McGill University

Laser Safety Manual

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Prepare by: Environmental Health & Safety

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Introduction

This Laser Safety Manual was produced by and is available from the McGill University Environmental Health & Safety Office. It describes in detail the provisions of McGill University's Laser Safety Program and the requirements for using lasers on campus. The McGill University Laser Safety Program is intended to assist members of the university community to conform not only with the requirements of the Quebec Occupational Health and Safety Act, but also with the provisions of ANSI Z136.1-2007 standard for Safe Use of Lasers and related regulations and standards. The Laser Safety Program covers Class 3B and Class 4 lasers, as well as embedded lasers with an output power above 5 mW.

1. McGill University Laser Safety Policy

Under its Health and Safety Policies and the general provisions of the Occupational Health and Safety Act of Quebec, McGill University is committed to the continuous improvement of the safety culture at the University by providing advice, guidance, training, and technical support to the McGill community; and to taking every reasonable precaution to protect the health and safety of its employees and students.

The Laser Safety Policy is intended to assist the University community in the effective control of laser hazards, and covers Class 3B and 4 lasers. High powered embedded Class 1 lasers with an output power above 5mW such as those in microscopy equipment (30mW) or flow cytometry systems (100mW) are also included in this policy, but low powered Class 1 lasers such as laser pointers (1 mW) or laser printers (0.1mW) are excluded.

This Laser Safety Policy applies to all university departments, employees, outside contractors, students, fellows, volunteers, and visiting scholars at the University or University-controlled sites.

1.1 Laser Safety Task Force

In 2009, the University Laboratory Safety Committee (ULSC) setup a Laser Safety Task Force with the mandate to develop and implement a laser safety program for McGill University. This working group consisted of McGill faculty experts in the field of laser research and members of the Environmental Health and Safety Office. We formally thank all members who were involved in the generation and implementation of this program. This legacy has been passed down to the current Laser Safety Officer, who now works under the supervision of the ULSC to continue developing new initiatives.

1.2 Laser Safety Program

The content of the laser safety program is based on the provisions of the latest American National Standards Institute (ANSI) standard For the Safe Use of Lasers Z136.1. The objective of the program is to effectively control laser hazards associated with the operation of Class 3B and Class 4 lasers and laser systems in controlled areas (indoors and outdoors in the case of field work projects) under the jurisdiction of McGill University. The program applies to all lasers and laser systems (whether purchased, borrowed, fabricated or brought in for use by others).

Essential components of the laser safety program are:

- Designation of a Laser Safety Officer, overseen by the ULSC.
- Establishment of responsibilities for ULSC, LSO, principal investigators, laser supervisors and laser workers.

- Registration of all Class 3B and 4 Lasers. Registration of all embedded Class 1 lasers with an output power above 5 mW. Requirement than EHS be notified of any new laser acquisitions or installations prior to their operation.
- Requirement for laboratory laser safety inspections.
- Provision of Education and Training. Requirement that all McGill personnel and students must obtain laser safety training from EHS prior to working with Class 3B and 4 lasers. Only equipment specific training is required for lower classes of lasers.
- Pre-assignment and termination or re-assignment eye examinations
- Requirement that all Class 3B and 4 lasers and laser systems be operated in accordance with the provisions of ANSI Z136.1 standard “For the Safe Use of Lasers", which require implementation of adequate engineering, administrative and procedural control measures and use of personal protective equipment.
- Requirement for reporting accidents, incidents (near accidents) and operating irregularities involving lasers to EHS for investigation, analysis and remedial action.

The implementation of the laser safety program relies on the Faculty and staff members responsible for the use of lasers. As required by the Internal Responsibility System (IRS), the Principal Investigator (PI) (consult section 4.3 for definition) is ultimately responsible for the safe use of lasers and must ensure that personnel have been properly trained. The details of the laser safety program and the requirements for using lasers on campus are found in the Laser Safety Manual.

1.3 Visitors (spectators)

A spectator is defined as an individual who wishes to observe or watch a laser or laser system in operation and may lack the appropriate laser safety training.

As required by the Laboratory Safety Responsibilities Policy, and the Laser Safety Program, all McGill personnel not directly associated with the laser facility, guests, contractors or non-laboratory personnel visiting or wishing to enter the laser facility (spectators) must first obtain permission from the Principal Investigator prior to accessing the laser facility, the degree of hazard and avoidance procedure must be explained to them, and appropriate protective measures taken.

2. Laser Safety Program

2.1 Objective and Scope

Objective

It is the objective of this laser safety program to effectively control laser hazards in accordance with the University Health and Safety Policies and the general provisions of the Occupational Health and Safety Act of Quebec.

Scope and application

This program applies to all Class 3B and Class 4 lasers and laser systems in controlled areas (indoors and outdoors in the case of field work projects) under the jurisdiction of McGill University and to all those identified as principal investigators, laser supervisors and laser workers. The program establishes requirements based on the provisions of ANSI Z136.1-2007 Standard for Safe Use of Lasers. The program covers Class 3B and Class 4 lasers, as well as Class 1 embedded lasers with output powers above 5 mW. Other lower hazard classes, laser pointers and laser printers are not covered by this program.

2.2 Components of the laser safety program

- Formation of a Laser Safety Task Force within the University Laboratory Safety Committee.
- Designation of an individual as the Laser Safety Officer (LSO) with the authority and responsibility to effect knowledgeable evaluation and control of laser hazards, and the implementation of appropriate control measures, as well as to monitor and enforce compliance with required standards and regulations.
- Establishment of responsibilities for ULSC, LSO, principal investigators, laser supervisors and laser workers. Every laser worker will complete and submit a McGill Laser Worker Registry Form to McGill Environmental Health & Safety Office.
- Registration of all Class 3B and 4 Lasers. Registration of all embedded Class 1 lasers with an output power above 5 mW. Requirement that EHS be notified of any new laser purchases, acquisitions or installations prior to their operation. The laser inventory is maintained by the LSO in the McGill Environmental Health & Safety Office.
- Requirement for laboratory laser safety inspections and development of a laser safety inspection procedure
- Provision of Education and Training. Requirement that all McGill personnel must obtain laser safety training from EHS prior to working with Class 3B and 4 lasers.
- Provision of medical surveillance. All laser personnel and incidental personnel shall attend a pre-assignment eye examination and the results of these examinations kept on file to establish baseline surveillance in the event of actual or suspected eye injury. A further eye examination shall be conducted when personnel leave the university or transfer to other duties without potential laser exposure. Initial eye examinations must be completed prior to scheduling for laser safety training. The examination is performed by a qualified

nurse under the supervision of the Occupational Health Program Administrator at the EHS office. The Laser Safety Officer in conjunction with the Occupational Health Program Administrator maintains results of the examinations.

- Requirement that all Class 3B and 4 lasers and laser systems be operated in accordance with the requirements established by the latest American National Standards Institute (ANSI) Z136.1 document, "Standards for the Safe Use of Lasers". Implementation of adequate engineering, administrative and procedural control measures and requirements for use of personal protective equipment as applicable.
- Requirement for reporting accidents, incidents (near accidents) and operating irregularities involving lasers to EHS for investigation, analysis and remedial action.

3. Definitions

The following select definitions are provided for quick reference. For definitions of other relevant terms, refer to ANSI Z136.1-2007 Standard for Safe Use of Lasers.

Amsler Grid Test
A test where a grid or similar pattern is used to test the macula (the center of the retina) for distortions and scotomas (blind spots).

Aphakic (eye or individual)
Describing an eye in which the crystalline lens is absent.

Aversion Response
The reflexive blinking or turning away from a sudden or painful light stimulus. Typical response time of 0.25 seconds.

Biological effect (bioeffect)
A thermal or a photochemical effect

Class 1 laser system
- Considered to be incapable of producing damaging radiation levels during operation
- Consists of low powered laser products such as laser pointers, as well as high powered laser products rendered inert by protective housing, enclosures, or other engineering controls.

Class 1M laser system
- Considered to be incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with an optical instrument such as an eye-loupe (diverging beam) or a telescope (collimated beam), and
- Exempt from any control measures other than to prevent potentially hazardous optically aided viewing; and is exempt from other forms of surveillance.

Class 2 laser system
- Emits in the visible portion of the spectrum (0.4 to 0.7 μm), and
- Eye protection is normally afforded by the aversion response.

Class 2M laser system
- Emits in the visible portion of the spectrum (0.4 to 0.7 μm), and
- Eye protection is normally afforded by the aversion response for unaided viewing
- However, Class 2M is potentially hazardous if viewed with certain optical aids.

Class 3 laser system (medium-power)
May be hazardous under direct and specular reflection viewing conditions, but is normally not a diffuse reflection or fire hazard. There are two subclasses:

Class 3R laser system

- Potentially hazardous under some direct and specular reflection viewing condition if the eye is appropriately focused and stable, but the probability of an actual injury is small. This laser will not pose either a fire hazard or diffuse-reflection hazard
- Beams can emits in the visible or invisible portion of the spectrum.

Class 3B laser system
- May be hazardous under direct and specular reflection viewing conditions
- Normally not a diffuse reflection or fire hazard
- Beams can emits in the visible or invisible portion of the spectrum.

Class 4 laser system (high-power)
- Is a hazard to the eye or skin from the direct beam, and
- May pose a diffuse reflection or fire hazard
- Beams can emits in the visible or invisible portion of the spectrum.
- May also produce laser generated air contaminants (LGAC) and hazardous plasma radiation

Controlled area (laser)
An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser radiation hazards.

Embedded laser
An enclosed laser that has a higher classification than the laser system in which it is incorporated, where the system's lower classification is appropriate due to the engineering features limiting accessible emission.

Funduscopic examination
Ophtalmoscopic examination of the eye fundus (interior rear surface of the eye, the retina)

Incidental Personnel
Persons, whose work makes it possible (but unlikely) that they will be exposed to laser energy sufficient to damage their eyes or skin, e.g., custodial, clerical, and supervisory personnel not working directly with laser devices.

Laser
A device, which produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions to low energy levels. An acronym for Light Amplification by Stimulated Emission of Radiation.

Laser Classification
An indication of the beam hazard level of a laser or laser system during normal operation or the determination thereof. The hazard level of a laser or laser system is represented by a number or a numbered capital letter. The laser classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B and Class 4. In general, the potential beam hazard level increases in the same order.

Laser Modification
Includes, but is not limited to, any change to a laser's hardware, lasing medium or media, firmware or software, or its control or safety systems, that results in, or will allow, operation outside of the laser's original specifications. This includes changes to a laser's class, power/energy output or operation beyond its original wavelength or range of wavelengths.

Laser Personnel
Persons who routinely work around hazardous laser beams. The ANSI standard Z136.1 requires such persons to be protected by engineering controls, administrative procedures, or both.
NOTE: Laser personnel generally include laser workers and may include principal investigators and laser supervisors.

Laser Safety Officer (LSO)
One who has authority and responsibility to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

Laser System
Assembly of electrical, mechanical, and optical components, which includes one or more lasers.

Laser Supervisor
An individual who has been delegated supervisory responsibilities by a principal investigator for Class 3B and Class 4 laser/laser systems and laser workers.

Laser Worker
One who operates or works in proximity to Class 3B or Class 4 laser/laser systems.

Maximum Permissible Exposure (MPE)
The level of laser radiation to which, an unprotected person may be exposed without adverse biological changes in the eye or skin.

Nominal Hazard Zone (NHZ)
The space within which, the level of the direct, reflected, or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE.

Optical Density (OD or D_λ)
The logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength:
$D_\lambda = \log_{10}(1/\tau_\lambda)$, where τ_λ is the transmittance at the wavelength of interest.

Principal Investigator
An individual who is in charge of a laser laboratory and/or principal authority for Class 3B or Class 4 laser/laser systems, usually an appointed professor.

Spectator
An individual who wishes to observe or watch a laser or a laser system in operation, and who may lack the appropriate laser safety training

4. Responsibilities

4.1 University Laboratory Safety Committee (ULSC)

The membership is appointed by the Chair of the ULSC and includes faculty or staff members with expertise in physical hazards namely in ionizing and non-ionizing radiation with knowledge in laser technology or in the assessment of laser hazards. Other committee members are Radiation Specialists, Medical Specialists, and other Environmental Health and Safety personnel.

The committee has the following responsibilities:

4.1.1 Establish and maintain policies and standards for the control of laser hazards.

4.1.2 Approve the laser safety program, periodically review and assess its effectiveness, and recommend changes if appropriate

4.1.3 Recommend and approve appropriate laser safety training program materials.

4.1.4 Maintain an awareness of applicable new or revised laser safety standards.

4.2 Laser Safety Officer (LSO)

The Laser Safety Officer is directed by the University Laboratory Safety Committee and will be knowledgeable in evaluation and control of laser hazards. The LSO has the following responsibilities:

4.2.1 Establish and maintain adequate policies and procedures for the control of laser hazards in compliance with applicable requirements, including federal, provincial and local regulations.

4.2.2 Maintain inventory of all lasers of interest on campus including Class 3B, Class 4, and Class 1 embedded lasers above 5 mW. Classify or verify the laser classification if necessary.

4.2.3 Be responsible for the hazard evaluation of laser work areas, including the establishment of verification of the extent of Nominal Hazard Zones.

4.2.4 Assure that prescribed control measures are implemented and maintained in effect, including approving substitute or alternate control measures.

4.2.5 Approve standard operating procedures (SOP), alignment procedures and other procedural control measures.

4.2.6 Recommend or approve protective equipment and assure that it is audited periodically to assure it is in proper working order.

4.2.7 Review the wording on area signs and equipment labels.

4.2.8 Review laser installations, facilities and equipment before use, including modifications.

4.2.9 Assure that adequate safety education and training are provided to laser personnel.

4.2.10 Determine the personnel categories for medical surveillance.

4.2.11 Maintain records required by various regulatory bodies. Ensure records are maintained of scheduled and performed medical examinations, training records, audits, SOP approvals, etc.

4.2.12 Inspect annually, if possible, all Class 3B and Class 4 lasers for compliance with the requirements of McGill University's Laser Safety Program. Inspect the presence and functionality of the laser safety features and required control measures. Ensure that corrective action is taken, where required.

4.2.13 Develop a response plan for incidents of actual or suspected exposure to potentially harmful laser radiation, including provisions for medical assistance, incident investigation, and documentation and reporting of investigation results.

