LASER SAFETY PROGRAM

York University

Prepared by Health, Safety and Employee Well-Being
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GLOSSARY

LSO - Laser Safety Officer
ANSI - American National Standard Institute
NHZ - Nominal Hazard Zone
MPE - Maximum Permissible Exposure

I. Objectives

The objectives for the establishment of the Laser Safety Program are:

1. To prevent personal injury resulting from the exposure to laser radiation through the implementation of safe work practices, proper signage and education for workers;

2. To conform to the requirements of the Ontario Ministry of Labour, the American National Standard for Safe Use of Lasers (ANSI Z136.1-2007) and related regulations and standards.

II. Laser Components and Characteristics

The acronym **LASER** stands for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.

Laser Components

All lasers contain three primary sections (Fig.1):

1. Active Medium
   The active medium contains atoms, molecules or ions whose electrons may be excited to a metastable energy level by an energy source to produce laser light. The active medium can be either solid crystalline materials such as ruby, or solutions of organic dyes, or gases such as Helium/Neon, or semiconductors such as Gallium/Aluminium/Arsenic. The material determines many of the laser beam's output characteristics, including its wavelength.

   There are four major types of lasers based on the lasing medium:
   - ♦ Solid State Lasers
     e.g. ruby laser, Nd:YAG (Neodymium:Yttrium/Aluminum/Garnet)
   - ♦ Semiconductor or Diode Lasers
     e.g. GaAlAs (Gallium/Arsenic/Arsenic)
   - ♦ Liquid (Dye solution) Lasers
   - ♦ Gas Lasers
     e.g. Carbon dioxide, rare gas-halogen, nitrogen

2. Excitation Mechanism
   The excitation mechanism is determined by the input energy device which pumps energy into the active medium. This mechanism can be optical, electrical or chemical.

3. Optical Resonator
The optical resonator consists of two specially designed mirrors. The high reflectance mirror reflects essentially 100% of the light hitting it while the other partially transmissive mirror (called the output coupler) reflects less than 100% of the light hitting it and transmits the remainder.

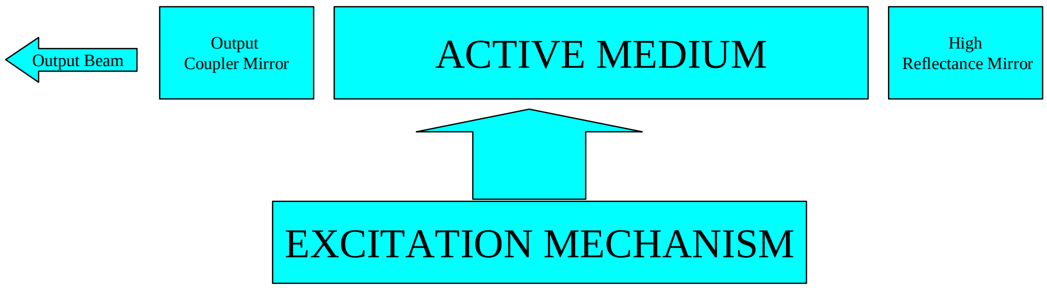


Fig. 1 - Laser Components

Laser Characteristics

Laser light is monochromatic, directional and coherent. Monochromatic means that all the light produced by the laser is of one wavelength. Directional means that the beam from the laser does not diverge as quickly as other light. Coherent means that all the waves of light are generated in phase with each other.

III. Classification of Lasers

All lasers are classified by the manufacturer and labelled with the appropriate warning labels. Any modification of an existing laser or an unclassified laser must be classified by the Laser Safety Officer (LSO) prior to use.

The following criteria are used to classify lasers:

1. Wavelength or wavelength range.

2. <u>For continuous wave (CW) or repetitively pulsed lasers</u>: average power output (Watts) and limiting exposure duration inherent in the design are considered.

3. <u>For pulsed lasers</u>: total energy (J) per pulse (or peak power), pulse duration, pulse repetition frequency, and the emergent beam radiant exposure (J/cm^2).

4. <u>For extended source lasers or laser systems</u> (e.g. laser arrays, laser diodes, and lasers having a permanent diffuser within the output optics): in addition to the parameters listed above, the maximum angle subtended must be known, and the source radiance or integrated radiance maybe needed.

Below is a brief summary of laser classification. For detailed classification, refer to ANSI Z136.1-2007.

Class 1 Lasers (Exempt)
Lasers that are not hazardous for continuous viewing or are designed in such a way that human access to laser radiation is prevented. They are low power lasers or high power embedded lasers (e.g. laser printers, CD ROM devices).

Class 2 Lasers (Low Power)
These lasers produce visible (wavelength: 400 to 700 nm) radiation, CW beams, with power up to 1 mW. They do not normally present a hazard from momentary exposure (less than 0.25 seconds) due to the normal human aversion responses, but would if viewed directly for extended periods of time (more than 0.25 s).

Class 3a Lasers (Medium-Power)
Lasers that normally would not cause injury to the eye or skin if viewed momentarily but would present a hazard if viewed using collecting optics (fibre optics loupe or telescope). All Class 3 lasers which have an accessible output power between 1 and 5 times Class 1 lasers for wavelengths less than 0.4um or greater than 0.7um (non-visible spectrum), or 5 times (5 mW) the Class 2 lasers for wavelengths between 0.4um and 0.7um (visible spectrum), are Class 3a.

