe limit.

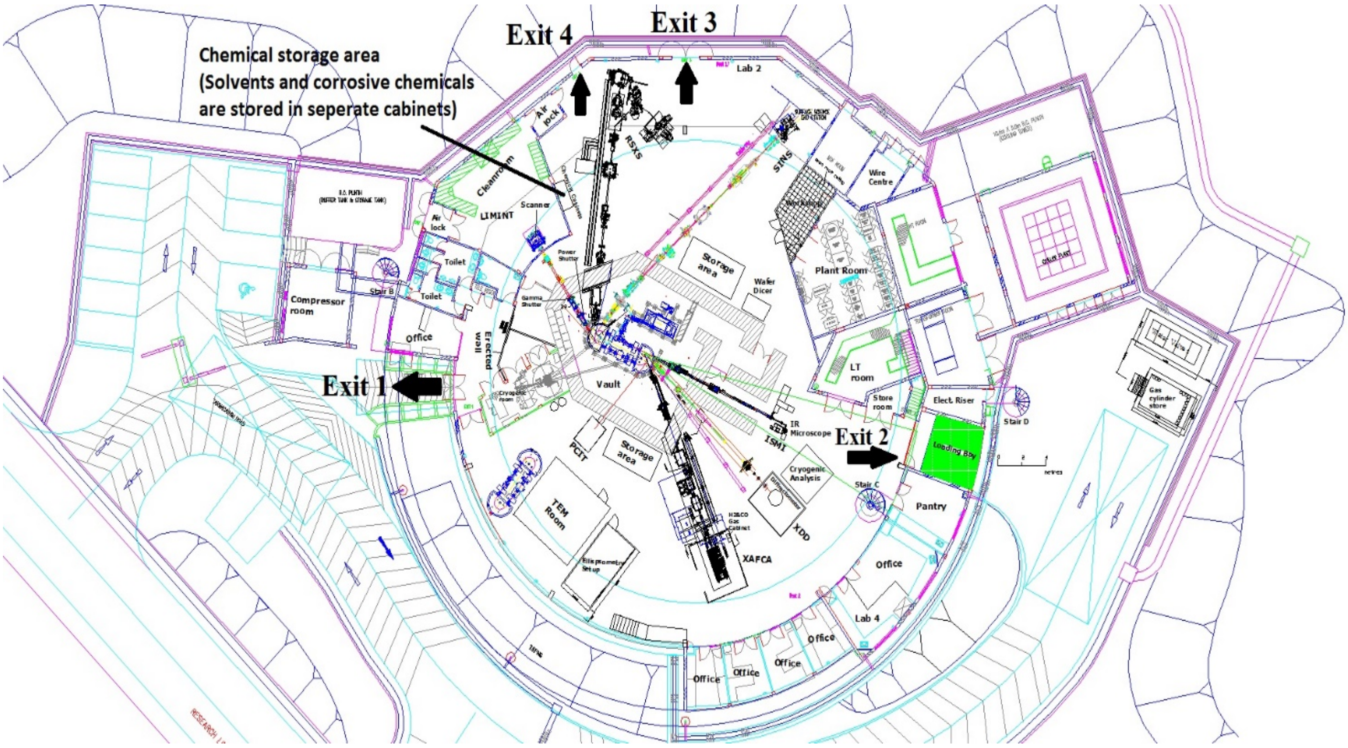
Anyone working on HELIOS should wear their personal dosimeters at all times.

A.7 ACCELERATOR AND CRYOGENICS EMERGENCY

Whenever there is an emergency, say a loud noise from cryogenics room, compressor trip, large amount of ice appears, or liquid nitrogen overflow, water flooding, quench and power failure, if you are not sure, please don’t try to rescue the machine, please call HP **9030 3023** LZW or HP **9030 3237** CEP

APPENDIX B CHEMICAL INVENTORY AT SSLS

Inventory of stored chemicals are listed in front of the solvent and corrosive chemical cabinets. Location of the cabinets are as show in the floor plan below.



APPENDIX C Radiation Safety Concerns at SSLS

Local Rules for the Safe Operation of HELIOS 2 at SSLS

C.1 Regulations and Documents:

1. Code of Practice for Fire Precautions in Building, 1997, Fire safety Bureau, Singapore Civil Defence Force.
2. Chubb FM-200 TM Gamma Series Systems, Chubb, 1997.
3. Roy Ryder, Radiation Safety Assessment of HELIOS II Accelerator at the National University of Singapore, DARESBURY LABORATORY, Health Physics report 98/208, October 1998.
4. The Ionizing Radiations Regulations of 1985, London, HER MAJESTY STATIONARY OFFICE, Reprinted 1987.
5. The Radiation Protection Regulations, 1974, Republic of Singapore, Gov. Gazette, Subsidiary legislation Supplement.
6. Radiation Protection Act (Chapter 262), Radiation Protection (IONISING RADIATION) Regulations, Radiation Protection (NON-IONISING RADIATION) Regulations, Published in the Gov. Gazette, Electronic Edition.
7. P. Berkvens, Shielding requirements for the Singapore synchrotron sight source, 14 February, 2000.
8. P. Yang, SSLS internal report: Safety-4, 19 August 1999.

Useful References with SSLS and OI:

- HSH 20/2: Safety Assessment for HELIOS (1) commissioning, Dec 88.
- H2-SH1/1: HELIOS 2 Shielding Wall Thickness, Nov. 8, 1990.
- HSH33/1: HELIOS Project Note, Jul. 29, 1991.
- H2-SA-DN 1/2: Lead shielding for HELIOS 2, Jan 1995.
- H2-SA DN 4/1: Radiation Safety Assessment for HELIOS 2 Commissioning at Oxford.

Telephones:

Service Name	Telephone
Fire/ HAZMAT/ Ambulance	995
Police	999
NUS Campus Security Post	6874 1616 or 61616

Singapore Synchrotron Light Source, NUS		
Telephone		651 61135
Fax		677 36734
WWW	http://ssls.nus.edu.sg/	
Postal Address	5 Research Link, Singapore 117603	
Director	Prof. Mark B. H. BREESE slshead@nus.edu.sg	651 67930
Radiation Safety Officer	Dr YANG Ping slsyangp@nus.edu.sg	651 64749
Radiation Safety Officer	Dr DIAO Caozheng slsdcz@nus.edu.sg	651 67965

Office of Safety, Health and Environment, NUS		
Telephone		651 66863
Fax		677 86031
WWW	http://www.nus.edu.sg/osh/	
Postal Address	8 Kent Ridge Drive, #03-02, Singapore 119246	
Director	Dr Peck Thian Guan oshhead@nus.edu.sg	651 65961
SSLS Liaison Officer Safety & Health Manager	Mr Jedison Ong oshoca@nus.edu.sg	651 65966

C.2 Introduction

Definition

These Local Rules comply with the requirements of "*Radiation Protection Act (Chapter 262), Radiation Protection (IONIZING RADIATION) Regulations 2000, Arrangement of Regulation, Published in the Gov. Gazette, Electronic Edition" & "The Radiation Protection Regulations, 1974, Republic of Singapore, Gov. Gazette", Subsidiary legislation Supplement* and *Section 11-(1) of the Ionizing Radiations Regulations of 1985, London, HER MAJESTY STATIONARY OFFICE, Reprinted 1987.* They define the working procedures which must be adopted to ensure the safe operation of "HELIOS 2" at the Singapore Synchrotron Light Source (SSLS). Although primarily concerned with radiation safety, they also cover some other safety areas - particularly electrical safety.

