Office of Safety, Health and Environment

NUS LABORATORY

LASER SAFETY MANUAL

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Approved by	:	Mr. Saravanan s/o Gunaratnam

Amendment

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00	24 Feb 2012	New manual	Pramoth
01	24 Mar 2015	1. Section 3.2 Revised from NUS Radiation Safety Policy to NUS General Safety and Health Policy 2. Revision of Centre for Radiation Protection and Nuclear Science to Radiation Protection and Nuclear Science Department 3. Revision of contact phone number for UHC in Section 16.2	Pramoth

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1 INTRODUCTION

Research and Development at National University of Singapore (NUS) involves extensive use of different types of laser sources. This Laser Safety manual is intended to provide guidance for establishing safe work procedures and prudent practices that will improve safety while using laser producing equipment. This manual forms a part of the Radiation Safety Program (RSP) administered by Office of Safety, Health and Environment (OSHE) to ensure safe use of radiation at NUS. The program ensures that any activity involving use of radiation is conducted in a manner as to protect and minimize one's risks to health, safety and property.

This Manual should be used in conjunction with other laboratory safety manuals, i.e.:

- **NUS General Laboratory Safety Manual** – provides safety and health requirements on issues common to all laboratories, for example, commissioning and decommissioning of laboratory, laboratory sign posting, personal protective equipment, first aid, contractors management, etc.

- **NUS Laboratory Chemical Safety Manual** – provides safety and health requirements for working with chemical substances, such as flammable materials, toxic chemicals, acids and base, peroxides, poisons, etc.

- **NUS Laboratory Biosafety Management Manual** – provides safety and health requirements for working with materials of biological origin, including genetically modified organisms (GMOs) in laboratories.

All personnel involved in laser radiation work are required to read and understand the content of this manual before they start work. They should be sufficiently trained and be equipped with the necessary knowledge, skill and techniques to prevent or minimize conditions that threaten the safety and health of his/her own and others in the vicinity. The possession and use of certain laser producing equipment are subjected to licensing, Staff and students must ensure that they are licensed/ authorized to work with such equipment or be adequately supervised while working with such equipment.

2 UNDERSTANDING LASER RADIATION HAZARD

The modification of Ultraviolet, Visible and Infrared radiation to produce a coherent (photons oscillating in phase) and mono chromatic (photons with single wavelength) beam results in what is termed as Laser radiation. The laser radiation have very high energy density (energy/unit cross sectional area of the beam) compared to normal electromagnetic radiation. Laser radiation needs unique attention because there are unique hazards associated with working with such high energy density beams.

The different wavelengths of the Ultraviolet, Visible and Infrared radiation groups are provided below.

Table 1: Wavelengths corresponding to various types of electromagnetic radiation

Source	Wavelength
Ultraviolet	100–400 nm
Visible light	400–780 nm
Infrared	780 nm – 1 mm

3 LASER SAFETY PROGRAM ADMINISTRATION

3.1 APPLICABLE LEGISLATION ON LASER RADIATION

The Radiation Protection and Nuclear Science Department (RPNSD), part of National Environment Agency, is the national authority for radiation protection and nuclear safety in Singapore. It administers and enforces the Radiation Protection Act and Regulations through a system of licensing, notification, authorization, inspection, and enforcement. For more information, visit http://app2.nea.gov.sg/topics_radiation.aspx. Radiation Protection (Non Ionising Radiation) Regulations, regulates the manufacture, possession, use and disposal of all laser sources.

The classification of lasers into different groups based on the energy levels is provided in Second Schedule of the Radiation Protection (Non Ionising Radiation) Regulations (see Appendix A). Lasers classified as Class 3b and Class 4 according to this scheduled are termed as high power lasers. (Please refer to Section 10 for more information on laser classification)

Accessible Emission Levels for different classes of lasers are provided in the Second Schedule of the Radiation Protection (Non Ionising Radiation) Regulations (see Appendix A).

Exposure limits for skin and eyes to laser radiation and to Ultraviolet radiation is provided in the Third Schedule of the Radiation Protection (Non Ionising Radiation) Regulations (see Appendix B and C).

The standard labels that need to be used with laser machines are specified in the Fourth Schedule of the Radiation Protection (Non Ionising Radiation) Regulations (see Appendix D).

3.2 NUS GENERAL SAFETY AND HEALTH POLICY

The NUS Senior Management has defined the NUS General Safety & Health Policy that formally expresses NUS's commitment to ensuring a high standard of occupational safety and health for its staff, students, visitors and contractors. The policy emphasizes safety ownership and establishment of safety and health culture. The policy also provides the responsibilities of various stakeholders in ensuring a safe working environment. Staff and students must comply with the requirements of this policy. The policy can be accessed through the following link:

http://www.nus.edu.sg/osh/policies.htm

3.3 NUS SAFETY DIRECTIVES

The NUS Safety Directives provide safety and health governance on specific issues. Refer to the following website for the Directives:

http://www.nus.edu.sg/osh/policies.htm

The Institutional Laboratory Safety Committee (ILSC) is the University level committee to oversee the development and implementation of the Radiation Safety Program. The Office of Safety, Health and Environment (OSHE) is the administrator of this Program.

3.4 ROLES AND RESPONSIBILITIES

3.4.1 NUS PRESIDENT

The President of the NUS represents the University as the Employer. The ultimate responsibility for safety and health in the University rests with the President. The President may delegate the authority and responsibility to the ILSC, Deans, Administrators, and HODs for the effective supervision of the occupational safety and health of staff and students under his/ her management.

The ILSC and OSHE can report any incident or conditions of non-compliance to the NUS President, Senior Deputy President, Provost, Deputy Presidents and Vice Presidents, who are entitled to partially or fully close the laboratories or facilities until all safety issues are addressed.

3.4.2 NUS INSTITUTIONAL LABORATORY SAFETY COMMITTEES (ILSC)

Institutional Laboratory Safety Committee (ILSC) has been formed to serve as an advisory to review standards and guidance documents related to general laboratory safety at the university level.

The ILSC is appointed by the Provost. The Terms of Reference for the ILSC are:

i. Review and approve the NUS Radiation Safety and Chemical Safety Program documents including safety manuals, Standard Operating Procedures (SOPs) and directives and recommend revisions to OSHE.

ii. Review any radiation safety audit and inspection findings conducted by OSHE or other independent parties on faculties and departments.

iii. Serve in an advisory capacity to OSHE on all chemical, radiation and physical safety related matters pertaining to laboratories.

iv. To endorse risk assessments that cannot be effectively evaluated at the departmental or faculty level, including appeals by PIs.

The Committee will be assisted by the Occupational Safety and Health Management Division of OSHE.

3.4.3 DEANS AND HEAD OF DEPARTMENTS

All Deans and HODs of respective lab-based faculties and departments will ensure that their respective faculty or departmental radiation SOPs, standards and guidance documents as well as components of the Radiation Safety Program implemented at departmental and faculty level are in order and reviewed periodically. Deans or HODs should empower Faculty Safety & Health Officers and personnel appointed to assume safety responsibilities (herein called the "Departmental Safety Committee"), to coordinate the NUS Radiation Safety Programme at the faculty and departmental level.

3.4.4 PRINCIPAL INVESTIGATOR AND/OR EQUIPMENT OWNER

Principal Investigators and/or laser equipment owners are directly responsible for compliance with all regulations governing laser safety in the laboratory, and for safety of individuals working under their supervision. Principal Investigators (PI) are obligated to:

- Be aware of and comply with requirements (regulatory and University) pertaining to the use of laser sources and also establish and maintain a safe working environment.
- Notify Faculty Safety and Health Officer prior to purchase and use of any laser producing equipment.
- Ensure all required laser radiation licenses exist and are current before any work with laser radiation is commenced. Ensure that all the high power laser users in the group have valid radiation licenses. Maintain relevant license records
- Notify Faculty Safety and Health Officer of any changes in license application information including addition or termination of laser radiation workers, or changes of locations where high power laser equipment are used or stored.
- Perform a risk assessment of experiments and protocols involving use of laser producing equipment. Identify risks, evaluate existing risk controls, ensure existing risk levels are

acceptable and also identify and implement any additional controls required to minimize risk.

- Ensure that all individuals have completed relevant OSHE laser safety trainings before any work with laser radiation is commenced. Maintain relevant records.
- Ensure that individuals are properly supervised and trained on laboratory specific safe work practices. Ensure workers are aware of and trained on all relevant safety documents (SOPs, manuals etc.,). Ensure all individuals are aware of procedures for identifying emergency situations and following emergency response protocols.
- Post appropriate warnings and labels as required by this manual to ensure adequate communication of laser radiation hazards.
- Ensure all individuals (including visitors and maintenance personnel) are sufficiently informed of the risks and hazards present in the lab and are warned of radiation hazards in the laboratory and follow applicable safety rules.
- Ensure that all high power laser users have completed relevant OSHE safety training before any laser work is commenced. Also, ensure that individuals are properly supervised and trained on laboratory specific safe work practices. Maintain relevant training records.
- Ensure all laser equipment are stored and used in a manner that minimizes exposure to themselves and other individuals.
- Implement controls to ensure all high power laser equipment are accessed and used only by individuals licensed to access/use them.
- Ensure necessary resources needed to ensure good safety practices and adequate infrastructures for the safe operation of the lab are available.
- Ensure all high power laser equipment are transferred/disposed before vacating any lab. PI should maintain any relevant records for review.
- Report all incidents/accidents related to laser radiation work involving real or suspected increased exposure to radiation during use of laser equipment. PIs should cooperate with any incident investigation by regulators and OSHE.

3.4.5 FACULTY SAFETY & HEALTH OFFICER

Faculty Safety and Health Officer (FSHO) are responsible for verifying PIs compliance with NUS Radiation Safety program and directives. FSHO are obligated to:

- Ensure that all high power laser radiation equipment used in the Faculty have the appropriate radiation licenses.
- Ensure laser hazard evaluation is performed on all high power laser producing equipment.

- Maintain a database of all radiation licenses pertaining to possession and use of high power laser producing equipment in the Faculty
- Serve as intermediary in communication between regulators and license holders on license applications, amendments, renewals and cancellations.
- Ensure all PIs properly dispose or transfer any high power laser producing equipment.
- Inform all incidents reported by PI to Radiation Safety Officer and help in incident investigation process.
- Maintain records related to internal safety inspections, incident investigation and all licenses for radiation use

3.4.6 LASER RADIATION WORKERS

All individuals working directly with high power laser producing equipment are termed as laser radiation workers. Since the workers themselves are the direct handlers of the equipment, they have an important role in ensuring safety and compliance. For this reason, it is critical that they be aware of the risks, safe practices and requirements for use of laser sources.

Laser radiation workers are obligated to:

- Comply with this Laser Safety Manual, regulatory requirements, as well as other University, Faculty and departmental specific safety manuals and SOPs.
- Adhere to all risk controls identified and implemented by the PIs.
- Respect all engineering and administrative controls implemented for use of high power lasers.
- Obtain user license from regulators prior to working with high power lasers.
- Successfully complete relevant OSHE safety training prior to working with high power lasers.
- Report immediately any real or suspected elevated exposure to laser, laser equipment failure or any other accidents/incidents to Principal Investigator.

3.4.7 RADIATION SAFETY OFFICER (RSO)

The Radiation Safety Officer is responsible for implementing the Radiation Safety Program established by OSHE. The RSO has been provided with the administrative authority by the ILSC to enforce the radiation protection activities at NUS. RSO has the authority to temporarily suspend an unsafe activities involving radiation deemed to be unsafe subject to review by the safety committee. Duties of the Radiation Safety Officer include (but not limited to)

- Develop and implement safety manual, procedures and directives subject to the approval by ILSC.

- Liaise with regulatory agencies, faculties and departments in the ongoing implementation of the University's Radiation Safety Program.
- Perform laser hazard evaluation on all high power laser equipment to verify the laser equipment classification and evaluate the adequacy of engineering controls. Provide recommendations on licensing requirements/exemptions, modifications in engineering controls and the required safety eyewear.
- Restrict or suspend use and/or possession of laser equipment whenever a significant deviation from established regulatory and university requirements has occurred or when there is threat to health or property.
- Perform annual laser safety inspection in all labs using laser producing equipment and report any non-compliance to the PIs and ILSC.
- Perform an investigation of all incidents/accidents related to laser radiation work at NUS and submit investigation reports, as required, to the regulators, ILSC and to Senior Management.
- Ensure that effective corrective actions are developed, implemented, and documented if violations of regulations, or license or registration conditions, or program procedures are identified.
- Maintain a central database of all high power laser equipment license information at NUS.
- Develop, update and provide all safety trainings related to safe use of laser radiation at NUS.

3.4.8 UNIVERSITY HEALTH CENTRE (UHC)

The University Health Centre is the medical service provider for the Occupational Health Program of the University. UHC provides any medical examinations that are required for obtaining radiation licenses from regulators.

4 RISK MANAGEMENT

The principle of risk management is to identify the safety and health hazards associated with works involving the handling of laser sources and assessing the risk level, prioritizing and implementing measures to control the hazards and reduce the risk to acceptable level.
As part of risk management, adequate and effective control measures are necessary to control the hazards identified during the risk assessment and reduce the risks to acceptable levels.