Class 3b Lasers (Medium-Power)
Lasers that produce acute eye hazards from momentary intrabeam viewing or specular (mirror-like) reflections. Class 3b lasers do not produce a hazardous diffuse reflection except when viewed at close proximity. All Class 3 lasers and laser systems, which do not meet the requirements for Class 3a, shall be classified as Class 3b. Eg. For CW lasers, the limits are between the Class 3a limits and 500mW.

Class 4 Lasers (High Power)
Lasers that can damage the skin as well as the eye during momentary intrabeam exposure or exposure to specular and diffuse reflection. In addition, such lasers can ignite combustible materials. Lasers exceeding 500mW.

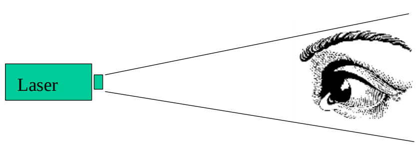
IV. Hazard Evaluation

A hazard evaluation of the laser being used is required for the purpose of classifying the laser and to determine the types of precautionary measures required. The following are some terms and conditions that should be determined for Class 3b and 4 lasers for the purpose of hazard evaluation (see ANSI Z136.1-2007 for details):

Viewing Conditions: intrabeam or from specular reflections versus **diffuse reflection**

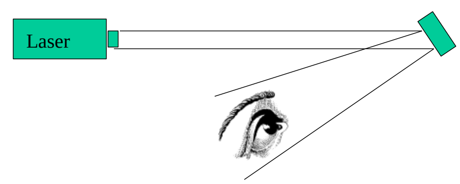
Intrabeam Viewing refers to viewing the direct beam or beam reflected off smooth surface. **Specular reflection** is mirror-like reflections and can reflect close to 100% of the incident light.

- Intrabeam Viewing – Direct



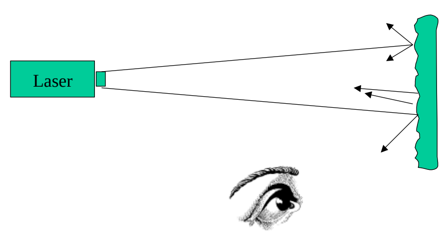
Intrabeam viewing of direct (primary) beam. This type of viewing is most hazardous.

- Intrabeam Viewing – Specular



Intrabeam viewing of a specularly reflected (secondary) beam from a flat surface reflector. Specular reflections are most hazardous when the reflecting surface is flat.

- Diffuse Reflection



Extended source viewing of a normally diffuse reflection. Diffuse reflections are not normally hazardous, except with very high power Class 4 lasers.

Diffuse Reflections (extended source) result when surface irregularities scatter light in all directions. Extended source viewing produces a larger retinal image.

MPE - Maximum Permissible Exposure (J/cm^2 or W/cm^2(for irradiance))

The MPE is defined in ANSI Z136.1-2007 as "The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin." The MPE is not an exact limit between safe and hazardous exposures; rather it is a maximum level which various experts agree should be occupationally safe for non-photosensitive individuals for repeated exposures. The biological effects of laser radiation are dependent on the wavelength of the laser, exposure duration and power intensity. Therefore MPE's are calculated using correction factors for these indices. The MPE has been expressed (normalized) relative to the limiting aperture area. Calculations of MPE's if required can be done with the assistance of the LSO for Class 3b and Class 4 lasers.

Nominal Hazard Zone

Where unenclosed beams are required, a Nominal Hazard Zone (NHZ) needs to be defined so as to determine an area in which control measures are required.

The NHZ is the space or distance within which the level of direct, reflected or scattered laser light exceeds the MPE level for the laser.

V. Laser Hazards

Exposure to laser radiation can produce eye and skin damage. The extent of the damage depends on the wavelength and intensity of the radiation, and on the duration of exposure. Powerful lasers may also present fire and chemical hazards.

<u>Effects on the Eyes</u>

Exposure of the eyes to laser radiation above the MPE is hazardous and must be avoided. The potential for injury to the different structures of the eye (Fig. 2) depends upon which structure absorbs the energy. Laser radiation may damage the cornea, lens or retina depending on the wavelength, intensity of the radiation and the absorption characteristics of different eye tissues.

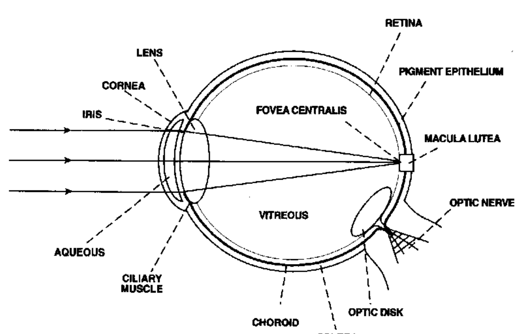


Fig. 2 - Structures of the Eye

Below are the effects of optical radiation at various wavelengths on various structures of the eye (refer to Fig. 3.):

Wavelength: **Visible and near-infrared wavelengths, 400 to 1400 nm**
Radiation is transmitted through the ocular media with little loss of intensity and is focused on the retina. Laser radiation in this range is termed the *retinal hazard region*. The focusing effects of the cornea and lens will increase the irradiance on the retina by up to 100,000 times.