"HELIOS 2" refers to a compact 700 MeV synchrotron x-ray source, which includes a 100 MeV microtron electron injector.

Authority

HELIOS 2 Local Rules are made by the Director of SSLS; any changes may only be made with his authority.

Applicability

These rules apply to all actions connected with the operation of HELIOS 2 at the Singapore Synchrotron Light Source (SSLS) building, i.e. to all operations within the HELIOS 2 Shielding Vault, Plant Area, Control Room, beam lines, experimental stations and to any other actions which may be affected by these operations. It is mandatory that all SSLS employees, users, sub-contractors and all visitors comply with these rules at all time. Failure to do so will lead to disciplinary action against the person concerned.

Other Documents

This document may be read in conjunction with the "Radiation Safety Assessment of HELIOS 2 Accelerator at the National University of Singapore" (Roy Ryder) & "Radiation Safety Assessment for HELIOS 2 Commissioning at Oxford" (H2-SA-DN 4/1) which provides a safety assessment, based on the original HELIOS 1 Safety Assessment (HSH 20/2). Lead shielding used in OI is described by H2-SA-DN 1/2. The Access Interlock System is described in HG-SA-SP 1/2 "An overview of the HELIOS 2 AIS". A succeeded work was done by P. Berkvens (Shielding requirements for the Singapore synchrotron sight source, 14 February, 2000) and P. Yang (SSLS internal report: Safety-4, 19 August 1999).

C.3 Personnel and their Responsibilities

Director of SSLS

The Director, Prof. Mark B.H. BREESE, is responsible for the formulation and enforcement of these local rules at SSLS during operation and for the appointment of other responsible staffs, especially the L5 of SSLS.

L5 License holders

The L5 license holders of SSLS are: Dr YANG Ping and Dr DIAO Caozheng. SSLS L5 license holders are responsible for:

Running the Helios system safely and within the current RPNSD dose limits for the general public;

Radiation dose assessment, shielding design and installation;

Radiation monitoring and safety inside and outside the Helios vault; Radiation level survey particularly for new equipment, i.e. beamline, undulator, etc.

Radiation safety and monitoring (TLD issue and recording) of SSLS staff, contractors and visitors if required;

Access control to the building and internal structures;

Issuing work permits for access or modification work;

Informing the RPNSD of any non-normal condition in running that might affect radiation levels and require special monitoring outside the vault;

Informing the RPNSD of critical times and places to monitor outside the vault, and keeping a detailed log of running parameters open to inspection at all times.

Shift Leaders

The shift leaders (SL) are responsible for every aspect of the safe operation of HELIOS 2 during the shifts. They must be informed in advance of any potentially hazardous operation proposed during their shifts and have the authority to forbid any operation which they consider to be unsafe.

The shift leaders are responsible for enforcing these local rules and for keeping adequate records of HELIOS 2 operation (particularly beam on-time, beam current, beam energy) in order to estimate radiation doses if necessary. They also monitor radiation levels, as appropriate.

C.4 Modes of operation and Designation of Areas

Working Areas will be designated according to the Mode of operation, as defined in the following paragraphs.

Fig. 7 Shows the vault plan, lead shielding & distribution of TLD.

Operating Modes

At any given time, HELIOS 2 will be defined to be in one of four modes, as follows. "Indicator light boards" on the wall of the shield vault shows the status.

Shutdown

Personnel Safety System (PSS) locked off removal of key switch HO1, RD1 & RD2 from the PSS key station, the keys to these key switches are locked in the key safe. RD1 & RD2 may be released for vault access after completion of a radiation survey. Duty Supervisor is in charge, if designated. HELIOS 2 is in shutdown mode.

Search

Searching procedure is under way before running.

Standby

The vault has been searched and is secure. The Ring door keys are inserted in the PSS key station. Operation of the HO1 key in the PSS key station will allow the system to change to RUN. This state may be used to disable the machine for brief periods during operations.

Run

The shield vault is locked. HELIOS 2 is enabled for beam operation. See section 6.2.

Shift Leader in charge, access to Shield Vault controlled by PSS. The SL is expected to be always in direct contact with the control room (e.g. via walkie-talkie or internal telephone). At least two responsible persons, one being the SL, are required to be present during "RUN" conditions. One of these persons should be available as a contact point for other staff - which may need to urgently contact the SL.

During running of Helios 2 there should always at least one person working in Control Room.

TEST Modes

RF Test (TM1) RF Test mode allows vault access during RF testing.

Operational Test (TM2)* This test mode allows access to vault with stored beam. Beam is injected in normal operational (RUN) mode. The microtron is locked off and TM2 key is inserted in the key station. Access can then be made subject to following notes:

minimum stored current required to reasonably achieve results;

minimum access time to achieve results;

radiation dose monitored at all times whilst in the vault.

* This rule was accepted in OI during factory test and may not be adopted at SSLS.

C.5 Designation of Working Areas

Definition of Areas

Four main working areas are defined; they are the Shield Vault (figure 6), experimental halls (south and north), Vault Roof, and Building Roof.

With the definitions given above, Working Areas (for different Modes of operation) are designated as in Table 1.

- In RUN Mode, the Shield Vault is a "No entry" area.
- The building roof and vault roof are Prohibited Areas at all times.
- The Shield Vault will normally be a Supervised Area in Shutdown Mode after the end of operational runs (because of the possibility of activation). **Personnel dosimeters (radiation dose badges) must be worn by staff entering the shield vault in this case.**

Vault access may be permitted in Test mode when hazards may be present.

Rest of the building is supervised area.

For long periods of shutdown, however, the Shift Leader or L5 may declare the shielding vault to be an Unsupervised Area, provided that a radiation survey has been carried out and accessible dose rates everywhere have been found to be less than 1.5 µSv/h. This means areas where rates above 1.5 µSv/h are clearly marked and chained off (see Section 8.4).

Personnel are prohibited from being in the shield vault during "RUN" mode. The search procedures (section 6) and the Personnel safety system (PSS) ensure that the shield vault remains a "No Entry" area during operation.

[Entry is allowed in Test Modes: see 6.4. - 6.6.]