4.2.14 Approve laser operation only when satisfied that control measures are adequate, including SOP for maintenance and service of enclosed systems and operation procedures for Class 3B and 4 lasers and adequate consideration of safety from non-beam hazards. Suspend, restrict or terminate the operation of a laser or laser system without adequate hazard controls, and advise Department Safety Committee Chair, Dean and ULSC of such action.

4.2.15 Maintain the Internal Permit management system and keep records of all related information, including: lists of Permit Holders, Laser users, Equipment details, and areas where laser devices are stored or used. Ensure that each Permit is amended when necessitated by changes to facilities, equipment, policies, intended use, procedures or personnel.

4.3 Principal Investigator

A Principal investigator is one that is in charge of a laser laboratory where Class 3B or Class 4 lasers and laser systems are operated. The principal investigator may delegate some of his/her responsibilities to a laser supervisor. However, the principal investigator cannot discharge these responsibilities to a laser supervisor. As required by the Internal Responsibility System (IRS), the Principal Investigator is ultimately responsible for the safe use of lasers under his/her authority.

The principal investigator has the following responsibilities:

4.3.1 To register all Class 3B or Class 4 lasers or embedded laser systems with EHS.

4.3.2 To provide the names of laser workers and supervisors working with Class 3B and Class 4 lasers to the LSO and provide information for medical surveillance scheduling and training.

4.3.3 To not permit the operation of a laser unless there is adequate control of laser hazards to employees, visitors, and the general public.

4.3.4 To not permit operation of a new or modified Class 3B or Class 4 laser or laser system under his/her authority without the approval of the LSO. To submit plans for new Class 3B or Class 4 laser installations or modifications to the LSO for approval.

4.3.5 To ensure that laser supervisors and laser workers have obtained laser safety training prior to working with or in proximity of Class 3B or Class 4 lasers or laser systems. If this is not possible, for laser workers, provide (either personally or through a laser supervisor) appropriate instruction and supervision until training is available.

4.3.6 To ensure that each laser supervisor/worker is trained in the safe operation of the specific Class 3B or Class 4 laser or embedded laser system that he/she will operate.

4.3.7 To permit only trained and authorized laser supervisors/workers to operate or work in proximity of Class 3B or Class 4 lasers or laser systems.

4.3.8 To ensure that all engineering controls are in place and all administrative procedure controls are followed.

4.3.9 To provide written standard operating procedures (SOP) for all Class 3B (recommended) and Class 4 (required) lasers and laser systems and to ensure that each laser is used only under the conditions outlined in the SOP.

4.3.10 To provide and enforce the use of appropriate personal protective equipment when and/or where required.

4.3.11 To ensure that all Class 3B or Class 4 lasers or laser systems are securely stored or disabled (for example by removal of the key) when not operating and to prevent unauthorized use.

4.3.12 To ensure that all laser workers and supervisors participate in the University’s medical surveillance program.

4.3.13 To ensure that any spectators are properly informed and protected from potential hazards.

4.3.14 To report any actual or suspected accidents or incidents to EHS. If necessary, assist in obtaining appropriate medical attention for any person involved in a laser accident.

4.3.15 To cooperate with the LSO during laser safety inspections and correct any unsafe conditions in a timely manner.

4.4 Laser Supervisor

A laser supervisor is one who has been authorized to supervise individuals working with or having the potential for being exposed to laser radiation levels greater than Class 1. The laser supervisor should have an overall knowledge of laser safety requirements for the lasers under the supervisor's authority.

The laser supervisor has the following responsibilities:

4.4.1 To obtain laser safety training prior to operating or working in proximity of Class 3B or Class 4 lasers or laser systems.

4.4.2 To not permit the operation of a laser unless there is adequate control of laser hazards to employees, visitors, and the general public.

4.4.3 To permit only authorized laser workers who have obtained laser safety training to work with or in proximity of Class 3B or Class 4 lasers or laser systems.

4.4.4 To be familiar with the specific hazards, the implemented control measures and the standard operating procedures for the lasers and laser systems under his/her authority.

4.4.5 To ensure that written SOP and other appropriate instructions and training materials are provided to users of Class 3B and Class 4 lasers and laser systems under his/her authority.

4.4.6 To provide instruction and supervision to laser workers when directed by the principal investigator.

4.4.7 To operate or permit the operation of a Class 3B or Class 4 laser or laser system only under the conditions authorized by the principal investigator as outlined in the written SOP.

4.4.8 To ensure that all engineering controls are in place and all administrative procedure controls are followed.

4.4.9 To ensure that any spectators are properly informed and protected from potential hazards.

4.4.10 To not permit operation of a new or modified Class 3B or Class 4 laser or laser system under his/her authority without the approval of the LSO.

4.4.11 To participate in the University's medical surveillance program.

4.4.12 To report any unsafe conditions to the principal investigator or to EHS.

4.4.13 To report any actual or suspected accidents or incidents to the principal investigator and/or EHS. If necessary, assist in obtaining appropriate medical attention for any person involved in a laser accident.

4.5 Laser Worker

A laser worker is one who operates, or works with or in proximity of a Class 3B or Class 4 laser or laser system or have the potential for exposure to levels of laser radiation greater than Class 1.

Laser workers have the following responsibilities:

4.5.1 To obtain Laser Safety training prior to operating or working in proximity to Class 3B or Class 4 laser/laser systems. If this is not possible, to obtain appropriate instruction and supervision from the principal investigator or laser supervisor until such training is available.

4.5.2 To not energize or work with or near a laser unless authorized by the laser supervisor or by the principal investigator

4.5.3 To comply with all safety rules, practices, requirements, written SOP and other procedures prescribed by the laser supervisor, the principal investigator and the LSO.

4.5.4 To be familiar with all operational procedures and specific safety hazards of the Class 3B or Class 4 laser/laser systems that he/she will operate or work with.

4.5.5 To operate Class 3b and Class 4 laser/laser systems only under the conditions authorized by the laser supervisor or principal investigator

4.5.6 To report all unsafe conditions to the laser supervisor or principal investigator

4.5.7 To participate in the University's medical surveillance program.

4.5.8 To immediately report any known or suspected accidents to the laser supervisor/principal investigator. If the laser supervisor and the principal investigator are not available, the worker shall notify the LSO.

4.5.9 Should not permit spectators within a laser controlled area which contains a Class 3B laser and shall not permit spectators within a laser controlled area which contains a Class 4 laser unless appropriate approval from the principal investigator or laser supervisor has been obtained; the degree of hazard and avoidance procedures has been explained; and appropriate protective measures are taken.

4.6 Other Personnel

Anyone involved in purchasing or acquiring a laser or laser system (including operational laser components and subassemblies) should contact the LSO. Such personnel may also include but is not limited to purchasing, accounting, building management, etc., as may be applicable.

5. Registration of Lasers

Environmental Health & Safety requires an inventory of all lasers located on both campuses. Anyone who owns lasers, laser systems and/or operational laser components or subassemblies, including embedded lasers, must register their lasers with EHS. In addition, EHS must be notified of any new laser purchases or installations prior to their operation.

5.1 Purpose

The purpose for registration and maintaining an inventory of all Class 3B and Class 4 lasers or laser systems, and embedded Class 1 lasers with an output power above 5 mW is:

- To identify lasers and laser systems, for which appropriate engineering and/or administrative or procedural controls may need to be implemented
- To be used as a basis for periodic laboratory laser safety inspections for compliance with the University's Laser Safety Program
- To help identify all personnel who routinely work around hazardous laser beams and need to be protected by engineering controls, administrative procedures or both.

5.2 Registration information

The laser registration shall include the following information:

- Department
- Principal Investigator's name and contact information
- Laser location (building and room number)
- Laser Class (e.g. 3B, 4, or embedded)
- Laser type (Nd:YAG, CO_2, Excimer, Argon, Diode, etc.)
- Laser category (commercial, home-built, component, subassembly, etc.)
- Intended application (e.g. research, medical, undergraduate teaching, etc.)
- Laser manufacturer
- Laser model number (or model number for larger piece of equipment system if embedded)
- Laser serial number (or for larger piece of equipment system if embedded as before)
- Wavelength(s) laser is capable of producing during operating conditions
- Maximum power output that the laser or laser system is capable of
- Laser mode (e.g. Continuous wave, Single Pulse, Repeat Pulse)
- Initial beam diameter
- Authorized user's list when applicable

5.3 Registration procedure

The principal investigator is responsible to the registration of Class 3B and Class 4 lasers or laser systems, and embedded Class 1 lasers with an output power above 5 mW under his/her authority with EHS. The laser inventory is maintained by the LSO in the McGill

Environmental Health & Safety Office. A Laser Registration Form is available from EHS to facilitate laser registration (see Appendix A).

6. Laser Safety Inspections

Laser safety inspections are an essential component of the Laser Safety Program. The Laser Safety Officer is responsible for inspecting all new or modified Class 3B or Class 4 lasers and laser systems and (at least annually) all existing Class 3B or Class 4 lasers and laser systems for compliance with the Laser Safety Program. Class 1 embedded high powered lasers will also be evaluated under this program but under reduced requirements compared to higher classes.

6.1 Purpose

The purpose of the laser safety inspections is to verify the presence and functionality of the laser safety features and control measures required for each Class of laser or laser system, including, but not limited to the following:

- Engineering controls
- Administrative and procedural controls
- Standard Operating Procedures
- List of authorized personnel
- Training and medical surveillance records

New or modified existing laser installations shall also be inspected prior to operation.

6.2 Procedure

The laser safety inspections may or may not be scheduled together with Laboratory Safety Inspections. The inspection procedure is similar to the Laboratory Inspections Procedure.

6.2.1 Notification.

Individual laboratories will not receive prior warning as inspections are unannounced. Laser Safety Inspections are only conducted when someone is present in the laboratory, preferably the Principal Investigator or if unavailable, a delegate, such as a laser supervisor. If no one is present at an unannounced inspection, an appointment can be arranged.

6.2.2 Inspection checklist

Each laser installation or laser facility is inspected using a *Laser Safety Inspection Checklist*. Each item is graded as Pass, Fail, Not Applicable, or LSO (e.g. if a more detailed assessment of alternate, substitute or other equivalent control measures by the LSO is necessary). The *Laser Safety Inspection Checklist* is provided in Appendix B.

6.2.3 Laser Safety Inspection Report

After the inspection, the Principal Investigator responsible for the laser or laser system will receive a copy of the inspection checklist providing the inspection results and including instructions and recommendations for corrective action as may be applicable.

6.2.4 Laser Safety Inspection Response
Each report has a *Receipt Acknowledgement Form* that must be signed and returned to EHS within 2 weeks after the report is issued; electronic signatures are accepted.

Principal Investigators are required to respond to the inspection reports in writing within 1 month of reception of the report. An inspection report response should indicate how each item of non-compliance was corrected and for those items not yet corrected target dates are required. The response also provides an opportunity to comment on the inspection process.

7. Education and Training

Education of authorized personnel (LSOs, operators, service personnel and others) in the safe use of lasers and laser systems and the assessment and control of laser hazards is an essential component of the Laser Safety Program.

7.1 Applicability
Employee training is required to be provided for Class 3B or Class 4 lasers and laser systems. Employee training is not required, but recommended to be provided for laser systems containing embedded Class 3B and Class 4 lasers, otherwise considered Class 1. If training is warranted for embedded lasers, it shall extend to those routinely around the systems, who will be present when maintenance or service procedures may require access to the Class 3B or Class 4 open beams.

7.2 Affected personnel

7.2.1 LSO training
McGill University management shall provide for the LSO training on potential hazards (including bioeffects), control measures, applicable standards, medical surveillance and other pertinent information pertaining to laser safety and applicable standards. When necessary, management provides to the LSO adequate consultative services. The LSO training shall be commensurate to at least the highest class of laser under the jurisdiction of the LSO. The training shall also include consideration for the evaluation and control of any non-beam hazards associated with the lasers and the laser systems under the jurisdiction of the LSO.

7.2.2 User training
Laser safety training shall be provided to the users of Class 3B or Class 4 lasers and laser systems.

Users include:

- principal investigators
- laser supervisors
- laser workers (students or other operators, technicians, engineers, maintenance and service personnel, and any other persons working with or potentially exposed to laser radiation in excess of Class 1).

7.3 Recommended laser safety training topics

7.3.1 Users and personnel routinely working with or potentially exposed to Class 3B or 4 laser radiation:

(a) Fundamentals of laser operation (physical principles, construction, etc.)
(b) Bioeffects of laser radiation on the eye and skin
(c) Significance of specular and diffuse reflections
(d) Non-beam hazards of lasers
(e) Laser and laser system classifications
(f) Control measures
(g) Overall responsibilities of management and employee
(h) Medical surveillance practices
(i) CPR for personnel servicing or working on lasers with exposed high voltages and/or the capability of producing potentially lethal electrical currents

The above training topics are covered in various sections of this manual as follows:

Recommended training topic	Manual Reference:
(a) Laser fundamentals	Appendix E
(b) Bioeffects	Appendix E
(c) Significance of specular and diffuse reflections	Appendix E
(d) Non-beam hazards of lasers	Section 10
(e) Laser and laser system classifications	Section 2
(f) Control measures	Section 9
(g) Overall responsibilities of management and employee	Section 4
(h) Medical surveillance practices	Section 8

CPR training can be obtained through McGill's First Aid in the Workplace Training.

7.3.2 LSO or other individuals responsible for the laser safety program, evaluation of hazards, implementation of control measures, or any others directed by management to obtain a thorough knowledge of laser safety:

(a) The topics in 7.3.1 above
(b) Laser terminology
(c) Types of lasers, wavelengths, pulse shapes, modes, power/energy
(d) Basic radiometric units and measurement devices
(e) Maximum Permissible Exposure (MPE)
(f) Laser hazard evaluations and other calculations

7.3.3 Other topics of interest:

- laser safety standards and regulations
- laser accidents and case studies

7.4 Training records

The LSO will maintain records of all personnel (principal investigators, laser supervisors and laser users) who participated in the laser safety training.

7.5 Refresher training

Following the Provincial standard for workplace trainings, Laser Safety Trainings will remain valid for a period of three years. Refresher trainings will be offered as an abbreviated version of the original training intended to assure that the users have the necessary laser safety knowledge to continue to work safely with their lasers.