Wavelength: **Middle, far-infrared (1400nm-1mm) and Middle Ultraviolet (180nm-315nm)**
The surface of the cornea absorbs radiation at these wavelengths. The absorption of middle ultraviolet radiation by the cornea produces photokeratitis (welders flash) by a photochemical process. For middle and far-infrared radiation, damage to the cornea results from the absorption of energy by tears and tissue water causing a temperature rise. Middle- infrared radiation penetrates deeper and may lead to the development of cataracts.

Wavelength: **Near-ultraviolet (315nm-400nm, UV-A)**
Radiation at the near-ultraviolet is absorbed in the lens and may contribute to certain forms of cataracts.

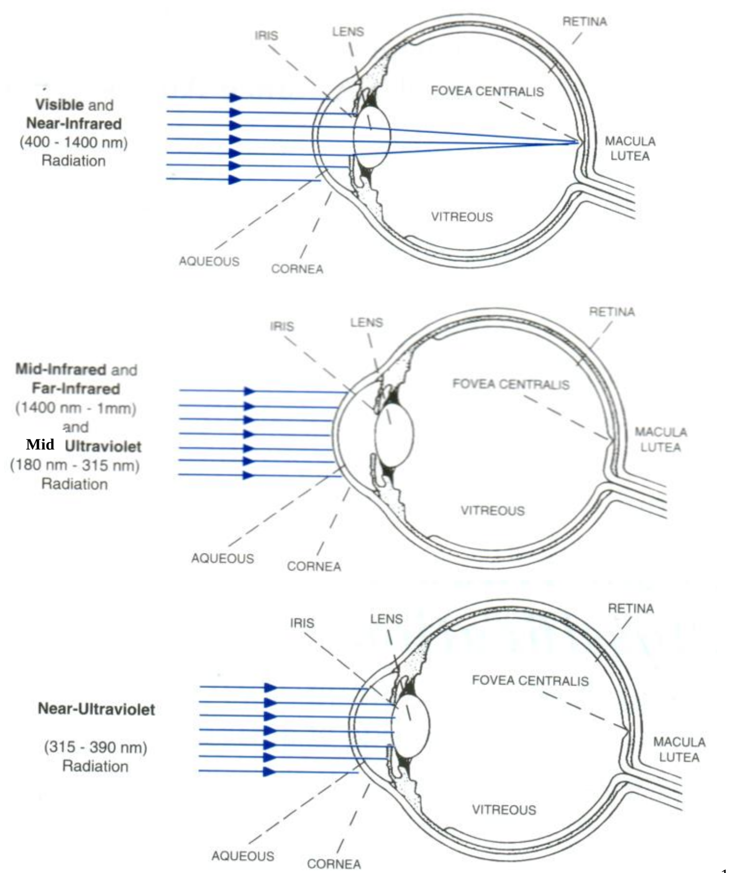


Fig.3 - Absorption of various wavelengths of light by the human eye.

Effects on the Skin

Skin effects are usually considered of secondary importance, however, with the more widespread use of lasers emitting in the ultraviolet spectral region as well as higher power lasers, skin effects have assumed greater importance.

Erythema (sunburn), skin cancer and accelerated skin aging are possible in the 230 to 380 nm wavelength range. The most severe effects occur in the UV-B (280 - 315 nm). Increased pigmentation can result from chronic exposures in the 280 to 400 nm range. In addition, photosensitive reactions are possible in the 310- 600 nm wavelength regions. The bioeffects in the infrared (700 - 1000nm) will be skin burns and excessive dry skin.

Other Associated Hazards:

Electrical Hazards

* Both pulsed and CW lasers may have high voltage and high current power supplies, and pulsed lasers utilize capacitor banks. Some gas lasers have radio-frequency power supply circuits.
* Improper grounding or shielding, or failure to follow standard electrical safety procedures during maintenance and service may result in electrical shock, burns or blistering, or electrocution. For example, since static electricity can be built up when some solvents flow through plastic tubing, grounding wire should be installed inside the tubing.

Chemical Hazards

* Many dyes used as lasing medium are toxic, carcinogenic, mutagenic or corrosive. Exposure to dyes during solution preparation should be minimized. Safety information regarding the dye can be obtained by reading the appropriate Material Safety Data Sheet.
* 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.
* Solvents used for mixing the dye may be flammable and/or toxic (irritants, narcotics, or anaesthetics). A low dye concentration may mean solvents are of the greater concern.
* Cryogenic fluids, such as liquid nitrogen, helium and hydrogen, are used in cooling systems of certain lasers. Skin and eye contact with such materials could cause frostbite.
* Compressed gases used in some lasers can be hazardous. For example, chlorine gas is corrosive; helium and argon are asphyxiant (displaces oxygen); and hydrogen is a flammable gas. There is also the hazard of unsecured cylinders: if a

cylinder should have its valve broken off in a fall, it becomes an uncontrolled missile.

Fire Hazards

* Class 4 lasers represent a fire hazard. Depending on construction material beam enclosures, barriers, stops and wiring are all potentially flammable if exposed to high beam irradiance for more than a few seconds.
* Flammable solvents, if used in an enclosed area without adequate dilution or exhaust ventilation, pose a fire or explosion hazard in the presence of an ignition source.