The aim of the control measure should be to reduce the likelihood of occurrence of the adverse consequences and/or the severity of the potential injury. When determining the type of control measures, one should always consider the hierarchy of control, i.e. elimination, substitution, engineering control, administrative control and lastly personal protective equipment. In most instances, a combination of controls is required to manage the risk effectively.

5 RISK ASSESSMENT

All PIs are obligated to perform a thorough evaluation of risks and hazards associated with their projects and identify and implement controls to minimize such risks. The risk assessment should be comprehensive and address all risks associated with the laser beam and ancillary hazards associated with the laser equipment.

5.1 PROJECT RISK ASSESSMENT SCHEME

All PIs are responsible for the conduct of risk assessment prior to the commencement of research projects. PIs can only commence work after their risk assessment has been approved. Refer to Project Risk Assessment Scheme http://www.nus.edu.sg/osh/programmes/ra_submission.htm for the detailed risk assessment methodology, and submission and approval procedure.

The Project Risk Assessment is gradually being phased out, it will be replaced by the Laboratory OSH Certification Scheme as described below.

5.2 LABORATORY OSH CERTIFICATION SCHEME

The Laboratory OSH Certification Scheme was launched to certify PIs who have effectively implemented laboratory-based safety and health management system. Upon award of the certification to the NUS Occupational Health and Safety Management System Standard for Laboratories, PIs would generally not be required to submit risk assessments on a per-project basis. For more information, refer to

http://www.nus.edu.sg/osh/programmes/ohscert.htm.

6 LASER LICENSES

The possession and use of laser sources are enforced by RPNSD by means of licensing and imposing penalties on violations. Separate licenses are required for possession and for use of high power laser equipment. Class 3b and Class 4 lasers are termed high power laser equipment (Please refer to Section 10 for more information on different laser classes)

Blank license forms can be downloaded from the following link http://app2.nea.gov.sg/TemSub.aspx?pagesid=20080720226768161463&pagemode=live#radiation

The information on the license fees for different licenses can be found in the following link.

http://app2.nea.gov.sg/regulatory_info.aspx#licences.

All license applications, amendments, renewals and cancellations should be performed only by the FSHO to enable OSHE to track laser use at NUS. All completed license applications and the cheque for the license fees should be sent to FSHO who will then forward them to RPNSD. All license approval letters and renewal letters will be sent by RPNSD to the FSHO. RPNSD requires approximately 45-60 days for processing license fees and issuing the license. So it is advisable that users plan ahead of the laser radiation use. Upon approval of license application, the license will be sent to the FSHO.

NEA administers a license qualifying test for all N3 applicants. The passing of this test is a prerequisite for obtaining the license. NEA will contact the applicants on the schedule and details of the test. OSHE's Laser Safety Training includes the information that can help applicants successfully pass this license qualifying test. N3 license applications require details of the eye-examination completed within the past 12 months to be attached. Please refer to Section 7 on Medical Surveillance for more information.

Any change in the license information would require a license amendment. The change in information along with the cheque for license amendment should be sent to FSHO immediately. The license should be amended within two week of any change.

N2 license- To ***keep or possess*** high power laser equipment (other than sale).

This license authorizes the lab or building to possess Class 3b or Class 4 laser equipment. Each equipment should have a separate N2 license. The Faculty or the Department holds this license. PI or equipment owner should ensure that N2 license is obtained immediately after purchase of the equipment.

N3 license- To ***use*** high power laser equipment (other than sale).

The license authorizes an individual to use Class 3b or Class 4 laser equipment. Each user should have their own N3 license. There is no need to obtain separate N3 license to use different laser equipment by the same user. All laser equipment (and its associated N2 license number) used by a particular user must be listed on his/her N3 license application. The PI/equipment owner has the responsibility to ensure that all users (including him/herself if necessary) who will be using the high power laser equipment to have an N3 license.

The licensing of laser use at NUS follows the structure showed in Figure 1. In the Figure below, the department has three Class 3b or 4 lasers. There are two users in the department– User 1 uses all three lasers while User 2 uses only one Class 3b laser, Class 4 Laser.

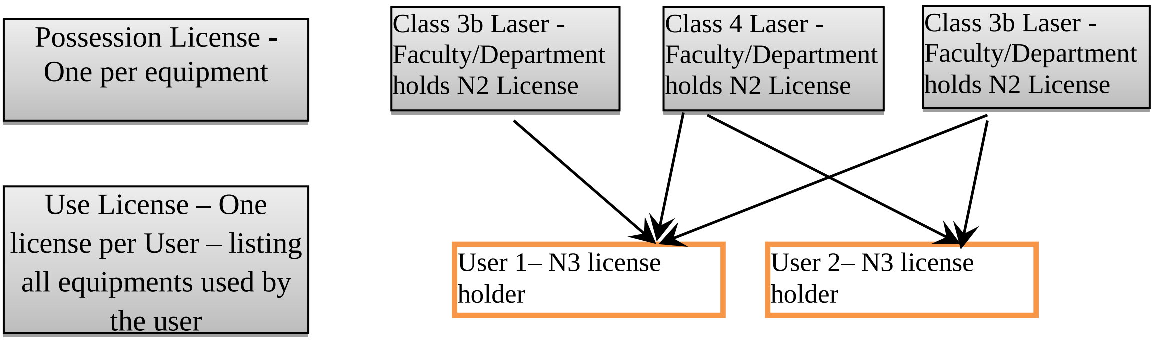


Figure 1: Laser producing equipment licensing guide

Contact the Radiation Safety Officer for more information or questions on radiation licensing.

6.1 LICENSE EXEMPTIONS:

Any student who uses Class 3b or Class 4 lasers do not need to possess an N3 license as long as they meet the both the conditions mentioned below.

- Using the equipment during teaching experiments in undergraduate course modules, and
- In the presence and direct supervision of a person holding a valid N3 license.

The laboratory supervisor should communicate the potential health and safety hazards of using the laser to the students prior to conducting the experiment. The laboratory supervisor should ensure the safety and health of all students under his care.

Users of Confocal Microscopes, Cell Sorters and other equipments with completely enclosed laser sources can be exempted from obtaining the N3 user license, if the equipment owner can provide documentation to show that the accessible laser radiation emission levels for the equipment meet either the Class 3A, Class 2 or Class 1 levels. (Please refer to Section 10 for more information on accessible emission levels)

The following documents need to be sent to RPNSD for this exemption.

- A written letter (either from the manufacturer or the PI/equipment owner) stating that the accessible laser radiation emission levels meet Class 3A, Class 2 or Class 1 levels.
- The technical data sheet or worksheet or any other document that proves the above claim.
- A written letter (from the PI/equipment owner) stating that no modifications were

performed on the equipment after the purchase.

These documents should be forwarded to the FSHO, who will then submit the information to RPNSD. The N3 user license is exempted ONLY after RPNSD approves the exemption and the owner has received the confirmation letter from RPNSD. The exemption letter should be maintained by the owner as long as the equipment is being used. Individuals providing maintenance and service for such equipments will not be exempted from N3 license.

Note: The exemption is only for N3 license. These equipment will need an N2 license and no exemptions are provided for N2 license.

7 MEDICAL SURVEILLANCE

7.1 PRE-PLACEMENT EXAMINATION

All N3 license applicants are required to attach a report of eye examination performed within the past 12 months along with their license application. The eye examination can be conducted at the University Health Center (UHC). The funding for the medical examination should be approved prior to approaching the clinic for the medical exam. The Request for Funding for Occupational Health Related Medical Services form is provided in A**ppendix E** should be completed and submitted to the FSHO for approval. The user will then register for an eye examination appointment at the registration desk at UHC. A baseline eye exam establishes a baseline against which ocular damage may be measured. The eye examination should be performed by a qualified ophthalmologist.

7.2 PERIODIC MEDICAL EXAMINATION

Any subsequent eye examinations that a user would like to undergo after beginning to use the lasers or before leaving NUS can also be done at the University Health Center. These exams are not mandatory. However, these exams can reveal if there is any deterioration in the eyesight due to work with lasers. These eye exams should be approved by the individual PI or department.

In the event of real or suspected accidental exposure to lasers, the PI shall ensue that the affected individual undergoes a medical examination as soon as possible. The examination may include eye examination and any other examination as may be required by the authority and/or OSHE. The eye examination should be performed by a qualified ophthalmologist.

8 TRAINING

8.1 LASER SAFETY TRAINING

All N3 license applicants must undergo training on safe use of lasers. All NUS staff applying for N3 licenses must undergo the Laser Safety training conducted by OSHE. More information on all the trainings provided by OSHE and the training registration details can be found at https://inetapps.nus.edu.sg/osh/portal/shmgt/ssts.html

8.2 LAB SPECIFIC SAFETY TRAINING

In addition to the mandatory training mentioned above, PIs/equipment owners may conduct laboratory specific and equipment specific training on the safe operation of the laser equipment.

9 REGULATORY LIMITS

Radiation Protection (Non Ionising Radiation) Regulations have specified Accessible Emission Levels (AEL) of laser radiation for classification of different laser products. These are available in the Second Schedule of the Radiation Protection (Non Ionising Radiation) Regulations (see Appendix A). The maximum level of exposure to the eye and the skins have also been specified as Personnel Exposure Limits (PEL) in the Tables 1-3 in the Third Schedule of the Radiation Protection (Non Ionising Radiation) Regulations (see Appendix B).

10 LASER CLASSIFICATION

Lasers are classified based on their potential to cause biological damage. The classification of lasers is based on the maximum AEL of the laser radiation from the laser system. The AEL values depend on the wavelength of the radiation and type of beam (pulsed beam or continuous beam), duration of exposure, viewing aperture of the beam, the power or energy and cross sectional area of the laser beam at the point of interest. Based on AEL the lasers are classified into Class 1, Class 2, Class 3A, Class 3b and Class 4 lasers. Most commercial lasers have an attached label specifying the classification of that laser.

10.1 CLASS 1

Class 1 lasers are those that are inherently safe so that the maximum AEL as specified in Table 1 of Second Schedule of the Radiation Protection (Non Ionising Radiation) Regulations (see Appendix A) cannot be exceeded under any condition, or the lasers are safe by virtue of their engineering design. This class includes high-power lasers within an enclosure that prevents exposure to the radiation and that cannot be opened without shutting down the laser. When such lasers are dismantled for service or any other purpose they should be considered as belonging to the appropriate higher class lasers and laser safety measures followed accordingly.

10.2 CLASS 2

Class 2 lasers are those emitting visible laser radiation in the wavelength rage from 400 nm to 780 nm. Table 2 of Second Schedule of the Radiation Protection (Non Ionising Radiation) Regulations (see Appendix A) provides the maximum AEL for Class 2 lasers. Class 2 laser is safe because the blink reflex will limit the exposure to no more than 0.25 seconds. Intentional suppression of the blink reflex could lead to eye injury.

10.3 CLASS 3A

Class 3A lasers are those that laser radiation with the AEL greater than that of Class 1 (for invisible) or Class 2 (for visible) lasers but less than that specified in Table 3 of Second Schedule of the Radiation Protection (Non Ionising Radiation) Regulations (see Appendix A). These lasers are considered marginally unsafe for intra-beam viewing. With a Class 3A laser, the PELs can be exceeded, but with a low risk of injury.

10.4 CLASS 3b

Class 3b lasers are those emitting laser radiation with AEL greater than that of Class 3A lasers but less than that specified in Table 4 of Second Schedule of the Radiation Protection (Non Ionising Radiation) Regulations (see Appendix A). Class 3b lasers are considered hazardous if the eye is exposed directly, but diffuse reflections such as from paper or other matte surfaces are not harmful. Class 3b lasers generally do not cause skin injury.

10.5 CLASS 4

Class 4 lasers are those emitting laser radiation at levels exceeding the AEL as specified in in Table 4 of Second Schedule of the Radiation Protection (Non Ionising Radiation) Regulations (see Appendix A). By definition, a Class-4 laser can burn the skin, in addition to potentially devastating and permanent eye damage as a result of direct or diffuse beam viewing. These lasers may ignite combustible materials, and thus may represent a fire risk.

11 LASER BEAM HAZARDS

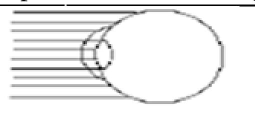
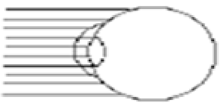
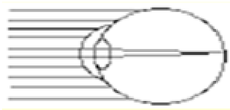
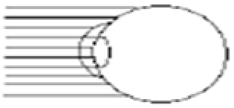
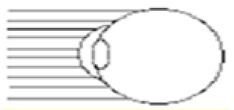
The extent of damage caused by exposure to laser radiation will vary depending on the wavelength, type of source (point or extended), the exposure duration, type of beam (pulsed or continuous) and also on the intensity of the beam (energy per unit area). The hazards associated with lasers are due to thermal energy associated with the beam, the property to induce photochemical reactions in cells and also due to its capability to induce shock waves (photoacoustic effect) in tissue due to instantaneous vaporization of tissue. The threshold for injuries to eye and skin vary due to the difference in sensitivities of the cells that constitute them.

11.1 LASER RADIATION EFFECTS ON EYE

The extent of eye injury from exposure to laser radiation varies depending on the wavelength and the energy density of the laser radiation. Operating lasers under reduced external light conditions increases the optical hazards because of pupil dilation. Laser radiation with wavelength ranging in the Retinal Hazard Region (RHZ) (400 nm to 1400 nm) are particularly dangerous because, cornea and lens are transparent to these wavelengths and hence results in retinal damage. Please refer to the Third Schedule of Radiation Protection (Non Ionising Radiation) Regulations for maximum skin exposures for all types of lasers with different wavelengths.