8. Medical Examinations and Surveillance

8.1 Examination following accidental laser exposure

In case of an accidental exposure to laser radiation, and where an actual injury has occurred or is suspected, medical examinations must be performed as soon as practical (usually within 48 hours). The laser wavelength, emission characteristics and exposure situation must be taken into consideration in order to ensure appropriate medical referral. If the involved laser is operating in the retinal hazard region 400 nm – 1400 nm, the examinations shall be performed by an ophthalmologist.

NOTE: Appendix E of the ANSI Z136.1 provides details on the recommended examination protocol commensurate with the observed symptoms and laser system.

8.2 Medical surveillance

8.2.1 Purpose of pre-assignment medical examinations

- To establish a baseline against which damage (primarily ocular) can be measured in the event of an actual or suspected accidental injury
- To identify certain workers who might be at a special risk from chronic exposure to some continuous emission lasers

Early detection of biological changes or damage would make active intervention possible to stop further biological damage or to allow recovery from biological effects

8.2.2 Applicability

Medical surveillance is limited to those who are clearly known to be at risk from particular kinds of laser radiation. It is required for all laser personnel and incidental personnel who may be exposed to Class 3B and Class 4 lasers radiation. The two personnel categories that are considered for surveillance are defined as follows:

Incidental Personnel - those whose work makes it possible (but unlikely) that they will be exposed to laser energy sufficient to damage their eyes or skin, e.g., custodial, clerical, and supervisory personnel not working directly with laser devices.

Laser Personnel - those who work routinely in laser environments, and are ordinarily fully protected by engineering controls or administrative procedures, or both.

The LSO shall determine each employee’s category.

8.2.3 Examination details

Incidental personnel will have eye examination for visual acuity. Laser personnel is subject to the following baseline eye examination:

- Ocular history
- Visual acuity
- Amsler Grid Test (macular function)
- Color vision

If the ocular history shows no problems and visual acuity is normal in each eye for far and near with correction, and Amsler Grid Test and Color vision responses are normal, no further examination is required. Laser workers with certain medical conditions (e.g. using photosensitizing medications or aphakic individuals) should be evaluated carefully with respect to the potential for chronic exposure to laser radiation. Any deviations from acceptable performance will require an identification of the underlying pathology either by:

- a funduscopic examination, or
- other tests as determined appropriate by the responsible medical or optometric examiner.

This examination is performed by a qualified nurse under the supervision of the Occupational Health Program Administrator at the EHS office.

8.2.4 Periodic medical examinations are not required by this program

8.2.5 Termination medical examinations

A termination or a re-assignment eye examination shall be conducted when personnel leave the university or are transferred to other duties without potential for laser exposure.

8.3 Examination records

The Laser Safety Officer in conjunction with the Occupational Health Program Administrator maintains records of scheduled and performed medical examinations, (pre-assignment and termination or re-assignment eye examinations).

9. Control measures

General

- Control measures are devised to reduce the possibility of exposure of the eye and skin to hazardous levels of laser radiation and other hazards associated with laser devices during operation and maintenance.
- The LSO shall have the authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards and conduct surveillance of the appropriate control measures.
- For all uses of lasers and laser systems, it is recommended that the **minimum laser radiation required for the application** be used.
- Also, it is recommended that the beam height be maintained at a **level other than the normal position of the eye** of a person in the standing or seated positions.
- **Engineering controls** (items incorporated into the laser or laser system or designed into the installation by the user) **shall be given primary consideration** for limiting access to hazardous laser radiation.
- **Enclosure of the laser equipment or beam path is the preferred method of control**, since the enclosure will isolate or minimize the hazard.
- If engineering controls are impractical or inadequate, administrative and procedural controls and personal protective equipment shall be used.
- The limits of any type of control measure (for example, failure modes of enclosures and eye protection, or the inability of some personnel to understand written warnings) shall be considered in developing and implementing a laser hazard control program.
- In some cases, more than one control measure may be specified. A single control measure that accomplishes the same purpose as multiple control measures may be used as a substitute for multiple control measures.
- During periods of service or maintenance, control measures appropriate to the class of the embedded laser shall be implemented when the beam enclosures are removed and beam access is possible
- Instructions for the safe operation of lasers and laser systems are normally provided by the manufacturer. When such instructions are not sufficiently detailed for specific application due to special use conditions, the LSO shall provide additional safety instructions
- Class 3B and Class 4 lasers or laser systems **shall be operated at all times under the direct supervision or control of an experienced, trained operator** who shall maintain visual surveillance of conditions for safe use and terminate laser emission in the event of equipment malfunction or any other condition of unsafe use. The operator shall maintain visual access to the entire laser controlled area during all conditions of operation.
- If a Class 3B or Class 4 laser or laser system is **not operated at all times under** the direct **supervision** or control of an experienced, trained operator, control measures such as beam traps, barriers, windows, or other means of area control will be employed so that unprotected spectators in the area shall not be exposed to levels that exceed the applicable MPE limits in any space in the area that they may occupy or enter.
- The unattended use of Class 3B or Class 4 lasers or laser systems shall be permitted only when the LSO has implemented appropriate control measures that provide adequate

protection and laser safety training to those who may enter the laser controlled area during times of unattended use

- All areas where unattended Class 3B or Class 4 lasers and laser systems operate shall be provided with standard laser safety warning area signs containing the “Danger” signal word and appropriate instructions regarding the hazards of entry into the space when no operator is present.

Alternative Control Measures

- In some research and development environments, the engineering control measures for Class 3B and Class 4 lasers or laser systems, may be replaced by procedural, administrative, or other alternate engineering controls which provide equivalent protection. Any substitute control measures must be reviewed and approved by the LSO. When alternate control measures are instituted, the personnel directly affected by the measures shall be provided the appropriate laser safety and operational training.

9.1 Engineering Controls

Commercial laser products are normally certified by the manufacturer and incorporate the engineering controls required by the respective manufacturer standards (FLPPS or the IEC 60825-1).
The use of the additional controls outlined in this section must be considered in order to reduce the potential for hazard associated with some applications of lasers and laser systems. The LSO shall implement any additional engineering control measures that are required.

The engineering controls for a Class 3B and Class 4 laser or laser system are summarized in the following table.

Engineering Control Measures	Laser Class	
	3B	4
Protective Housing	☑	☑
Operation without Protective Housing	LSO	LSO
Interlocks on Removable Protective Housing	☑	☑
Service Access Panels	☑	☑
Key Control	R	☑
Viewing Windows and Display Screens	Assure viewing limited <MPE	
Collecting Optics	Assure viewing limited <MPE	
Fully Open Beam Path	☑, NHZ	☑, NHZ
Limited Open Beam Path	☑, NHZ	☑, NHZ
Enclosed Beam Path	-	-
Remote Interlock Connector	R	☑
Beam Stop or Attenuator	R	☑
Laser Area Warning Signs	☑, NHZ	☑, NHZ
Activation Warning Systems	R	☑
Equipment Labels	☑	☑
Controlled Operation	-	R
Indoor Laser Controlled Area	☑, NHZ	☑, NHZ
Temporary Laser Controlled Area	MPE	MPE

LEGEND

☑ Required
R Recommended
- No requirement
NHZ Nominal Hazard Zone analysis required
LSO Alternative Controls to be established by the Laser Safety Officer
MPE Required when access to the NHZ is necessary where MPE may be exceeded

9.1.1 Protective housing

The protective housing is an enclosure that surrounds the laser or laser system and prevents access to laser radiation above the applicable MPE and to other hazards (such as electrical). The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing may require interlocks. Labels such as hazard symbols or cautionary signage is required for protective housing to indicate the enclosed hazard.

Special safety procedures may be required when the protective housing is removed or open, e.g. for alignment. A temporary control area may need to be established, and the use of appropriate eyewear is strongly recommended.

Normally the protective housing is provided by the laser manufacturer. If a user-created enclosure does not meet the requirements of a protective housing (e.g., a non-interlocked cover), it is only considered as a barrier or curtain and other controls are required per section "**9.1.2 Laser operation without protective housing"** below.

9.1.2 Laser operation without protective housing

In some applications in research and development, or during service, operation of a laser without the protective housing may be necessary. In such cases the LSO shall perform a hazard analysis and ensure that control measures are instituted appropriate to the class of maximum accessible emission level to ensure safe operation. These controls may include, but are not be limited to:

- Restricted access (laser controlled area)
- Eye protection
- Appropriate beam controls (barriers, shrouds, beam stops, etc.)
- Administrative and procedural controls
- Education and training

9.1.3 Interlocks on removable protective housings

Protective housings which enclose Class 3B or Class 4 lasers are provided with interlocks that are activated when the protective housing is opened or removed during operation and maintenance. The interlock prevents access to laser radiation above the applicable MPE by terminating power to the laser once triggered. The principal Investigator or Laser Supervisor is responsible for testing the interlock every 90 days as recommended by most manufacturers and representatives of the American National Standards Institute (**ANSI**). The LSO should effect the regular inspection of the protective housing interlocks and verify they are functioning.

The protective housing interlock shall not be defeated or overridden during operation unless the provisions of section **"9.1.2 Laser operation without protective housing"** (above) have been fully implemented.

9.1.4 Service access panels

These panels are parts of the protective housing that are only intended to be removed by service personnel and which permit direct access to laser radiation. They must either:

- Be interlocked (fail-safe interlock not required), or

- Require a tool for removal and have an appropriate warning label on the panel.

If the interlock can be bypassed or defeated, an appropriate warning label shall be located on the protective housing near the interlock.

9.1.5 Key control

All Class 3B or Class 4 lasers are provided with a master switch, which is operated by a key, or by a coded access (such as a computer code). The authority for access to the master switch shall be vested in the appropriate supervisor or PI. When the laser is not used for an extended period (e.g., laser storage), the master switch should be left in a disabled condition (key removed or equivalent).

9.1.6 Viewing windows and display screens

All viewing windows and/or diffuse (reflective or transmitted) display screens included as an integral part of a laser system must incorporate a suitable means (such as interlocks, filters, attenuators) to maintain the laser radiation at the viewing position at or below the applicable MPE.

9.1.7 Collecting optics

All optical devices or instruments integrated with the use of a laser system (such as lenses, telescopes, microscopes, endoscopes, eye-loupes, etc.) must incorporate suitable means (such as interlocks, filters, attenuators) to maintain the laser radiation transmitted through the collecting optics to levels at or below the applicable MPE

9.1.8 Fully open beam path

In applications of Class 3B or Class 4 laser systems, where a beam path is unenclosed, a laser hazard evaluation shall be performed by the LSO, including the environment, the geometry of the application, or the spatial limitations of other hazards, e.g., location of walls, barriers, or other equipment in the laser environment. When hazard analysis determines the area, where the classification of the maximum level of accessible laser radiation is Class 3B or 4, a **laser controlled area** must be established and adequate control measures implemented in this area.

9.1.9 Limited open beam path

In applications of Class 3B or Class 4 laser systems where the beam path is confined by design to significantly limit the degree of accessibility of the open beam, a hazard analysis must be performed by the LSO. The analysis will determine the area where laser radiation is accessible at levels above the MPE and will define the appropriate control measures in that area. The LSO shall establish controls appropriate to the magnitude and extent of the accessible radiation.

9.1.9.1 Class 1 Conditions. Frequently the hazard analysis (including measurements when necessary to confirm that accessible levels during operation are at or below applicable MPE) will define an extremely limited NHZ and **procedural controls** can provide adequate protection. For those limited open beam path lasers or laser systems where analysis, including measurements when necessary, confirms that the accessible levels during operation are at or below applicable MPE levels, Class 1 conditions shall be considered as fulfilled.

Once Class 1 conditions have been established for a high powered laser by the LSO, the university maintains the following reduced requirements and responsibilities for the PI:

- Only equipment specific training is required for use of the laser equipment. McGill Laser Safety Training is not mandatory.
- Baseline Eye testing is not required for use of the laser equipment.
- Warning tags or symbols must be administered to the equipment as a deterrent to unauthorized use or modification.
- Lab info cards must have the laser hazard warning symbol displayed, although additional laser safety signs are not required outside the door.
- High Powered enclosed lasers must be registered with the university in the same manner and detail as any other laser with an output power above 5mW. For those lasers which are components of a larger piece of equipment or laser system, the identifiable model and serial numbers of the equipment will be accepted in the registration form. Authorized user lists are also not required.
- "Reduced Requirements" laser permits will be issued to owners of High Powered Enclosed Lasers indicating the conditions of their laser use. These permits must be displayed outside the working area.
- Verification will be done during general lab inspections to ensure that Class 1 conditions are still being met. Engineering controls and safety enclosures must be well maintained without wear or damage.
- The laser user must have quick access to the manufacturer's name and contact number in case of emergency equipment malfunction.
- The laboratory must be equipped with an advisory sign and appropriate Stanard Operating Procedure (SOP) for alignment and maintenance procedures. During maintenance or alignment procedures where the enclosed laser is exposed, only those immediately involved are to be allowed in the room.

9.1.10 Enclosed beam path

In applications of Class 3B or 4 lasers where the entire beam path is enclosed, and the enclosure fulfills all requirements of a protective housing (i.e., limits the laser radiation exposure at or below the applicable MPE) the requirements of Class 1 are considered fulfilled and the conditions of section **"9.1.9.1 Class 1 Conditions"** (above) will apply.

When the protective housing requirements are temporarily relaxed, such as during service and repair, the LSO must then implement the appropriate controls such as a temporary laser control area, and administrative and procedural controls to secure the equipment.

9.1.11 Remote interlock connector

The remote interlock connector is a feature incorporated in the laser by the manufacturer, which facilitates electrical connections to an emergency stop, or to a room, entryway, floor, or area interlock, as may be required for a Class 4 controlled area. When the terminals of the connector are open-circuited, the accessible radiation must not exceed the applicable MPE. The principal Investigator or Laser Supervisor is responsible for testing the interlock every 90 days. The LSO should effect the regular inspection of the interlock and verify function.

9.1.12 Beam stop or attenuator

The beam stop or attenuator is a permanently attached device, which prevents access to laser radiation above the MPE when the laser system output (the laser beam) is not required (such as during warm-up). It is a recommended feature for Class 3B lasers and is required for Class 4 lasers.

9.1.13 Laser area warning signs

The purpose of a laser area warning sign is to provide quick hazard-alerting message that:
(1) Warns of the presence of a laser hazard in the area
(2) Indicates specific policy in effect relative to laser controls (such as access restriction, authorization, use of specific protective equipment, etc.)
(3) Indicates the severity of the hazard (e.g., class of laser, NHZ extent, etc.)
(4) Instructs appropriate action(s) to take to reduce the hazard (eyewear requirements, etc.)