Explosion Hazards

* Explosion hazards may exist if high pressure arc lamps, filament lamps or capacitor banks fail during operation. These components should be enclosed in a housing which will withstand the maximum explosive force that may be produced.
* Laser targets and some optical components may also shatter if heat cannot be dissipated quickly enough. Consequently, care must be used to provide adequate mechanical shielding when exposing brittle materials to high intensity lasers.

Collateral Radiation

* X-rays can be generated from high voltage (over 15 kV) power supply tubes. Exposure to X-rays may cause tissue damage, leukemia or other cancers, or permanent genetic effects.
* UV and visible radiation may be generated from some laser discharge tubes and pumping lamps. The levels produced may exceed the Maximum Permissible Exposure and thus cause skin and eye damage.
* Plasma radiation may be emitted from interactions between very high powered laser beams and target materials (e.g. in laser welding). The plasma generated may contain hazardous UV emissions.
* Radio frequency (RF) is emitted from some pumping systems. Q switches and plasma tubes are RF excited components.

VI. Program Application

The Laser Safety Program applies to all Laser Workers at York University. Laser Workers are persons operating or working in the proximity to Class 3b and Class 4 lasers.

VII. Laser Safety Standards and Guidelines

Any requirements, guidelines and reference standards (including ANSI Z136.1-2007) established or adopted by the Ontario Ministry of Labour for the safe use of lasers will be followed in this program.

VIII. Roles and Responsibilities

Radiation Safety Committee (see Appendix I)

In reference to the York University Radiation Safety Program, the Radiation Safety Committee ensures the control of sources of potentially harmful radiation and implements appropriate measures for the protection of persons working with and exposed to radiation from such sources.

Where required, the Radiation Safety Committee may establish a working group, which should include the Laser Safety Officer (LSO) and faculty or staff members with expertise in laser technology, to establish and maintain policies and standards for the control of laser hazards.

The Radiation Safety Committee responsibilities are:

- to ensure that criteria for the safe use of lasers are established for users in the University in accordance with the requirements of the Ontario Ministry of Labour and related regulations;
- to recommend a level of resources sufficient to meet the requirements of the Laser Safety Program;
- to receive reports from the LSO on laser safety and recommend remedial action to correct any deficiencies;
- to suspend, restrict or terminate any unsafe operation of lasers or laser systems;
- to review the Laser Safety Program once every 2 years.

Laser Officer (LSO)

The LSO is directed by the Radiation Safety Committee and has attended training in laser safety in the area of: hazards, inspection and controls.

In reference to section 14 of the Radiation Safety Manual (Health and Safety Manual), the responsibilities of the LSO are:
- to ensure that all laboratories containing laser equipment are labelled in accordance with the code of practice;
- to provide advice and consultation in the safe operation of lasers;
- to assist users of lasers in complying with related legislation;
- to maintain an inventory of all Class 3b and Class 4 lasers. This includes classifying or verifying classification if necessary;
- to provide consultative services on evaluation and control of laser hazards;
- to provide or coordinate laser safety training for Laser Workers;
- to report to the Radiation Safety Committee on lasers or laser systems without adequate hazard controls;
- to maintain records as required by regulatory agencies in laser safety.
- Conduct safety audits of laser laboratories in accordance to the schedule.

Laser Supervisors

Laser supervisors are persons who have charge of a laser laboratory or authority over a worker who works with lasers.

Laser supervisors should be familiar with the general operating procedures of lasers under their control. The responsibilities of supervisors include the following:

- to ensure that Laser Workers are trained in Laser Safety (see Section XI) and have completed the Laser Worker Checklist (Appendix III) prior to operating or working in proximity to Class 3b and Class 4 lasers;
- to ensure that all Class 3b and Class 4 lasers in their possession are registered with the LSO;
- to investigate known or suspected accidents related to the lasers under their control and report such accidents (see Appendix IX for report form) to the LSO or the Radiation Safety Committee and the Workers Compensation Coordinator;
- to ensure that all administrative and engineering controls are followed;
- to ensure that Standard Operating Procedures are written and made available to Laser Workers under their supervision;

In addition, the supervisor is also responsible for complying with the requirements as stated for employer under the Occupational Health & Safety Act.

Laser Workers

The roles and responsibilities of Laser Workers are:

- to complete the Laser Worker Checklist (refer to Appendix III- Laser Worker Checklist and Registration Form);
- to work as directed by their Laser Supervisors, in compliance with the Occupational Health & Safety Act and the Laser Safety Program;
- to participate in the Laser Safety Training course;
- to report known or suspected accidents or safety violations to their Laser supervisors;
- to ensure that laser operation does not constitute a hazard to other people working in the laboratory and members of the public.

IX. Registration of Lasers and Laser Inventory

All Class 3b and Class 4 lasers shall be registered with the LSO by the completion of the Registration form (Appendix II).

The LSO and the Radiation Safety Committee shall maintain a laser inventory for all Class 3b and Class 4 lasers at York University in accordance with the Ontario Ministry of Labour requirements. The inventory, at a minimum, should include the following information: name and phone number of owner, location of laser, laser type (CO_2, Nd:YAG etc.) and the number of lasers.

