Western

THE UNIVERSITY OF WESTERN ONTARIO
Human Resources
Occupational Health and Safety

LASER SAFETY MANUAL

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Approved by the Radiation Safety Committee

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1.1 Internal Permit Holders and Laser Users

The University issues an Internal Permit to a University employee who is the Principal Investigator and Person in Charge of the location where the Class 3b or Class 4 lasers/laser systems is used or stored. All Permit Holders and Users of Class 3b or Class 4 lasers/laser systems must meet the following requirements:

1. Be 16 years of age.
2. Have an Internal Permit or work under an Internal Permit.
3. Be registered as a Laser Worker.
4. Comply with the Ontario Occupational Health and Safety Act, University Policies and Procedures, American National Standard for Safe Use of Lasers and follow the safe use and operation of the lasers/laser systems.
5. Be familiar with the University Laser Safety Manual.
6. A Permit Holder must ensure that all Laser Workers under their permit complete the University Laser Safety Training Program: Laser Safety Training Course by Occupational Health and Safety. Additional, specific hands-on training on particular lasers/laser systems must be given by the Permit Holder or Person in Charge of the laser laboratory.
7. Participate in the University Medical Surveillance program or sign a Waiver form provided by the University Staff/Health Services

1.2 Radiation Safety Coordinator

The Radiation Safety Coordinator (RSC) is the Laser Safety Officer at the University of Western Ontario. RSC administers the Laser Safety Program and serves as the primary contact for the Ministry of Labour in matters of laser safety. RSC exercises direction over the safe use and operation of the laser laboratory and equipment at the University of Western Ontario.

1.3 Senior Management

The Vice President (Administration) has overall corporate responsibility for the Ontario Occupational Health and Safety Act and applicable regulations and standard for the safe use of lasers.

1.4 Radiation Safety Committee

The Radiation Safety Committee is a sub-committee of the University Health and Safety Committee. This committee is composed of individuals with expertise or a stake in radiation safety matters. The individuals are appointed by the Deans of Faculties and act to advise Senior Management and the University Radiation Safety Coordinator on matters of all radiation safety including nuclear substances and radiation devices, particle accelerators, X-ray equipment and lasers/laser systems. Appointment will be a 3-year renewable term.

The University Health and Safety Committee constitute the Radiation Safety Committee membership to achieve equal representation from the five faculties involved in the Radiation Safety Programs as well as a representative for laser safety.

Membership
Voting Members:
Office of Vice-President Research (1)
Faculty of Science (4)
Faculty of Medicine and Dentistry (2)
Faculty of Social Science (1)
Faculty of Engineering (1)
Faculty of Health Sciences (1)

Non-Voting Members:
Director of Occupational Health and Safety
Radiation Safety Coordinator
Construction and Facility Safety Coordinator
Physical Plant Department Representative
Department Chair
Society of Graduate Students Representative

1.5 University Health and Safety Committee

The University Health and Safety Committee is the senior safety committee of the University. It has the responsibility for reviewing the overall safety performance of the University, for recommending health and safety policy, and for overseeing of any sub-safety committees reporting to it. This advisory committee reports directly to the President of the University.

Membership
Voting Members:
Vice-President (Administration): Chair
Provost & Vice-President (Academic)
Vice-President (Research)
Assistant Vice-President-Human Resources Division
Physical Plant Department
Two Deans, one from Engineering Science, Medicine or Science, appointed by the Provost for a 3-year renewable term

Non-Voting Members:
Director of Occupational and Health and Safety
Chairs, Subcommittees
Resource Persons

Section 2: Laser Hazards and Laser Safety Procedures

2.1 Radiation Hazards from Laser Beams

Lasers and laser systems emit beams of optical radiation. Optical radiation (ultraviolet, visible, and infrared) is termed non-ionizing radiation to distinguish it from ionizing radiation such as X-rays or gamma rays. Eye hazards and/or skin hazards are the primary concerns associated with optical radiation.

2.1.1 Eye Hazards

Corneal or retinal burns (or both) depending upon laser wavelength, are possible from acute exposure. Corneal or lenticular opacities (cataracts), or retinal injury may be possible from lengthy exposure to excessive levels of short wavelength light and ultraviolet radiation due to photochemical effects.

Ocular hazards represent a potential for injury to several different structures of the eye. Ocular injury from heating is generally dependent on which structure absorbs the most radiant energy per volume of tissue. Photochemical injury also depends upon the energy per photon of the energy absorbed (i.e. shorter wavelength radiant energy has more energetic photons). Retinal effects are possible when the laser emission wavelength occurs in the visible and near-infrared spectral regions, that is 400 to 1400 nanometers. Light directly from the laser or from a specular (mirror-like) reflection entering the eye at these wavelengths can be focused to an extremely small image on the retina. The incidental corneal irradiance (or radiant exposure) will be increased approximately 100,000 times at the retina due to the focusing effects of the cornea and lens (Fig. 1).

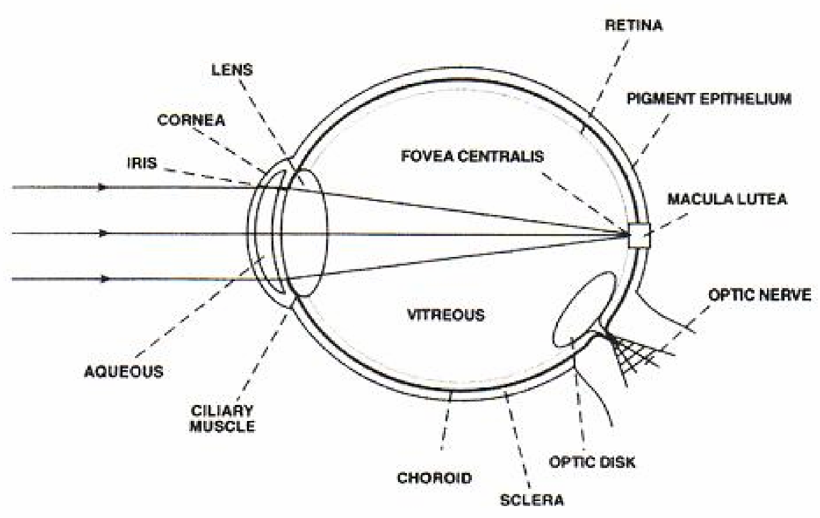


Figure 1 - Schematic diagram of the human eye showing structures of interest. Parallel rays of light can be focused to a very small area on the retina when the eye is relaxed.

Laser emissions in the ultraviolet and far-infrared spectral regions (outside 400 to 1400 nm) produce ocular effects primarily at the cornea. However, laser radiation at certain wavelengths may reach the lens and cause damage to the structure.

Effects of optical radiation at various wavelengths on various structures of the eye are shown in Figure 2.