An area which contains a Class 3B or Class 4 laser must be posted with the appropriate “DANGER” sign (see Appendix C). **The OD of protective eyewear and wavelength shall be shown on the sign for a location requiring the use of eyewear.** The exterior boundary of a temporary laser controlled area must be posted with a “NOTICE” sign (see Appendix C).

Warning signs for non-beam hazards (e.g. LGAC, electrical, compressed gases) must be posted, when such hazards are present.

9.1.14 Activation Warning Systems

An activation warning system is recommended for Class 3B, and required for Class 4 lasers or laser systems during activation or startup. The warning may be audible (sound) or visible (light).

For single pulse lasers, an audible warning system may start when the laser power supply is charged for operation. Distinctive and clearly identifiable sounds from equipment (such as a vacuum pump or fan), which are uniquely associated with the laser emission are also acceptable as audible warnings.

A visible warning device can be a red light or a lighted laser warning sign, flashing when the laser is operating. The warning must be visible within the area and readably visible through laser protective eyewear. The light can be electrically interfaced and controlled by the laser power supply.

9.1.15 Equipment labels

All commercial Class 3B and 4 lasers are labeled. Home-built lasers or laser protective housings must have the appropriate warning labels affixed on a conspicuous place on the laser housing or control panel. Such labels should be placed on both the housing and the control panel if these are separated by more than 2 meters.

An advisory protective housing label that indicates the relative hazard of laser radiation contained within the housing shall be placed on all removable protective housings which have no safety interlock and which can be removed or displaced during operation, maintenance, or service, and thereby allow access to laser radiation in excess of the applicable MPE. The required text is:

For all Class 3B lasers and laser systems, “Laser Radiation – Avoid Direct Exposure to Beam”
For Class 4 lasers and laser systems, “Laser Radiation – Avoid Eye or Skin Exposure to Direct or Scattered Radiation”.

9.1.16 Controlled Operation
Whenever appropriate and possible, Class 4 lasers or laser systems should be controlled and monitored at a position as distant as possible from the emission portal of the laser or laser system.

9.1.17 Indoor Laser Controlled Area
When the laser hazard analysis performed by the LSO determines that the classification associated with the maximum level of accessible radiation is Class 3B or Class 4, a laser controlled area shall be established and adequate control measures instituted.

9.1.17.1 Control measures for Class 3B and Class 4 lasers
The Class 3B or Class 4 laser controlled area shall:

(1) Be controlled to permit laser operation only by personnel trained in laser safety and in the operation of the laser or laser system.

(2) Be posted with the appropriate warning signs. A warning sign must be posted at the entryway and, if considered necessary by the LSO, within the laser controlled area.

(3) Be operated in a manner such that the beam path is well defined

(4) Be well defined and controlled if the laser beam extends outdoors and projects into a public area or controlled airspace, particularly under adverse atmospheric conditions, e.g., rain, fog, snow, etc.

In addition to the above, a Class 3B controlled area should, and a Class 4 controlled area shall:

(5) Be under direct supervision by an individual knowledgeable in laser safety

(6) Be located such that access to the area by spectators is limited and requires approval.

(7) Have any potentially hazardous beam terminated in a beam stop of an appropriate material

(8) Have only diffusely reflecting materials used in or near the beam path, where feasible

(9) Provide personnel within the laser-controlled area with the appropriate eye protection

(10) Have the laser secured such that the exposed beam path is above or below eye level of a person in any standing or seated position.

(11) Have all windows, doorways, open portals, etc. from an indoor facility either covered or restricted in such a manner as to reduce the transmitted laser radiation to levels at or below the applicable ocular MPE

(12) Require storage or disabling (for example, removal of the key) of the laser or laser system when not in use to prevent unauthorized use.

9.1.17.2 Control measures required for Class 4 lasers

1. Entryway safety controls must allow both rapid exit by laser personnel at all times and entrance to the laser controlled area under emergency conditions
2. All personnel requiring entry into a laser controlled area must be appropriately trained, provided with appropriate protective equipment, and must follow all applicable administrative and procedural controls. The requirements for spectators in a laser controlled area are outlined in section 9.2.6 below.
3. For emergency conditions there must be a clearly marked “Emergency Stop” or other appropriately marked device appropriate for the intended purpose (remote controlled connector or equivalent device) available for deactivating the laser or reducing the output to levels at or below the MPE.
4. In addition, the Class 4 laser controlled area must incorporate one of the following alternative options for Entryway Safety Controls (see Appendix F for examples):

a) Non-defeatable (non-override) Area or Entryway Safety Controls.
These may be safety latches, entryway or area interlocks (e.g., electrical switches, pressure sensitive floor mats, infrared, or sonic detectors) used to deactivate the laser or reduce the output to levels at or below the MPE in the event of unexpected entry into the laser controlled area,

b) Defeatable Area or Entryway Safety Controls.
Defeatable safety latches, entryway, or area interlocks may be used if non-defeatable area/entryway safety controls limit the intended use of the laser or laser system, when operation without interruption is necessary (e.g., long term testing). If it is clearly evident that there is no laser radiation hazard at the point of entry, overriding of safety controls is permitted to allow access to authorized personnel. Such personnel must have been adequately trained and provided with adequate personal protective equipment.

c) Procedural Area or Entryway Safety Controls.
Where safety latches or door interlocks are not feasible or are inappropriate, the following must apply:

(i) All authorized personnel must be adequately trained and adequate personal protective equipment must be provided upon entry.

(ii) A door, blocking barrier, screen, curtains, etc. must be used to block, screen, or attenuate the laser radiation at the entryway to assure that the level of laser radiation at the exterior of these devices does not exceed the MPE, nor any personnel is exposed to levels above the MPE immediately upon entry.

(iii) At the entryway there must be an activation warning system (light or sound) indicating that the laser is energized and operating at Class 4 levels.

9.1.18 Temporary Laser Controlled Area

In some conditions (such as alignment, maintenance or service), when removal of protective housing panels, overriding of protective housing interlocks, or entry into the NHZ becomes necessary, and the accessible laser radiation exceeds the MPE, a temporary laser controlled area must be established for the laser or laser system. Such an area by its nature will not have the built-in protective features of a permanent laser controlled area. However, the temporary controlled area must provide all safety requirements for all personnel, both within and outside the area.

A Notice sign must be posted outside the temporary laser controlled area to warn of the potential hazard. When a temporary laser controlled area is created, the area outside the temporary area remains Class 1, while the area within is either Class 3B or Class 4 and the appropriate "Danger" warning is also required within the temporary laser controlled area.

9.1.19 Outdoor Laser Controlled Area

The use of Class 3B and 4 lasers in outdoor environments is not condoned by the University,

When outdoor laser use is unavoidable, Transport Canada must be given a minimum of 90 days notice before Class 3B and 4 lasers are used in navigable airspace in accordance with the provisions of ANSI Z136.6. Advise the LSO of your intention, complete the Notice of proposal to conduct outdoor laser operation(s), send it to the Transport Canada regional office closest to you, and await reply before conducting outdoor laser operations.

9.2 Administrative and procedural controls

Engineering controls must be given primary consideration in instituting a control measure program for limiting access to laser radiation. If engineering controls are impractical or inadequate, administrative and procedural controls and personal protective equipment shall be used.

Administrative and procedural controls are methods or instructions which specify rules, or work practices, or both, which implement or supplement engineering controls and which may specify the use of personal protective equipment. Unless otherwise specified, administrative and procedural controls apply only to Class 3B and Class 4 lasers or laser systems.

The administrative and procedural controls for Class 3B and Class 4 laser or laser systems are summarized in the following table.

Administrative and Procedural Control Measures	Laser Class	
	3B	4
Standard Operating Procedures	R	☑
Output Emission Limitations	LSO	LSO
Education and Training	☑	☑
Authorized Personnel	☑	☑
Alignment Procedures	☑	☑
Protective Equipment	R	☑
Spectators	R	☑
Service Personnel	☑	☑
Demonstration with General Public	☑	☑
Laser Optical Fiber Transmission Systems	☑	☑
Protective Eyewear	R	☑
Window Protection	☑	☑, NHZ
Protective Barriers and Curtains	R	R
Skin Protection	☑	☑, NHZ
Other Protective Equipment	Use may be required	
Warning Signs and Labels (Design Requirements)	☑, NHZ	☑, NHZ
Laser System Modifications	LSO	LSO

LEGEND

☑ Required
R Recommended
NHZ Nominal Hazard Zone analysis required
LSO To be determined by the Laser Safety Officer

9.2.1 Standard Operating Procedures

Written standard operating, maintenance and service procedures (SOPs) are recommended for Class 3B lasers and are required for Class 4 lasers. The written SOP must be approved by the LSO and be maintained with the laser equipment for reference by the operator, and maintenance or service personnel.

9.2.2 Output Emission Limitations

The LSO must take action to reduce the levels of accessible power or radiant energy to a level which is commensurate with the required application, if in his/her opinion, excessive power or energy is accessible during operation or maintenance.

9.2.3 Education and Training

Education and training must be provided for all personnel involved in the use, operation, maintenance and service of Class 3B or Class 4 lasers; and laser systems containing embedded Class 3B or Class 4 lasers. The level of training must be commensurate with the level of potential hazard.

9.2.4 Authorized Personnel

Lasers or laser systems must be operated, maintained, or serviced only by authorized personnel.

9.2.5 Alignment Procedures

Laser incident reports have repeatedly shown that an ocular hazard may exist during beam alignment procedures. Alignment of laser optical systems (mirrors, lenses, beam deflectors, etc.) must be performed in such a manner that the primary beam, or a specular or diffuse reflection of a beam, does not expose the eye to a level above the MPE.

- A temporary beam attenuator may be placed over the beam aperture to reduce the level of accessible laser radiation to levels at or below the applicable MPE.

- Written SOP outlining alignment methods should be approved for Class 3B and must be approved for Class 4 lasers or laser systems. SOPs must also be applicable for laser systems containing embedded Class 3B or Class 4 lasers for conditions which may allow access during alignment procedures.

- The use of lower power (Class 1, Class 2 or Class 3R) visible lasers for path simulation of higher power lasers is recommended for alignment of higher power Class 3B or Class 4 visible or invisible lasers and laser systems.

- Alignments should be done only by those who have received laser safety training. In addition, the following actions should be taken:

  (1) Exclude unnecessary personnel from the laser area during alignment.
  (2) Whenever possible, use low-power visible lasers for path simulation of high power visible or invisible lasers.
  (3) Wear protective eyewear and clothing to the extent practicable.

(4) When aligning invisible (and in some cases visible) laser beams, use beam display devices such as image converter viewers or phosphor cards to locate beams.
(5) Use remote control viewing CCD cameras to perform alignment from a safe distance to the extent practicable.
(6) Perform alignment tasks that use high power lasers, at the lowest possible power level.
(7) Use neutral density filters to reduce wavelength or OD.
(8) Use a shutter or beam block to block high power beams at their source except when actually needed during the alignment process.
(9) Use a laser-rated beam block to terminate high power beams down range of the optics being aligned.
(10) Use beam blocks and/or laser protective barriers in conditions where alignment beams could stray into areas with uninvolved personnel.
(11) Place beam blocks behind optics (e.g., turning mirrors) to terminate beams that might miss mirrors during alignment.
(12) Locate and block all stray reflections before proceeding to the next optical component or section.
(13) Be sure all beams and reflections are properly terminated before high power operation.
(14) Post appropriate area warning signs during alignment procedures where lasers are normally Class 1 (enclosed). A temporary laser controlled area may need to be established.

9.2.6 Spectators

Spectators must not be permitted within a laser controlled area unless:

1) Appropriate approval from the supervisor has been obtained
2) The degree of hazard and avoidance procedure has been explained
3) Appropriate protective measures are taken

9.2.7 Laser Demonstrations Involving the General Public

Only Class 1 lasers or laser systems are to be used for general public demonstration, display, or entertainment purposes when no trained and experienced operators are present.

Class 2 and 3a lasers or laser systems shall have restricted access to areas where direct or specularly reflected beams are a potential hazard during demonstration, display, or entertainment purposes. A Nominal Hazard Zone (NHZ) must be clearly marked and enforced.

Under no circumstances shall invisible laser emissions, defined as those wavelengths greater than 700nm or less than 400nm, be exposed to the general public.

Demonstrations, displays, or entertainment involving Class 3B or 4 lasers are not recommended by the University. Such uses are governed by additional requirements that are not covered in this manual. For details on operational requirements, emission limitations, distance requirements, beam termination requirements and posting, refer to Section 4.5.1.

Laser Demonstrations Involving the General Public of the ANSI standard Z136.1-2007 for Safe Use of Lasers.

9.2.8 Service Personnel
Personnel who require access to Class 3B or Class 4 lasers or laser systems enclosed within a protective housing or protected area enclosure must comply with the appropriate control measures of the enclosed or embedded laser or laser system. The LSO must confirm that service personnel have the education and safety training commensurate with the class of the laser or laser system contained within the protective housing.

9.2.9 Laser Robotic Installations
In applications where Class 3B and 4 lasers are used in conjunction with robots, the robot working envelope as defined by its range of movement should also include the NHZ associated with the laser. In all cases where the beam is focused by a lens associated with the robotic device, appropriate laser-robotic safeguards can be assured if:

(1) The design or control measures in combination provide for positive beam termination during operation.

(2) The beam geometry is limited to only the necessary work task.

(3) All workers are located at a distance greater than or equal to the lens-on-laser NHZ value for the laser robotic system.

In many instances, including those created by hardware failure and software errors, the laser beam from robotic delivery systems can be incident on the target surface at angles that could lead to potential scattering geometries that are very complex and require extensive evaluation. **Measurements are often required to confirm the NHZ boundaries.**

9.3 Protective Equipment

Enclosure of the laser equipment or beam path is the preferred method of control, since the enclosure will isolate or minimize the hazard. When other control measures do not adequately prevent access to direct or reflected beams at levels above the MPE, it may be necessary to use personal protective equipment such as goggles, face shields, barriers, windows, clothing and gloves, and other devices that have been specifically selected for suitable protection against laser radiation.

NOTE: It should be noted that personal protective equipment may have serious limitations when used as the only control measure with higher-power Class 4 lasers or laser systems; the protective equipment may not adequately reduce or eliminate the hazard, and may be damaged by the incident laser radiation.