Different parts of the eye absorb different wavelengths and the injuries can vary due to the variance in how tissues absorb energy. Following table summarizes the wavelength, the part of the eye that absorbs the radiation and the resulting chronic injuries from low level exposure over a long period of time.

Table 2: Effects to the eye from chronic exposure to electromagnetic radiation

Ultraviolet	Far Middle	200-280 nm 280-320 nm	Cornea		• Photo keratitis, irritation to the eye that causes pain and watering in the eye. • Welder's flash - pigmentation of the Cornea
Ultraviolet	Near	320-400 nm	Lens		Cataracts - Changes proteins in lens causing them to become cloudy and blurs vision
Visible Infrared	All Near	400-780 nm 780-1400 nm	Retina		• Photo bleaching - induce a photochemical reaction which causes the light receptors in the eye to loose sensitivity. • Burns Retina
Infrared	Near Middle	780-1400 nm 1400-2600 nm	Lens		Cataracts - Changes proteins in lens causing them to become cloudy and blurs vision
Infrared	Far	2600 nm to 10600 nm	Cornea		Photo keratitis, irritation to the eye that causes pain and watering in the eye

11.2 LASER RADIATION EFFECTS ON SKIN

Acute Exposure: The extent of skin injury can vary from minor reddening of the skin to instant vaporization of body tissue depending on the energy density of the radiation. For continuous wave lasers, the maximum exposure should be kept below 1 mW/cm^2, 0.2 to 1 W/cm^2 and 100 mW/cm^2 for wavelength ranges of 315 – 400 nm, 400-1400 nm and >1400 nm respectively. The levels are much smaller for pulsed lasers. Please refer to the Third Schedule of Radiation Protection (Non Ionising Radiation) Regulations for maximum skin exposures for all types of lasers with different wavelengths.

Chronic Exposure: The long term effects on the skin from exposure to laser radiation vary depending on the wavelength. Skin effects are generally considered of secondary importance except for high power infrared lasers. However with the increased use of ultraviolet lasers, skin effects have assumed greater importance.

Ultraviolet Region: Erythema (sunburn), skin cancer and accelerated skin aging are produced by emissions in the 100 to 280 nm range. Increased pigmentation results from exposure to light with wavelengths of 280 to 400 nm. Exposure of skin to light from 310 to 400 nm results in photosensitization (reaction of ultraviolet radiation with certain skin molecules creates dangerous free radicals and elements that damage the skin)

Visible and Infrared Region: Laser emitting radiation in the visible and infrared regions produces effects that vary from a mild reddening to blisters and charring. These conditions are usually repairable or reversible. However depigmentation, ulceration and scarring of the skin, and damage to underlying organs may occur from extremely high-powered lasers.

Following table summarizes the resulting chronic injuries to the skin due to exposure to different wavelengths

Table 3: Effects to the skin from chronic exposure to electromagnetic radiation

SPECTRUM	EFFECT
Ultraviolet (100-280 nm)	Erythema, cancer, accelerated aging
Ultraviolet (280-310 nm)	Erythema, increased pigmentation, cancer, accelerated aging
Ultraviolet (310-400 nm)	Erythema, increased pigmentation, skin burn
Visible (400-780 nm)	Photosensitive reactions, skin burn
Infrared (780 nm -1 mm)	Skin burn

11.3 CRITERIA FOR EXPOSURE TO EYES AND SKIN

The exposures to eyes and skin should be maintained well below the regulatory PELs as specified in Third Schedule of the Radiation Protection (Non Ionising Radiation) Regulations (see Appendix B). The PELs vary depending on the wavelength, exposure time and type of laser beam (continuous wave or pulsed). Exposure to levels at the regulatory limit may be uncomfortable to view or feel upon the skin. Thus it is a good practice to maintain exposure well below the regulatory PELs. While the use of engineering controls ensures the regulatory limits are not exceeded, the use of administrative controls and protective equipment will ensure the exposures are well below the regulatory limits. Please refer to Section 13 on Laser Radiation Protection for ways for minimizing radiation exposure.

12 LASER NON BEAM HAZARDS

While injury to the body from direct exposure to laser beams is a primary concern, most common accidents that occur in laser laboratories are not from exposure to laser beams. The ancillary equipment used in labs and the poor housekeeping conditions cause more accidents in laser labs that the primary laser beam. So it is necessary that all users are aware of the non beam related hazards and ensure risk assessments involve evaluating all such hazards. It is necessary to ensure adequate control measures are in place for such hazards and are addressed in the SOP for such operations. The PI/equipment owner can contact the FSHO for any evaluation of non beam hazards. The FSHO shall co-ordinate such hazard evaluations with the RSO and other OSHE staff.

12.1 ELECTRICAL HAZARDS

Most lasers contain high-voltage power supplies and capacitors or capacitor banks that store lethal amounts of electrical energy. This can result in shocks, excessive heat or cause sparks that might ignite flammable materials. The electrical hazards can be avoided or minimized in all laser systems using high voltage power supplies by

- Covering or insulating all electrical terminals and routine inspection for damage of insulating materials, wires and terminals
- Routine inspection to determine any damages to the equipment or cooling systems
- Using electrical surge protection to prevent any spikes and outages
- Properly discharging and grounding capacitor banks. Capacitor systems are of particular concern because they can remain hazardous long after the main power is disconnected
- Properly grounding laser equipment
- Good housekeeping to ensure all wires are organized and taped to the floor.
- Preventing daisy-chaining (plugging one extension cord into another extension cord) and ensuring the total power load on the extension cords is well below the maximum rated load.
- Locking and tagging out power supplies during maintenance.
- Allowing only qualified persons to perform maintenance or repair on high voltage laser systems. A second person (preferably knowledgeable in CPR) should always be in attendance when high voltage work is being performed
- Having the “power on” warning lights in visible location
- Avoid having any flammable materials close to high voltage supplies
- Having an additional or redundant power supply circuit and associated switch to control the power supply in case of emergencies
- Labeling and posting electrical high voltage hazards and switches that control power supply

12.2 LASER-GENERATED AIR CONTAMINANTS (LGAC)

The interaction of high intensity laser beams with target material, results in heating and resulting vaporization/ degeneration of the material. This is particularly true during material processing (welding, cutting, vapor deposition, etc.). The resulting airborne material can be in the form of dusts, fumes, mists, aerosols, fibers or vapors. Depending on the target material, the contaminants can be carcinogenic, toxic or noxious gases. Very high beam intensities of the order of 10^7 W/cm^2 are usually needed for creating such contaminants.

In addition to the intended target material, any other ancillary equipment like windows and lenses can also generate LGAC. The user should refer to safety data sheets of the any ancillary equipment to determine the composition of any LGAC that can be generated. If the users feel difficulty breathing or suspect creation of LGAC from their equipment, contact OSHE for performing an indoor air quality check. It may be necessary for controlling the concentration of the contaminants through the use of adequate ventilation and filtration.

12.3 COLLATERAL AND PLASMA RADIATION

Collateral and plasma radiation refers to radiation produced by system components other than the primary laser beam.

12.3.1 X RAYS (IONISING RADIATION)

X – rays can be produced from electrical components of laser systems greater than 15 kV and some times from laser-metal interactions. X-ray monitoring may be required in such labs. Contact RSO for performing this monitoring if such conditions exist in the labs.

12.3.2 ULTRAVIOLET (UV) AND VISIBLE RADIATION

UV radiation is emitted from laser discharge tubes and pump lamps. They should be suitably shielded to ensure that the exposure levels are below the regulatory limits shown in Appendix C. UV exposure can result in skin reddening, increase pigmentation and also sensitize certain skin components to cause allergic reactions and other skin damage. Eye exposure to UV can result in cataracts, pigmentation and irritation of cornea .

12.3.3 RADIOFREQUENCIES (RF) AND ELECTRIC AND MAGNETIC FIELDS

Power supplies and other electrical equipment associated with some lasers are capable of causing intense electric and magnetic fields and radiofrequency waves. RPNSD does not provide regulatory guidelines for exposure to such fields. There is no concrete scientific evidence of biological effects due to an individuals exposure to such fields. However, all users should minimize their presence close to sources generating such fields.

12.3.4 PLASMA RADIATION

Laser radiation with very high intensities (> 10^{12} W/cm^2) can create plasma, which in turn generates radiation in the wavelength of 180 nm to 550 nm. This can raise concern to long term ocular viewing and skin exposure without protection. Appropriate UV protection measures for skin and eye should be implemented to minimize such exposure.

12.4 FIRE HAZARDS

The presence of any flammable material in the vicinity of Class 3b and Class 4 lasers (except for completely enclosed beams) should be avoided. Flame retardant or non combustible materials should be used for all screens, filters, blocks and any other part that can be in the path of the Class 4 laser beam. Although, the laser barrier screens are effective in containing the beam within the control area, they may not be able to withstand very high intensity beams more than the rated exposure time. The documentation on beam energy or beam intensity absorption capacity and the maximum exposure time should be obtained from the manufacturer. They should be evaluated to determine if it is suitable for the conditions corresponding to the laser. Lasers operating in the infrared regions can cause any plastic or other combustible materials to catch fire from accumulation of heat from reflected and scattered beams. The sparks from high voltage supplies can result in fires and fire extinguishers designed for electrical systems should be present in Class 4 laser control area.

12.5 EXPLOSION HAZARDS

Laser targets and other parts, interacting with laser beam could shatter if the beam intensity is much higher than that is what the parts are rated for. High-pressure arc lamps, filament lamps, and capacitor banks in laser equipment must be enclosed in housings which can withstand the maximum explosive pressure resulting from component disintegration. The LGAC dust collected in the filters in ventilation ducts could have explosive properties and the filters should be cleaned routinely. Special consideration should be given to proper storage, use and control of flammable solvents and gases (both compressed and cryogenic) to prevent such hazards.

12.6 COMPRESSED CYLINDERS

High power lasers generally involve use of compressed gases as lasing media, for cooling, to create an inert environment and for several other purposes. Uncontrolled sudden release of the gas will cause severe damage to personnel and equipment. So they should be secured properly to prevent tipping over and puncturing or damaging the container.

The leakage of these gases can displace oxygen and can result in reduction of oxygen levels in the lab. So it is advisable to use oxygen monitors if such cylinders are used in poorly ventilated environments.

In addition to the above mentioned hazard, the gases may themselves be toxic, corrosive, flammable or have other hazards associated with it. The user should refer to safety data sheets of the compressed gases to determine the associated hazards. SOPs may be required for operation of such compressed gas cylinders to implement controls to prevent any accidents. The low temperature created by compressed liquids present skin and eye hazards from their extremely low temperatures and should be handled with insulated gloves and goggles.

12.7 CHEMICAL HAZARDS

Complex organic dyes are used as lasing media in certain lasers and may need to be frequently changed. These dyes are usually toxic and carcinogenic and are usually in powder form and hence are readily dispersible. Special care should be taken while handling the dyes, preparing solutions or operating the machines with such dyes. A lab coat, disposable gloves, safety glasses or goggles, and a properly functioning chemical fume hood must be used when handling or mixing the dyes. The commonly used solvent - dimethylsulfoxide (DMSO), aids in the transport of dyes through the skin and into the blood stream, and hence its use should be avoided. Good housekeeping should be maintained before, during, and after the mixing. Use double containment adequate to contain the entire volume of the dye solution when they are being mixed, stored, and used. Clean up any spills immediately using the appropriate protective equipment. The user should refer to safety data sheets of the dyes to determine the associated hazards. SOPs may be required for using such chemicals to implement controls and prevent any accidents.

12.8 NOISE

Experiments involving certain pulsed lasers (like excimer lasers) may create high noise levels and so adequate noise control or hearing protection measures should be taken. Using acoustical material for floors, ceilings and walls, erecting sound barriers, limiting the exposure time to such experiment and using hearing protection are some commonly used techniques to reduce exposure to noise. All PI/equipment owners with such equipment should comply with the rules specified under the Workplace Safety and Health (Noise) Regulations 2011 for noise control, noise monitoring, hearing protectors, training program and documentation.

12.9 OTHER HAZARDS

Other hazards that might be associated with using lasers systems include ergonomic hazards from restricted work environment or repetitive motion, mechanical hazards from fast moving robotic instruments and biological hazards from the samples being analyzed. PI/equipment owner should perform a thorough risk assessment to identify all associated hazards and implement risk controls to minimize the risks.

13 LASER RADIATION PROTECTION

Although chronic injury from laser radiation in the ultraviolet, visible and near infrared region is theoretically possible, the most common risks to users are primarily from acute injuries. This chapter describes the control measures to be implemented for safe use of Class 3b and 4 lasers to minimize any acute or chronic injuries.

13.1 ELIMINATION & SUBSTITUTION

The most effective way of keeping hazards at bay is by eliminating the use of laser totally or by substituting the high power irradiating apparatus with a less powerful one.