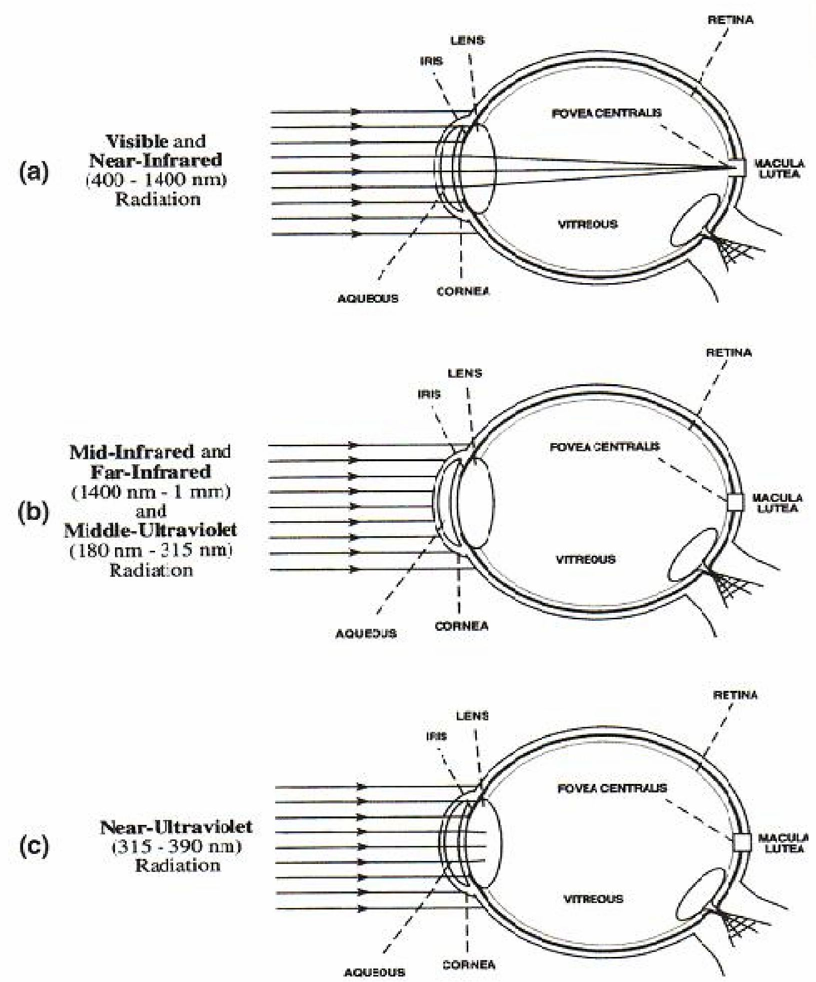


Figure 2 - Absorption sites of (a) visible and near infrared radiation; (b) middle, far-infrared radiation and middle ultraviolet radiation; (c) and near-ultraviolet radiation.

Actinic-ultraviolet, at wavelengths of 180 to 315 nm, is absorbed at the cornea. These wavelengths are responsible for "welder's flash" or photokeratitis (injury to the cornea). Actinic-ultraviolet radiation also produces "sunburn" or erythema (reddening) of the skin. Near-ultraviolet (UV-A) radiation between 315 and 400 nm is absorbed in the lens and may contribute to certain forms of cataracts. At high irradiances, these wavelengths also produce "long-wave" erythema of the skin and photokeratitis.

Radiation at visible wavelengths, 400 to 700 nm, and near infrared wavelengths, 700 to 1400 nm, is transmitted through the ocular media with little lose of intensity and is focused to a spot on the retina 10 to 20 micrometers (µm) in diameter (1 micrometer (µm) is one ten-thousandth of a centimeter). Such focusing can cause intensities high enough to damage the retina. For this reason, laser radiation in the 400 to 1400 nm range is termed the retinal hazard region. Wavelengths between 400 to 550 nm are particularly hazardous for long-term retinal exposures, exposures lasting for minutes or hours. This photochemical effect is sometimes referred to as the blue light hazard.

Far-infrared (IR-C) radiation with wavelengths of 3000 nm to 1 millimeter is absorbed in the front surface of the eye (the cornea). However, some middle-infrared (IR-B) radiation between 1400 and 3000 nm penetrates deeper and may contribute to "glass blower's cataract". Extensive exposure to near-infrared (IR-A) radiation may also contribute to such cataracts.

The localization of injury is always the result of strong absorption in the specific tissues for the particular wavelength.

The International Commission on Illumination (CIE) divides the optical spectrum into spectral bands. Most biological effects are limited to two or three spectral bands as shown in Figure 3

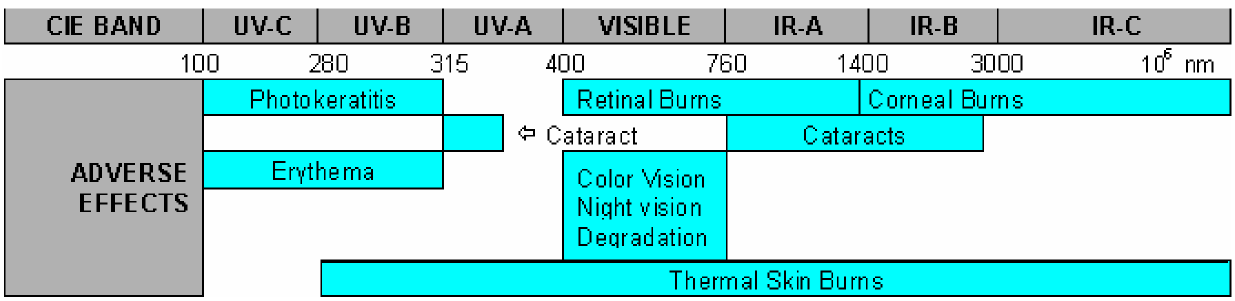


Figure 3 – Summary of biological effects of optical radiation

2.1.2 Skin Hazards

Skin burns are possible from acute exposure to high levels of optical radiation. At some specific ultraviolet wavelengths, skin carcinogenesis may occur.

Skin effects are generally considered of secondary importance except for ultraviolet and higher-power lasers. Sunburn, skin cancer and accelerated skin aging are possible in the 230 to 380 nm wavelength ranges (0.23 to 0.38 µm-actinic ultraviolet). The most severe effects occur in the UV-B (290 nm – 315 nm). Increased pigmentation can result following chronic exposures in the 290 to 400 nm wavelength ranges. In addition, photosensitive reactions are possible in the 310 to 400 nm (near ultraviolet) and 400 to 600 nm (visible) wavelength regions. Bioeffects in the 700 to 1000 nm (infrared) regions will be skin burns and excessively dry skin.

2.2 Non-Beam Hazards

Non-beam hazards may be categorized into physical, chemical or biological agents. Physical agents include, but are not limited to electrical hazards, collateral and plasma radiation, noise and mechanical hazards. Chemical agents may be subdivided into laser-generated airborne contaminants (LGAC), compressed gases, dyes and solvents. Biological agents include airborne infectious materials and microorganisms.

2.2.1 Physical Agents

Lethal electrical hazards may be present in most lasers, particularly in high power laser systems. Electrical safety practices must be followed when working with high voltage sections of laser equipment.

Plasma radiation is produced when the output from an energetic laser beam interacts with target materials. This has been demonstrated most often for pulsed emissions from carbon dioxide lasers when welding, drilling or otherwise treating metallic materials.

Collateral radiation includes those wavelengths emitted by the laser or laser system other than optical radiation. An example of this is x-radiation emitted by a high-energy switch, such as a thyratron, in a pulsed laser. Collateral x-radiation is produced by the process known as bremsstrahlung, or braking radiation.

2.2.2 Chemical Agents

Some materials used in lasers (i.e. excimer, dye, and chemical lasers) may be hazardous and/or contain toxic substances. Various gases are exhausted by high-power lasers (beam irradiance $>10^7$ W/cm^2) and produced by targets.

Common laser gases may be inert (argon, nitrogen), flammable (hydrogen), toxic (chlorine, fluorine), corrosive (hydrogen chloride).

Cryogenic fluids are used in cooling systems of certain lasers. As these materials evaporate, they replace the oxygen in the air. Adequate ventilation must be ensured.

2.2.3 Biological Agents

Lasers may be used in surgery in the medical, dental, and veterinary environments. This creates the potential for the generation of Laser Generated Airborne Contaminants (LGAC) and airborne infectious materials, when the laser beam interacts with tissues.

2.3 Laser Hazard Classifications

The American National Standard for Safe Use of Lasers (ANSI Z136.1) has four hazard classifications. Hazard classification may apply to the laser alone or to a laser system. The classification is based upon the beam output power or energy per pulse for pulsed lasers, contained within the limiting aperture. The term “limiting aperture” is often used when discussing laser classification. It is a function of wavelength and defined as the maximum circular area over which irradiance and radiant exposure can be averaged. For visible and near-infrared wavelengths, the limiting aperture is 7mm, simulating a dark-adapted pupillary diameter.

The classification scheme is used to describe the capability of the laser or laser system to produce injury to personnel. For commercial lasers, the Radiation Safety Coordinator uses the manufacturer’s listed classification. Higher-class numbers indicate greater potential hazards. Brief descriptions of each laser class are as follows:

Class 1: Lasers or laser systems that do not, under normal operating conditions, pose a hazard such as laser printers, CD players, etc.