9.3.1 Eye protection

When engineering or other procedural and administrative controls are inadequate to eliminate potential exposure in excess of the applicable MPE, protective eyewear specifically designed for protection should be administratively required and their use enforced within the NHZ for Class 3B lasers and must be administratively required and enforced for Class 4 lasers.

The principal investigator is responsible for ensuring that appropriate protective eyewear is available and worn by personnel within the Nominal Hazard Zone of Class 3B and Class 4 lasers when exposure to levels above the MPE can occur.

The principal investigator must assure that the laser protective eyewear is **clearly labeled with the optical density and the wavelength(s)** for which protection is afforded. Color coding or other distinctive identification of laser protective eyewear is recommended in multi-laser environments.

Laser protective eyewear must be specifically selected to withstand either direct or diffusely scattered beams depending upon the anticipated exposure. In this case, the protective filter shall exhibit a damage threshold for a specified exposure time, typically 10 seconds. The eyewear shall be used in a manner so that the damage threshold is not exceeded in the "worst case" exposure scenario.

Some protective filters (plastic, glass, interference, or hybrid filters) exhibit non-linear effects such as saturable absorption when exposed to ultrashort (e.g. femtosecond) pulses. Users of femtosecond lasers are advised to request test data from the laser eyewear manufacturers.

Protective eyewear must be periodically cleaned and inspected for integrity (cracks, discoloration, etc.). Eyewear in suspicious condition should be tested for acceptability or discarded and replaced.

UV Laser Protection

Particular care must be taken when using ultraviolet (UV) lasers. Exposure to UV radiation must be minimized by using beam shields and clothing which attenuate the radiation to levels below the applicable MPE for the specific UV wavelengths. Personal Protective Equipment (PPE) must be used when working with open beam Class 3B or Class 4 UV lasers. This must include both eye and skin protection.

Optical Density.

Optical Density is a measure of the absorption (or transmission) of optical radiation by an optical material. The higher the optical density, the higher is the material absorption and the lower is the transmission. It is expressed as the logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength:

$$OD \text{ (or also } D_\lambda) = \log_{10}(1/\tau_\lambda)$$

where τ_λ is the transmittance at the wavelength of interest. If the potential eye exposure to incident laser radiation is given by H_p, the optical density OD, required for protective eyewear to reduce this exposure to the MPE level is given by:

$$OD = \log_{10}(1/\tau_\lambda) = \log_{10}(H_p/\text{MPE}),$$

where the incident laser radiation H_p must be expressed in the same units as the MPE.

The optical density OD of laser protective eyewear at a specific wavelength must be specified. Many lasers emit at more than a single wavelength and eyewear designed to have a proper OD and provide protection for a particular wavelength, may have inadequate OD at another wavelength emitted by the same laser. This issue is particularly serious with tunable lasers that emit within broad wavelength ranges. In such cases, alternative methods of eye protection, such as indirect viewing using TV cameras may be more appropriate.

9.3.2 Skin Protection

In some laser applications, such as use of excimer lasers emitting UV radiation, skin protection must be employed if chronic (repeated or long term) exposures are anticipated at levels at or near the applicable MPEs for skin. Skin protection can best be achieved through engineering controls. If potentially damaging skin exposure is possible, particularly for ultraviolet lasers (295-400 nm), the use of skin-covers and/or “sun screen” creams is recommended. Most gloves will provide some protection against laser radiation. Tightly woven fabrics and opaque gloves provide the best protection. In some cases a laboratory jacket or coat may fulfill the requirement.

9.3.3 Other Personal Protective Equipment

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

10 Non-beam hazards

- Non-beam hazards are hazards that do not result from direct human exposure to the laser beam. Non-beam hazards include physical, chemical, and biological agents. Non-beam hazards may occur when:
  - a material is exposed to a laser beam (e.g. fire or airborne contaminants)
  - materials used to generate the laser beam (e.g. flow-through gases, dyes and solvents) are released into the atmosphere, or
  - individuals enter in contact with system components (e.g. shock or electrocution).

- In some cases, these hazards can be life threatening (such as electrocution). As a result, the non-beam hazards require use of control measures that are different from the laser beam control measures in Section 9.

- All written SOPs must address non-beam hazards as well as beam hazards.

- Because of the diversity of non-beam hazards, the LSO may resort to safety and/or industrial hygiene personnel to effect non-beam hazard evaluations and make decisions on appropriate control measures for non-beam hazards.

- Non-beam hazards are further covered in the Laboratory Safety Manual including the sections on electrical safety, fire safety, WHMIS, compressed gases safety, etc.

- The following summary is provided to "flag" specific non-beam hazards associated with laser operation that may need to be addressed in further detail.

NOTE: For further details on the non-beam hazards identified as associated with your laser application, refer to the respective sections of the Laboratory Safety Manual.

10.1 Physical Agents

10.1.1 Electrical Hazards

- Electric shock
- Resistive heating
- Spark ignition of flammable materials

10.1.2 Collateral and Plasma Radiation.

- X radiation may be generated by electronic components of the laser system, e.g., high-voltage vacuum tubes, usually greater than 15 kV, and from laser-metal induced plasmas
- Ultraviolet (UV) and visible radiation may be produced by laser pump lamps and during laser-matter interactions

- Electric, Magnetic and Electromagnetic Fields. MPEs for exposure to such fields are found in the IEEE Standards for Safety Levels with Respect to Human Exposure to Electromagnetic (C95.6-2002) or Radio Frequency Fields (C95.1-2005)
- Plasma generated from high power laser interaction with targets may contain significant amount of UV, which may require control measures

10.1.3 Fire Hazards

Class 4 laser beams represent a fire hazard. Unprotected wires and plastic tubing may catch on fire if exposed. Operators should be particularly concerned when the lasers operate at invisible wavelengths. Unenclosed beams may be easily misaligned by bumping a single mirror, which could re-direct the beam in an undesired direction.

10.1.4 Explosion Hazards

Explosion hazards are associated with high-pressure arc lamps, filament lamps, and capacitor banks in laser equipment, as well from explosive reactions of chemical laser reactants or other laser gases. The laser target and optical elements in the beam path may shatter during laser operation if they become contaminated and as result start to strongly absorb the laser radiation instead of transmitting or reflecting it. Enclosing, shielding or other protective measures are required to prevent injuries.

10.1.5 Mechanical Hazards Associated with Robotics

In applications where lasers are employed in conjunction with robots, in addition to beam hazards, the design of the safety system must include the possibility that robots can:

- punch holes in protective housing, and
- damage the beam delivery system, and cause a laser beam to be aimed at operators or enclosures;

The mechanical safety of the robot installation must consider that:

- a worker can be pinned between a robot and a confining object (“pinch effect”)
- a worker can be injured by a moving part of the robotic system.

The LSO should ensure that control measures to prevent these types of accidents are in place. These control measures may include the use of surface interlock mats, interlocked light curtains, or non-rigid walls and barriers.

Additional guidance on safety of robot systems is provided in CAN/CSA standard Z434-03(R2008) Industrial Robots and Robot Systems – General Safety Requirements.

10.1.6 Noise

Noise levels from certain lasers, such as pulsed excimer laser, and their work environment, may be of such intensity that noise control may be necessary. Following the Provincial Standard, a laser user should not be exposed to more than a maximum of 90 dBA for 8 hrs a day consecutively without being provided appropriate hearing protection to negate the noise.

10.2 Chemical Agents

All chemicals handled at the McGill University must be accompanied by a material safety data sheet (MSDS) and all workers must have completed a WHMIS course offered by the McGill Environmental Health & Safety. The MSDS will supply appropriate information pertaining to the toxicity, personal protective equipment and storage of chemicals.

Various gases are exhausted by lasers and produced by targets. Proper ventilation is required to reduce the exposure levels of the products or exhausts below standard exposure limits (For further information, contact the Safety Office).

10.2.1 Laser Generated Airborne Contaminants (LGAC)

- When the target irradiance reaches a threshold of approximately 10^7 W/cm^2, target materials including plastics, composites, metals, and tissues may liberate carcinogenic, toxic and noxious airborne contaminants.
- The amount of the LGAC may be greater for lasers that have most of their energy absorbed at the surface of the material
- Special optical materials used for far infrared windows and lenses have been the source of potentially hazardous levels of airborne contaminants. For example, calcium telluride and zinc telluride will burn in the presence of oxygen when beam irradiance limits are exceeded.
- Exposure to cadmium oxide, tellurium, and tellurium hexafluoride should also be controlled.

10.2.2 Compressed Gases

- Hazardous gases used in laser applications including chlorine, fluorine, hydrogen chloride, and hydrogen fluoride.
- All compressed gases having a hazardous material information system (HMIS) health, flammability, or reactivity rating of 3 or 4 must be contained in an approved and appropriately exhausted gas cabinet that is alarmed with sensors to indicate potential leakage conditions.
- Standard operating procedures must be developed for safely handling compressed gases.

10.2.3 Laser Dyes and Solvents

- Certain dyes are highly toxic or carcinogenic. Special care must be taken when handling them to prepare solutions from them, and operating dye lasers. An MSDS for dye compounds shall be available to all appropriate workers.
- The use of dimethylsulfoxide (DMSO) as a solvent for cyanine dyes in dye lasers should be discontinued if possible.
- Fire hazards must be considered for dye lasers containing flammable liquids

10.2.4 Assist Gases

Assist gases may be used to:

- produce inert atmosphere,
- remove material from the beam-interaction area, and
- minimize contamination of optics (e.g. mirrors or lenses).

Assist gases have been shown to appear in types of LGAC and affect the spectral distribution of plasma radiation.

10.2.5 Control Measures to reduce concentration of chemical agents

- Exhaust Ventilation
- Process Isolation
- Respiratory Protection
- Sensors and Alarms (e.g. for hazardous gas cabinets and exhaust ventilation ducts)

10.3 Biological Agents

These include LGAC and infectious materials. LGAC may be generated when high power laser beams interact with tissue. Infectious materials, such as bacteria and viral organisms, may survive beam irradiation and become airborne. (For further information, contact the Safety Office).

10.4 Human Factors

10.4.1 Ergonomics

Recently, ergo-ophthalmological issues such as glare, startle reactions, afterimages and temporary flash blindness have been reported in the laser environment as distractions that lead to other primary or secondary effects of a more serious biological nature. The LSO should be aware that these types of ergo-ophthalmologic issues may create visual distractions in the workplace.

10.4.2 Limited Work Space

Limited work space can present a problem while working near or around mechanical or high voltage equipment. There must be sufficient room for personnel to turn around and maneuver freely. This issue is further compounded when more than one type of laser is being operated at the same time. Wires and cables on the floor of limited work areas create trip and slip hazards. Whenever lasers or laser systems are used in limited work space, local exhaust, mechanical ventilation and respiratory protection shall be used if LGACs are present.

10.4.3 Work Patterns. Swing and third shift work patterns as well as extended or excessive work hours have been shown to affect worker alertness, and hence safety compliance.

10.4.4 Visual Interference

Laser work can often involve darkened working areas for the sake of light generated data collection. This can produce indirect safety hazards when performing critical visual tasks. Examples of critical tasks include, but are not limited to, operating complex equipment, navigating the room safely, using dissection or chemical protocols on experimental samples, etc. Additional hazards include transient visual and psychological effects of laser beams such as afterimage, glare, and startle produced from the contrast of light and dark.

10.5 Laser and Laser Waste Disposal

10.5.1 Laser Disposal

- Give or donate the laser to an organization that can use it (universities, research institutes, industrial companies, hospitals, etc.). The donor should ensure that the equipment being given complies with all applicable product safety standards, and is provided with adequate safety instructions for operations and maintenance. The donor should ensure that the laser will be used by individuals who are trained in laser safety.
- Return the laser to the manufacturer for credit onto a new laser if applicable
- Eliminate the possibility of activating the laser by removing all means by which it can be electrically activated. After this the laser can be disposed of by contacting the Laser Safety Officer.

Use of the last method may be limited due to land fill restrictions and the possible presence of hazardous materials inside the laser components, such as mercury switches, oils, and other chemicals. It is best to discuss this problem with the Laser Safety Officer.

As of June 2011 it became illegal to sell class 3B and 4 lasers to general consumers per Section 2 of the Canada Consumer Product Safety Act. These classes of lasers can only be sold to academic, research, or commercial institutions. Re-selling of Class 3B and 4 lasers or laser systems to persons not fitting this criteria is strictly prohibited.

10.5.2 Laser Waste Disposal

Proper waste disposal of contaminated laser-related material, such as filters, organic dyes, and solvent solutions shall be handled in conformance with appropriate federal, provincial and local guidelines.

11. Emergency procedures and accident reporting

11.1 Medical referral and examination in case of suspected or actual laser injury.

- Medical examinations shall be performed as soon as practical (usually within 48 hours after the exposure) when a suspected injury or adverse effect from a laser exposure occurs. In addition to the acute symptoms, consideration must be given to the exposure wavelength, emission characteristics and exposure situation to assure appropriate medical referral.
- The referral for medical examinations must be consistent with the medical symptoms and the anticipated biological effects based upon the laser system in use at the time of the incident.
- For injury to the eye from lasers operating in the retinal hazard region (400 – 1400 nm), the examinations shall be performed by an ophthalmologist.
- Employees with skin injuries should be seen by a physician.

11.2 Emergency procedures

In the case of an accident, or incident requiring ambulance, fire and police call 911. Then contact McGill Security Services so that they can direct emergency vehicles to the proper location. For the downtown campus call 514-398-3000 and for the Macdonald campus call 514-398-7777.

In the case of hazardous materials spills call McGill Security Services and the Hazmat response team will be dispatched.

11.3 Reporting of laser accidents/incidents

All accidents, incidents (near accidents) and operating irregularities involving lasers must be reported to the Departmental Safety Committee and EHS for investigation, analysis and remedial action. The McGill Accident, Incident, Occupational Disease Report Form must be completed and sent to EHS.