C.6 Keys and Key switches

Inventory of Keys

Table 2 lists the keys concerned with radiation safety and summarizes their use. Keys HO1, RD1 & RD2 are the primary radiation safety keys; the remainder is for exceptional maintenance use only.

Safe Keeping of Keys

The Keys listed in Table 2, are normally kept in the Radiation Safety Key Press in Control Room and are only issued against the signature of the appropriate user. The key to the radiation key press is normally kept by the L5 and is issued to the Shift Leader against his signature. A Shift Leader may pass on this key to the next Shift Leader (against his signature).

A Duplicate set of keys (HO1, RD1, RD2, TM1 & TM2) are kept in a "duplicate key press", which is supervised by the L5. These keys are labelled "HO1D, RD1D, RD2D, TM1D & TM2D".

For the rest of this document "Key Safe" refers to the main Radiation Safety key safe.

Issue & return of Radiation Safety Keys

The radiation safety keys are taken out by Shift Leaders against their signature. Once issued, the keys and hence the safe operation of HELIOS 2, become the Shift Leader's responsibility. He must keep the keys secure at all times.

The only exception to this rule is the use of keys for PSS maintenance work, which must always be subject of a permit to work in accordance with rule 5.1. Certain Test sequences in PSS maintenance also require the use of duplicate keys. These will only be issued under the PSS Permit to Work procedure.

Keys should be returned to the key press at the end of a day's operation. A Shift Leader may pass keys on to a second SL if two (or more) shifts are in operation in a day. The second SL must then return the keys at the end of the day.

C.7 Permits to Work

Permits to work are formal written forms which authorise specific - potentially hazardous - operations. That is, they aim to impose a level of authorisation and checking on any operations that may place people in danger. The permits should be signed by SSLS L5 and DIRECTOR.

Permit to Work on personnel safety system (PSS)

Any work affecting the PSS may only be carried out under a written permit as reproduced in Appendix 1. The permit must be signed by the Director, who will only issue it if HELIOS 2 is in shutdown Mode. The Microtron must be locked off; the keys GM1 and KM1 must be deposited in the key safe before the work permit is issued. Also, the RF transmitter should be disabled if connected to the RF cavity; its high voltage supply should be earthed and its safety key, labelled "HEL2", should be locked in the Key safe.

Certain Test sequences on the PSS require duplicate keys to be used. If these are issued, they will be recorded on the Permit to Work.

The SL will keep a duplicate copy of the Permit in the HELIOS 2 Key Press as a reminder that work is in progress. When the person carrying out the work has finished, he will thoroughly check his work and sign the permit. The person initiating the work will verify these checks and will then check all PSS functions before signing the permit. See document HG-SA-TP 2/1 for details of the PSS Test Procedure. The Director will then sign the permit and thereby clear for operation mode. The completed permit will be placed in the Work Permit Log.

Permit to Work on HELIOS 2 Vault Walls, Lead Shielding and Stands

Here Vault walls include the concrete bricks inside the beamline apertures & around cryogenic pipes and sealing concrete blocks as well. Lead shielding is surrounding the HELIOS2, microtron and behind the transfer lines if proper. The stands are the lead shielding stands.

At certain times during operation it will be necessary to modify the walls of the HELIOS 2 Shield Vault or re-route the lead shielding & its stands. This work may only be carried out under a written permit as reproduced in Appendix 2. The permit must be signed by SSLS L5 and Director, who will only issue it if HELIOS 2 is in Shutdown Mode.

Any structural modification to the Vault must be reported to the Director before action. To handle lead plates, one should wear an aspired and gloves to avoid direct touch with the skin.

SSLS L5 and the person who carries the work will hold a copy of the permit respectively. The L5 will keep a duplicate copy in the HELIOS 2 Key Press as a reminder that work is in progress as well. When the person carrying out the work has finished, he will check his work and sign the permit. The L5 will verify these checks and will then check the integrity of the shield overall before signing the permit and thereby clear for RUN mode. The completed Permit will be placed in the Work Permit Log.

Permit to Work on the Building Roof or Vault Roof

The SSLS building roof and vault roof are prohibited areas. Staff may only be present on the roofs after a written permit is issued, as reproduced in Appendix 3. This permit must be signed by the L5, who will only issue it if HELIOS 2 is in shutdown Mode.

Any ladder longer than 5m should be locked. Availability is upon the application. See Appendix 3.

The L5 will keep a duplicate copy of the Permit in the HELIOS 2 Key Press as a reminder that work in progress. When work on the roof is complete the person carrying out the work and the person initiating the work will sign the permit to confirm that the roof warning signs are intact and the gates are locked off and all ladders have been removed, returned and locked.

The L5 will then sign the permit, thereby clearing HELIOS 2 for operation. The completed permit will be placed in the HELIOS 2 Work Permit Log.

C.6 Electrical Permit to Work

Whenever it is necessary for work to be carried out on the electrical distribution system or on parts of equipment which cannot be isolated locally, an electrical permit to work must be obtained. In summary, the issuer will only issue a permit after being satisfied that proper safety precautions are being followed. Contact SSLS Electronics designated engineer for the permit.

Permit to Override Electrical Interlocks

Interlocks which are concerned with the electrical safety of high voltage equipment may only be overridden in exceptional circumstances to carry out necessary maintenance or modifications. This work should be carried in accordance with rule 9.4 and only with a Permit to work, as reproduced in Appendix 4, initiated by a responsible person and authorized by the SL.

The person carrying out the work must check it when complete and sign the permit. These checks must be verified by the person initiating the work who will also check the function of all interlocks in that piece of equipment. The SL will then clear the equipment for operation and will also inform the Designated Engineer responsible for the equipment about the work that has been done.

Permit to Work in RF TEST Mode

RF TEST Mode allows access to the shield vault with the RF operational; HELIOS 2 is otherwise disabled from producing radiation by locking off the Microtron. Section 6.4 describes the procedures to be followed in RF Test Mode. A Work Permit- as in Appendix 5 - must be issued by the L5.

The L5 will keep a duplicate copy of the Permit in the HELIOS 2 Key Press as a reminder that work in progress. When "RF Test" work is complete the Work Permit will be closed- as shown on the form, thereby clearing HELIOS 2 for normal operation. The completed permit will be placed in the HELIOS 2 Permit Log.

Permit to Work in Operational TEST Mode

OPERATIONAL TEST Mode allows access to the shield vault with the RF operational; HELIOS 2 is otherwise disabled from producing radiation by locking off the Microtron. Section 6.5 describes the procedures to be followed in OPERATIONAL Test Mode. A Work Permit- as in Appendix 6 - must be issued by the L5.

The L5 will keep a duplicate copy of the Permit in the HELIOS 2 Key Press as a reminder that work in progress. When "OPERATIONAL Test" work is complete the Work Permit will be closed- as shown on the form, thereby clearing HELIOS 2 for normal operation. The completed permit will be placed in the HELIOS 2 Work Permit Log.