The Laser inventory will be sent to Laser Supervisors for review and update annually.

X. Laser Safety Inspections

The LSO will conduct laser safety inspections of on a random basis. Inspections include checking signage in laboratories and on lasers, the existence written operating procedures, eye protection, beam enclosures and interlocks on protective housing, etc.

XI. Training

Education and training is required for Laser Workers prior to the commencement of work. The level of training shall be commensurate with the level of potential hazard.

Classroom and audio-visual training are provided by York University. Classroom training will be arranged by the LSO. For audio-visual training, videos called "Laser Safety Comes to Light" or "Laser Safety the Blink of an Eye" are available at York University - Scott Library in the Sound and Moving Image Library.

All Laser Workers are required to do the following prior to start of laser work:

- Review the Laser Safety Program
- View the video "Laser Safety Comes to Light" or "Laser Safety the Blink of an Eye"
- Complete the "Laser Registration Form" if not completed previously by the supervisor or by another worker in the lab. (See appendix II)
- Complete the "Laser Worker Checklist" (See appendix III)
- Complete the eye screening exam, the Laser Safety Training Session and the written test offered by HSEWB.
- Complete the laser safety training

Where contact with or usage of high voltage power supplies are involved, training shall include cardiopulmonary resuscitation (CPR) and electrical safety. A half-day CPR training can be obtained by registering through Sport and Recreation at the website below. For further details contact Tait McKenzie Client Services at ext. 55185.
http://www.yorku.ca/dohs/training_registration.html

Below are some of the topics included in the laser safety training program:

- Laser fundamentals
- Bioeffects of laser radiation on the eye and skin
- Relations of specular and diffuse reflections
- Nonradiation hazards (electrical, chemical etc.)
- Laser classifications
- Control measures: protective equipment, signage etc.
- Overall management and employee responsibilities

XII. Medical Surveillance

Medical surveillance is only required for personnel using Class 3b and 4 lasers. Eye examination must be arranged by contacting Health, Safety and Employee Well-Being at York University.

(i) Types of Examination

As per baseline examination protocol recommended by ANSI, the following tests will be conducted for laser personnel:

(a) Visual Acuity
(b) Macular Function
(c) Colour Vision

Where all the responses are normal, no further examination is required. For individuals whose ocular function in any of the above (a to c) test is not normal, referral will be made to a doctor or Optometrist for further examination.

(ii) Frequency of Eye Screening Exam

Eye screening exam is required for all using Laser Workers using class 3b or 4 lasers. It should be taken prior to participation in laser work and following any suspected laser injury. Periodic eye screening examinations are not required.

(iii) Suspected or Known Laser Injury

Any employee with suspected laser eye damage must contact Health Safety and Employee Well-Being and medical professional.

XIII. Personal Protective Equipment

Eye Protection

Within the NHZ, eye protection (e.g. goggles, face shields, prescription eyewear using special filter or coating) is required and its use is to be enforced by the supervisor when engineering controls may fail to eliminate potential exposure in excess of the applicable MPE. It is important to select eye protection specifically for the wavelength and power of the particular laser.

The amount of attenuation offered by the eye protection is measured by OPTICAL DENSITY (OD). The OD is given by the equation:

$OD = \log(\Phi_i / \Phi_t)$ where Φ_i is the incident power on the eye protector
Φ_t is the power transmitted through the eye protector

Since the power transmitted must not exceed the MPE,

$OD = \log(E_o / MPE)$ where E_o is the power of a laser beam (through the appropriate aperture) before it strikes the eye protector, expressed as W/cm^2 or J/cm^2.

Therefore, the greater the OD, the greater the attenuation (less light will reach the eye).

Laser Protective Eyewear Requirements

1. Laser protective eyewear is to be available and worn by all personnel within the Nominal Hazard Zone (NHZ) of Class 3b and Class 4 lasers where exposures above the Maximum Permissible Exposure (MPE) can occur.

2. All laser protective eyewear shall be clearly labelled. The associated wavelength dependent transmissive properties of the eyewear must be available to the user.

3. Laser protective eyewear shall be inspected for damage periodically and prior to use.

XIV. Engineering Controls

Commercial laser products will be certified by the manufacturer and will incorporate some engineering controls. Additional controls such as those shown below are required in order to reduce the potential for hazard associated with some applications of lasers and laser systems.

In some circumstances, such as research and development, some of these controls may impracticable. In such cases, the LSO shall affect a hazard analysis and ensure that control measures are instituted to assure safe operation.