Class 2: Low-power visible lasers or laser systems are incapable of causing eye injury the duration of the blink or human bright-light aversion response (0.25 sec). These lasers can not cause eye injury under normal circumstances but may present some potential hazard if viewed directly for extended periods of time. The majority of Class 2 lasers are helium-neon devices. For Continuous Wave (CW) (400 – 700 nm) lasers the upper limit for Class 2 is 1mW.

Class 3a: Lasers or laser systems that normally would not injury the eye if viewed within the duration of the blink or aversion response with the unaided eye but a hazard may be present if the beam is viewed through binoculars or similar optical devices. Some Class 3a lasers have danger labels are capable of exceeding maximum permissible exposure (MPE) levels for the eye within 0.25 sec, but still pose a low risk of injury. For Continuous Wave (CW) (400 -700 nm) lasers the upper limit for Class 3a is 5 mW.

Class 3b: Lasers or laser systems can produce accidental injuries to the eye from viewing the direct beam or a specular reflection. Class 3b laser normally will not produce a hazardous diffuse reflection from a matte (not shiny) target unless viewed through an optical instrument. Class 3b lasers ultraviolet (0.18 to 0.4 μm) and infrared (1.4 μm to 1 mm) cannot emit an average radian power in excess of 0.5 W for ≥ 0.25 s or cannot produce a radiant energy greater than 0.125 J within an exposure time < 0.25 s. Class 3b lasers visible (0.4 to 0.7 μm) or near-infrared (0.7 to 1.4 μm) cannot emit an average radian power in excess of 0.5 W for ≥ 0.25 s and cannot produce a radiant energy greater than 0.03 J per pulse.

Class 4: Lasers of laser systems present the eye and skin hazards from direct beam, specular reflections or diffuse reflections. In addition, class 4 laser can ignite flammable target, create hazardous airborne contaminants and usually a potentially lethal high voltage supply. Class 4 lasers and laser systems are those that emit radiation exceed the Class 3b.

Table 1 – Ocular and skin exposure limits* of some representative lasers

Laser Type	Wavelength	Ocular Exposure Limit	Skin Exposure Limit
Argon	488 nm 514.5 nm	15 nJ/cm^2 for 0.1 ps to 10 ps; 2.7 $t^{3/4}$ J/cm^2 for 10 ps to 1 ns; 0.5 μJ/cm^2 for 1 ns to 18 μs; 1.8 $t^{3/4}$ mJ/cm^2 from 18 μs to 10 s	20 mJ/cm^2 for 1 ns to 100 ns; 1.1 $t^{1/4}$ J/cm^2 for 100 ns to 10 s; 200 mW/cm^2 for greater duration
	488 nm	1 mW/cm^2 from 10 s to 58 s; 58 mJ/cm^2 from 58 s to 100 s; 0.58 mW/cm^2 for greater duration	
	514.5 nm	1 mW/cm^2 from 10 s to 30,000 s	
Helium Neon	632.8 nm	15 nJ/cm^2 for 100 fs to 10 ps; 2.7 $t^{3/4}$ J/cm^2 for 10 ps to 1 ns; 0.5 μJ/cm^2 for 1 ns To 18 μs; 1.8 $t^{3/4}$ mJ/cm^2 from 18 μs to 10 s; 1 mW/cm^2 for greater duration	Same as Argon
Neodymium:	1064 nm	150 nJ/cm^2 for 0.1ps to 10 ps; 27 $t^{3/4}$	100 mJ/cm^2 for 1 ns to 100 ns; 5.5 $t^{3/4}$

YAG		J/cm^2 for 10 ps to 1 ns; 5 μJ/cm^2 for 1 ns to 50 μs; 9 $t^{3/4}$ mJ/cm^2 from 50 μs to 10 s; 5 mW/cm^2 for greater duration	J/cm^2 for 100 ns to 10 s; 1 W/cm^2 for greater duration
Gallium Arsenide	905 nm	39 nJ/cm^2 for 100 fs to 10 ps; 6.9 $t^{3/4}$ J/cm^2 for 10 ps to 1 ns; 1.3 μJ/cm^2 for 1 ns To 18 μs; 4.6 $t^{3/4}$ mJ/cm^2 from 18 μs to 10s; 2.6 mW/cm^2 for greater durations.	51 mJ/cm^2 for 1 ns to 100 ns; 2.8 $t^{1/4}$ J/cm^2 for 100 ns to 10 s; 0.51 W/cm^2 for greater durations
Carbon Dioxide	10.6 μm	10 mJ/cm^2 for 1 ns to 100 ns; 0.56 $t^{1/4}$ J/cm^2 from 100 ns to 10 s; 100 mW/cm^2 for greater durations.	Same as ocular values

* The exposure limit is averaged over a 7-mm aperture for wavelengths between 400 and 1400 nm for the eye only. The other exposure limits are defined for a 1-mm or a 3.5-mm limiting aperture. Pulsed exposure limits were for a single pulse. Repetitively pulsed lasers require more adjustment of exposure limits.

2.4 Viewing Laser Radiation

The laser can be considered as a highly collimated source of extremely intense monochromatic electromagnetic radiation. Due to these unique beam properties, most laser devices can be considered as a light source of great brightness. Conventional light sources or a diffuse reflection of a Class 2 or Class 3 laser beam are extended sources of low brightness because the light radiates in all directions. Brightness is of considerable consequences from a hazard point of view, since the eye will focus the rays (400- 1400nm) from a highly collimated laser to very a small spot on the retina, whereas the rays from an extended source will be imaged, in general, over a much larger retinal area. When one is relatively far away from a diffuse target (far enough that the eye can no longer resolve the image), the retinal exposure from a diffuse reflection approximates direct exposure to a laser beam. Diffuse reflections generally only need to be visible and IR-A radiation (400-1400nm).

The most frequently encountered types of laser exposure are shown in Figures 4 through 7

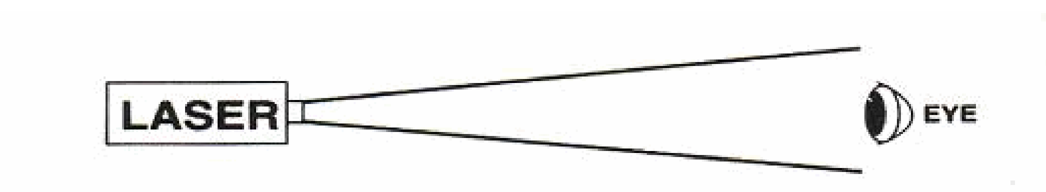


Figure 4 - Intrabeam viewing of direct (primary) beam. This type of viewing is most hazardous.

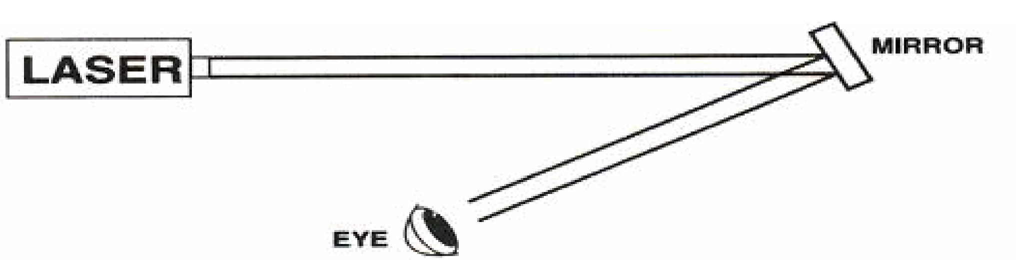


Figure 5 - Intrabeam viewing of a specularly reflected (secondary) beam from a flat surface reflector. Specular reflections are most hazardous when the reflecting surface is flat.

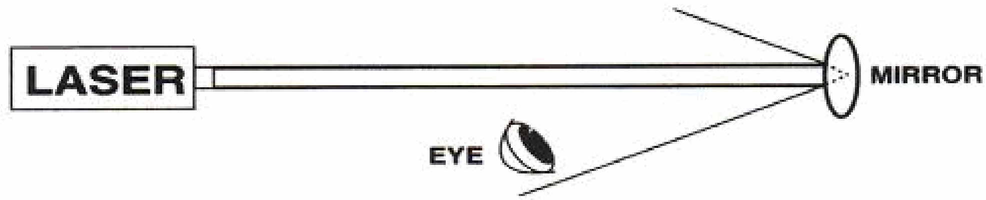


Figure 6 - Intrabeam viewing of a specularly reflected (secondary) beam from a curved surface reflector, which is less hazardous than that of a flat source reflection.