C.9 Control of Access to Radiation Areas

Building Roof and Vault Roof

At all times, the vault roof and the Building Roof are prohibited areas, subject to "Permit to work" procedures. Notices shown in Fig. 1 have been displayed on the entrances and around inner perimeter of the roofs. It will not normally be searched before beam operations.

Entering "RUN" Mode

The Shift Leader (SL) is responsible for ensuring that proper procedures are followed, particularly to ensure that the shield vault is searched (as below) to ensure that no persons remain in the shield vault when it is locked for operation.

To enter RUN Mode from Shutdown Mode the SL must work through the following sequence:

a) Ensure no work permits are outstanding.

b) Sign out the following keys from the key safe: HO1, RD1 & RD2 (if the shield area has been left locked).

c) Display his name prominently by the Control Room (e.g. on the "whiteboard").

d) Lock door 2 with key RD2.

e) Insert key HO1 in the ***"Initiate Search" key switch*** labelled "HO1" in the ***PSS box*** by the shield vault door 1 and turn the key.

f) Enter the shield vault by door 1 and search the whole Shield Vault, pressing search buttons 1 to 4 in the sequence **12134**, and walking round inside the inner wall perimeter.

g) Leave the shield vault by door 1 and lock it with keys RD1 and remove the key - within 400 seconds of pressing the final search button.

h) Remove key HO1 from the initiate search key switch.

i) Turn keys RD1, RD2 in the ***PSS key station***. Mode changes to "***STANDBY***"

j) Broadcast the following standard message in English, Mandarin, Malay and Tamil over the loudspeakers within the Shield Vault and in the plant area.

- 'Attention: HELIOS 2 is about to operate.

- If you are inside the Concrete Vault, leave immediately. Push open the door and report to the Control Room.

- In emergency, press the red "Emergency OFF" button.

k) Wait 20 seconds (or more).

l) Turn the key HO1 in the PSS Key station when ready to enter "RUN" mode.

m) Operate HELIOS 2.

Absence of shift Leaders

While in RUN mode, the Shift Leader should normally remain within the SSLS Building and in communication with the control room at all times. For short absences from the building he must temporarily disable the Run Mode by removing key HO1. For longer absences from the building he must terminate the STANDBY Mode by removing keys HO1, RD1 & RD2. This action will require a repeat of the search procedure on his return.

C.10 HELIOS 2 "RF TEST" Mode

Under most circumstances, RF testing should be done while in the RUN Mode. If it is necessary for personnel to have access to the shield vault while the RF cavity is powered, the SL must engage RF Test Mode as follows:

This is a potentially hazardous procedure, because of the hard X-rays that may be emitted by the RF cavity. Thus, a Work Permit is used: see section 5.6. The shield vault is designated a "CONTROLLED AREA" in this mode and a "WRITTEN SYSTEM OF WORK" is required for entry by non-classified radiation workers. The procedure described below is such a "Written system of work".

a) Take out a "RF Test Mode" Work Permit, as in section 5.6.

b) Sign out keys HO1, RD1, RD2 &TM1.

c) Display notices as depicted in Fig. 3(A) at the shield vault entrance.

d) Insert keys in the PSS Key station.

e) Enter the shield vault and search the Shield Vault, pressing search buttons in the correct sequence, as in 6.2. [Use key HO1 to initiate a search, search].

f) Remove key HO1 from the Search Initiate Key switch.

g) Temporarily lock the ring door with keys RD1, RD2- this prevents uncontrolled entry at this stage. Insert keys RD1 & RD2 in the key station.

h) Broadcast the following standard message in English, Mandarin, Malay and Tamil over loudspeakers in the Shield Vault.

- 'Attention: HELIOS 2 is about to operate.
- If you are inside the Concrete Vault, leave immediately. Push open the door and report to the Control Room.
- In emergency, press the red "Emergency OFF" button.

i) Wait 20 seconds.

j) Insert key TM1.

k) Operate RF Transmitter when required.

l) Remove RD1 or RD2 to gain access to the vault.

m) When it is necessary for personnel to enter the vault the SL will unlock the Shield Vault Door and hang a loose chain across the entrance. He will send for the L5 (or an appropriate deputy - normally an appointed shift leader- who will:

- Ensure that only suitably responsible staff is permitted within the Shield Vault and that they are wearing their personal dosimeters.
- Monitor radiation levels at a defined distance from the cavity and record them in the Radiation Protection Logbook.

  [Measurement of Beta-gamma dose rate are sufficient; no neutrons are produced]
- Order any worker to leave the Shield Vault for that shift if, in the L5's estimation, that worker has received a dose of more than 60 µSv or if the dose rate exceeds 100 µSv/h.[Note that the UK "Ionising Radiation Regulations 1985" do not designate the shield vault as "CONTROLLED" if the time-averaged dose-rate is <7.5µSv/h and the total dose received in 8 hrs is no more than 60 µSv. However, we choose to treat the area as a formally controlled area - for added safety]

C.11 HELIOS 2 "OPERATIONAL TEST" Mode

To be described when requirement (for beam lines) is needed.

C.12 "SHUTDOWN" Mode

When in RUN Mode, it is sometimes necessary to re-enter the Shield Vault for making adjustments etc. To do so, the Shift Leader will remove keys HO1, RD1, RD2 from the PSS Key station and use RD1 or RD2 to open the shield vault door. On completion of work within the Shield Vault the Shift Leader may then either: shutdown following the procedures below or, alternatively, reverts to the Run state by working through the actions (d) to (m) of paragraph 6.2.

The SL must keep a hand-held beta-gamma dosimeter with him during his stay in the shield vault. If any significant dose-rates are detected (e.g. above 7.5 μSv/h), the aim should be to stay in the vicinity for as short a time as possible.

On completion of a run in RUN Mode (or HELIOS 2 RF Test Mode or OPERATIONAL Test Mode) the Shift Leader will:

a) Remove keys HO1, RD1, RD2 (or if in RF Test Mode TM1 or TM2) from the PSS key station.

b) Check that a Display notice as indicated in Fig. 2 is posted at the shield vault Entrance.

c) Return key HO1 (if RF Test Mode TM1) to the key safe. Also return keys RD1, RD2 or do the following steps:

Steps needed if vault is to be left open.

d) Use key RD1 or RD2 to open the Ring Labyrinth door (or Ring door shortly named).

e) If the Microtron has been operational with beam the SL (or L5) will carry out a radiation survey in accordance with rule 8.4.

f) If there is a need for general access to enter the Shield Vault the SL (or the L5) must carry out a radiation survey in accordance with rule 8.4. If no dose rate exceeding 1.5 μSv/h is found or if barriers can be placed such that the accessible dose rate is less than 1.5 μSv/h, replace Fig. 2 notice at the shield vault entrance with Fig. 4 notice.