Engineering Controls Measures for the Four Classes

Control Measures	**Classification**				
***Engineering Controls**	1	2	3a	3b	4
Protective Housing	X	X	X	X	X
Without Protective Housing	LSO shall establish alternative controls				
Interlocks on Protective Housing	▽	▽	▽	X	X
Service Access Panel	▽	▽	▽	X	X
Key Control	—	—	—	▪	X
Viewing Portals	—	MPE	MPE	MPE	MPE
Collecting Optics	MPE	MPE	MPE	MPE	MPE
Totally Open Beam Path	—	—	—	X NHZ	X NHZ
Limited Open Beam Path	—	—	—	X NHZ	X NHZ
Enclosed Beam Path	None required if equipped with interlocks				
Remote Interlock Connector	—	—	—	▪	X
Beam Stop or Attenuator	—	—	—	▪	X
Activation Warning Systems	—	—	—	▪	X
Emission Delay	—	—	—	—	X
Indoor Laser Controlled Area	—	—	—	X NHZ	X NHZ
Class 3b Indoor Laser Controlled Area	—	—	—	X	—
Class 4 Laser Controlled Area	—	—	—	—	X
Laser Outdoor Controls	—	—	—	X NHZ	X NHZ
Laser in Navigable Airspace	—	—	▪	▪	▪
Temporary Laser Controlled Area	▽ MPE	▽ MPE	▽ MPE	—	—
Remote Firing and Monitoring	—	—	—	—	▪
Labels	X	X	X	X	X
Area Posting	—	—	▪	X NHZ	X NHZ

LEGEND
X – Shall
▪ - Should
— - No requirement
▽ - Shall if enclosed Class 3b or Class 4
MPE – Shall if MPE is exceeded
NHZ – Nominal Hazard Zone analysis required
* See following pages for details

Engineering Controls

Protective Housing
A protective housing is a physical barrier preventing laser radiation in excess of the MPE from exiting the laser.

Laser Use without Protective Housing
In some circumstances, e.g. research and development and manufacturing operation without protective housing may be necessary. In these cases, the Laser Safety Officer shall assess the hazard and ensure that appropriate controls are instituted. The controls may include (but are not limited to):

* access restriction
* eye protection
* area controls
* barriers, shrouds, beam stops
* administrative and procedural controls
* education and training

Interlocks on Protective Housing
An interlock system which is activated when the protective housing is opened during operation and maintenance. The interlock prevents access to laser radiation above the applicable MPE.

Service Access Panels
Portions of the protective housing which are intended to be removed from any laser, by service personnel only and permit direct access to Class 3b or 4 laser radiation shall either: (1) be interlocked (fail-safe interlock not required), or (2) require a tool for removal and shall have an appropriate warning label on the panel.

Key Control
A master switch which is operated by a key, or by a coded access (such as a computer code).

Viewing Portals and Display Screens
All viewing portals and display screens included as an integral part of a laser or laser system shall incorporate a suitable means (such as interlocks, filters, attenuators) to maintain the laser radiation at the viewing position at or below the applicable MPE for all conditions of operation and maintenance.

Collecting Optics
All collecting optics (such as lenses, telescopes, microscope, endoscopes, etc.) intended for viewing use with a laser or laser system shall incorporate suitable means (such as interlocks, filters, attenuators) to maintain the laser radiation transmitted through the collecting optics to levels at or below the appropriate MPE, under all conditions of operation and maintenance.

Beam Paths
Control of the laser beam path shall be accomplished as described in the following sections:

Totally Unenclosed Beam Path
Where the entire beam path is unenclosed, a laser hazard analysis shall be affected to establish the NHZ if not furnished by the manufacturer.

Limited Open Beam Path
Where the beam path is confined by design to significantly limit the degree of accessibility of the open beam, a hazard analysis shall be effected to establish the NHZ.

Enclosed Beam Path
When the protective housing requirements are temporarily relaxed, such as during service, the LSO shall affect the appropriate controls. These may include a temporary area control and administrative and procedural controls.

Remote Interlock Connector
The remote interlock connector, such as a "Panic Button", deactivates or reduces the accessible radiation below the MPE on entry to an area protected.

Beam Stop or Attenuators
The beam stop or attenuator is a device capable of preventing access to laser radiation in excess of the appropriate MPE level when the laser or laser system output is not required.

Laser Activation Warning System
An audible system e.g. an alarm, a warning light (visible through protective eyewear), or a verbal "countdown" command during activation or start-up of the laser.

Emission Delay
A warning system which provides sufficient time prior to emission of laser radiation to allow appropriate action to be taken to avoid exposure to the laser radiation.

Equipment Labels
All commercial lasers are labelled. Homemade lasers, except Class 1, must have a label (with laser sunburst symbol) affixed to a conspicuous place on the laser housing or control panel.

Area Posting Signs (see Fig. 4 (i), (ii))
An area which contains a Class 3b or 4 laser or laser system shall be posted with the appropriate sign. A notice sign shall be posted outside a temporary laser controlled area.
Signage can be obtained from the LSO.

Laser Controlled Area
The following items are required for the various types of laser control areas:

Class 3b Laser Controlled Area

1. Posted with the appropriate warning sign(s).
2. Operated by qualified and authorized personnel.
3. Under the direct supervision of an individual knowledgeable in laser safety.
4. Located so that access to the area by spectators is limited.
5. Have any potentially hazardous beam terminated in a beam stop of an appropriate material.
6. Have personnel within the controlled area provided with the appropriate eye protection if there is any possibility of viewing the direct or reflected beams.
7. Where possible, have the laser secured such that the beam path is above or below eye level of a person in any standing or seated position.
8. Have all windows, doorways, open portals, etc. from an indoor facility be either covered or restricted in such a manner as to reduce the transmitted laser radiation to levels at or below the appropriate ocular MPE.
9. Ensure appropriate steps are available to prevent unauthorized use.