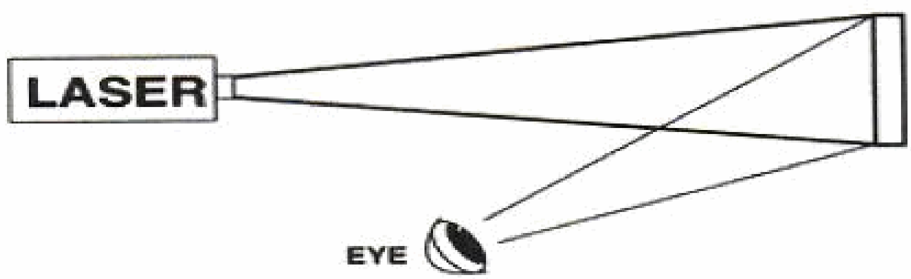


Figure 7 - Extended source viewing of a normally diffuse reflection. Diffuse reflections are not normally hazardous, except with very high power Class 4 lasers.

2.5 Safety Procedures for Each Laser Classification

Hazard controls for laser radiation vary with the following factors:

1. The laser classification
2. The environment where the laser is used
3. The people operating the laser

Safety measures could be engineering control, personal protective equipment or administrative and procedural control. Engineering controls should always be the first choice.

2.5.1 Safety Procedures for Class 1 Lasers

There is no known hazard for exposure to the output from a Class 1 laser or laser product. Therefore, these are truly considered to be “eye safe” lasers. For example, the output from a visible laser, such as a helium-neon (He-Ne) laser often used in laser scanning systems at a grocery store check- out counters, may be Class 1. If the beam from this laser product is viewed, the observer would see a red light, but because the beam is scanned, the laser product would pose no risk.

Some Class 4 lasers may be contained within the protective housing in such a manner that the user is not exposed to hazardous levels of laser radiation. In his case, the laser product would be classified as Class 1 laser under normal operation, although there is a high- power embedded laser within the protective housing panels. During service, both standards require that the access panels have warning labels alerting the user of a higher power embedded laser, and/or a safety interlock preventing exposure to hazardous levels of laser radiation.

2.5.2 Safety Procedures for Class 2 Lasers

These are "low- power" lasers that only emit visible laser radiation between the wavelengths 400 and 700nm. Therefore by definition, they are incapable of causing eye injury within the normal aversion response to bright light, which occurs within 0.25 second. At these wavelengths, an ocular hazard can only exist if an individual overcomes their natural aversion to bright light and stares directly into the laser beam. Class 2 lasers do not pose a skin hazard. The majority of low- power lasers today are gallium – aluminum arsenide (GaA1As) diode lasers and helium- neon (HeNe) devices with a CW power of one milliwatt or less. A growing number of diode lasers are also found in this class. Generally speaking, a visible (400- 700nm) laser beam that is comfortable to look into is below the Maximum Permissible Exposure limit (MPE).
The two operational safety rules are:

- Do not overcome the aversion response and stare into the laser beam.
- Do not point the laser at a person's eye.

2.5.3 Safety Procedures for Class 3 Lasers

These "medium power" lasers usually present a serious potential for eye injury resulting from intrabeam viewing, (especially Class 3b laser beams), they generally do not represent a diffuse reflection hazard, a skin hazard, or a fire hazard.

Safety procedures for Class 3a and 3b lasers are concentrated on eliminating the possibility of intrabeam viewing by:

1. Never aiming a laser at a person's eye.
2. Using proper laser safety eyewear if there is a chance that the beam or a hazardous specular reflection will expose the eyes.
3. Avoid placement of the unprotected eye along or near the beam axis. Some alignment procedures may place personnel at risk by requiring close proximity to the beam where the chance of hazardous specular reflections is greatest.
4. Attempting to keep laser beam paths above or below eye level for either sitting or standing positions. Assuring that individuals do not look directly into a laser beam with optical instruments unless an adequate protective filter is present within the optical train.
5. Eliminating unnecessary specular (mirror- like) surfaces from the vicinity of the laser beam path, or avoid aiming at such surfaces.
6. Not aiming at doorways or windows.

Additional safety procedures for Class 3b lasers include:

1. Assuring that individuals who operate Class 3b lasers are trained in laser safety and authorized to operate a laser.

2. Permitting only experienced personnel to operate the laser and not leaving an operable laser unattended if there is a chance that an unauthorized use may attempt to operate the laser. A key switch should be used if untrained persons may gain access to the laser. A warning light or buzzer may be used to indicate when the laser is operating.
3. Enclosing as much of the beam's path as practical.
4. Terminating the primary and secondary beams if possible at the end of their useful paths.
5. Using low power settings, beam shutters and laser output filters to reduce the beam power to less hazardous levels when the full output power is not required.
6. Assuring that any spectators are not potentially exposed to hazardous conditions.
7. Attempting to operate the laser only in a well-controlled area. For example, within a closed room with covered or filtered windows and controlled access.
8. Not permitting tracking of non- target vehicles or aircraft if the laser is used outdoors.
9. Labeling lasers and room with appropriate Class 3b warning sign.
10. Mounting the laser on a firm support to assure that the beam travels along the intended path.

2.5.4 Safety Procedures for Class 4 Lasers

The "high-power" lasers present the most serious of all laser hazards. Besides presenting serious eye and skin hazardous, these lasers may ignite flammable targets, create hazardous airborne contaminants, and may also have a potentially lethal, high current/ high voltage power supply. In addition to control measures for Class 3 lasers (section 2.5.3), the following rules should be carefully followed for all high-power lasers:

1. Enclose the entire laser beam path if possible.
2. Confine open beam indoor laser operations to a light-tight room.
3. Interlock entrances to assure that the laser cannot emit when the door is open. Administrative or procedural entryway safety controls may be used where interlocks are not feasible or are inappropriate. Examples of administrative controls are a barrier, screen or curtain. The Radiation Safety Coordinator shall review and approve alternate interlock (access) control.
4. Insure that all personnel wear adequate eye protection, or ensure that a suitable shield is present between the laser beam(s) and personnel.
5. Use remote firing and video monitoring or remote viewing through a laser safety shield where feasible.
6. When the laser is used outdoors, assure that the beam cannot intercept occupied areas or intercept aircraft.
7. Use lower power settings, a beam shutter or laser output filters to reduce the laser beam irradiance to less hazardous levels whenever the full beam power is not required.
8. Assure that the laser device has a key- switch master control to permit only authorized personnel to operate the laser.
9. Labeling lasers and room with appropriate Class 4 warning sign.
10. Use dark, absorbing, diffuse, fire resistant target and backstops where feasible.

Table 2. Engineering control measures for each of the laser classifications From ANSI Z136.1 (2000)

Control Measures	**Classification**				
Engineering Controls	1	2	3a	3b	4
Protective Housing	X	X	X	X	X
Without Protective Housing	Laser Safety Officer shall establish controls				
Interlocks on Protective Housing	▼	▼	▼	X	X
Service Access Panel	▼	▼	▼	X	X
Key Control	-	-	-	O	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 if Laser Safety Officer approves enclosure				
Remote Interlock Connector	-	-	-	O	X
Beam Stop or Attenuator	-	-	-	O	X
Activation Warning Systems	-	-	-	O	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	X
Laser in Navigable Airspace	-	-	O	O	O
Temporary Laser Controlled Area	▼ MPE	▼ MPE	▼ MPE	-	-
Remote Firing and Monitoring	-	-	-	-	O
Labels	X	X	X	X	X
Area Posting	-	-	O	X NHZ	X NHZ

Legend

X Shall
O Should
MPE Shall if MPE is exceeded
- No Requirement
▼ Shall if enclosed Class 3b or Class 4
NHZ – Nominal Hazard Zone analysis required

Table 3. Administrative and procedural control measures for each of the laser classifications. From ANSI Z136.1 (2000)