C.13 Log Books

The following logbooks will be maintained as part of the HELIOS 2 operational safety procedures.

Operational Logs

The shift leaders for HELIOS 2 operation have the responsibility to maintain logbooks, during every operational shift.

These operation logs record when the shield vaults are made secure (PSS operational), when beam is on, beam current, energy etc.

Radiation Dose Levels

The SSLS L5 has the responsibility of maintaining two sets of records:

a record of personnel dosimeter readings and a record of environmental radiation surveys (by SSLS L5).

Key Press Log

This Log is to be kept by Key Press. It records:

a) Issue and return of radiation safety keys HO1, RD1 & RD2.

b) Issue and return of test mode keys TM1 & TM2.

Issue of any special electrical maintenance keys (e.g. for RF cabinets) - to be designated as required.

Date, time and name of Shift Leader.

Permit to Work Log

This loose leaf binder, to be kept on or near the HELIOS 2 Control room, will archive all Permits to Work, as issued and completed under rules 5.1., 5.2., 5.3., 5.5. and 5.6. Note that a separate "Electrical Permit to Work" log (see section 5.4.) is kept by Electronics designated engineer.

C.14 Operational Cycles and Radiation Monitoring

Radiation Monitoring dosimeters are listed in Table 3.

Radiation Monitoring

A pre-defined limit on the beam current of the Microtron is set at the commencement of operation. This "Maximum Average Current" (MAC) limit is intended to ensure that radiation doses are limited until it has been verified (by monitoring) that the shielding is adequate. It is expected the Microtron will be able to operate at its full specified beam currents, once the shielding has been checked. The MACs are set by the SSLS L5 and must be enforced by the Shift Leaders.

Definition of "MAC": Maximum Average Current

This is the microtron extracted beam current at 100 MeV which gives an instantaneous dose-rate of no more than 1.5 µSv/h outside the shield vault. In the case of the Microtron the repetition rate and pulse-length are variable; the effective current is the product of all three. The MAC is defined for 10 Hz repetition-rate and 100 ns pulse length. If the repetition rate is reduced by half, the beam current may exceed the MAC by two times, etc.

The SL may exceed the MAC by a factor of up to 6 for short periods (this could give a dose-rate of 9 µSv/h), provided the average beam current in any hour does not exceed the MAC and the total dose in any hour does not exceed 1.5 µSv. The SSLS L5 must also ensure that the total dose in any 7 consecutive days does not exceed 20 µSv above background, e.g., by keeping an electronic dosimeter permanently powered "on" in the accessible spot with the highest rate.

Every time the operation of HELIOS 2 is changed in a manner which might cause more radiation outside the shield (e.g. more beam power, different shield arrangement etc) the SSLS L5 will make a Radiation Survey outside the vault. This survey, which will be made with the Microtron running at its "MAC" will separately measure Beta-gamma and fast neutron dose rates at a variety of monitoring points.

The SSLS L5 will verify that the dose-rates outside the shielding walls are everywhere less than 1.5 µSv/h above background. Comparisons of these measurements will also be made with the predictions of shielding calculations. If significant discrepancies are found which could expose personnel to excessive dose rates, the SSLS L5 will set a new lower MAC. He will then confer with the Director or OSHE or DRP about the steps which should be taken to improve the shield efficiency or ensure that appropriate operating procedures are followed.

The dosimeters for radiation dose monitoring are listed in Table 3 and TLD are distributed as shown in Table 4 & Fig. 7.

Personal Dosimeters

Staff must always wear their radiation dose badges (TLD dosimeters included) when in a Supervised Area.

Induced Activation: Shield Vault Supervised

In accordance with rule 6.6 the SL (or L5) will make a survey of potentially activated components whenever Shutdown Mode is entered after a period of Microtron operation. The survey will measure dose rate at the surface of the components and will be recorded in the Radiation Protection Log Book for dose-rates above 1.5 µSv/h. Depending on the result, the L5 will:

For surface dose rates above 7.5 µSv/h, erect a barrier around the component such that dose rates at the barrier are less than 1.5 µSv/h; attach notices to the component and the barrier as depicted in Fig. 5 (A).

For surface dose rates above 1.5 µSv/h but less than 7.5 µSv/h, attach a label to the component as shown in Fig. 5 (B).

Induced Activation: Shield Vault Unsupervised

In accordance with rule 6.6, the Shift Leader may decide that there is a need for the Shield Vault to be declared an Unrestricted Area. He should inform the L5, who will measure Beta-gamma dose rates and record them in the Radiation Protection Log Book. If dose rates everywhere are less than 1.5 µSv/h or if local barriers have been erected such that dose rates at the barriers are less than 1.5 µSv/h, the Shift Leader may declare the Shield Vault to be an Unsupervised Area and display the notice depicted in Fig. 4 at the Labyrinth Entrances. Where local barriers are used, they must carry a notice as depicted in Fig. 5 (A).

Dismantling of Activated Components

After any beam operation of HELIOS 2, whenever it is necessary to dismantle any component in the electron beam path (HELIOS 2), particularly within the vacuum vessel, the L5 must be informed and normally staff from OSHE will be called in. The L5 will measure beta-gamma surface dose rates at suitable stages of the dismantling process and will take the following actions:

For components with a surface dose rate >7.5 μSv/h, erect a barrier around the component such that dose rate at the barrier is less than 1.5 μSv/h; attach labels to the barrier and component as shown in Fig. 5. The L5 will then work out a strategy for completing the dismantling work without subjecting personnel to excessive radiation dose.

For components with a surface dose rate of >1.5 μSv/h but <7.5 μSv/h, the L5 will attach a label to the component as shown in Fig. 5 (B) and will continue to monitor the dismantling process closely.

For components with a surface dose rate of >0.1 μSv/h but <1.5 μSv/h, the L5 will attach a label as shown in Fig. 5 (C). He will keep an ongoing record of the activated component store inside the Shielding Vault and will take steps to ensure that no welding or machining operations are performed on it. If it is necessary to dispose of the item, he will consult with the Director.

For components with a surface dose rate of <0.1 μSv/h, no special procedures for movement or disposal are needed.

New beamline

Before commencement of new beamline coming into use, radiation dose survey should be carried out. For its components, an instantaneous dose-rate from the surface is no more than 1.5 μSv/h. The beamline can be claimed to be radiation secure.

Visitors & Contact Workers

Unless they have personnel dosimeters, they should not normally enter Supervised areas. That is, they should not enter the shield vault unless it has been declared an "Unsupervised area", according to section 8.4. In special circumstances, when it is necessary for them to enter the shield vault when it is a Supervised area, the Shift Leader or L5 should accompany them - carrying a Beta-gamma dosimeter. The SL/L5 must ensure that the visitor(s) is not exposed to a radiation dose rate above 1.5 μSv/h.