13.2 ENGINEERING CONTROL

13.2.1 PROTECTIVE HOUSING:

Class 3b and Class 4 laser should have a protective housing with a safety interlock that prevents human access to radiation that exceeds the PELs. The safety interlocks should be provided with visual or audible alarm that will alarm when interlocks are defeated. The interlocks can be electrically or mechanically interfaced with the shutter which interrupts the beam when the protective housing is opened or removed. The safety interlocks should be tested prior to the use and also annually during safety inspections. Interlocks must be designed so that after they are actuated, the capacitor banks, shutters, or power supplies cannot be re-energized except by manually resetting the system. Adjustments or procedures during service shall not cause the interlocks to be inoperative when the laser is placed back in operation. The protective housing should be made of materials that are non-flammable and that do not decompose/damage on continued exposure to power levels that are typical within the housing.

In the situations where,

- use of protective housing with an interlock is not possible OR
- lasers are operational after interlocks are defeated (in alignment or maintenance) OR
- the exposure levels are above PELs even after use of a protective housing with interlock

the PI should establish a laser control area within which the PELs are exceeded. Please refer to Section 13.2.2 for more information on laser control area.

13.2.2 LASER CONTROL AREA:

A laser control area should be established in all situations which involve use of lasers where the exposure levels cannot be maintained below PELs. Such situations involve

- using machines in which use of an interlocked protective housing is not feasible or
- using machines with the protective housing removed for performing service or maintenance or
- during performing laser alignment with the laser radiation levels are above the PELs

The laser control area will enclose any area around the laser producing equipment where the PELs will be exceeded. The laser control area is established using appropriate barriers, curtains, screens, shrouds, beam stops to reduce the laser levels below PEL outside the control area. The barriers should be made of materials that are non-flammable and that do not decompose/damage on continued exposure to power levels that are typical within the area. They should not be made of material that can release toxic gases, fumes or other regulated air contaminants. They should be of sufficient strength and resilience to absorb energy and intensity levels from both direct and scatter radiation. The documentation on beam energy or beam intensity absorption capacity and the maximum exposure time should be obtained from the manufacturer. They should be evaluated to determine if it is suitable for the conditions corresponding to the laser.

If the barriers do not cover the top of the controlled area and if the side barriers do not extend all the way to the ceiling, the PI/equipment owner should ensure that no reflective (diffuse or direct) surfaces are present on the ceiling that could reflect the beam back into the uncontrolled area.

The control area should

- be under direct supervision of an individual knowledgeable in laser safety
- be accessible only by individuals who have valid N3 license
- be located so that access to the area by spectators is limited or requires approval
- have all windows, doorways, open portals either covered or restricted in such a manner as to reduce the transmitted laser radiation to levels at or below the PELs
- allow rapid egress by users at all times
- have only diffuse reflecting materials in and around the beam path
- have beam terminated by a beamstop of appropriate material
- have sufficient laser eye protection devices available
- be posted with appropriate warning signs on the entryway to the control area (See Section 13.3.9 on Warning Signs for more information)
- not have the beam height at the normal eye position of a person in a standing or seated position.
- have a well defined and controlled beam path

In the case of a control area with a Class 4 laser, the control area should incorporate one of the following entry control mechanisms.

Non-defeatable Entry way control: any mechanism that will deactivate the laser or reduce the output to levels below the PEL in the event of unexpected entry into the area. eg., pressure sensitive floor mats, electrical switches, infrared detectors.

OR

Defeatable Entry Way control: Safety latches and door interlocks that can be defeated and will deactivate the laser or reduce the output to levels below the PEL. However, the override of the safety controls shall be permitted only to authorized personnel with N3 license.

OR

Procedural Entry way control: If safety latches and interlocks are not possible, other means of access controls (like door, blocking barrier, screen, curtains etc.,) shall be used to block, or attenuate the laser radiation to levels below the PELs. However, this will be permitted only if control measures are in place to ensure only approved N3 users have access to this entryway and there is a warning system to indicate the laser is energized.

13.2.3 WARNING LIGHTS:

All Class 3b and Class 4 lasers should have a visual indicator indicating that the laser is operating. The light may be electrically interfaced and controlled by the laser power supply so that the light is on when the laser is operating.

The Laser Control Area should have an emission indicator, in the form of audible or visual alarm, be used to warn users prior to the activation of the laser within the control area. The alarm should provide sufficient time for the users to leave the control area before the PELs are exceeded. The location of emission indicator should be selected in such a way that viewing of the indicator does not result in exposure above PELs. The signal from the emission indicator should be clearly visible through the protective eyewear designed for using with the machine.

13.2.4 SERVICE ACCESS PANELS:

The protective housing that is intended to be removed during service (service access panels) should have safety interlocks. The interlocks can be exempted if it is required to use a tool to remove the panel and has an appropriate warning label.

13.2.5 KEY CONTROL SWITCH:

All Class 3b and Class 4 lasers should have a key actuated master control switch to terminate the beam and/or shut the equipment. The key can be either a physical key or a computer coded access. The key should be maintained in such a way to prevent unauthorized use of the laser machine. The machines should be designed to permit any lock out / tag out to prevent unauthorized use / accidents during servicing or repair.

13.2.6 EMERGENCY SHUT OFF SWITCH:

All Class 3b and Class 4 lasers should have a remote interlock connector that facilitates beam shut off or system shut off when activated. The remote interlock connector should be connected to the power supply switch or any other parts of the machine that will facilitate immediate stop of the beam.

13.2.7 MANUAL RESET:

All Class 3b and Class 4 lasers should be provided with a manual reset to enable resumption of laser radiation emission terminated by the use of the remoter interlock or after an interruption of emission in excess of 5 seconds duration due to unexpected loss of main electric power.

13.2.8 VIEWING WINDOWS AND DIFFUSE DISPLAY SCREENS:

The viewing windows and diffuse display screens are commonly used to facilitate the observation of the laser experiment by the user. They should have suitable filters to absorb or scatter the incident radiation to ensure the exposure levels are below the PELs. They should be made of material that do not burn or decompose easily. They should not be made of material that can release toxic gases, fumes or other regulated air contaminants. They should be of sufficient strength and resilience to absorb energy and intensity levels from both direct and scatter radiation. If the viewing screens are purchased separately from the laser instrument, the documentation on beam energy or beam intensity absorption capacity and the maximum exposure time should be obtained from the manufacturer. They should be evaluated to determine if it is suitable for the conditions corresponding to the laser. If the windows and display screens are removable, they should have either interlocks, filters or attenuators to ensure laser radiation is below the PELs at the user location.

13.2.9 COLLECTING OPTICS:

Lenses, telescopes, microscopes, endoscopes and other collecting optics should be included in the equipments in a way that the laser radiation transmitted through such optics is below the PEL. They should be of sufficient strength and resilience to absorb energy and intensity levels from both direct and scatter radiation. If the collecting optics are purchased separately from the laser instrument, the documentation on beam energy or beam intensity absorption capacity and the maximum exposure should be obtained from the manufacturer. They should be evaluated to determine if it is suitable for the conditions corresponding to the laser.

13.2.10 BEAM STOPS AND ATTENUATORS:

Some lasers or laser systems have long warm-up times, and it may not be practical to turn the power off to the laser when the laser is not in use. In these cases, Class 3b lasers should be equipped with a permanently attached beam stop or attenuator and Class 4 lasers shall be equipped with a permanently attached beam stop or attenuator. The beam stop or attenuator must limit accessible laser radiation to below the PELs and be employed when the laser is not in use. For lasers that do not require warm-up time, turn the power off to the laser when not in use.

13.3 ADMINISTRATIVE CONTROL

13.3.1 PROCUREMENT, COMMISSIONING AND LASER HAZARD EVALUATION

The PI/equipment owner must notify the FSHO of all Class 3b or Class 4 lasers/laser systems being purchased. PI/equipment owner should be identified/assigned and will have the responsibility of safe use of the machine. The FSHO will notify the Radiation Safety Officer who will perform a Laser Hazard Evaluation to quantify the Accessible Emission Levels and the Exposure Levels pertaining to the use of the laser machine. The evaluation will also determine the adequacy of engineering controls. RSO will inspect the machine and provide recommendations on licensing requirements/exemptions, modifications in engineering controls and any personal protective equipment that might be required. The Laser Hazard Evaluation Form shown in Appendix F will be completed by the Radiation Safety Officer. All Class 3b and Class 4 lasers with a partially or fully open beam path must possess a completed Laser Hazard Evaluation Form provided by the RSO

13.3.2 TRANSFER AND DISPOSAL

PI/equipment owner should notify the FSHO before any Class 3b or 4 laser is transferred from the jurisdiction to another PI/equipment owner on-campus. The RSO will perform hazard evaluation and complete the Laser Hazard Evaluation Form for the new location and provide any safety recommendations. The new PI/Equipment owner must obtain necessary licenses and complete trainings prior to use of the equipment.

If the machine is being sold, the equipment owner should verify that the new owner possess a valid N2 and N3 license. If the machine is being condemned, the equipment owner should ensure that source of the laser radiation is completely impaired in a way that it will be impossible to produce any future laser radiation. Please contact the Radiation Safety Officer for details before condemning any laser equipment. The FSHO must be notified when a Class 3b or 4 laser is sold or disposed/condemned. The FSHO will notify the RPNSD of the removal of the equipment and will cancel all licenses if necessary.

13.3.3 LICENSING REQUIREMENT

All Class 3b and Class 4 laser machines and users of such machines should possess the necessary license as required by RPNSD. It is the PI/equipment owner's responsibility to ensure all appropriate licenses have been obtained prior to using a laser producing equipment. Please refer to Section 6 on details of obtaining the license. Unless exempted, no Class 3b and Class 4 laser machine should be used before obtaining N2 license and no individual should use such machines before obtaining N3 license from RPNSD.

13.3.4 TRAINING REQUIREMENT

All laser users should satisfy training requirements specified under Section 8. All individuals any (including an external contractor) providing service or maintenance to laser equipment is adequately trained to perform the work. All trainings shall be commensurate with the level of potential hazard, both from laser radiation and non-beam hazards. The PI/equipment owner should ensure this requirement is satisfied and should maintain proof of such training records.

13.3.5 AUTHORIZED PERSONNEL REQUIREMENTS

The PI or the equipment owner should ensure that all Class 3b or Class 4 lasers shall be operated only by individuals with valid N3 license. The access to laser control area should be restricted by using card access, key access or transponder access to the room with the laser machine. The use of machines with enclosed beam path can be restricted by restricting the access to the master key used to operate the machine. The lasers should be under the direct and personal supervision of a licensed laser operator.

Spectators and visitors may be allowed to enter the laser location only after approval from the PI/equipment owner and has been briefed on the hazards and control measures.

Service personnel may be allowed to work with the lasers only after the PI/equipment owner has verified the license and safety training requirements and the personnel has been briefed on the lab specific safety hazards and control measures.

13.3.6 STANDARD OPERATING PROCEDURES

The SOPs on regular operation, performing laser alignment and servicing or maintaining equipment should be developed and reviewed routinely. The SOP should be communicated to all laser workers and be made readily available in the laboratory. The SOP should be maintained with the laser equipment for reference by the operator, and also maintenance or service personnel. The PI/equipment owner should develop the SOPs and review whenever there is a change in the associated work process, an accident or atleast once every three years.

13.3.7 UNATTENDED EQUIPMENT

When lasers are to be operated for extended period, it may not be possible to have the licensed operator present near the equipment at all times. Class 3b and Class 4 lasers may be operated unattended, as long as either

- the equipment has either a protective housing with safety interlock to reduce the exposure levels below PELs outside the machine
  OR
- a laser control area is established with necessary warning signs according to Section 13.2.2 and control measures in place to prevent accidental entry of unauthorized personnel into the

control area.

If the laser machine is not operational for extended period of time, de-energize the power supplies or capacitor banks and remove the keys from power switches or master interlocks to prevent unauthorized activation of the equipment. The operation of unattended lasers is only allowed when a specific risk assessment and SOP has been written and approved by the PI.

13.3.8 LASER SERVICING OR MAINTENANCE

The laser equipment should be serviced at intervals recommended by the manufacturer or vendor. The servicing and maintenance of the machine should be performed only by individuals who have through knowledge in the operation of the equipment and all aspects of laser safety. The individuals performing maintenance should have a valid N3 license. If the servicing involves removal of protective housing and resulting laser radiation levels are above the PELs, then a temporary laser control area should be established and maintained as mentioned in Section 13.2.2. The service provider should use all means of protective equipment including eyewear, light barriers etc., to minimize exposure.

13.3.9 WARNING SIGNS

Laser warning signs are used to convey the presence and severity of the laser hazard and also on the safety precautions to minimize or eliminate exposure. Any room or area that is designated as a "Laser Control Area" as in Section 13.2.2 or where levels of laser radiation in excess of the PELs exist shall be clearly identified by posting a sign or by the use of barriers or guards or both to prevent unauthorized entry into these areas. The warning signs should be sufficiently large and clearly visible to any outsider during operation. The warning sign should be posted at the entryway to the control area and also at any other location as desirable by the PI/equipment owner. The warning signs should clearly mention the wavelength (in nanometers), the type of the laser (diode, He-Ne, Ar, Nd-YAG etc.,), the Class of the laser (3b or 4) and the power (average power for continuous wave lasers and peak power for pulsed lasers). Such signs should be similar to the template provided in Appendix G. The warning sign can be downloaded from the following link **(link to be provided later)**

13.3.10 WARNING LABELS

All laser systems or machines (of all classes) purchased from vendors will have appropriate safety warning labels. It is the responsibility of the PI/equipment owner to verify that all sufficient labels are present on the machine. If the labels are not sufficient, the PI/equipment owner should attach the required labels as per following requirements.