Control Measures	Classification				
Administrative and Procedural Controls	1	2	3a	3b	4
Standard Operating Procedures	-	-	-	O	X
Output Emission Limitations	-	-	Laser Safety Officer Determination		
Education and Training	-	O	O	X	X
Authorized Personnel	-	-	-	X	X
Alignment Procedures	-	X	X	X	X
Protective Equipment	-	-	-	O	X
Spectator	-	-	-	O	X
Service Personnel	▼ MPE	▼ MPE	▼ MPE	X	X
Demonstration with General Public	MPE	X	X	X	X
Laser Optical Fiber Systems	MPE	MPE	MPE	X	X
Laser Robotic Installation	-	-	-	X NHZ	X NHZ
Eye Protection	-	-	-	O MPE	X MPE
Protective Windows	-	-	-	X MPE	X NHZ
Protective Barriers and Curtains	-	-	-	O	O
Skin Protection	-	-	-	X MPE	X NHZ
Other Protective Equipment	Use may be required				
Warning Signs and Labels (Design Requirements)	-	O	O	X NHZ	X NHZ
Service and Repairs	Laser Safety Officer Determination				
Modification and Laser Systems	Laser Safety Officer Determination				

Legend
X Shall
O Should
MPE Shall if MPE is exceeded
- No Requirement
▼ Shall if enclosed Class 3b or Class 4
NHZ Nominal Hazard Zone analysis required

2.6 Eye Protection

Although engineering control, such as enclosure of the laser beam, are far more preferable than the use of laser eye protection, there are instances when the use of laser eye protection is the most affective safety measure. The eye protection must have an appropriate optical density at the wavelengths of the beams to be encountered, the beam irradiance, and the expected exposure conditions. The necessary optical densities (D_λ) of laser protective eyewear at a specific wavelengths is given by the equation:

$$D_\lambda = \log_{10} (E_o / MPE)$$

where E_o is the anticipated worse case irradiance (expressed usually in units of W/cm^2 for CW sources). The MPE is expressed in units identical to those of E_o. Tables Ia and Ib provide MPEs for many lasers. For pulsed sources, the necessary optical density at a specific wavelength is given by a similar equation with E_o replaced by the worse case radiant exposure per pulse, H_o and the MPE/pulse expressed as J/cm^2:

$$D_\lambda = \log_{10}[H_o(MPE/pulse)]$$

As an example, consider a single-pulse Neodymium: YAG laser operating at a wavelength of 1064 nm with an emergent beam diameter of 2 mm and a beam divergence of 1.0 mrad. The output is a TEM_{oo} pulse of 80 mJ delivered in a pulse duration of 15 ns. The MPE = 5×10^{-6} J/cm^2. The worse case exposure would be the emergent raw beam (H_{raw}) which can be shown to be $H_{raw} = 2.55$ J/cm^2 (the irradiance of the 80 mJ pulse in the 2 mm beam diameter). For the determination of H_o, however, since ANSI values of the MPEs for visible and near-infrared wavelengths are determined using a limiting aperture of 7mm (maximum pupil size), the value of H_o for beams smaller than 7 mm should be calculated as though the beam were distributed over the limiting aperture, thus for a single pulse laser the formula is:

$$H_o = \frac{\text{Output Power}}{\text{Area of the beam}} = \frac{(Q)}{\frac{\pi (D)^2}{4}}$$

$$H_o = \frac{80 \times 10^{-3}}{\frac{\pi (0.7)^2}{4}} = 0.21 \text{ J/cm}^2$$

The required optical density would be

$$D_\lambda = \log_{10} [H_o / (MPE/pulse)] = \log_{10} (0.21 / 5\times10^{-6})$$
$$= 4.6 \text{ (at } \lambda = 1064\text{nm)}$$

Thus, a direct exposure into the eye would require a filter density of nearly 5 to reduce the incident radiant exposure to the “safe” MPE level.

Table 3 provides a simplified approach for determining the optical density requirements for contemplated exposure conditions.

Table 3. Simplified method for selecting laser eye protection for intrabeam viewing of laser wavelengths between 400 and 1400 nm.
From ANSI Z136.1 (2000)

Q-Switched Laser (10^{-9} – 10^{-2} s)		Non-Q-Switched Lasers (0.4 x 10^{-3} – 10^{-2})		Continuous-Wave Laser Momentary (0.25 – 10 s)		Continuous-Wave Lasers Long-term Staring		Attenuation	
Maximum Output Energy (J)	Max Beam Radiant Exposure (J cm^{-2})	Max Laser Output Energy (J)	Max Beam Radiant Exposure (J cm^{-2})	Max Power Output (W)	Max Beam Irradiance (W cm^{-2})	Max Power Output (W)	Max Beam Irradiance (W cm^{-2})	Attenuation Factor	OD
10	200	100	200	10^5 *	2 x 105 *	100 *	200 *	10^8	8
1	2	10	20	10^{4} *	2 x 104 *	10 *	20 *	10^7	7
10^{-1}	2 x 10^{-1}	1	2	10^{3} *	2 x 103 *	1	2	10^6	6
10^{-2}	2 x 10^{-2}	10^{-1}	2 x 10^{-1}	100 *	200 *	10^{-1}	2 x 10^{-1}	10^5	5
10^{-3}	2 x 10^{-3}	10^{-2}	2 x 10^{-2}	10	20	10^{-2}	2 x 10^{-2}	10^4	4
10^{-4}	2 x 10^{-4}	10^{-3}	2 x 10^{-3}	1	2	10^{-3}	2 x 10^{-3}	10^3	3
10^{-5}	2 x 10^{-5}	10^{-4}	2 x 10^{-4}	10^{-1}	2 x 10-1	10^{-4}	2 x 10^{-4}	10^2	2
10^{-6}	2 x 10^{-6}	10^{-5}	2 x 10^{-5}	10^{-2}	2 x 10-2	10^{-5}	2 x 10^{-5}	10	1

2.7 Security and Control Access of Class 3b and Class 4 Lasers

All class 3b and class 4 laser rooms are restricted areas and must be locked at all times when unattended. Only the Permit Holder and authorized laser users listed on the permit are allowed to be left alone in the laser room when class 3b or class 4 laser(s) is in operation or can be operated.

All visitors must be accompanied by the Permit Holder or authorized users listed on the permit and follow all applicable regulations, policies, guidelines and procedures.

Section 3: OH&S Act, University Policies and Procedures

3.1 OH&S Act and Guidelines

The University of Western Ontario is committed to taking every reasonable precaution for the health and safety of its employees, students and the public. The Laser Safety Program is designed to ensure that all laser facilities at Western are compliant with the following applicable act and guideline:

1. Ontario Occupational Health and Safety Act (R.S.O 1990, c. O.1)
2. Ontario Ministry of Labour follows the American National Standard for Safe Use of Lasers (ANSI Z136.1 – 2000)

3.2 Purchase and Disposal Policy

Class 3b and Class 4 lasers must be reviewed and approved by the Radiation Safety Coordinator prior to purchasing or transferring to the University. Authorized staff within the UWO Purchasing Department will purchase or transfer laser equipment on behalf of the Permit Holder.

The Permit Holder is responsible to notify the Radiation Safety Coordinator that she/he disposes of or no longer has any Class 3b or Class 4 laser. In the absence of the Permit Holder, the Department Chair will assume these duties.

3.3 Location and Operation Policy

The Permit Holder is responsible to provide all information of laser equipment (new or modified) and a location where Class 3b or Class 4 laser installed or used to the Radiation Safety Coordinator.

Class 3b or Class 4 equipment shall not be installed or used until the location is reviewed and acceptable to the Radiation Safety Coordinator.

3.4 Training Policy

Class 3b or Class 4 laser users including Permit Holder must complete the University laser safety training course offered by Occupational Health and Safety. The permit holder or person in charge of laser facility is responsible to provide hands-on training on particular laser equipment to all laser users. All Class 3b or Class 4 laser users including Permit Holders are retrained every two years.

Class 1, Class 2, Class 3a, embedded Class 3b and embedded Class 4 laser users are not required to take laser safety training course offered by Occupational Health and Safety.