List of acronyms

AEL	Accessible Emission Limit
ANSI	American National Standards Institute (USA)
CSA	Canadian Standards Association
CCOHS	Canadian Centre for Occupational Health and Safety
CDRH	Centre for Devices and Radiological Health (USA)
CPR	Cardio-Pulmonary Resuscitation
CW	Continuous Wave
FDA	Food and Drug Administration (USA)
HCLS	Health Care Laser System
He-Ne	Helium-Neon (laser)
IEC	International Electrotechnical Commission
LED	Light Emitting Diode
LGAC	Laser Generated Air Contaminant
LSO	Laser Safety Officer
MPE	Maximum Permissible Exposure
MSDS	Material Safety Data Sheet
NHZ	Nominal Hazard Zone
NOHD	Nominal Ocular Hazard Distance
OD	Optical Density
OHSA	Ontario Health and Safety Act
OSHA	Occupational Safety and Health Administration (USA)
PRF	Pulse Repetition Frequency
SCC	Standards Council of Canada
SOP	Standard Operating Procedure
TL	Threshold Limit
YAG	Yttrium-Aluminium Garnet

Bibliography

1) ANSI Z136.1-2007, American National Standard for Safe Use of Lasers.
2) ANSI A136.4-2005, American National Standard Recommended Practice for Laser Safety Measurements for Hazard Evaluation.
3) ANSI Z136.5-2000American National Standard for Safe Use of Lasers in Educational Institutions.
4) ANSI Z136.6-2005, American National Standard for Safe Use of Lasers Outdoors.
5) Laser Safety Manual, Laser Institute of America, Orlando, USA 2005.
6) IEC 60825-1 Safety of laser products - Part 1, Equipment classification and requirements. Edition 2.0, IEC, Geneva, 2007.
7) IEC 60825-2 Safety of laser products – Part 2, Safety of optical fibre communication systems. Edition 3.0, IEC, Geneva, 2006.
8) FDA/CDRH Federal Laser Product Performance Standard (FLPPS), 21CFR Part 1040.10.
9) Canadian Aviation Regulations (SOR-96-433), http://laws.justice.gc.ca/en/SOR-96-433/
10) CAN/CSA standard Z434-03(R2008) Industrial Robots and Robot Systems – General Safety Requirements.
11) Laser Safety Management, Taylor & Francis Group, Boca Raton, USA 2006.
12) American National Standard for Safe Use of Lasers Outdoors - ANSI Z136.6-2015

Appendix A

To locate the McGill Laser Registration Forms please follow the link to our website: https://www.mcgill.ca/ehs/laboratory/laser-safety/laser-registration

McGill Environmental Health and Safety

Laser Registration Form

If you own lasers, laser systems, operational laser components, laser subassemblies, including embedded lasers, complete and return this form as soon as possible. If uncertain about a particular field, please consult your equipment manual and complete to the best of your ability.

Name	
Department	Building
E-mail	Tel Number

Laser Inventory

	Location Room, Building	Type *Ex: Nd:YAG, Argon*	Manufacturer	Application *Ex: research, medical, teaching*	Category *Ex: Commercial, Home-built, component, subassembly*	Laser Class Indicate if embedded
1						
2						
3						
4						
5						
6						
7						
8						

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Operating Conditions

	Model Number	Serial Number	Wavelength(s)	Maximum Power Indicate W or mW units	Mode *Ex: Continuous Wave, Single Pulse, Repeat Pulse*	Initial Beam Diameter
1						
2						
3						
4						
5						
6						
7						
8						

Authorized Users

	Name	Position *Ex: Faculty, graduate student, visitor*	Training Date & Type	Baseline Eye Exam Date
1				
2				
3				
4				
5				
6				
7				
8				

Send completed form to Environmental Health and Safety
ehs@mcgill.ca fax 514-398-8047

Appendix B

LASER SAFETY INSPECTION CHECKLIST

Identification

Date of Inspection ______________ Location (Building/Room) ______________ Department ______________

Principal Investigator ______________ Phone ______________ Laboratory Contact ______________ Phone ______________

Laser Type ______________ Class ______________ Model ______________ Serial # ______________

Other Information: ____

Verdicts:

Pass: Meets requirements:

Fail: Does not meet requirements:

N/A Not applicable or Not required (provide details in Comment section)

LSO: Needs further assessment by LSO (e.g. for alternate, substitute or other equivalent control measures)

1 Documentation review (may be performed prior to lab inspection)

Checklist Items	P-F-N/A				Comments	
1 LASER SAFETY	**Rooms**					
Administrative and procedural Control Measures						
5110 Laser Registration						
5120 Standard Operating Procedures (SOPs)						
5130 Alignment, Calibration, and Servicing Procedures						
5140 Modified or home build lasers classified						
5150 Emergency Preparedness						
5160 Personnel adequately trained and Baseline Eye Testing has been done						

Indoor Laser Controlled Area							
5210	*Entrance posted with warning signs, outside/inside*						
5220	*Windows/doorways/open portals covered*						
5230	*Exposed beam not at eye level in any standing or seated position*						
5240	*Laser beam disabled when not in use (e.g. Activation key removed/secured)*						
5250	*Beam is well defined, unobstructed, and properly terminated*						
Engineering Control Measures							
Beam path is: Enclosed ☐ Limited ☐ Open ☐							
5310	*Laser Enclosures*						
5320	Viewing windows/optics do not allow exposure >MPE						
5330	*Laser labels (class, aperture, access, etc.) present*						
5340	Other Engineering Controls (Warning Lights, Sirens, Remote Viewing Stations, etc.)						
Non-Beam Hazards							
5410	*Electrical (HV) hazards*						
5420	*Hazardous Products in or near the beam path and Laser Generated Air Contaminants (LGACs)*						
5430	*Collateral Radiation or Plasmas*						
5440	*Fire/explosion hazard*						
5450	*Noise hazard*						

Appendix C

Area Signs

DANGER

VISIBLE and/or INVISIBLE LASER RADIATION
AVOID DIRECT EXPOSURE
TO BEAM

TYPE WAVELENGTH PULSE DURATION MAXIMUM OUTPUT

CLASS 3B LASER

DANGER

LASER RADIATION
AVOID EYE OR SKIN EXPOSURE
TO DIRECT OR SCATTERED RADIATION

TYPE WAVELENGTH PULSE DURATION MAXIMUM OUTPUT

CLASS 4 LASER

DANGER

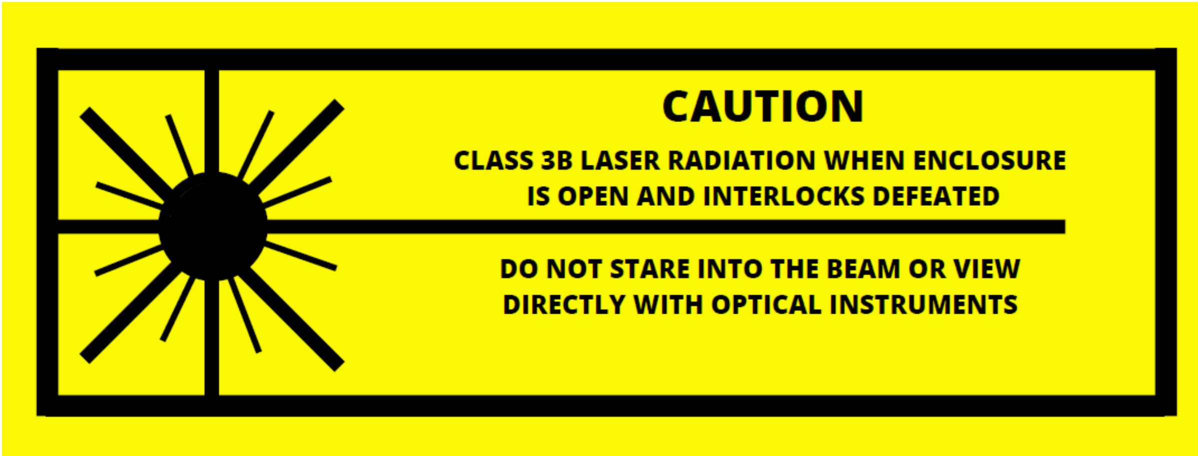
INVISIBLE LASER RADIATION
AVOID EYE OR SKIN EXPOSURE
TO DIRECT OR SCATTERED RADIATION

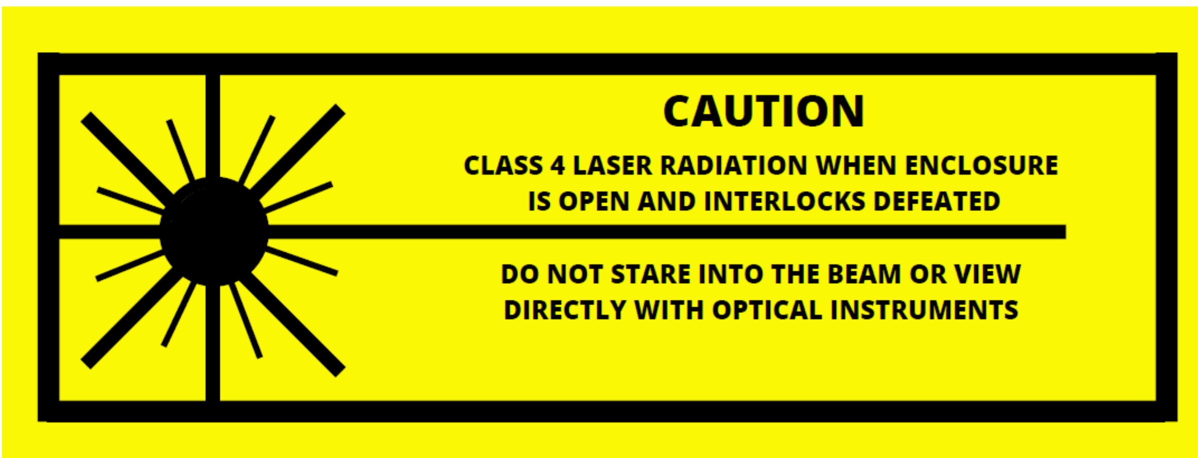
TYPE WAVELENGTH PULSE DURATION MAXIMUM OUTPUT

CLASS 4 LASER


DANGER
VISIBLE and/or INVISIBLE LASER RADIATION
AVOID EYE OR SKIN EXPOSURE
TO DIRECT OR SCATTERED RADIATION
TYPE
WAVELENGTH
PULSE DURATION
MAXIMUM OUTPUT
CLASS 4 LASER


NOTICE
LASER REPAIR IN PROGRESS
DO NOT ENTER
EYE PROTECTION REQUIRED
TYPE
WAVELENGTH
PULSE DURATION
MAXIMUM OUTPUT
CLASS 4 LASER


CAUTION
CLASS 3B LASER RADIATION WHEN ENCLOSURE IS OPEN AND INTERLOCKS DEFEATED
DO NOT STARE INTO THE BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS


CAUTION
CLASS 4 LASER RADIATION WHEN ENCLOSURE IS OPEN AND INTERLOCKS DEFEATED
DO NOT STARE INTO THE BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS

Appendix D

Laser Worker Check List

1. As a start, consult the Laser Safety manual.
2. If using class 3B or 4 laser(s), attend the McGill laser safety training course.
3. Call the Laser Safety Officer or the Occupational Health Program Administrator to arrange a baseline eye exam if working with class 3B or 4 laser(s).
4. Review written standard operation procedures (SOP) for the particular laser(s) that you will be working with. The SOP will also contain the Nominal Hazard Zone (NHZ) type of Personal Protective Equipment (PPE) such as eye protection.
5. If working with class 3B or 4 laser(s), advise the laser permit holder (responsible PI) to update their authorized users list with the Laser Safety Officer.
6. Inform the Laser Safety Officer at the end of your employment or research so that a post employment eye exam may be arranged.

Laser Safety Officer: (514)-398-2391, Megan.Smith@McGill.ca
Occupational Health Program Administrator: (514) 398-4766, Kathryn.Wiens@mcgill.ca

Appendix E

E1. Laser Fundamentals

The word **LASER** is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. It reflects the physical principle of a laser: light generated through stimulated emission. Regardless of its type, design and construction, every laser contains three basic components (see Figure 1):

Active Medium (or amplifying, gain or lasing medium), which may be solid, liquid or gas.

Source of Energy (excitation or "pumping" mechanism), which may be optical, electrical or chemical.

Optical Resonator (or laser cavity), which consists of two mirrors, one of which is highly reflecting and reflects essentially 100% of the laser light. The second mirror reflects less than 100% of the laser light and transmits the remaining light as the emerging laser beam.

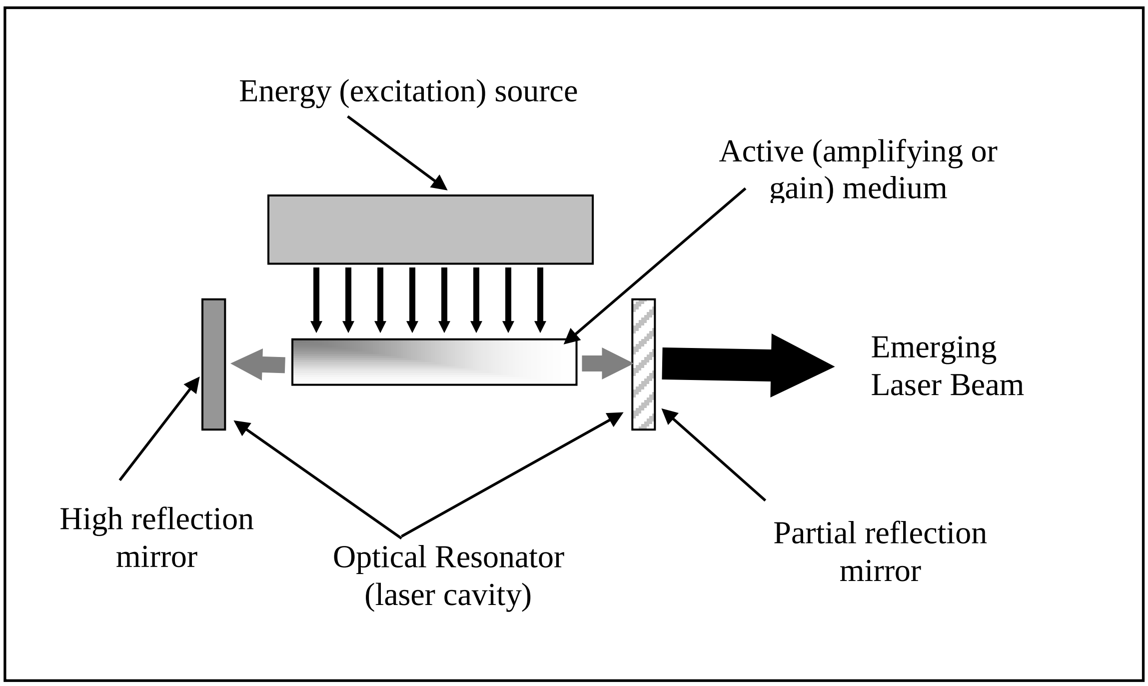


Figure 1. Laser Components

Laser operation

When the laser active medium (e.g. a crystal) is excited with a flash lamp (optical pumping), its atoms absorb the optical energy and the electrons move from a so-called "ground state" energy level to a high energy "excited state" (Figure 2a). This electron can randomly return to its low energy "ground" state level by releasing a photon of light. This process is called spontaneous emission (Figure 2b). When an electron is still in the excited high energy state, and another photon passes nearby, it can cause the excited atom to emit a photon of the same frequency, in the same direction and in phase with the incoming photon. This process is called "stimulated emission" (Figure 2c). When the external excitation is sufficient so that the majority of atoms are in the excited state, any photon emitted within the active medium will stimulate other excited atoms to emit. The laser cavity serves the purpose of bouncing back and forth only those photons that propagate along the cavity axis. This creates a sustained avalanche-like process, which allows a laser beam to be generated through the partially reflecting mirror.