- The labels should be permanently fixed, legible and clearly visible during operation, maintenance or service.

- The labels should be position so that they can be read without exposure to laser radiation above the AELs
- Class 1, Class 2, Class 3A, Class 3b and Class 4 laser machines should have the corresponding warning label shown in Appendix D.
- For Class 3b and Class 4 lasers, all apertures through which laser radiation in excess of Class 1(for invisible) or Class 2(for visible) AELs is emitted should have a label with words: " **Laser Aperture**" or "**Avoid Exposure – Laser Radiation Is Emitted From This Aperture**"
- All protective housing panels, service access panels should have a label with words: "**Caution – Laser Radiation When Open**" In addition such label should have the following words:

  For Class 2 lasers – "**Do Not Stare Into Beam**"

  For Class 3A lasers – "**Do Not Stare Into Beam or View Directly With Optical Instruments**"

  For Class 3b lasers – "**Avoid Exposure To Beam**"

  For Class 4 lasers – "**Avoid Eye or Skin Exposure to Direct or Scattered Radiation**"
- All safety interlocks should have a label with following words: "**Caution – Laser Radiation When Open and Interlocks Defeated**" Such labels should be visible prior to and during interlock override and be in close proximity to the opening created by defeating the interlock.
- All viewing windows, display screens, collecting optics, protective eyewear should be labeled with the optical density (Please refer to Section 13.4 for more information on optical density) and wavelength for which the protection is afforded.

13.3.11 REQUIRED ALIGNMENT PROCEDURES

Alignment of Class 2, 3A, 3b, or Class 4 laser optical systems (mirrors, lenses, beam deflectors, etc.,) should be performed in such a manner that the primary beam, or a specular or diffuse reflection of a beam, does not exposure the eye to a level above the applicable PELs in Appendix B.

Laser beam alignment SOPs should be written and followed for any alignment being performed that will emit radiation levels above PELs.

The following factors should be considered while performing laser beam alignment.

- Securely mount the laser system to maintain the beam in a fixed position during operation and limit beam movements during adjustments.
- If possible, the power of laser beam should be reduced to as low as possible during beam alignment. This is possible in adjustable power continuous wave lasers. For pulsed lasers,

single pulses can be used or pulses with minimum energy levels can be used.

- The use of alternative low power visible lasers with radiation levels below Class 2 PELs is recommended for aligning high power visible or invisible lasers.
- If alignment in a laser system that uses multiple wavelengths in multiple sections, the alignment should be performed one section at a time with one particular wavelength.
- When alignment is performed using visible laser beams, the beams should be viewed indirectly. Thermal paper, diffuse reflectors, image-retaining screens, exposed Polaroid film, and other diffuse devices that will minimize eye exposure may be used.
- When the alignment is performed using invisible laser beams, image converter viewers or phosphor cards should be used to locate beams.
- Only persons required to perform alignment shall be in or near the beam path.
- All necessary personal protective equipment should be used. This includes (but not limited to) protective eyewear, face shields for scattered UV, skin protection etc., The protective eyewear should be of the correct optical density rating. (Please refer to Section 13.4 for more information on optical density). Use of eyewear designed for normal laser operation during laser alignment with minimal power will not be suitable.
- Establish a laser control area if the radiation levels exceed the PELs during beam alignment. Follow the requirements of laser control area as established in Section 13.2.2.
- Ensure tools or items used in an around the beam path have non-reflective, diffusing surfaces at the wavelength(s) to be aligned. Have all necessary alignment tools close by to avoid leaving the area during alignment. Examples of tools include targets, beam stops/blocks, power meter/detector, beam profiling system, curtain, signage, caution tape etc.,
- Ensure the surrounding work area/bench top/optical table does not contain objects with shiny reflective surfaces that are not needed for alignment (e.g., glass bottles, razor blades, forceps, screw drivers, optical posts, photographic paper, plastic, dye cells, etc.). Avoid wearing any jewelry, watches or other objects that could act as shiny reflectors. If removal not possible, then ensure all such objects are sufficiently covered with multiple layers of electrical tape. Remove any objects in shirt pockets that might accidentally fall into the beam path.
- Ensure beam shutter is closed at the source except when needed during alignment process
- Use beam blocks of suitable material to restrict or terminate the beams at all locations where there is a possibility of the beam striking any unintended areas (example - protective barriers, walls, windows etc.,)

13.4 PERSONAL PROTECTIVE EQUIPMENT (PPE)

When engineering and administrative controls do not provide adequate means to prevent access to direct or reflected beams, it may be necessary to use PPE to minimize exposure levels. It is not advisable to use PPE as the only control measure for Class 3b and Class 4 lasers, since it may not reliably reduce exposure levels below PELs at all times (especially when it is damaged from prolong use). Specially designed goggles or eyewear, laser barriers, windows, clothing, gloves are commonly used as PPE.

13.4.1 EYE PROTECTION

Laser protective eyewear must be used while using Class 3b or Class 4 lasers and in conditions where the PELs can be exceeded. Laser protective eye wear may include goggles, face shields, or any material with special filters and/or reflective coatings to ensure the potential ocular exposure to below exposure levels. The eyewear is characterized by Optical Density (OD) – a number that represents the laser attenuation power of the eyewear.

$OD = \log_{10}$ (radiation level at the eye / regulatory exposure level)

The OD depends on the power or energy levels at the viewing location, the wavelength and the corresponding regulatory exposure level. Contact the Radiation Safety Officer for advice on determining the OD and purchasing the right type of eyewear.

Factors determining the selection of the appropriate laser protective eyewear include:

Filter material used in the eyewear:

The selection of the filter material is determined by the beam energy or beam intensity absorption capacity and the physical use conditions (shock or vibration). The comfort of wearing the eyewear, the durability of use and the protection offered at various viewing angles are characterized by the type of filter material selected.

Absorbing filter material:

The common absorbing filter materials used are glass or plastic or composite of glass and plastic. Glass filters have very low impact resistance and can break easily. Glass filters also crack and shatter when exposed to intense pulsed lasers. Glass filters also become photobleached after exposed to pulsed lasers. Glass filters can be easily scratched and are usually heavier than other types.

Plastic filters have better impact resistance and have light weight. They can be molded in different shapes to perfectly fit the individuals face. However, they have poor chemical resistance as the chemicals forming part of the eyewear are readily affected by the heat and/or ultraviolet radiation. This results in darkening of the filters. The plastic eyewear can absorb far less energy or beam intensity compared to glass filters before being damage. Composite filter materials combine the advantages of both glass and plastic filter and are hence recommended.

Reflective filter material:

The reflective filter material is usually coated on the glass or plastic eyewear to provide added advantages. Dielectric coated eyewear can absorb higher energy or beam intensity than pure plastic or glass filters. The dielectric reflective coatings are advantageous as they have the capability to selectively reflect certain wavelengths and allow only visible wavelengths to pass through. However, the reflective and transmitting property depends on the angle at which the beam is incident on the eyewear.

Wavelength of the beam:

The OD value is tied to the particular wavelength or a range of wavelengths of the laser beam and hence the eyewear should be used only for the designed wavelength range.

Viewing condition:

Although laser eyewear is intended to protect against accidental intra-beam viewing, they are not recommended for prolonged intra-beam viewing. Commercially available eyewears are generally designed for following conditions.

For intra-beam viewing - 0.25 second view of the continuous wave lasers in the visible wavelengths (400 nm to 780 nm), 10 second intra-beam view of wavelengths in the near infrared region and far infrared region (780 nm to 10600 nm) and 8 hour viewing in the ultraviolet region.

For diffuse reflection viewing - 600 second exposure of diffuse reflection in the visible and near infrared (400 to 1400 nm) wavelengths from continuous wave lasers, 10 second exposure of diffuse reflection in the far infrared region (1400 nm to 10600 nm) and 8 hour viewing in the ultraviolet region

Working condition:

Since most of laser work is conducted in a dark environment, the laser eyewear should be designed to allow sufficient light in the visible spectrum, while maintaining exposure levels below regulatory limits and eliminating radiation from non visible wavelength range. The possibility of exposure through laser passing through the sides of the eyewear should be considered. Hence side shields shall be included in laser eyewear but care should be taken to ensure that the side shields do not limit the peripheral vision.

Comfort and fit:

The weight of the eyewear should be considered during the selection of the eyewear. Loose fitting eyewear may fall from the face during critical situations and pose exposure hazard. Individuals wearing prescription eyewear should select laser eyewear that fit comfortably over the prescription eyewear or purchase specially designed laser eyewear that allow prescription lens inserts or built with filters with prescription power.

General requirements for laser protective eyewear:

- The eyewear should be able to provide protection against both laser beam and non beam hazards like chemical or physical hazards. If a single eyewear cannot provide all round protection, separate protective devices can be used and care should be taken to ensure, the use of one protective device does not compromise the protection provided by the other device.
- Purchase of the any laser protective eyewear should request the manufacturer for the

wavelength and corresponding optical density, manufacturer's recommendations on shelf life, storage conditions, cleaning and use and also information on maximum energy or power absorption capacity. The energy or intensity absorption capacity of a protective eyewear may be much lower when exposed to ultra short pulsed lasers (like femtosecond pulses). Contact the manufacturer to determine if the eyewear will be suitable for such conditions.

- Laser protective eyewear must be clearly labeled with optical densities and wavelengths for which protection is afforded. Color coding or other distinctive identification of laser protective eyewear is recommended in multi-laser environments.
- Eyewear must be inspected periodically by the user for pitting and cracking of the attenuating material, for mechanical integrity, light leaks and damage to the coating in the frame.
- Routine cleaning shall be made to ensure the proper maintenance and working of the eyewear. Cleaning should be performed in a way to avoid damage to the absorbing and reflective surfaces. Refer to the manufacturers instructions for proper cleaning methods.
- Direct intra-beam viewing of the lasers is not recommended even with wearing an appropriate eyewear.

13.4.2 SKIN PROTECTION

Skin-covers, beam shields, clothing (opaque gloves, tightly woven fabrics, lab coats etc.,) and sun-screen creams can be used to minimize effects from exposure to ultraviolet radiation. The protective shields should be able to attenuate the radiation to levels below the PELs for specific UV wavelengths.

For lasers with sufficient power to cause skin burns, engineering and administrative controls are the only means of protection.

For lasers with wavelengths in the middle and far infrared region (1400 nm to 10600 nm), excessive amount of heat created in the room results in skin dryness and heat stress. Personnel protection is implemented by minimizing the exposure time and using heat retardant clothing.

13.4.3 OTHER PPE

Respirators, other local exhaust ventilation, fire extinguishers and hearing protection may be required whenever engineering controls cannot provide protection from a harmful ancillary environment.

14 ACCIDENT / INCIDENT REPORTING AND INVESTIGATION

14.1 RADIATION ACCIDENTS

A radiation accident shall be considered to have occurred if, any individual has been exposed OR has reasonable cause to believe any individual has been exposed to radiation levels in excess of the limits specified in the Third Schedule.

14.2 ACCIDENT RESPONSE PROCEDURES

In the event of accidental exposure in excess of the limits specified in the Third Schedule of the Radiation Protection (Non-Ionising Radiation) Regulations 2001 (see **Appendix B**), the PI shall ensue that the affected individual undergo a medical examination as soon as possible. The examination may include eye examination and any other examination as may be required by the authority and/or OSHE. The eye examination should be performed by a qualified ophthalmologist.

All accidents and incidents must be investigated by NUS in order to identify the root cause(s) and contributing factor(s). The investigation team will be headed by Radiation Safety Officer and may comprise of representatives from OSHE, the Departmental Safety and Health Committee, the Faculty Safety & Health Officer, PI, Laboratory Supervisor or other members if required.

Pending the investigation results to confirm whether an excessive exposure has indeed occurred, the RSO shall immediately suspend the radiation worker from work in which he will be exposed to radiation and arrange for medical examination for the radiation worker and affected personnel. The RSO shall also obtain the contact details of the affected personnel (which may be a visitor, contractor, or a member of public).

Where the investigation confirms that there is indeed an excessive exposure, OSHE shall be responsible to notify the Chief Executive of RPNSD.

For more information, refer to the SOP '*Accident / Incident Reporting and Investigation'* (OSHE/SOP/GL/02) available in the website http://www.nus.edu.sg/osh/sop.htm.

All accidents, known exposures and near misses (which does not result in injury) MUST be reported to OSHE via the online Accident/ Incident Reporting System (AIRS) http://nus.edu.sg/osh/services/airs.htm. All injuries requiring first aid treatment shall be recorded in the First Aid Log Book.

Reporting must be done within twenty-four (24) hours. It can be submitted by the informant, injured staff/ student, PI, Laboratory Supervisor or other representative if the staff/ student are unfit or unable to do the initial report.

15 LASER LABORATORY INSPECTIONS:

Inspections of laboratories using open beam Class 3b and Class 4 lasers (including confocal microscopes) will be done the Radiation Safety Officer once every year to verify compliance with Radiation protection regulations. The Inspection will be performed against the Laser Safety

Inspection Checklist provided in the **Appendix H.** The inspection report along with the results of the inspection will be forwarded to the principal investigator, and a recheck may be conducted in the event problems have been detected that need corrective action.