Class 4 Laser Controlled Area

1. Fulfil all items of Class 3b Control areas and in addition incorporate the following:
2. Personnel who enter a Class 4 controlled area shall be adequately trained, provided with the appropriate protective equipment, and follow all applicable administrative and procedural controls.
3. Fire exits and entryway shall be designed to allow both rapid egress by laser personnel at all times and admittance to the laser controlled area under emergency conditions.
4. For emergency conditions, appropriate means shall be available (e.g. "Panic Button") for deactivating the laser or reducing the output to the appropriate MPE levels.
5. Ensure that controls are in place to prevent unexpected and unauthorized entry into the laser controlled area. These controls may be non-defeatable, defeatable or procedural as determined by the LSO following ANSI Z136.1-2007.

Laser Outdoor Controls

Contact the LSO for appropriate controls

Laser in Navigable Airspace

Contact the LSO for appropriate controls

Remote Firing and Monitoring (Class 4)

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.

Temporary Laser Controlled Area

Where removal of panels or protective housings, over-riding of protective housing interlocks, or entry into the NHZ becomes necessary (such as for service), and the accessible laser radiation exceeds the applicable MPE, a temporary laser controlled area shall be set up. This control area shall provide all safety requirements for all personnel, both within and outside the area and shall be posted outside the temporary laser controlled area to warn of the potential hazard.

Fig. 4 (ii) - Sample Temporary Laser Controlled Area sign.
This sign shall be posted outside a temporary controlled area, for example, during periods of service. The area outside the temporary controlled area remains Class 1, while the area within is either Class 3b or 4.

Area Posting

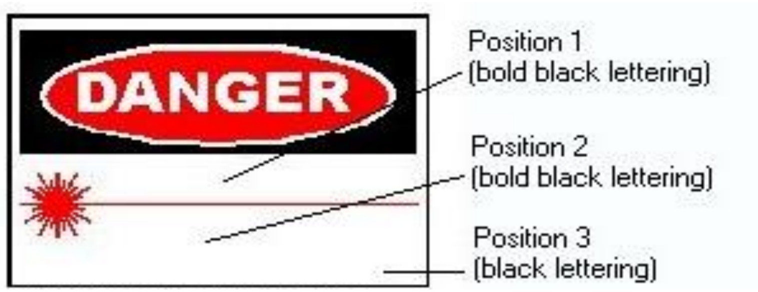


Fig. 4 (I) - Sample warning sign for certain Class 3a, 3b and Class 4 lasers.
Position 1 states precautionary or protective instructions.
Position 2 describes the type of lasers, emitted wavelength, maximum output, and pulse duration if applicable.
Position 3 states the laser class.

XIV. Administrative and Procedural Controls

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. The Table below indicates the University requirement, which is consistent with ANSI requirements for laser systems.

Administrative and Procedural Controls for the Four Classes

Control Measures	Classification				
***Administrative and Procedural Controls**	1	2	3a	3b	4
Standard Operating Procedures	—	—	—	▪	X
Output Emission Limitations	—	—	LSO Determination		
Education and Training	—	▪	▪	X	X
Authorized Personnel	—	—	—	X	X
Alignment Procedures	—	X	X	X	X
Protective Equipment	—	—	—	▪	X
Spectator	—	—	—	▪	X
Service Personnel	▽ MPE	▽ MPE	▽ MPE	X	X
Demonstration with General Public	MPE[1]	X	X	X	X
Laser Optical Fibre Systems	MPE	MPE	MPE	X	X
Laser Robotic Installations	—	—	—	X NHZ	X NHZ
Eye Protection	—	—	—	▪ MPE	X MPE
Protective Windows	—	—	—	X NHZ	X NHZ
Protective Barriers and Curtains	—	—	—	▪	▪
Skin Protection	—	—	—	X MPE	X MPE
Other Protective Equipment	Use may be required				
Warning Signs and Labels (Design Requirements)	—	▪	▪	X NHZ	X NHZ
Service and Repairs	LSO Determination				
Modifications and Laser Systems	LSO Determination				

LEGEND
X – Shall
▪ - Should
— - No requirement
▽ - Shall if enclosed Class 3b or Class 4
MPE – Shall if MPE is exceeded
NHZ – Nominal Hazard Zone analysis required
[1] – Applicable only to UV and IR Lasers
* See following pages for details

ADMINISTRATIVE AND PROCEDURAL CONTROLS

Standard Operating Procedures (SOP's)

Written SOP's shall be maintained with the laser equipment for reference by the operator, and maintenance or service personnel.

Output Emission Limitations

If, in the opinion of the LSO, excessive power or radiant energy is accessible during operation or maintenance of, the LSO shall take such action as required to reduce the levels of accessible power or radiant energy to that which is commensurate with the required application.

Operator's Training

Education and training shall be provided for operators, maintenance or service personnel prior to the commencement of work. The level of training shall be commensurate with the level of potential hazard. Below are the recommended topics to be included in a laser safety training program:

- Laser fundamentals
- Bioeffects of laser radiation on the eye and skin
- Relations of specular and diffuse reflections
- Nonradiation hazards (electrical, chemical etc.)
- Laser classifications
- Control measures: protective equipment, signage etc.
- Overall management and employee responsibilities

Where applicable, training shall include cardiopulmonary resuscitation (CPR) and electrical safety. The LSO shall ensure that CPR skill is accessible.