Safety Rules for Visitors and Contract Workers to enter the Building can be found in Safety-6. Corresponding signs are shown in Fig. 6.

Annual radiation inspection

Radiation dose level should be checked and inspected annually. Date and duration should be selected after discussion with operation team and the Direction. Usually the event should occur after end of a year, before new operation season begins.

C.15 Electrical Safety Procedures

C.15.1 Very Low Voltage

No special procedures are needed for working on equipment in which voltages do not exceed 30 V.

C.15.2 Isolation

Equipment containing voltages in excess of 30 V should normally be isolated before it is worked on. Isolation should either be via a local isolator if available or by obtaining a Permit to Work and locking out part of the distribution system in accordance with rule 5.4.

C.15.3 Working on Live Equipment

If exceptional circumstances make it necessary for equipment to be worked on live, this should only be done by qualified personnel, who are fully aware of the hazards involved. They must never leave live equipment unattended.

High Voltages

If equipment containing voltages (referred to ground) in excess of 280 V must be worked on live, two qualified persons who are fully aware of the hazards involved must be in attendance at all times. The immediate area should be cordoned off. The live equipment must never be left unattended.

C.15.4. Interlocks on High Voltage Equipment

Interlocks which are concerned with the electrical safety of high voltage equipment may only be overridden in exceptional circumstances for limited periods of time to carry out essential maintenance or modifications. The following procedures should be applied.

a) Work may only be carried out with a Permit to Work, as described in rule 5.5 and presented in Appendix 4. The Shift Leader or Duty Supervisor (if designated) must authorize the Permit, but only after items 'b' & 'c' (below) have been satisfied.

b) The person carrying out the work must submit a written description of the work to be done. This must include an assessment of the hazards involved and plans for safety precautions, e.g. temporary insulating screens.

c) The person carrying out the work should be qualified to do so and well versed in the hazards involved.

d) He must cordon off the area immediately around the equipment and ensure that two people are always in attendance when the equipment is live with interlocks overridden.

e) When the work is complete, the person carrying it out must thoroughly check that all interlocks function correctly.

f) These interlock checks must be certified by the Shift leader or Duty Supervisor (if designated), who authorized the work.

C.15.5 Capacitors

Any capacitor with an energy storage capability of greater than 10 joules must have its terminals shorted before being removed from the equipment in which it is housed.

C.15.6 RF Power Feeds

High power RF feeds (wave-guide/coax) to HELIOS 2 must not be tampered with; a risk of severe burns may occur.

C.15.7 Modifications

No modification affecting the PSS or electrical safety function of any piece of equipment may be made without informing the person responsible for that item of equipment.

C.16 Contingency Plan

The appointed Shift Leader is responsible for executing the following contingency plans.

C.16.1 Fire in RUN Mode

If there is an outbreak of fire* when in RUN Mode, the Shift Leader should:

a) Shut down HELIOS 2 and remove key HO1 from the PSS key station.

b) Press EMERGENCY OFF button.

c) Sound the alarm; break glass on nearest alarm.

d) Dial "61616" and inform the NUS security - in normal working hours.

Or, Call the Fire Brigade (9-995) or Police (9-999) - out of normal hours.

e) Evacuate the area.

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* One needs to check if it is false fire alarm when inside vault (zone 5 & 6, MIMIC panel near Ring Exit 2) is in alarm:

1) hold toggle up (FM 200 gas control panel);

2) another person goes into the vault to check the case;

3) if there is a real fire, release the gas to put the fire out; if there is none, go to the waiting area and reset the system (another panel in waiting area);

Report to **6874 2368** (main response desk) - office hours Mon - Fri: 8.30am - 6.00pm or **6874 1616** / inside the NUS campus **61616** (campus security) - other time.

f) Make a judgement as to whether the fire can safely be brought under control using local extinguishers and take steps accordingly to either fight the fire or leave the area.

g) Liaise with the Building Fire wardens in checking that the area has been evacuated.

h) Meet the Fire Brigade and assist as necessary, specifically by interlocking the labyrinth doors if required.

i) Keep the labyrinth doors locked until arrival of Fire Brigade (nobody is inside, entry could lead to asphyxiation)

[Note document, Chubb FM-200 TM Gamma Series Systems, describes the FM-200 TM fire protection system: this may be active to protect the shield vault when it is empty and locked]

C.16.2 Fire in Shutdown Mode

If there is an outbreak of fire during Shutdown Mode, the Shift Leader or Duty Supervisor (if designated) should:

a) Press EMERGENCY OFF button.

b) Sound the alarm; break glass on nearest fire alarm.

c) Broadcast an alarm over loudspeakers within the Shield Vault.

d) Dial "61616" and inform the NUS security

- in normal working hours.
- Or, Call the Fire Brigade (9-995) or Police (9-999) - out of normal hours.

e) If it is safe to do so, check whether anyone is inside the Shield Vault and get him out.

f) Evacuate the area.

g) Make a judgment as to whether the fire can safely be brought under control using local extinguishers and take steps accordingly to either fight the fire or leave the Area.

h) Liaise with the Building Fire Wardens in checking that the area has been evacuated.

i) Meet the Fire Brigade and assist as necessary.

C.16.3 Electric Shock

If anyone receives an electric shock, the first person at the scene should:

a) Press EMERGENCY OFF button and/or local isolator.

b) Remove person from live components.

c) If necessary, apply resuscitation procedures as described on the resuscitation 'snatchcard'.

d) Get a colleague to call an ambulance (9-995) and inform the Shift Leader.

C.16.4 Person within the Shield Vault

Any person who is accidentally within the Shield Vault after the Search has been completed should, on hearing the warning message or seeing the warning lights, immediately walk towards the labyrinth exit and press "EMERGENCY OFF" button, leave the Shield Vault via the Labyrinth door and report to the Control Room.

C.16.5 Person on Vault Roof

Any person who is accidentally on the Vault roof after the search has been completed should, on hearing the warning message, leave immediately and report to the Control Room.

C.16.6 Radiation Incident

In an unlikely event of a person being accidentally irradiated by being inside the Shield Vault while HELIOS 2 is operating, the Shift Leader should:

a) Shut down HELIOS 2.

b) Endeavour to ascertain the length of time that the person was irradiated and his location during irradiation.

c) If the person has sustained physical injury that requires treatment, take him/her to Emergency Department at the National University Hospital, 5 Lower Kent Ridge Road, Singapore 119074, Tel. 6772 5000 (or 6779 5555 in general). This action should have priority over any longer term treatment for radiation exposure.

d) Preferably in consultation with the Director, & SSLS L5 if practical, make an estimation of the dose received.

e) Contact the OSHE, Office of Safety, Health and Environment, NUS

Office of Safety, Health and Environment, NUS		
Telephone		651 66863
Fax		677 86031
WWW	http://www.nus.edu.sg/osh/	
Postal Address	8 Kent Ridge Drive, #03-02, Singapore 119246	
Director	Dr Peck Thian Guan oshhead@nus.edu.sg	651 65961
SSLS Liaison Officer Safety & Health Manager	Mr Jedison Ong oshoca@nus.edu.sg	651 65955

f) Ask the Radiation Physicists for advice on how to proceed.

g) Ensure that the person's film badge is kept safe and is processed as quickly as possible.

h) Inform the Director if necessary, after assessing the situation.