16 EMERGENCY PHONE NUMBERS AND SAFETY PERSONNEL CONTACTS

16.1 EMERGENCY PHONE NUMBERS

SCDF - Ambulance/Fire	995
Police	999
Campus Security (24hrs)	x 1616 (6874 1616)
General Maintenance/ Breakdown of Services (24 hrs)	x 1515 (6516 1515)

16.1.1

In the event of emergency, please call Campus Security and SCDF or Police

16.1.2

16.1.3

16.2 UNIVERSITY HEALTH CENTRE (UHC)

(http://www.nus.edu.sg/uhc/)

Main Clinic

Kent Ridge Campus

20 Lower Kent Ridge Road

University Health Centre, Level 1

Operating Hours

Mon – Thurs	8.30am – 6pm
Fri	8.30am – 5.30pm
Closed on	Sat, Sun & Public Holidays

Closed for lunch from 12.30pm – 1.30pm

Last registrations are 15 mins before closing time

General Enquiries: 6776 1631

uhc_health@nus.edu.sg

Satellite Clinic

Bukit Timah Campus

469G Bukit Timah Road

Block B, #02-01, Multipurpose Auditorium

Operating Hours

Mon/ Wed/ Fri	8.30 – 10.30am (during term only)
Closed on	Tue, Thu, Sat, Sun & Public Holidays

Last registrations are 15 mins before closing time

General Enquiries: 6467 5492

uhc_health@nus.edu.sg

16.3 NEAREST HOSPITAL

In the event of critical injury/ illness after office hours, proceed to the Accident & Emergency Unit of a nearby hospital. The nearest hospital in the vicinity of the University is:

National University Hospital (NUH)
Lower Kent Ridge Road
Singapore 119074
Main Line (24hr general enquiries) Tel: (65) 6779 5555
Emergency Tel: (65) 6772 5000
www.nuh.com.sg

16.4 OFFICE OF SAFETY, HEALTH AND ENVIRONMENT (OSHE)

A. OSHE

Office of Safety, Health and Environment
University Health Centre, Basement
20 Lower Kent Ridge Road
Singapore 119077
General Enquiries: 6516 1084
Fax: 6774 6979
Email: safety@nus.edu.sg
www.nus.edu.sg/osh/

B. Faculty/ Department Safety and Health Officers/ Coordinators

Contacts for Safety & Health Officers/ Coordinators on safety and health issues pertaining to your faculty are accessible at:

http://www.nus.edu.sg/osh/aboutus/staff.htm#staff_fac.

17 LIST OF APPENDICES

Appendix A Accessible Emission Limits for Laser Apparatus

Appendix B Non Ionising Radiation Exposure Limits for Skin and Eye Exposure

Appendix C Ultra Violet Radiation Exposure Limits

Appendix D Labeling For Laser Apparatus

Appendix E Request for Funding for Occupational Health Related Medical Services (OSHE/51/D01)

Appendix F Laser Hazard Evaluation Form

Appendix G Laser Control Area Warning Sign

Appendix H Laser Safety Inspection Checklist

APPENDIX A: ACCESSIBLE EMISSION LIMITS FOR LASER APPARATUS

(Source: Second Schedule, Radiation Protection (Non Ionising Radiation) Regulations 2001

SECOND SCHEDULE — *continued*

TABLE 1

ACCESSIBLE EMISSION LIMITS FOR CLASS 1 LASER APPARATUS

Wavelength λ(nm) \ Emission Duration t(s)		$< 10^{-9}$	10^{-9} to 10^{-7}	10^{-7} to 10^{-6}	10^{-6} to 1.8×10^{-5}	1.8×10^{-5} to 5×10^{-5}	5×10^{-5} to 10	10 to 10^{3}	10^{3} to 10^{4}	10^{4} to 3×10^{4}
180 to 302.5		2.4×10^{4} W	2.4×10^{-5} J							
302.5 to 315			$7.9\times10^{-7}C_1$ J$(t<T_1)$ / $7.9\times10^{-7}C_2$ J$(t>T_1)$					$7.9\times10^{-7}C_2$ J		
315 to 400			$7.9\times10^{-7}C_1$ J					7.9×10^{-3} J	7.9×10^{-6} W	
400 to 550		200 W	2×10^{-7} J			$7\times10^{-4}t^{0.75}$J		3.9×10^{-3} J		3.9×10^{-7} W
	or*	10^{11} W.m^{-2}sr^{-1}	$10^{5}t^{0.33}$ J.m^{-2}sr^{-1}					2.1×10^{5} J.m^{-2}sr^{-1}		21 W.m^{-2}sr^{-1}
550 to 700		200 W	2×10^{-7} J			$7\times10^{-4}t^{0.75}$ J$(t<T_2)$		$3.9\times10^{-3}C_3$ J$(t>T_2)$		$3.9\times10^{-7}C_3$ W
	or*	10^{11} W.m^{-2}sr^{-1}	$10^{5}t^{0.33}$ J.m^{-2}sr^{-1}					$(t<T_2)$ $3.9\times10^{4}t^{0.75}$ J.m^{-2}sr^{-1} / $2.1\times10^{5}C_3$ J.m^{-2}sr^{-1} $(t>T_2)$		21 C_3 W.m^{-2}sr^{-1}
700 to 1050		$200C_4$ W	$2\times10^{-7}C_4$ J			$7\times10^{-4}t^{0.75}C_4$ J			$1.2\times10^{-4}C_4$ W	
	or*	$10^{11}C_4$ W.m^{-2}sr^{-1}	$10^{5}C_4t^{0.33}$ J.m^{-2}sr^{-1}					$3.9\times10^{4}t^{0.75}C_4$ J.m^{-2}sr^{-1}	$6.4\times10^{3}C_4$ W.m^{-2}sr^{-1}	
1050 to 1400		2×10^{3} W	2×10^{-6} J				$3.5\times10^{-3}t^{0.75}$ J		6×10^{-4} C_4 W	
	or*	5×10^{11} W.m^{-2}sr^{-1}	$5\times10^{5}t^{0.33}$ J.m^{-2}sr^{-1}					$1.9\times10^{5}t^{0.75}$ J.m^{-2}sr^{-1}	3.2×10^{4} W.m^{-2}sr^{-1}	
1400 to 1530		8×10^{4} W	8×10^{-5} J	$4.4\times10^{-3}t^{0.25}$ J				8×10^{-4} W		
1530 to 1550			8×10^{-3} J		$4.4\times10^{-3}t^{0.25}$ J					
1550 to 10^{5}			8×10^{-5} J	$4.4\times10^{-3}t^{0.25}$ J						
10^{5} to 10^{6}		10^{7} W	10^{-2} J	$0.56t^{0.25}$ J				0.1 W		

* Dual limits requirements for Class 1 .

SECOND SCHEDULE — *continued*

TABLE 2

ACCESSIBLE EMISSION LIMITS FOR CLASS 2 LASER APPARATUS

Wavelength λ (nm)	Emission duration t (s)	Class 2 AEL
400 to 700	$t<0.25$	Same as Class 1 AEL
	$t\geq0.25$	10^{-3} W

SECOND SCHEDULE — *continued*

TABLE 3

ACCESSIBLE EMISSION LIMITS FOR CLASS 3a LASER APPARATUS

<table>
<tr><th>Emission Duration t(s) / Wave-length λ(nm)</th><th>$<10^{-9}$</th><th>10^{-9} to 10^{-7}</th><th>10^{-7} to 10^{-6}</th><th>10^{-6} to $1.8x10^{-5}$</th><th>$1.8x10^{-5}$ to $5x10^{-5}$</th><th>$5x10^{-5}$ to 0.25</th><th>0.25 to 10</th><th>10 to 10^{3}</th><th>10^{3} to $3x10^{4}$</th></tr>
<tr><td>180 to 302.5</td><td>$3x10^{10}$ W.m^{-2}</td><td colspan="8">30 J.m^{-2}</td></tr>
<tr><td>302.5 to 315</td><td rowspan="2">$1.2x10^{5}$ W
and
$3x10^{10}$ W.m^{-2}</td><td colspan="6">$4x10^{-6}C_1$ J and C_1 J.m^{-2} $(t<T_1)$
$(t>T_1)$ $4x10^{-6}C_2$ J and C_2 J.m^{-2}</td><td colspan="2">$4x10^{-6}C_2$ J and C_2 J.m^{-2}</td></tr>
<tr><td>315 to 400</td><td colspan="6">$4x10^{-6}C_1$ J and C_1 J.m^{-2}</td><td>$4x10^{-2}$ J and 10^{4} J.m^{-2}</td><td>$4x10^{-5}$ W and 10 W.m^{-2}</td></tr>
<tr><td>400 to 700</td><td>1000 W
and
$5x10^{6}$ W.m^{-2}</td><td colspan="3">10^{-6} J
and
$5x10^{-3}$ J.m^{-2}</td><td colspan="2">$3.5x10^{-3}t^{0.75}$ J
and
$18t^{0.75}$ J.m^{-2}</td><td colspan="3">$5x10^{-3}$ W and 25 W m^{-2}
(Aversion responses protect for emission >0.25 s)</td></tr>
<tr><td>700 to 1050</td><td>1000WxC_4 W
and
$5xC_4x10^{6}$ W.m^{-2}</td><td colspan="3">$10^{-6}xC_4$ J
and
$5xC_4x10^{-3}$ J.m^{-2}</td><td colspan="4">$3.5x10^{-3}xt^{0.75}$ C_4 J
and
$18xC_4xt^{0.75}$ J.m^{-2}</td><td>$6x10^{-4}xC_4$ W
and
$3.2xC_4$ W.m^{-2}</td></tr>
<tr><td>1050 to 1400</td><td>10^{4} W
and
$5x10^{7}$ W.m^{-2}</td><td colspan="4">10^{-5} J
and
$5x10^{-2}$ J.m^{-2}</td><td colspan="3">$1.8x10^{-2}xt^{0.75}$ J
and
$90xt^{0.75}$ J.m^{-2}</td><td>$3x10^{-3}$ W
and
16 W.m^{-2}</td></tr>
<tr><td>1400 to 1530</td><td rowspan="3">$4x10^{5}$ W
and
10^{11} W.m^{-2}</td><td>$4x10^{-4}$ J
and
100 J.m^{-2}</td><td colspan="5">$2.2x10^{-2}t^{0.25}$ J
and
$5600xt^{0.25}$ J.m^{-2}</td><td colspan="2" rowspan="3">$4x10^{-3}$ W
and
1000 W.m^{-2}</td></tr>
<tr><td>1530 to 1550</td><td colspan="2">10000 J.m^{-2}</td><td colspan="4">$2.2x10^{-2}t^{0.25}$ J
and
$5600xt^{0.25}$ J.m^{-2}</td></tr>
<tr><td>1550 to 4000</td><td>$4x10^{-4}$ J
and
100 J.m^{-2}</td><td colspan="5">$2.2x10^{-2}t^{0.25}$ J
and
$5600xt^{0.25}$ J.m^{-2}</td></tr>
<tr><td>4000 to 10^{6}</td><td>10^{11} W.m^{-2}</td><td>100 J.m^{-2}</td><td colspan="5">$5600xt^{0.25}$ J.m^{-2}</td><td colspan="2">1000 W.m^{-2}</td></tr>
</table>

SECOND SCHEDULE — *continued*

TABLE 4

ACCESSIBLE EMISSION LIMITS FOR CLASS 3b LASER APPARATUS

Wave-length λ (nm) \ Emission Duration t(s)	$<10^{-9}$	10^{-9} to 0.25	0.25 to 3×10^{4}
180 to 302.5	3.8×10^{5} W	3.8×10^{-4} J	1.5×10^{-3} W
302.5 to 315	$1.25 \times 10^{4}C_2$ W	$1.25 \times 10^{-5}C_2$ J	$5 \times 10^{-5}C_2$ W
315 to 400	1.25×10^{8} W	0.125J	0.5 W
400 to 700	3.14×10^{11} W.m^{-2}	$3.14 \times 10^{5}t^{0.33}$ J.m^{-2} and $<10^{5}$ J.m^{-2}	0.5 W
700 to 1050	$3.14 \times 10^{11}C_4$ W.m^{-2}	$3.14 \times 10^{5}C_4t^{0.33}$ J.m^{-2} and $<10^{5}$ J.m^{-2}	0.5 W
1050 to 1400	1.57×10^{12} W.m^{-2}	$1.57 \times 10^{6}t^{0.33}$ J.m^{-2} and $<10^{5}$ J.m^{-2}	0.5 W
1400 to 10^{6}	10^{14} W.m^{-2}	10^{5} J.m^{-2}	0.5 W

Notes to Tables 1 to 4

1. There is only limited evidence about effects for exposure of less than 10^{-9}s. The AEL's for these exposure times have been derived by maintaining the irradiance, radiance or radiant exposure applying at 10^{-9}s.
2. Correction factors C_1 to C_4 and breakpoint T_1 and T_2 used in Tables 1 to 4 are defined in the following expressions:

Parameter	*Spectral region*
$C_1 = 5.6 \times 10^{3}\ t^{0.25}$	302.5 to 400 nm
$T_1 = 10^{0.8(\lambda-295)} \times 10^{-15}$s	302.5 to 315 nm
$C_2 = 10^{0.2(\lambda-295)}$	302.5 to 315 nm
$T_2 = 10 \times 10^{0.02(\lambda-550)}$s	550 to 700 nm
$C_3 = 10^{0.015(\lambda-550)}$	550 to 700 nm
$C_4 = 10^{(\lambda-700)/500}$	700 to 1050 nm

3. The wavelength range λ_1 to λ_2 means $\lambda_1 \leq \lambda < \lambda_2$

TABLE 5

ACCESSIBLE EMISSION LIMITS FOR COLLATERAL RADIATION FROM LASER PRODUCTS

1. Accessible emission limits for collateral radiation having wavelengths greater than 180 nm but less than or equal to 1.0×10^6 nm are identical to the accessible emission limits of Class 1 laser radiation —
   (i) in the wavelength range of less than or equal to 400 nm, for all emission durations;
   (ii) in the wavelength range of greater than 400 nm, for all emission durations less than or equal to 1×10^3 seconds.