The Permit Holder must ensure that Class 3b or Class 4 laser users complete the University laser safety training course. All laser users are responsible for the safe use of laser equipment, are familiar with the UWO laser safety manual and follow the standard operating procedures.

3.5 Standard Operating Procedures Policy

The Permit Holder is responsible to establish the standard operating procedures for Class 3b or Class 4 lasers. All standard operating procedures must be acceptable to the Radiation Safety Coordinator.

The Permit Holder must ensure all laser workers follow the standard operating procedures.

3.6 Eye Protection Policy

All persons assigned to, or entering laser areas (Class 3b or Class 4) where eye hazards are present must wear appropriate laser eye protection provided by the Permit Holder or Person in Charge of the laser facility.

The Permit Holder or Budget Unit Head is responsible to provide laser protective eyewear to Class 3b or Class 4 laser users. The Permit Holder or Budget Unit Head shall contact the laser supplier for the recommended laser protective eyewear. The purchase of laser eye protectors is the responsibility of the individual budget unit.

3.7 Medical Surveillance Policy

The medical examination is necessary to establish a baseline against which damage (primary ocular) can be measured in the event of an accidental injury and to identify certain Class 3b or Class 4 laser users who might be at special risk from chronic exposure to selected continuous wave lasers.

All Class 3b or Class 4 laser users are required to complete a medical examination and surveillance program designed to monitor and protect their vision provided by the University Staff/Faculty Health Services or to sign a waiver form (Appendix 4.3.4)

3.8 Inspection Policy

Inspection of laser equipment/facility is necessary to reduce or eliminate the risk of radiation laser incident to laser users, employees, students and the public and to comply with applicable act and guidelines.

The Permit Holder and Person in Charge of the laser facility are responsible for their own in-house inspection on the regular basis in accordance with the laser safety manual. The Permit Holders are responsible for maintaining the engineering controls and administrative and procedural controls of their laser equipment/facility.

The Radiation Safety Coordinator will inspect all laser facility/equipment (Class 3b or Class 4) at least once a year or at anytime using the UWO inspection checklist. The inspections can be announced or un-announced. The inspection result will be graded A, B, C or D. All deficiencies must be corrected and reported in writing to the Radiation Safety Coordinator. Any operations that are considered unsafe will be immediately suspended by the Radiation Safety Coordinator.

The Ministry of Labour Inspector may enter in upon any workplace at anytime without warrant or notice. All University personnel shall give a Ministry of Labour Inspector all reasonable assistance to carry out his/her duties and functions under the Occupational Health and Safety Act.

3.9 Compliance Enforcement Policy

The University of Western Ontario assumes the responsibility of ensuring to the Ministry of Labour that the use of laser equipment in compliance with the Occupational Health and Safety Act and guidelines. To aid in determining the level of risk or immediate danger to safety and health, all compliance violations will be categorized as major and minor offences. Any offence occurring twice in any one year period will be considered as a second offence and so on.

A major offence would result from violations that cause immediate risk or danger to health and safety of any person or place the Ministry of Labour Registration in jeopardy. For example, a major offence would be one of the following deficiencies:
1. Operating laser equipment with known failed interlock.
2. Inadequate or no training for Class 3b or Class 4 lasers.
3. Unauthorized possession of Class 3b or Class 4 lasers.
4. Unauthorized laser location.

Major Offence Actions:
1. First Offence: An inspection report will be sent to the Permit Holder, copy to the Department Chair, Director OHS and Radiation Safety Committee Chair. The corrective action must be taken immediately by the Permit Holder and a written reply must be sent to the Radiation Safety Coordinator within 7 days of the inspection report. If the written reply is not received after 7 days, the second notice will be sent to the Permit Holder, copy to the Dean of Faculty, Department Chair, Director OHS and Radiation Safety Committee Chair.
   A meeting will be arranged with the Permit Holder, Department Chair, Director OHS, Radiation Safety Committee Chair and Radiation Safety Coordinator if there is no response from the Permit Holder after 7 days of the second notice.
2. Second Offence: The Permit Holder will be notified in writing by the Radiation Safety Coordinator that the permit will be suspended until a meeting with the Radiation Safety Committee can be held.
3. Third Offence: The Radiation Safety Coordinator will recommend permit cancellation to the Radiation Safety Committee.

Note: For the second and third offences, notification of the above actions will be copied to the Dean of Faculty, Department Chair, Director OHS and Radiation Safety Committee Chair.

A minor offence would be an infraction that poses no immediate risk to threat to health and safety of any person. For example, a minor offence would be one of the following deficiencies:
1. Inadequate warning signs.
2. Standard operating procedure is not available.
3. Failing to notify laser worker’s departure.

Minor Offence Actions:

1. First Offence: A written inspection report will be sent to the Permit Holder, copy to Department Chair, Director OHS and Radiation Safety Committee Chair. The corrective action must be taken as soon as possible by the Permit Holder and a written reply must be sent to the Radiation Safety Coordinator within 21 days of the inspection report. If the written reply is not received after 21 days, the second notice will be sent to the Permit Holder, copy to the Dean of Faculty, Department Chair, Director OHS and Radiation Safety Committee Chair.
   A meeting will be arranged with the Permit Holder, Department Chair, Director OHS and Radiation Safety Coordinator if there is no response from the Permit Holder after 14 days of the second notice.
2. Second Offence: A meeting will be arranged with the Permit Holder, Department Chair, Director OHS, Radiation Safety Committee Chair and Radiation Safety Coordinator to review the issues.
4. Third Offence: The Permit Holder will be notified in writing by the Radiation Safety Coordinator that the permit will be suspended until a meeting with the Radiation Safety Committee can be held.
5. Fourth Offence: The Radiation Safety Coordinator will recommend permit cancellation to the Radiation Safety Committee.

Note: For the second, third and fourth offences, notification of the above actions will be copied to the Dean of Faculty, Department Chair, Director OHS and Radiation Safety Committee Chair.

3.10 Application for Laser Internal Permit Procedure

1. Applicant must be a University employee who is the Principal Investigator or Person in Charge of the location where laser equipment is used or stored.
2. Complete the “Laser Permit Application” form with the approval of the Department Chair and send it to the Radiation Safety Coordinator. Application form is available in the Appendices.
3. The application is reviewed and approved by the Radiation Safety Coordinator and Radiation Safety Committee Chair or Designate.

3.11 Purchasing New Laser Equipment Procedure

1. The Permit Holder completes the requisition and sends it to the Radiation Safety Coordinator for approval.
2. The approved requisition will be forwarded to Purchasing Department.

3.12 Permit Amendments Procedure

The Permit Holder is responsible to notify in writing (i.e. email) to the Radiation Safety Coordinator in the following changes:

1. Lasers/laser systems (add, delete or dispose of, move, modify etc.)
2. Laser locations (add, delete, renovate, etc.)
3. Laser workers (add, delete, training, etc.)

The Radiation Safety Coordinator will confirm the changes in writing and send the updated permit to the Permit Holder.

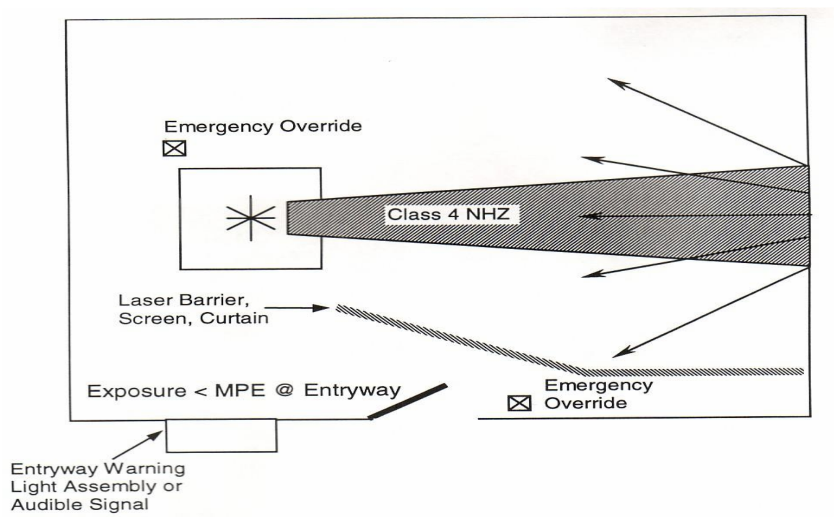
3.13 Medical Surveillance Procedure

1. Go to Staff/Faculty Health Services website shs.uwo.ca/sfhs and fill out the Position Hazard Communication Form online.
2. Staff/Faculty Health Services personnel will contact you for a medical examination after the Position Hazard Communication Form is submitted.