C.16.7 Bursting Discs

If any cryostat bursting disc ruptures, personnel must leave the Shield Vault as quickly as possible and inform the Shift Leader.

C.16.8 First Aid Boxes

First Aid boxes are on the shelves in the pantry, SINS beamline and near Engineer Room.

Table 1 Designation of Areas

Area	Mode	Designation
Shield Vault	Shutdown	Unsupervised
	Search	No Entry
	Standby	No Entry
	Run	No Entry Controlled
	HELIOS 2 RF Test	No Entry Controlled
	Operational Test	Unsupervised
Vault Roof and Building Roof	Shutdown	Prohibited*
	Run	Prohibited
	Standby	Prohibited
	HELIOS 2 RF Test	Prohibited
Rest of building	All Modes	supervised

Note"*" the vault roof is normally prohibited access. But, during SHUTDOWN access maybe permitted ("unrestricted" access) - but a work permit is needed before access.

Table 2 List of Keys for access control

PERSONNEL SAFETY SYSTEM

Key Number/ Name	Function	Location in OPERATIONAL Modes	Location in SHUTDOWN mode
RD1 **Ring Door 1**	Key for door 1	PSS Key station	Key safe/Ring Door 1
RD2 **Ring Door 2**	Key for door 2	PSS Key station	Key safe/ Ring Door 2
HO1 **Run Enable**	Initiates search/Permits Operation, provided interlocks OK	PSS Key station	Key safe
TM1 **HELIOS 2 RF test**	Permits opening of shield vault door for RF Test	PSS Key station	Key Safe
RF HEL 2 **RF HV Grounding key**	Enable/Disable RF, HV	RF HV Supply	RF HV Supply
TM2 **OPERATIONAL test**	Permits vault Access with beam	PSS Key station	Key Safe

MICROTRON

Key Number/ Name	Function	Location in OPERATIONAL Modes	Location in SHUTDOWN mode
Microtron Grid mod. & Klystron mod. GM1 & KM1	Enables/Disable Microtron	In Microtron Racks	Key safe (essential for some Work Permits) or Klystron cabinets (normal shutdown)

BEAM LINES

Key Number/ Name	Function	Location in OPERATIONAL Modes	Location in SHUTDOWN mode
BK1	Shut down all beam lines	PSS Key station	Key safe or Held by SL

BUILDING KEYS

Key Number/ Name	Function	Location in OPERATIONAL Modes	Location in SHUTDOWN mode
Key 01 for ladder outside Building	Permits access to Building roof	Key safe	Key safe
Key 02 for access to Vault roof	Permits access to vault roof	Key safe	Key safe

Note: (1) Issued to shift Leader, when necessary, e.g. if needed for early morning shift.

(2) For other building keys, contact with SSLS secretary for the KEY BOX near the office 4.

TABLE 3 Radiation monitoring instruments

Model & (Number)	Name	Detector	Manufacturer
N91 (1)	Neutron Survey Meter	3He Proportional Counter	Harwell Instruments, UK
E600/NRD	Neutron Survey Meter	BF3 Proportional Counter	Eberline Instruments, USA
E600/SHP-400	Gamma Detector	Smart Ion Chamber	Eberline Instruments, USA
900X (1)	Geiger Mueller Counter	Geiger Mueller Tube ZP1481M	Mini Instruments, UK
900 type42B (1)	900 Scintillation Monitor	Sodium iodide crystal	Mini Instruments, UK
900D (1)	Geiger Mueller Monitor	Geiger Mueller Tube	Mini Instruments, UK
TLD600 &TLD700 (20 sets)	Thermal Luminescent Dosimeters	LiF	Harshaw/Bicron, Germany
RAD-50S (3 sets)	Digital Pocket Alarm Dosimeter	Silicon diode with energy-compensating filter	RADOS Technology Oy Turku, Finland
FH 40 G-L (2 sets)	Dose Rate Measuring Unit	Proportional Counter	Thermo-Eberline ESM

This list includes all the instruments specified by Daresbury Laboratory Health Physics Report 98/208 “Radiation Safety Assessment of the Helios II Accelerator at the National University of Singapore" (attached).

APPENDIX D Permit to work on HELIOS 2 personnel safety system (PSS) (in the separate file)

APPENDIX E Permit to work on HELIOS 2 vault walls/lead shielding/stands (in the separate file)

APPENDIX F Permit to work on SSLS building roof or vault roof and using ladders (in the separate file)

APPENDIX G Permit to override electrical interlocks (in the separate file)

APPENDIX H Permit to operate HELIOS 2 in RF test mod (in the separate file)

APPENDIX I Permit to operate HELIOS 2 IN OPERATIONAL test mode (in the separate file)

APPENDIX J Labels and notices used at SSLS

DANGER

PROHIBITED AREA

RADIATION HAZARD when Synchrotron is in operation.

Do not walk on this roof without a written Permit to Work

Fig. 1a Permanent Notices for the entrance of roofs.

RESTRICTED AREA

NO

ACCESS

WITHOUT PERMIT

Fig. 1b Permanent Notices for inner perimeter of shield vault roof.

The coloured light boxes display the current mode of HELIOS 2:

(a) If HELIOS 2 is in "**RUN"** Mode

PROHIBITED AREA - NO ENTRY <u>RADIATION HAZARD</u>

(b) If HELIOS 2 is in "**Shutdown**" Mode or "**Search**" mode or "**Standby**" mode

SUPERVISED AREA **Possible radiation hazard from activated components** **Do not enter unless**: a) you are wearing your personal dosimeter (radiation badge) and b) indicator light shows "**Shutdown**" [Shift Leader - as posted at the Control Room - authorisation needed]

Fig. 2 Notices for use on vault door

HELIOS 2 in RF Test Mode

CONTROLLED AREA
Do not enter unless:
a) authorized by a "RF Test" Work Permit
b) You are wearing a personal dosimeter (radiation badge)
and c) the RADIATION SAFETY OFFICER or deputy (Shift Leader) is present with a hand-held beta-gamma radiation dosimeter.

HELIOS 2 in OPERATIONAL Test Mode

CONTROLLED AREA
Do not enter unless:
a) authorized by a " OPERATIONAL Test " Work Permit
b) You are wearing a personal dosimeter (radiation badge)
and c) the RADIATION SAFETY OFFICER or deputy (Shift Leader) is present with a hand-held beta-gamma radiation dosimeter.