2. Accessible emission limit for collateral radiation within the X-ray range of wavelength is 5 μSv/hr, averaged over a cross-section parallel to the external surface of the apparatus, having an area of 10 cm^2 with no dimension greater than 5 cm.

APPENDIX B: NON IONISING RADIATION EXPOSURE LIMITS FOR SKIN AND EYE EXPOSURE

(Source: Third Schedule, Radiation Protection (Non Ionising Radiation) Regulations 2001)

THIRD SCHEDULE

Regulations 16, 19, 20 and 22 (1)

TABLE 1

EXPOSURE LIMITS FOR SKIN EXPOSURE FROM A LASER BEAM

Wavelength, (nm)	*Exposure Duration, (sec)*	*Exposure Limits, (EL)*
200 to 400	10^{-3} to 3×10^{4}	same as TABLE 2
400 to 1400	10^{-9} to 10^{-7}	$0.2\ M_A\ kJ/m^2$
400 to 1400	10^{-7} to 10	$11\ M_A\ t^{1/4}\ kJ/m^2$
400 to 1400	10 to 3×10^{4}	$2\ M_A\ kW/m^2$
1400 to 10^{6}	10^{-9} to 3×10^{4}	same as TABLE 2

For wavelength of λ, the modification factors are:

λ = 400 to 700 nm, $M_A = 1$

λ = 700 to 1050 nm, $M_A = 10^{[0.002(\lambda-700)]}$

λ = 1050 to 1400 nm, $M_A = 5$

λ = 400 to 550 nm, $M_B = 1$

λ = 550 to 700 nm, $M_B = 10^{[0.015(\lambda-550)]}$

λ = 400 to 550 nm, $T_1 = 10$ sec

λ = 550 to 700 nm, $T_1 = 10^{[1 + 0.02(\lambda-550)]}$

THIRD SCHEDULE — *continued*

TABLE 2

EXPOSURE LIMITS FOR DIRECT OCULAR EXPOSURES FROM A LASER BEAM (INTRABEAM VIEWING)

Wavelength (nm)	*Exposure Duration (s)*	*Exposure Limits*
180 to 302	$10^{-9}$to 3×10^{4}	0.03 kJ/m^2
303	$10^{-9}$to 3×10^{4}	0.04 kJ/m^2
304	$10^{-9}$to 3×10^{4}	0.06 kJ/m^2
305	$10^{-9}$to 3×10^{4}	0.10 kJ/m^2
306	$10^{-9}$to 3×10^{4}	0.16 kJ/m^2
307	$10^{-9}$to 3×10^{4}	0.25 kJ/m^2
308	$10^{-9}$to 3×10^{4}	0.40 kJ/m^2
309	$10^{-9}$to 3×10^{4}	0.63 kJ/m^2
310	$10^{-9}$to 3×10^{4}	1.00 kJ/m^2
311	$10^{-9}$to 3×10^{4}	1.60 kJ/m^2
312	$10^{-9}$to 3×10^{4}	2.50 kJ/m^2
313	$10^{-9}$to 3×10^{4}	4.00 kJ/m^2
314	$10^{-9}$to 3×10^{4}	6.30 kJ/m^2
315 to 400	$10^{-9}$to 10	5.6 $t^{1/4}$ kJ/m^2
315 to 400	10 to 10^{3}	10.0 kJ/m^2
315 to 400	10^{3} to 3×10^{4}	0.01 kJ/m^2
400 to 700	10^{9} to 1.8×10^{-5}	0.005 J/m^2
400 to 700	$1.8 x 10^{-5}$ to 10	18 $t^{3/4}$ J/m^2
400 to 550	10 to 10^{4}	100 J/m^2
550 to 700	10 to T_1	18 $t^{3/4}$ J/m^2
550 to 700	T_1 to 10^{4}	100 M_B J/m^2
400 to 700	10^{4} to 3×10^{4}	0.01 M_B W/m^2
700 to 1050	10^{-9} to 1.8×10^{-5}	0.005 M_A J/m^2
700 to 1050	1.8×10^{-5} to 10^{3}	18 M_A $t^{3/4}$ J/m^2

THIRD SCHEDULE — *continued*

Wavelength (nm)	*Exposure Duration (s)*	*Exposure Limits*
1050 to 1400	10^{-9} to 5×10^{-5}	0.05 J/m^2
1050 to 1400	5×10^{-5} to 10^3	90 $t^{3/4}$ J/m^2
700 to 1400	10^3 to 3×10^4	3.2 M_A W/m^2
1400 to 1 mm	10^{-9} to 10^{-7}	100 J/m^2
1400 to 1 mm	10^{-7} to 10	5600 $t^{1/4}$ J/m^2
1400 to 1 mm	10 to 3×10^4	1000 W/m^2

Notes to Tables 1 and 2

The limiting aperture for all ELs for 100 to 1,000 μm is 11 mm. For all other skin ELs, and ocular ELs for ultraviolet and far infrared, the limiting aperture is 1 mm. For ocular ELs in the visible and infrared region, the limiting aperture is 7 mm.

APPENDIX C: ULTRA VIOLET RADIATION EXPOSURE LIMITS

(Source: Third Schedule, Radiation Protection (Non Ionising Radiation) Regulations 2001)

THIRD SCHEDULE — *continued*

TABLE 3

EXPOSURE LIMITS FOR ULTRAVIOLET RADIATION

Wavelength (nm)	*Exposure Limits* J/m^2
180	2500
190	1600
200	1000
205	590
210	400
215	320
220	250
225	200
230	160
235	130
240	100
245	83
250	70
254	60
255	58
260	46
265	37
270	30
275	31
280	34
285	39
290	47
295	56
297	65
300	100
303	250
305	500

Wavelength (nm)	*Exposure Limits* J/m^2
308	1200
310	2000
313	5000
315	1.0×10^4
316	1.3×10^4
317	1.5×10^4
318	1.9×10^4
319	2.5×10^4
320	2.9×10^4
322	4.5×10^4
323	5.6×10^4
325	6.0×10^4
328	6.8×10^4
330	7.3×10^4
333	8.1×10^4
335	8.8×10^4
340	1.1×10^5
345	1.3×10^5
350	1.5×10^5
355	1.9×10^5
360	2.3×10^5
365	2.7×10^5
370	3.2×10^5
375	3.9×10^5
380	4.7×10^5
385	5.7×10^5
390	6.8×10^5
395	8.3×10^5
400	1.0×10^6

APPENDIX D: LABELING FOR LASER APPARATUS

(Source: Fourth Schedule, Radiation Protection (Non Ionising Radiation) Regulations 2001)

FOURTH SCHEDULE

Regulations 35 (2) and
38 (3) to (6) and (8)

LABELLING FOR LASER APPARATUS

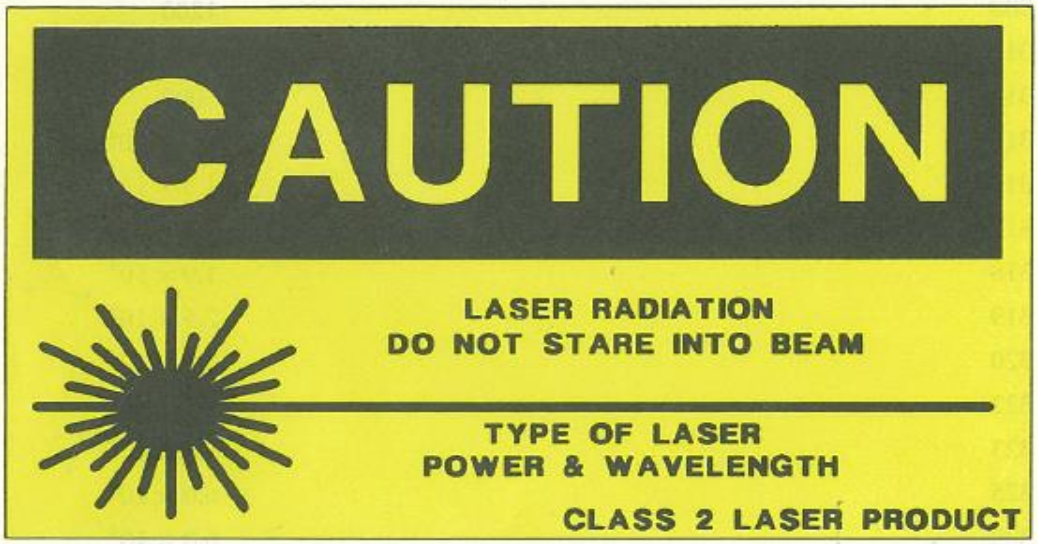


FIGURE 1 *Warning Label for Class 2 Laser Product*

FIGURE 2 *Warning Label for Class 3a Laser Product*

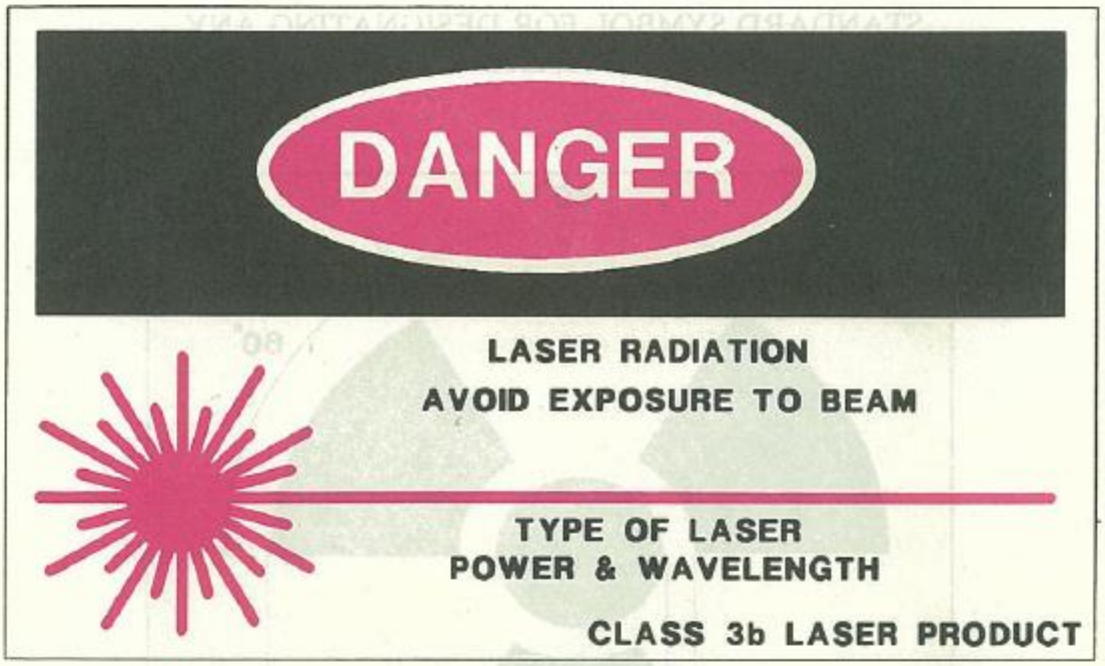


FIGURE 3 *Warning Label for Class 3b Laser Product*

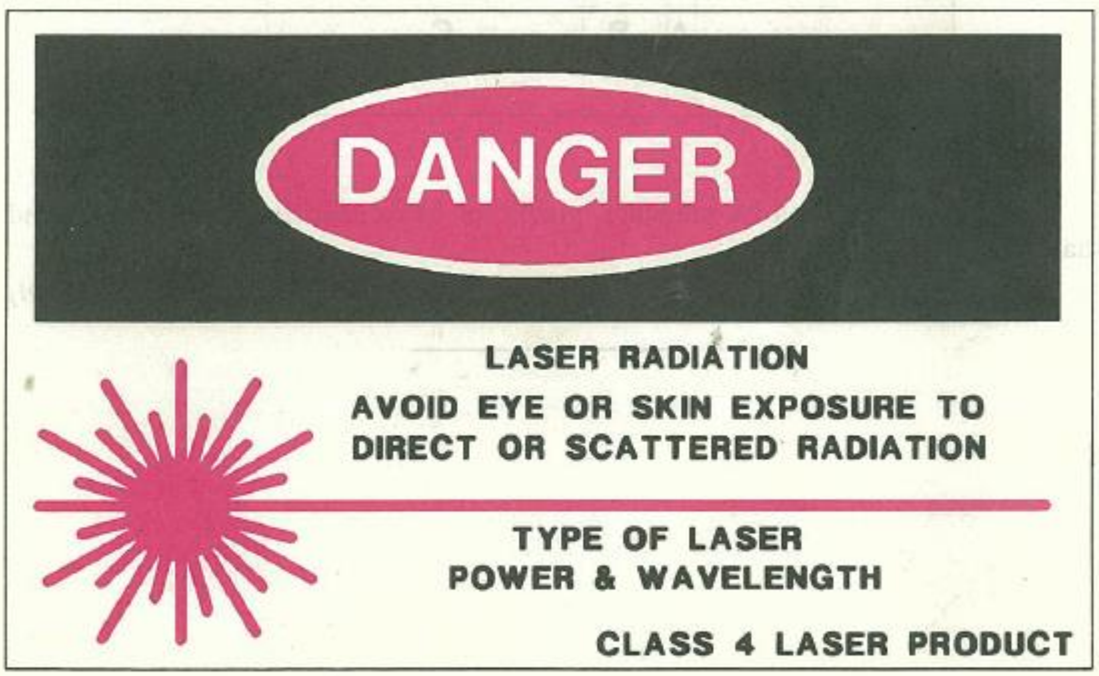


FIGURE 4 *Warning Label for Class 4 Laser Product*

APPENDIX E: REQUEST FOR FUNDING FOR OCCUPATIONAL HEALTH RELATED MEDICAL SERVICES
(OSHE/51/D01)

Office of Safety, Health & Environment

OSHE/51/D01.01

REQUEST FOR FUNDING FOR OCCUPATIONAL HEALTH RELATED MEDICAL SERVICES

General Instructions

1. Each staff or student to submit this form to their PI or Head of Department for approval (one form per staff or student).
2. The completed form is to be submitted to Dr. Gregory Chan, Senior Occupational Health Physician at Office of Safety, Health & Environment for approval. Please liase with Nurse Kim, who is contactable @ **6516 7333** or e-mail: oshlkg@nus.edu.sg
3. Please bring along relevant forms, MSDS, respirator or any other necessary tools during the medical appointment.