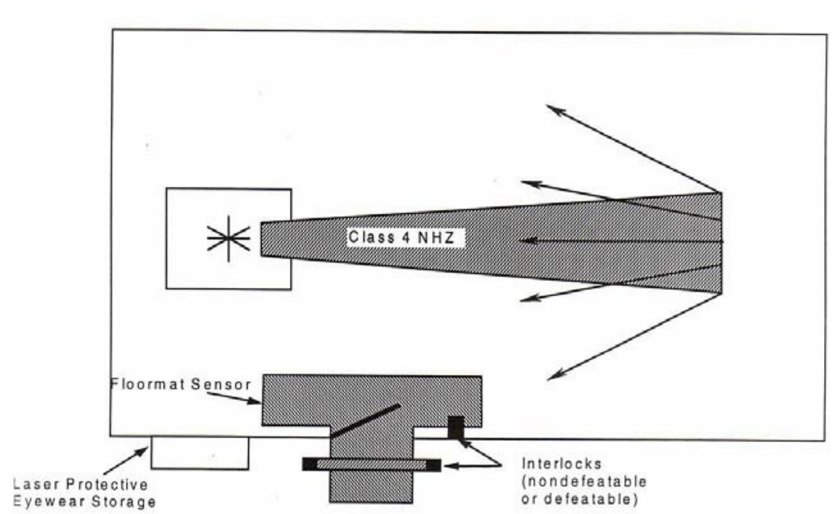
Section 4: Appendices

4.1 Entryway Controls and Laser Installations

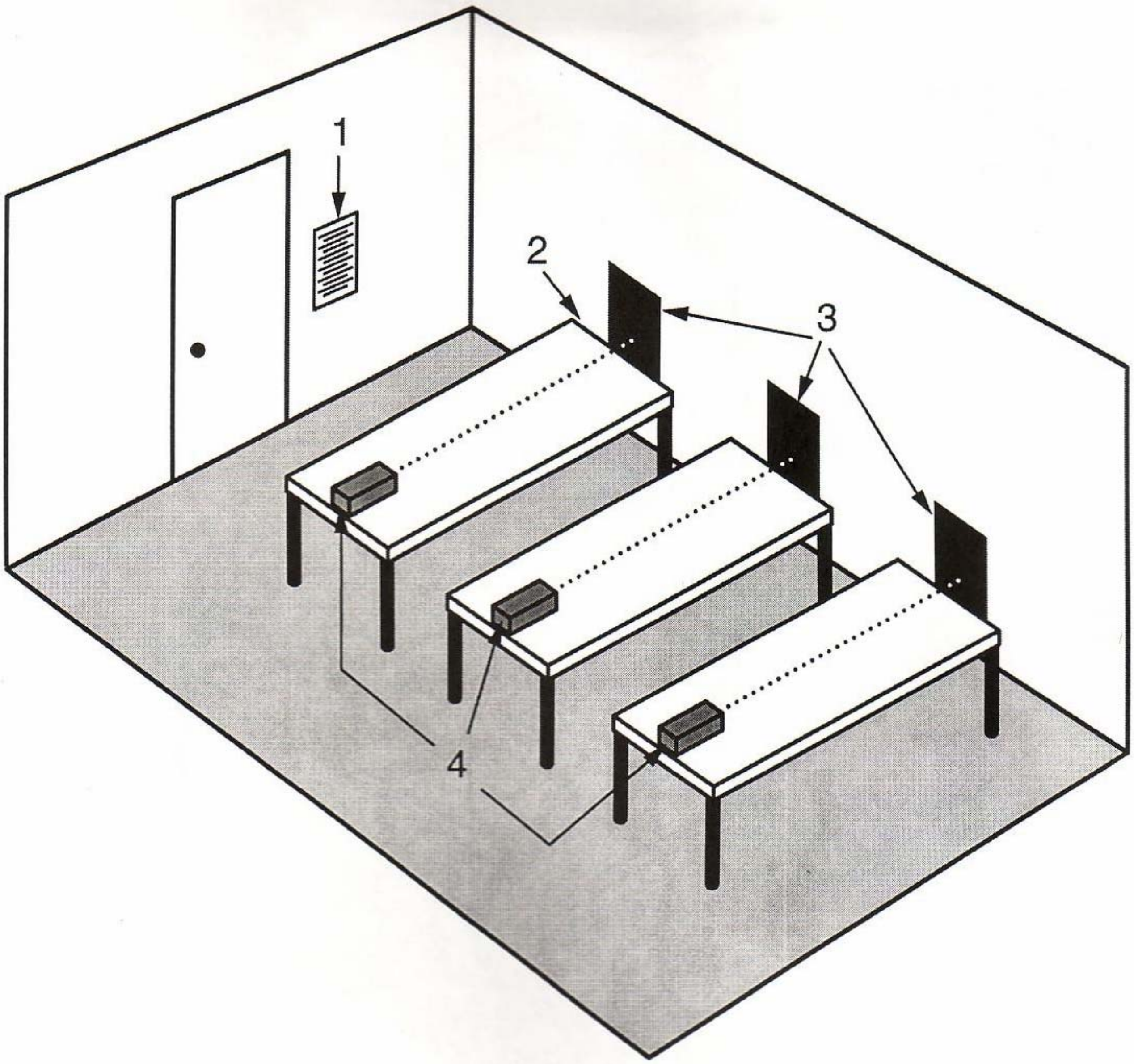
4.1.1 Area/Entryway Safety Controls for Class 4 Lasers without Entryway Interlocks



4.1.2. Area/Entryway Safety Controls for Class 4 Lasers utilizing Entryway Interlocks



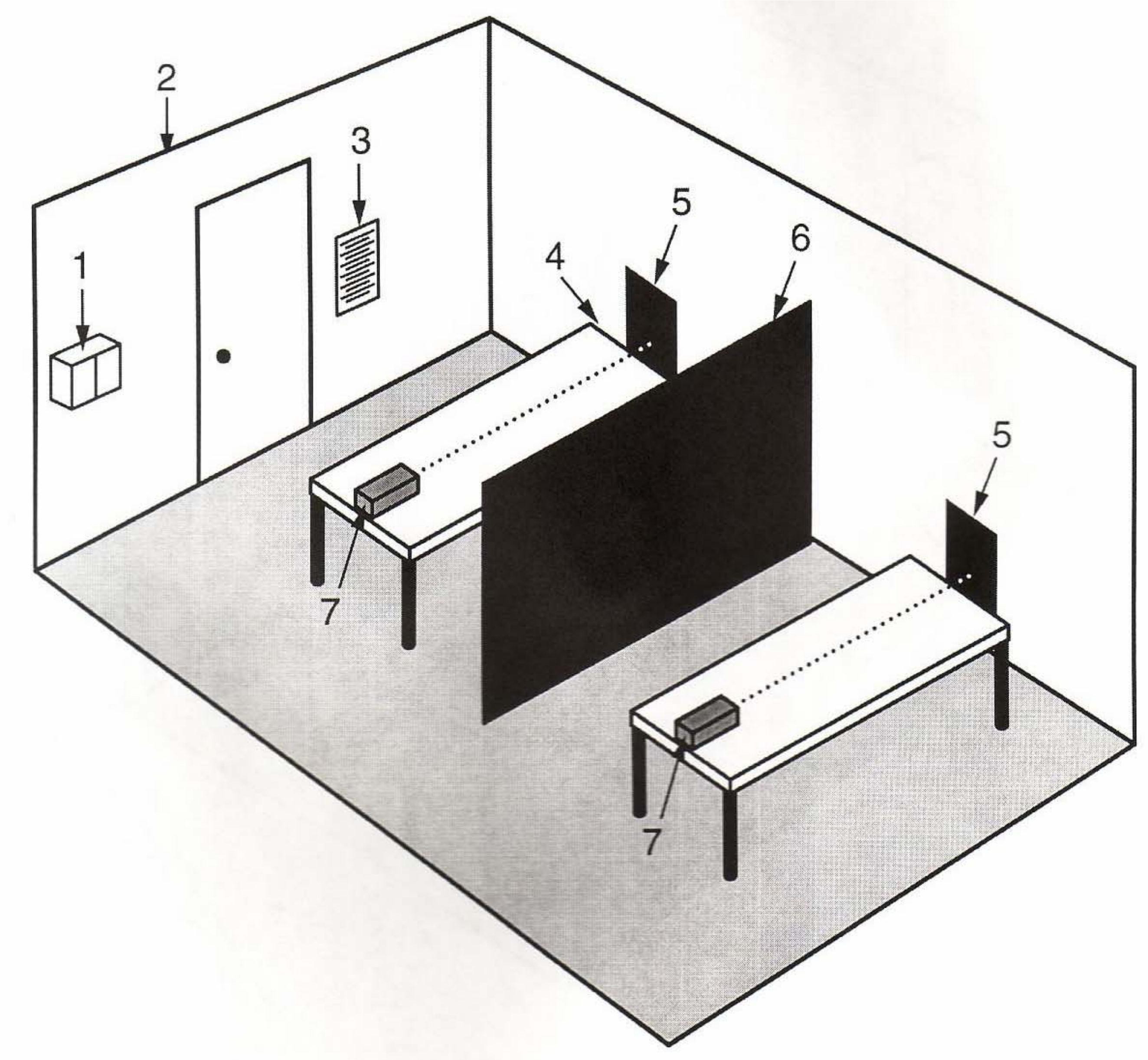
4.2 Laser Laboratory Layouts
4.2.1 Suggested Class 2 Laser Laboratory