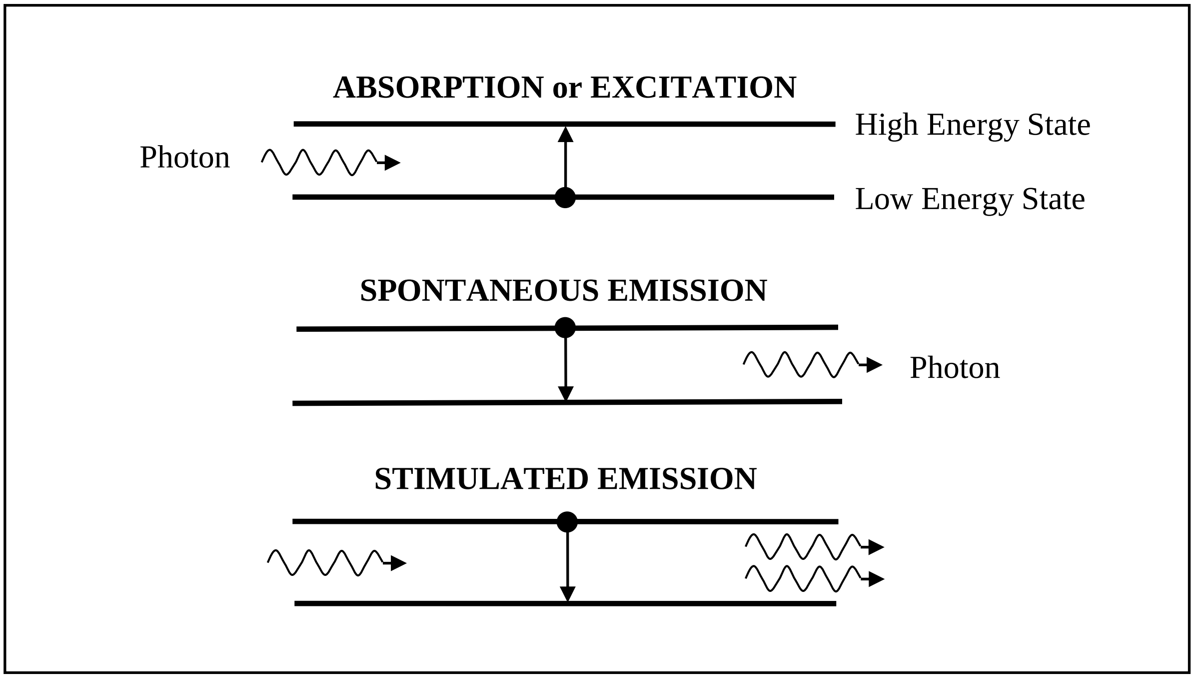


Figure 2. Laser Operation

Laser construction

The excitation source for many solid state lasers such as Nd:YAG laser are high intensity lamps or infrared emitting diodes. The energy comes in the form of short flashes of light, which excite the atoms in the laser medium (Nd doped YAG crystal). Schematically, such construction is presented in Figure 1.

The excitation source for gas lasers is usually an electric discharge that excites ions in gas lasers such as the Argon ion laser. A strong electric field of several kV/m causes electrons emitted by the cathode to be accelerated towards the anode. Some electrons will excite the atoms of the gas medium and raise them to the excited state. In other gas lasers, one type of atoms is excited by the electric discharge. These atoms then transfer their energy to another type of atoms, which provide the laser emission. Typical examples are the common He-Ne laser, where Helium atoms are electrically excited and transfer their energy to Neon atoms, and the Carbon Dioxide (CO_2) laser, where electrically excited Nitrogen atoms transfer their energy to the CO_2 gas molecules. The mirrors of the laser cavity may be attached at the ends of the tube containing the laser gas (figure 3) or be external to the tube.

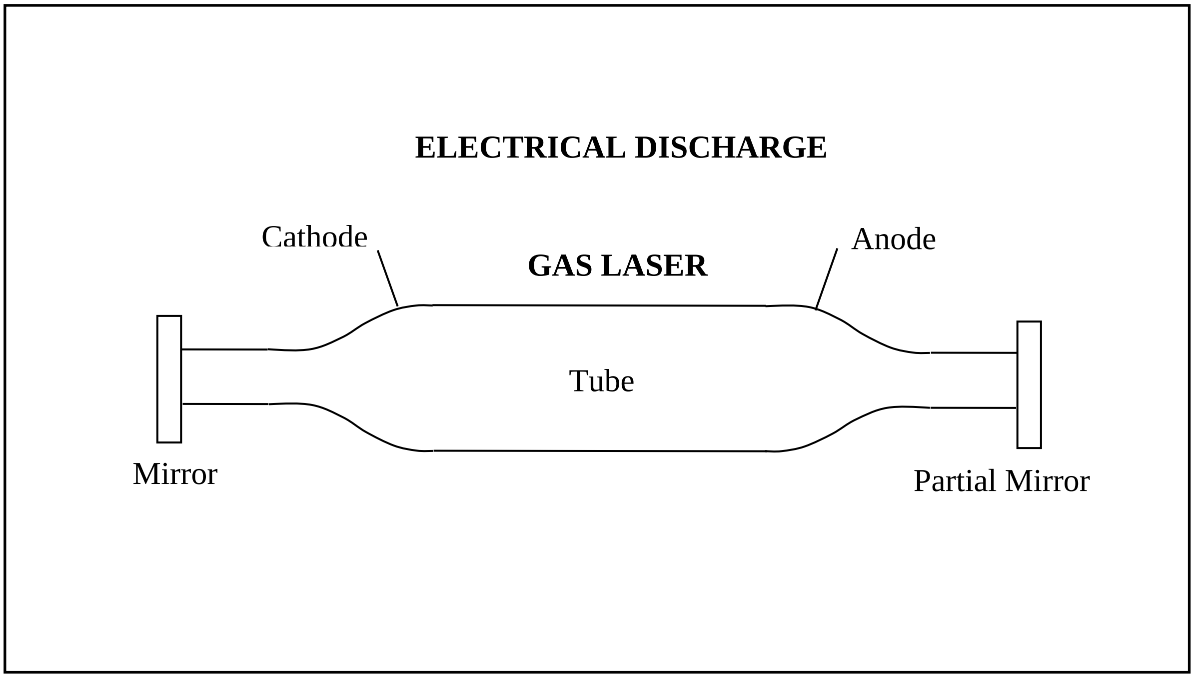


Figure 3. Gas laser construction

Semiconductor diode lasers are directly excited by electrical current flowing through the laser medium. The mirrors of the cavity can be the polished ends of the laser crystal or the semiconductor material (figure 4).

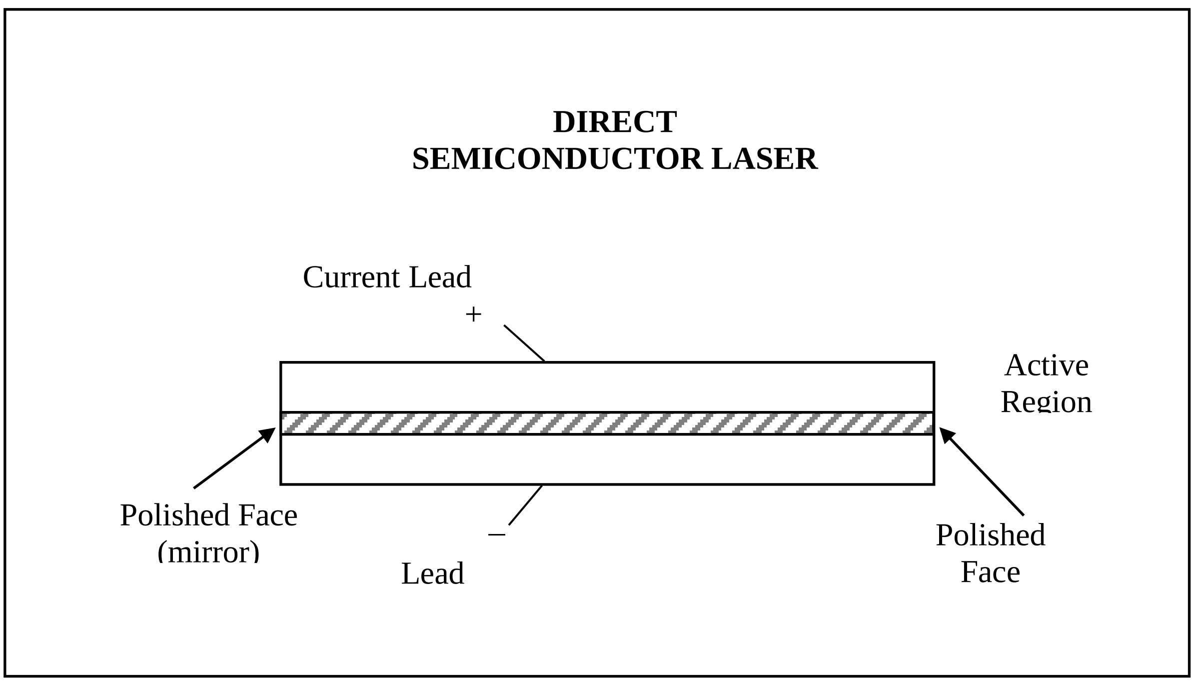


Figure 4. Semiconductor (diode) laser

Modes of operation

Lasers can be operated in both continuous emission mode (continuous wave or CW) and in pulsed mode. Pulsed lasers can emit single pulses or sequences of pulses various repetition frequencies. Some lasers produce very short (~10-250 ns) high peak power laser pulses by first storing in and then dumping the accumulated energy out of the lasing medium. This is achieved by the means of device called a Q-switch. While the excitation source is on, the Q-switch temporarily blocks the emission though the partial reflector, which allows more energy to be accumulated within the laser cavity. Then, the Q-switch unblocks the exit mirror for a short time and all the accumulated energy is dumped out. As result, the emitted laser pulses are very short (~10-250 ns) and the emission's peak power is very high. Lasers can emit pulses as short as 1 femtosecond (10^{-15} sec).

Properties of laser beams

Laser beams are characterized by the following properties:

- Low divergence (high directionality)
- High brightness or radiance
- Monochromaticity (narrow spectral bandwidth)
- Coherence
- High power density in the beam spot
- High peak power for short and ultra-short pulses

Common Lasers and Wavelengths

Laser Type	Active Medium	Wavelength, nm
Excimer Gas Lasers	Argon Fluoride Krypton Fluoride Xenon Chloride Xenon Fluoride	193 nm 248 nm 308 nm 351 nm
Gas Lasers	Nitrogen Helium Cadmium Argon Krypton Helium Neon Carbon Dioxide	337 nm 325 nm, 442 nm 488 nm, 514 nm 647 nm 633 nm 10,600 nm
Solid State Lasers	Doubled Nd:YAG Nd:YAG Ruby Ti:Sapphire	532 nm 1,064 nm 694 nm 700-1,100 nm
Dye Lasers	Rhodamine 6G	570-650 nm
Semiconductor Lasers	Galium Arsenide (GaAs) InGaAlP GaAlAs InGaAsP	850 nm, 905 nm 670 nm 750-900 nm 1300-1600 nm
Fiber lasers	Er:doped optical fiber	1550 nm

E2. Laser Hazards and Bioeffects

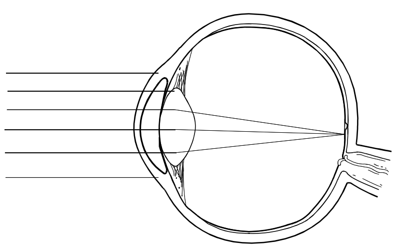
Laser hazards can be grouped in two categories based on the nature of the hazards

- Beam (laser radiation) hazards result from potential exposure to the laser beam or its specular or diffuse reflections and include:
    - Eye hazards and
    - Skin hazards
- Non-beam hazards are any other hazards that do not result from exposure to the laser beam (electrical, fire, chemical, noise, etc.)

E2.1 Eye Hazards

The potential for eye injury depends on the wavelength, the intensity of the laser radiation and the absorption characteristics of different eye tissues. Absorption of laser radiation occurs predominantly in the cornea, the lens and the retina. Absorption occurs at atomic and molecular level and is a wavelength-specific process.

Radiation at wavelengths between 400 nm and 1400 nm is transmitted through the eye's cornea, lens and vitreous fluid and may be focused on the retina into a very small spot of approximately 20-25 microns. This wavelength range is called the "Retinal Hazard Range" and includes both visible (400-700 nm) and infrared (700-1400 nm) wavelengths as the invisible infrared radiation in the 700-1400 nm range is also hazardous for the eye retina. Damage to the retinal tissue occurs by absorption of light and its conversion into heat or by photochemical reactions. The focusing effect of the eye increases the irradiance on the retina by up to 100,000 times compared to the corneal irradiance.