University Health Centre is located at 20 Lower Kent Ridge Road

Telephone No: 67761631 Fax No: 6778 3173

Occupational Health services is available between: 9 am to 11.30 am and 2 pm to 4.30 pm from Monday to Friday

The Occupational Health Clinic is available on Tuesday mornings and Thursday afternoons by appointment basis. Please make your appointment with our OSHE Occupational Health Nurse.

On-site chest x-ray: 8.30 am to 11.30 am and 1.30 pm to 5pm (Tuesday, Wednesday & Thursday only, unless advised otherwise)

The centre is closed on Saturday, Sunday and Public Holiday.

Section A: To be Completed by Authorized Personnel (Principal Investigator/Laboratory Supervisor or Head of Department)

Authorized Personnel Name:		**Department/Program:**
Contact No.	**Staff No.:**	**Email Address:**

Please tick one of the following:

☐ Teaching Activities ☐ Research Activities

Brief Description of Research ***(Please attach Material Safety Data Sheet of the Agent Used)***

☐ Staff or student working in BSL 2 laboratory ☐ Research Diving ☐ Others:
☐ Staff or student working in BSL 2+ / 3 laboratory ☐ Animal Care & Husbandry

Please list hazardous agents which the staff or students will potentially exposed to:

☐ Chemical: ☐ Biological: ☐ Others:
☐ Radiation: ☐ Noise

Medical assessment or treatment required:

☐ Hepatitis B screening, vaccinations, post screening
☐ Tetanus Vaccination
☐ Medical examination for Ionizing radiation, R1 license application. Please download the relevant form from the website: http://www.nea.gov.sg/cms/nst/doc/R1.doc
☐ Medical examination for laser / non-Ionizing radiation, N3 license application. Please download the relevant form from the website: http://www.nea.gov.sg/cms/nst/doc/N3.doc
☐ Other vaccination or immunizations required (please specify): ____________
☐ Respirator Fit Test
☐ Respirator Fitness examination
☐ Diving medical examination
☐ Audiometric testing
☐ Medical tests to confirm occupational related infection/illness/disease (please specify): ____________
☐ Others (please specify): ____________

PI Declaration

I declare that the attached departmental staff or students require the above assessment and / or treatment for teaching / research activities.

____________________ ____________

Signature of PI or Laboratory Supervisor **Date**

Section B: To Be Completed by Staff and Student Undergoing Medical Assessment or Treatment

Name of staff or student	Staff No./Student Matric No.	Contact email	Contact Number

Section C: Approval by OSHE and/or Faculty/Institute/School Safety and Health Officer

The request for the above medical assessment/treatment is

☐ Approved (Reference Number: OSHE/51/05-   )
☐ Not Approved

Subject to the following conditions:

________________________________ ____________________ ________________

Name of OSHE staff or Faculty/School Safety and Health Officer   Signature   Date

Section D: To Be Completed by UHC Staff

To: OSHE staff

☐ Cost of medical examination   : $

☐ The cost of the medical examination includes additional investigation, the total cost is : $

________________________________ ____________________ ________________

Name of UHC staff   Signature   Date

APPENDIX F: LASER HAZARD EVALUATION FORM

LASER HAZARD EVALUATION FORM

Laser Owner Information

Laser Owner Name: ____

Department #: ______________________________

Laser System Information

Laser Equipment Manufacturer: ______________________________________

Model Number of Equipment #: __________________ Serial Number #: ___________

Location of the Equipment (s) _____________________

Number of Lasers in the Laser Equipment (s) ______________________________

Laser Information

I. Laser Manufacturer: ____________________ Laser Medium:________________Wavelength: __________ nm

☐ Continuous Wave Average Power: _____ W

☐ Pulsed Pulse Rate: _____ Hz Pulse Duration: _____ sec Pulse Energy: _____ J

Beam Diameter or Dimensions at Aperture _____mm Beam Divergence, Full Angle _____ mrad

Beam Diameter on Lens:______________mm Lens Focal Length (Longest): ________________mm

II. Laser Manufacturer: ____________________ Laser Medium:________________Wavelength: _________ nm

☐ Continuous Wave Average Power: _____ W

☐ Pulsed Pulse Rate: _____ Hz Pulse Duration: _____ sec Pulse Energy: _____ J

Beam Diameter or Dimensions at Aperture _____mm Beam Divergence, Full Angle _____ mrad

Beam Diameter on Lens:______________mm Lens Focal Length (Longest): ________________mm

III. Laser Manufacturer: ____________________ Laser Medium:________________Wavelength: _________ nm

☐ Continuous Wave Average Power: _____ W

☐ Pulsed Pulse Rate: _____ Hz Pulse Duration: _____ sec Pulse Energy: _____ J

Beam Diameter or Dimensions at Aperture _____mm Beam Divergence, Full Angle _____ mrad

Beam Diameter on Lens:______________mm Lens Focal Length (Longest): ________________mm

If more lasers are present in the laser equipment, please attach a separate form

☐ Fully Enclosed Beam Path
☐ Fully Open Beam Path
☐ Partially Open Beam Path

Laser Hazard Evaluation

For Fully Enclosed Beam Path

Protective Housing with safety interlocks are present Yes No NA

For Fully or Partially Open Beam Path

Wavelength(s):____________________ nm Exposure Duration: ________________s

Limiting Aperture Diameter for MPE determination:__________________ mm

Ocular MPE:________________(W/cm^2) or (J/cm^2) Skin MPE:_____________(W/cm^2) or (J/cm^2)

Limiting Aperture Diameter for AEL determination:__________________ mm

Accessible Emission Level (AEL):__________(W) or (J)

Classification of the laser system based on AEL:__________

Minimum OD (intrabeam)___________Minimum OD (diffuse viewing)__________________

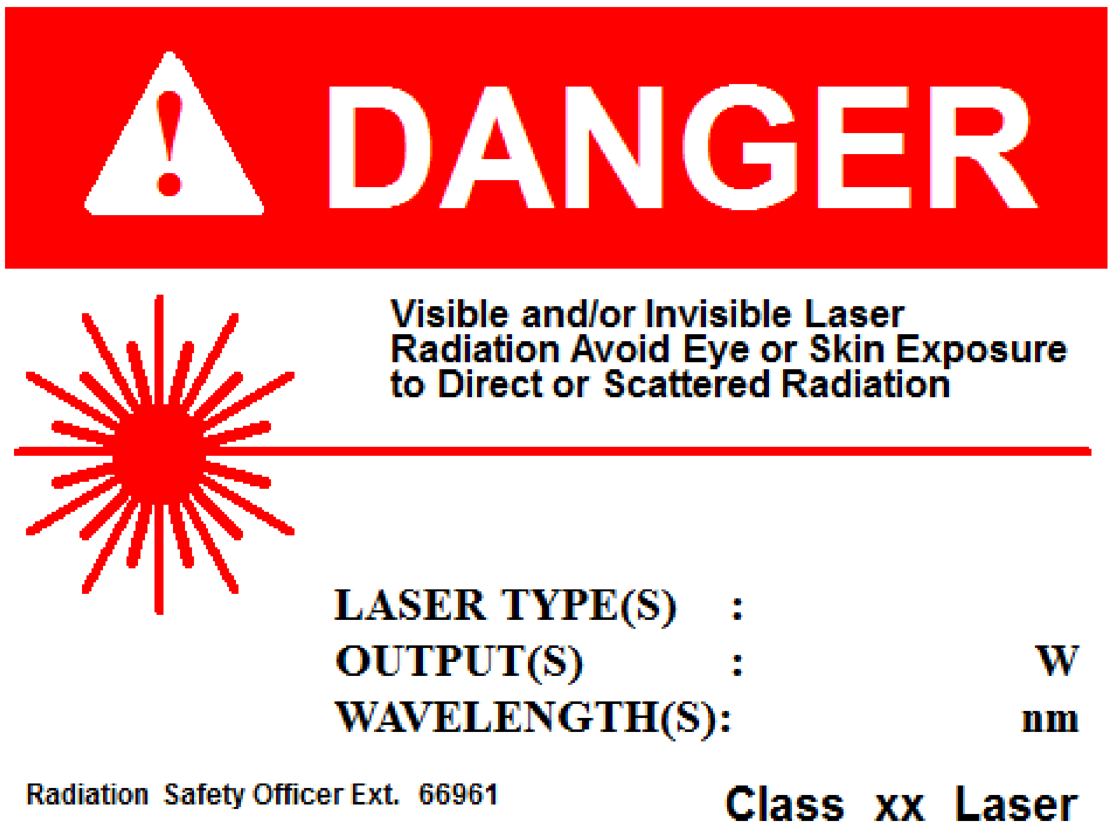
Eyewear OD Required: _____________@ Wavelength(s):____________nm

Distance required to reduce the exposure to below MPE value _______________m

Laser Control Area established and access is controlled Yes No NA

Radiatio Safety Officer:____________________________ Date:_______________

APPENDIX G: LASER CONTROL AREA WARNING SIGN



APPENDIX H: LASER SAFETY INSPECTION CHECKLIST

LASER SAFETY INSPECTION CHECKLIST FORM

Laser Owner Information

Laser Owner Name: ____

Department #: ______________________________

Laser System Information

Laser Equipment Manufacturer: ______________________________________

Model Number of Equipment #: __________________ Serial Number #: ___________

Location of the Equipment (s) _____________________

Number of Lasers in the Laser Equipment (s) ________________________________

<u>For Fully Enclosed Beam Path</u>			
Warning Labels on the laser system	Yes	No	NA
Protective Housing is Present	Yes	No	NA
Safety Interlock on the protective housing	Yes	No	NA
Warning Label on the protective housing	Yes	No	NA
<u>Fully or Partially Open Beam Path</u>			
Laser Control Area clearly established	Yes	No	NA
Access to laser control area is controlled	Yes	No	NA
Laser barriers for control area are suitable for laser type	Yes	No	NA
Laser barriers extend all the way to the roof	Yes	No	NA
If no, then there are no reflective surfaces on the roof	Yes	No	NA
Laser warning signs present at the entry of laser control area	Yes	No	NA
Entry way to laser control area is interlocked	Yes	No	NA
If no, then describe means of access control to entry area	Yes	No	NA
Entryway allows easy regress	Yes	No	NA
No shiny reflective objects in the control area or beam path	Yes	No	NA
No means of laser exiting the control area	Yes	No	NA
Activation Warning power indicator present	Yes	No	NA
Remote interlock connector present	Yes	No	NA
Beam Attenuator/stop present	Yes	No	NA
Beam Aperture present	Yes	No	NA

If yes, warning labels present on the aperture	Yes	No	NA
Laser Protective Eyewear	Yes	No	NA
Optical Density(OD)__________@Wavelength_______________nm			
OD and wavelength range are printed on the eyewear	Yes	No	NA
Beam Alignment performed	Yes	No	NA
If yes, beam alignment procedures present	Yes	No	NA

For all Laser Systems

Safety Interlock on the service panel	Yes	No	NA
If no interlock on service panel, service panel tightly screwed	Yes	No	NA
Warning Label on the service panel	Yes	No	NA
Viewing windows or optical lenses used to view the beam	Yes	No	NA
If yes, exposure levels are below PEL	Yes	No	NA
If yes, warning labels present on the windows and lenses	Yes	No	NA
Key Controlled master switch or computer code present	Yes	No	NA
Laser user manual or SOP present	Yes	No	NA

Radiation Safety Officer:_________________________________ **Date:**_______________