Authorized Personnel

Lasers shall be operated, maintained or serviced only by authorized personnel.

Written Alignment Procedures

Alignment shall 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 applicable MPE. Written SOP's outlining alignment methods shall be available.

Eye Protection

Eye protection shall be administratively required and their use enforced when engineering or other procedural and administrative controls are inadequate to eliminate potential exposure in excess of the applicable MPE.

Spectators

Spectators shall 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.

Service Personnel

Personnel who require access to Class 3b or Class 4 lasers shall comply with appropriate control measures.

Laser Demonstration with General Public

LSO should be consulted for those situations where lasers are used for demonstration with the General Public.

Laser Optical Fibre Systems

If a disconnection of a connector results in accessible radiation in an uncontrolled area and is above the MPE the LSO should be consulted.

Laser Robotic Installations (Class 3b and 4)

In instances including those created by hardware failure and software errors, the laser beam from robotic delivery systems could lead to scattering. Measurements are often required to confirm the NHZ.

Eye Protection (Class 3b and 4)

Eye protection devices, which are specifically designed for protection against radiation from Class 3B, should and Class 4 shall be administratively required and their use enforced when engineering or other procedural and administrative controls are inadequate to eliminate the potential exposure in access of the MPE.

Protective Windows (Class 3b or Class 4)

Facility windows (exterior or interior) that are located within the NHZ of a Class 3b or Class4 laser shall be provided with appropriate absorbing filter, scattering filter, blocking barrier, or screen which reduces any transmitted laser radiation to levels below the applicable MPE level.

Protective Barriers and Curtains

A blocking barrier, screen, or curtain (specifically selected to withstand direct and diffusely scattered beams) which block or filter the laser beam at the entryway should be used inside the controlled area to prevent the laser light from exiting the area at levels above the applicable MPE level.

Skin Protection

Some lasers, such as excimer lasers operating in the ultraviolet, the use of skin cover (e.g. gloves, lab coats and/or sun screen) are recommended. For wavelengths greater than 1.4 um, large-area exposures can cause heat loading – causing skin dryness and lead to heat stress.

Other Protective Equipment

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

Warning Signs and Labels

Warning shall conform to the required specifications and displayed in locations where they best serve to warn onlookers. Signs are available from the LSO.

Service and Repairs

Personnel who require access to Class 3b or Class 4 lasers shall comply with appropriate control measures.

Modifications and Laser Systems

The LSO may reclassify a laser, which has been modified.

APPENDIX I

Members of the Radiation Safety Committee

York University

Kathi Hudak (Chair)

Patty Lindsay (Committee Secretary)

Francis Arnaldo (Radiation Safety Officer)

Mark Bayfield

Rolando Ceddia

Tom Hodgson

Maria Mazzurco

Michael Mozurkewich

Brad Sheeller

Cody Storry

As of Sept., 2014

Laser Safety Advisers and Resource Personnel:

Chad Shew - Laser Safety Officer (LSO)

APPENDIX II

YORK UNIVERSITY

RADIATION SAFETY COMMITTEE

REGISTRATION OF LASERS
(Use one form for each laser)

Responsible Holder:____

Office Location: __________________________ Tel.: ______________
Building Room no.

Location of Laser: ____

A) CONTINUOUS OUTPUT POWER: _______________________________

Laser Class: ____

Wavelength Range: ___________________ Wavelength: _________

Beam Diameter at Aperture: ____mm Beam Divergence: ____mrad
(Limiting aperture)

B) PULSED OUTPUT POWER: ___________________________________

Laser Class: ____

Pulse Duration: _____________Frequency of Repetition: _____

Wavelength Range: ____________________ Wavelength: ________

Name of Users: ____

____

I have read and agree to abide by the regulations of the operation of lasers at York University specified in the York University Laser Safety Program.

Signature of Responsible Holder: _______________________________

PLEASE RETURN COMPLETED FORM TO: **Chad Shew, LSO**
Kinsmen Building Rm. 245

APPENDIX III

Laser Worker Checklist and Registration Form

I agree to abide by the requirements established for Laser Workers as stated in the York University Laser Safety Program. The following requirements have been completed by the undersigned worker:

1. I have viewed the **Laser Safety Video (Laser Safety Comes to Light or Laser Safety the Blink of an Eye)** at the Sound and Moving Image Library in the Scott library.

2. I have read the **Laser Safety Program o**ffered by York University.
   ____________________.
   (MM/DD/YY)

3. I have reviewed **written Standard Operation Procedures** (SOP) for the particular laser(s) that I will be working with. The SOP will also contain the Nominal Hazard Zone (NHZ) and the type of Personal Protective Equipment required.

4. I have called and arranged with Health, Safety and Employee Well-Being (ext. 55491) for Eye examination, **additional training and to complete the written quiz.**

Name of Laser Worker: _____________________________ ________________
Last Name First Name Signature

Laser Supervisor:
____

Date of Registration: ___________________________
(MM/DD/YY)

Completed form to be sent to: Laser Safety Officer, Kinsmen Building, Room 245