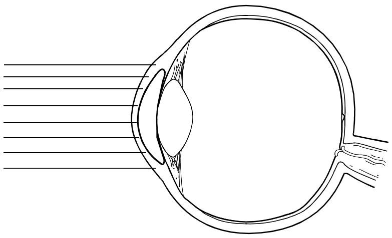
<u>Retinal Hazard Range</u>
400 nm to 1400 nm

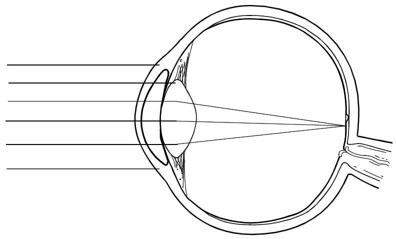
Visible and near infrared radiation is transmitted through and focuses on the retina

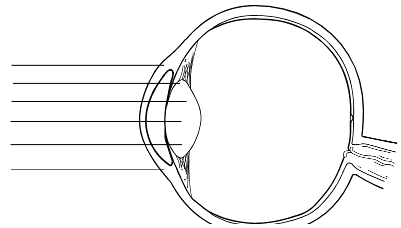
Absorption of optical radiation by the human eye

UVB and UVC wavelengths (180 - 315 nm), Mid-IR (1400-3000nm) and Far-IR (3000 nm - 1 mm) are absorbed in the eye's cornea. Excessive UV radiation causes photokeratitis, which is a chemical denaturation of the cornea proteins. UVA (315 - 400 nm) is strongly absorbed in the lens and causes photochemical denaturation of the proteins leading to cataracts. For those with added ocular photo-sensitivity due to medication or inborn conditions, UVA radiation may also penetrate to the retina. Far IR (3000 nm - 1 mm) is absorbed in a very thin layer of water on the outer surface of the eye, the cornea, which heats up and may cause corneal burns. Mid IR (1400-3000 nm) can penetrate deeper in the eye and cause thermal damage to the lens similar to the so-called "glass blower cataract".

The transition ranges between corneal and retinal hazard located at the wavelength bands separating the UV and visible regions and separating near infrared and infrared are not precise, and in these transition regions, there may be both corneal and retinal damage and, also damage to the lens and iris.







UVB and UVC (180-315 nm) and Far IR and Mid IR (1400 nm to 1 mm)

Visible (400–700 nm) and Near IR (700–1400 nm)

UVA (315 – 400 nm)

E2.2 Diffuse and Specular reflections

A diffuse reflection changes the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or a medium. A beam undergoing a diffuse reflection is not a beam anymore and becomes similar to a regular light source, which emits light in all directions. A specular reflection is a mirror-like reflection which does not change the beam spatial distribution, i.e. a beam remains a beam after the reflection, just its direction changes.

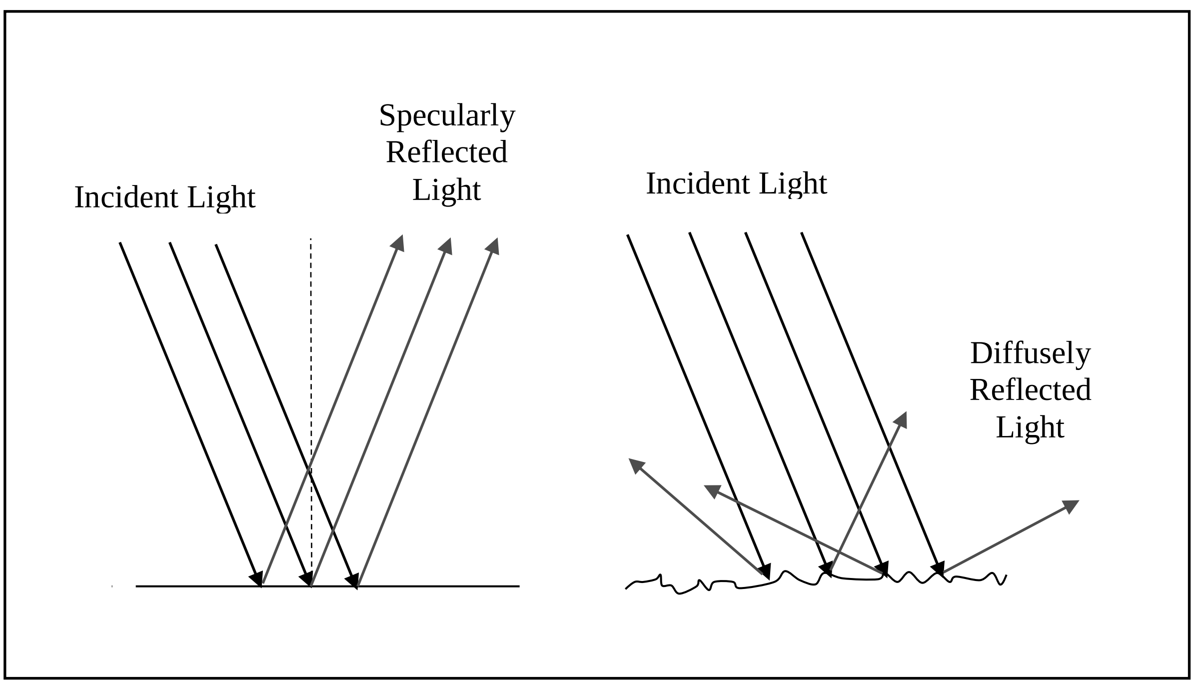


Figure 6. Specular and diffuse reflections

CAUTION: The same material may be diffuse for some wavelengths (e.g. visible), and specularly reflecting for other wavelengths (e.g. 10.6 μm from a CO_2 laser) depending on the surface roughness.

E2.3 Skin Hazards

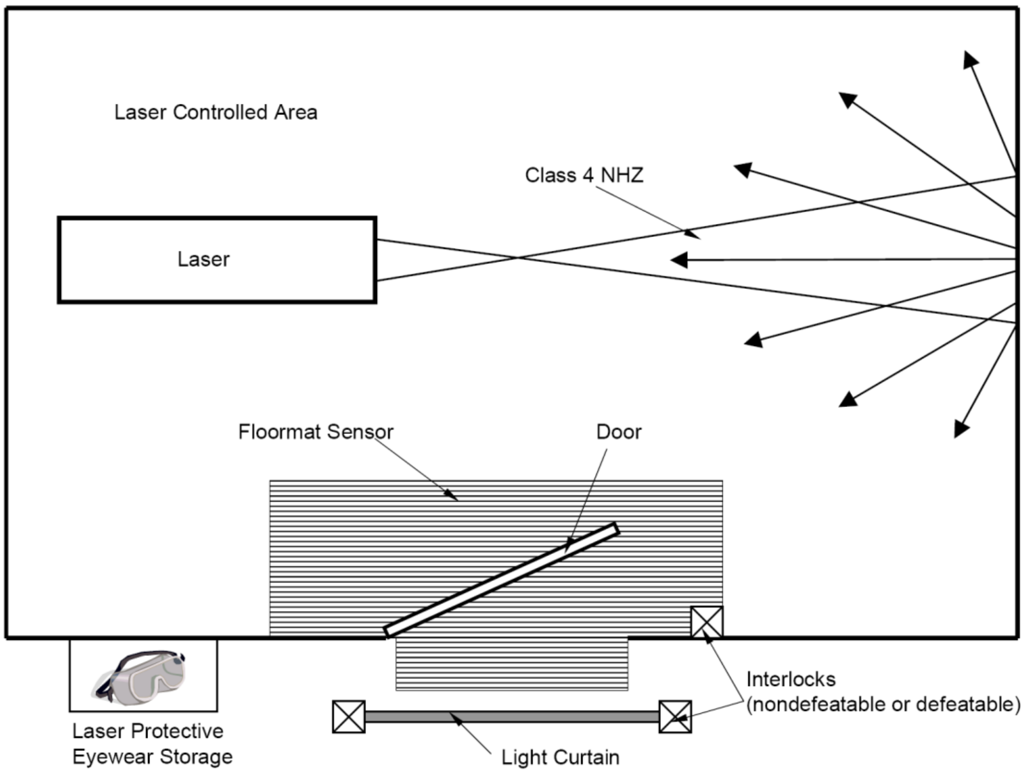
Skin effects are generally considered of secondary importance in laser safety except for high power infrared lasers, which can cause severe skin burns and UV lasers, which have the same effect as non-coherent UV radiation. UVB radiation (250 to 320 nm) is considered as the most injurious to skin. Exposure to the shorter wavelength UVC (less than 250 nm) and longer wavelength UVA (320 nm to 400 nm) is considered less harmful to normal human skin.

E2.4 Summary of biological effects of laser radiation on the eye and skin

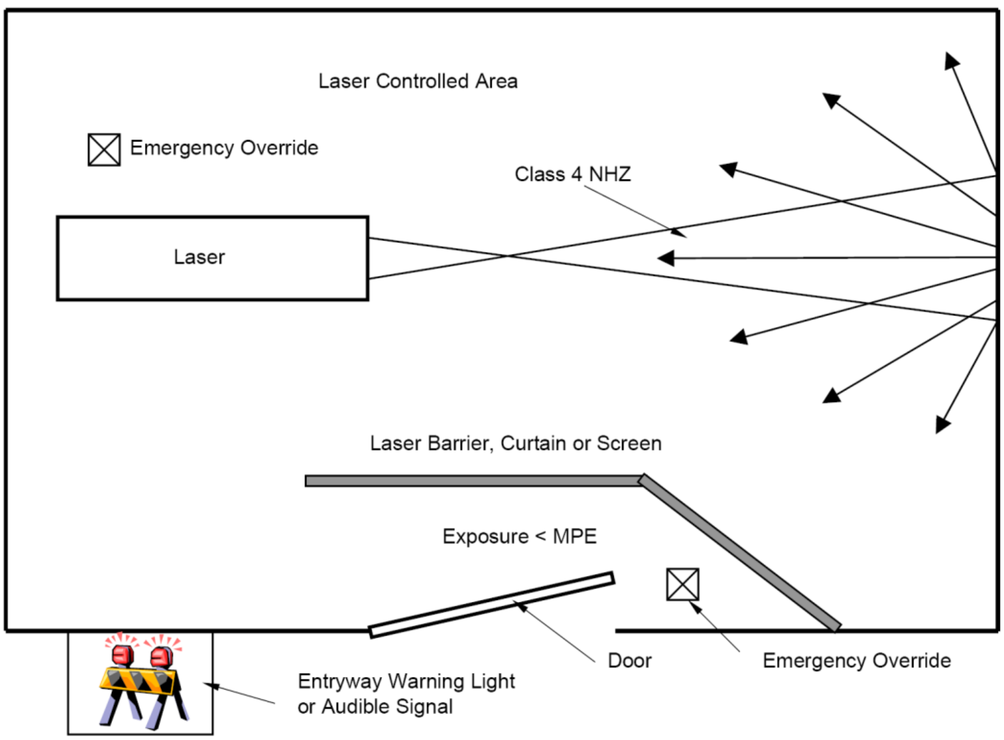
The following information from the international standard IEC 60825-1 for laser product safety is a summary of the biological effects of laser radiation on the human eye and skin. The CIE stands for the "*Commission internationale de l'éclairage",* translated as the "International Commission on Illumination'.

<table>
<tr><th>CIE Spectral region *</th><th>Eye</th><th colspan="2">Skin</th></tr>
<tr><td>Ultra-violet C
(180 nm to 280 nm)</td><td rowspan="2">Photokeratitis</td><td colspan="2" rowspan="2">Erythema (sunburn)
Accelerated skin ageing
Increased pigmentation</td></tr>
<tr><td>Ultra-violet B
(280 nm to 315 nm)</td></tr>
<tr><td>Ultra-violet A
(315 nm to 400 nm)</td><td>Photochemical cataract</td><td rowspan="2">Pigment darkening
Photosensitive reactions</td><td rowspan="5">Skin burn</td></tr>
<tr><td>Visible
(400 nm to 780 nm)</td><td>Photochemical and thermal retinal injury</td></tr>
<tr><td>Infra-red A
(780 nm to 1 400 nm)</td><td>Cataract, retinal burn</td><td rowspan="3"></td></tr>
<tr><td>Infra-red B
(1.4 µm to 3.0 µm)</td><td>Aqueous flare, cataract, corneal burn</td></tr>
<tr><td>Infra-red C
(3.0 µm to 1 mm)</td><td>Corneal burn only</td></tr>
<tr><td colspan="4">Note: *The spectral regions defined by the CIE are short-hand notations useful in describing biological effects and may not agree perfectly with spectral breakpoints in the MPE tables.</td></tr>
</table>

Appendix F



Example of entryway safety controls using interlocks



Example of entryway safety controls without interlocks

Appendix G

Laser Pointers

Laser pointers are widely available and used as toys as well as educational and business tools. Increasing numbers of incidents of irresponsible use have resulted in accidents and eye injury relating to laser pointers.

<u>What type of light is produced by a laser pointer?</u>

Laser pointers are small handheld diode lasers powered by AAA or other small batteries. The diode emits light at a wavelength of 670 nm red light or 532nm green light, producing a narrow intense beam which can be directed over long distances. In Canada, laser pointers with an output power above 1mW have been prohibited since June 2018. Laser pointer sold in Canada before June 2018 however do still have the potential to be hazardous with output powers up to 5mW.

Like all lasers, laser pointers are given a hazard classification that is defined by the ANSI Z136.1 Standard for Safe Use of Lasers. Laser pointers sold after 2018 must be Class 1, but those from before can be up to Class 3R. This is a device with the potential for eye damage from direct exposure to the beam.

<u>What is the danger from a laser pointer?</u>

Reports in the news media about people being flashed in the eyes by laser pointers have mentioned temporary blindness as a result of the exposure. As with photo-flashes, a brief exposure to laser light results in bright afterimages that may interfere with vision, particularly in dim lighting or at night. In addition, attempts to move out of the way of the laser beam may place the exposed person in a dangerous position. For example a driver may lose control of his vehicle while trying to avoid being hit by the laser beam.

It is possible that retinal burns could occur with sustained exposure to the laser beam. Calculations show that the theoretical exposure for a clinically detectable retinal injury is reached after a continuous exposure in excess of 100 seconds. However, this requires a fully dilated pupil and deliberately staring into the beam for the entire time. Most of the incidents reported in the media involve brief, flash exposures to the laser. Under these circumstances, there may be visual discomfort and afterimages that interfere with vision, however there should be no permanent retinal injury. Note that some police forces have taken the position that deliberately directing a laser beam into a persons eyes is assault, and may warrant a criminal charge of assault with a weapon.

What should I do if I am flashed in the eyes with a laser pointer?

As soon as you are aware of the laser, look away from the laser beam or close your eyes, and move out of its way. If possible, ask the person shining the laser at you to stop immediately. However, the person with the laser may be quite far away from you and it may not be possible to identify him or her, or communicate directly.

If afterimages and visual discomfort persist for more than a few minutes, see your eyecare professional as soon as possible for assessment.

Reference: University of Waterloo, School of Optometry