Fig. 3 Notice for RF Test Mode/ OPERATIONAL Test Mode - at vault Entrance

HELIOS 2 in Shutdown Mode

No Radiation Hazard in Vault

UNRESTRICTED ACCESS
at Vault Entrance after Radiation Survey Clearance.

Fig. 4 Notices for use in Shutdown Mode- for unrestricted access.

WARNING

Induced activation of component ____________________________

is producing a surface radiation dose rate of ______________ µSv/h.

Do not pass barrier without permission of RADIATION SAFETY OFFICER.

DO NOT REMOVE THIS LABEL

(A) On barrier and components - with surface dose rate > 7.5 µSv/h

WARNING

Induced activation of this component is producing a surface radiation dose rate of ________________ µSv/h.

Do not remain in proximity for longer than necessary.

Do not remove component from vault without permission of the RADIATION SAFETY OFFICER. Do not weld or machine this component.

DO NOT REMOVE THIS LABEL

(B) On components with surface dose rate >1.5 µSv/h, but <7.5 µSv/h.

WARNING

Mild activation of this component is producing a surface radiation dose rate of __________________ µSv/h.

It may be removed from the vault but must not be machined or welded.

It must not be disposed of without permission from the RADIATION SAFETY OFFICER.

DO NOT REMOVE THIS LABEL

(C) On components with surface dose rate > 0.1 µSv/h, but < 1.5 µSv/h.

Fig. 5 Notices for use with activated components

RESTRICTED AREA **Door to Be Locked at All Times.** **For Entry, Call: 9838 7292 (HP)** **Or Use Intercom (at Exit 2)** Visitors Sign on Entry and Be Accompanied. Contract Workers Read Safety Rules.

(A)

LADDER ACCESS TO VAULT ROOF PROHIBITED WITHOUT PERMIT Contact Control Room

(B)

Fig. 6 Notices for Entrance (Exit 2, 4) of the Building (A) and on vault wall (B)

APPENDIX K Location of Thermo-Luminescence Dosimeters

TABLE Preliminary check-points for TLD in May 2000.

No.	Location	Height [m]
1	Waiting area (outside vault near the concrete block)	1.2
1’	Waiting area (outside vault near the concrete block)	0.6 or 1.75
2	Waiting area (outside vault near the concrete block)	1.2
2’	Waiting area (outside vault near the concrete block)	0.6 or 1.75
3	Waiting area (outside vault near the concrete block)	1.2
3’	Waiting area (outside vault near the concrete block)	0.6 or 1.75
4	Behind transfer line C (outside vault near wall)	1.2
4’	Behind transfer line C (outside vault near wall)	0.6 or 1.75
5	Near microtron (outside vault near wall)	1.2
5’	Near microtron (outside vault near wall)	0.6 or 1.75
6	Outside exit 1 (near the door)	1.2
6’	Outside exit 1 (above head near the door)	2.5
7	Outside exit 2 near door (behind transfer line D)	1.2
7’	Outside exit 2 near door (behind transfer line D)	0.6 or 1.75
8	Outside the vault in Lab. 3	1.2
8’	Outside the vault in Lab. 3 or outside the Offices (on the desk of Fax machine)	0.6 or 1.75
9	Outside the vault in Lab. 3	1.2
9’	Outside the vault in Lab. 3	0.6 or 1.75
10	Cryogenic plant (on the plate-form)	0.6 or 1.75
10’	Control room (outside the window)	3.0
21	Spared	

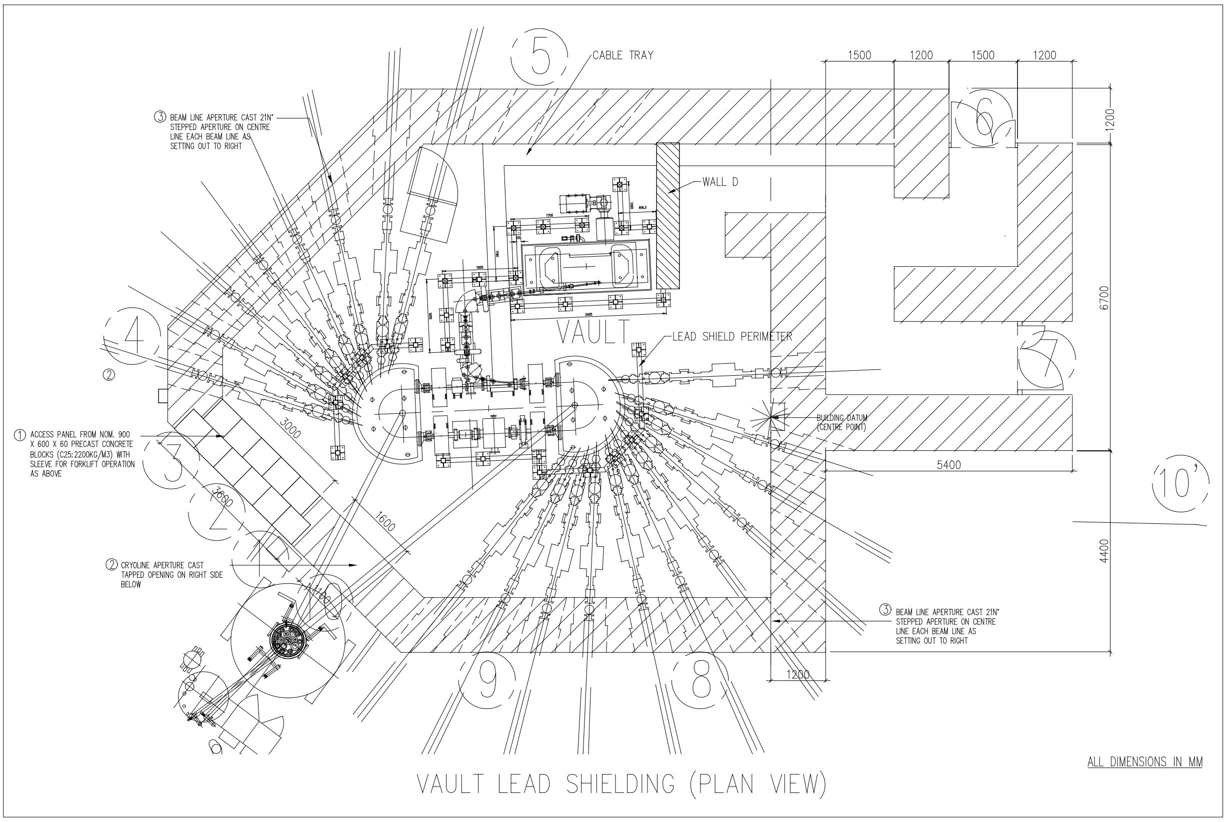

Fig. 7 Plan of the vault, lead shielding & distribution of TLD

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