Legend:

1. Operating instructions
2. Benches against the wall to prevent students from looking into the beam
3. Beam stops to prevent reflection of the laser beam
4. Multiple class 2 lasers in the room

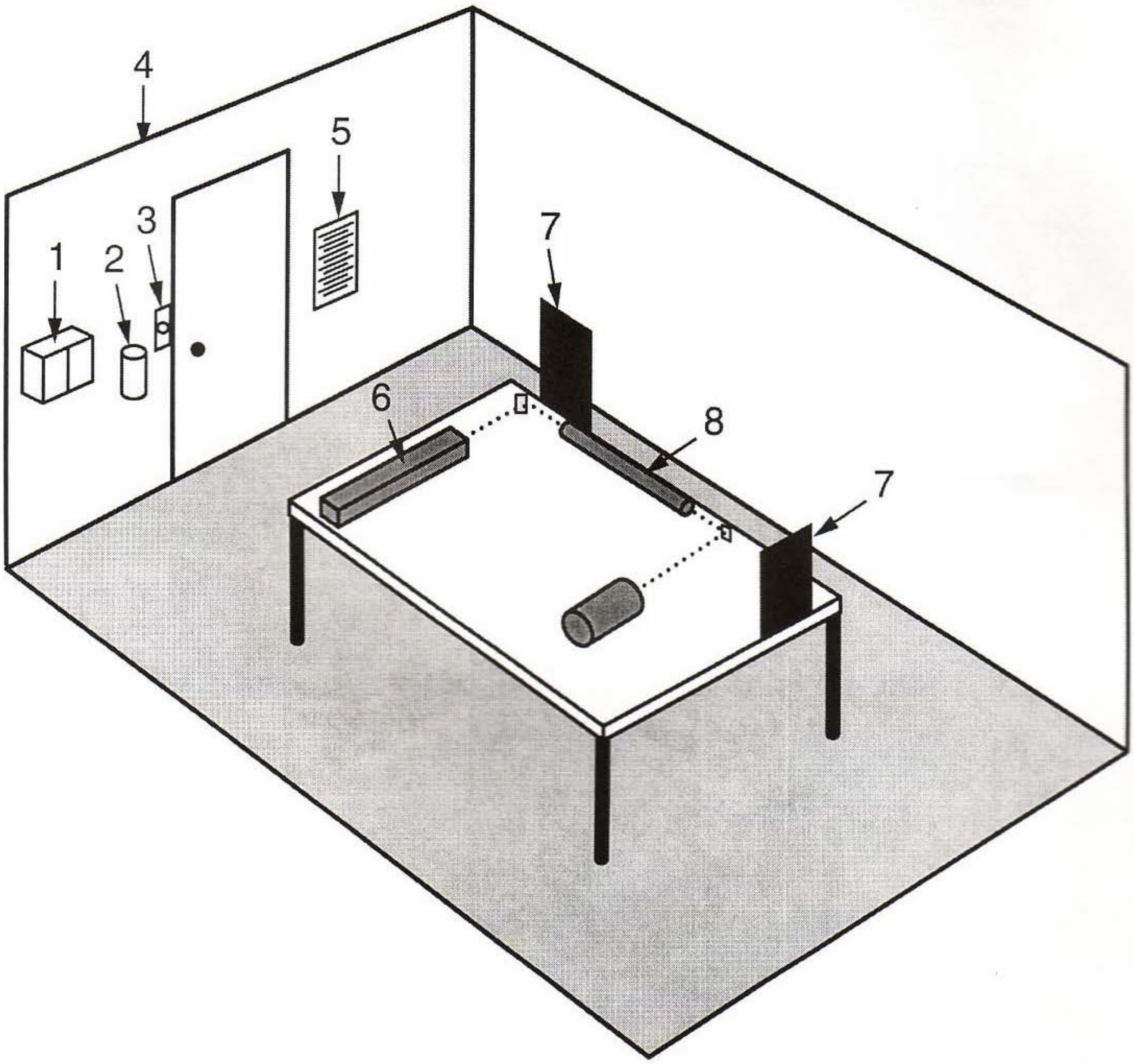
4.2.2 Suggested Class 3a Laser Laboratory



Legend:

1. Cabinet for safety glasses if necessary for alignment
2. Caution/Danger sign on the door
3. Operating instructions
4. Benches against the wall to prevent students from looking into the beam
5. Beam stops to prevent reflection of the laser beam
6. Wall separating laser stations
7. Multiple class 3a lasers in the laboratory

4.2.3 Suggested Class 3b and Class 4 Laser Laboratory



Legend:

1. Cabinet for safety goggles
2. Fire extinguisher
3. Door interlock override button
4. Danger sign on the door
5. Standard Operating Procedures
6. Only one Class 4 laser or laser system in the laboratory
7. Beam stops to prevent laser beam from leaving the optical table
8. Beam tube mounted on the table

4.2.4 Sample Standard Operating Procedures

Operating Instructions for Class 3b or Class 4 Argon Laser:

1. Obtain the interlock key from the Permit Holder or Person in Charge of laser laboratory.

2. Ensure that all unauthorized people leave the room.

3. Secure the laboratory door then activate the laboratory interlock system. Be ready to turn the laser off if any unauthorized person or a person without laser safety eyewear enters the laboratory.

4. Have emergency telephone numbers readily available.

5. Ensure all users remove wristwatches or other reflective jewelry from their bodies.

6. Set up the optical component necessary for the experiment.

7. Check that all beam stops are in place and that there are no unnecessary reflective surfaces in the optical path. One block should be placed behind the first optical component. A second beam stop should be placed behind the second optical component etc.

8. Turn on the cooling water to the laser (if appropriate)

9. Set the laser power control to the lowest power possible.

10. Ensure that appropriate laser safety eyewear is worn by everyone in the laboratory.

11. Insert the interlock key into the laser switch and unlock the laser.

12. Announce loudly, with a short countdown that you are turning the laser on.

13. Turn the laser on.

14. Align the optical components starting with the component nearest the laser. When it is aligned, move the first beam block behind the third optical component. Repeat this procedure until the entire optical system is aligned. It is important that the laser beam be limited to one new component at a time until the system is aligned. This will minimize uncontrolled reflection during the alignment procedure.

DO NOT REMOVE YOUR SAFETY EYEWEEAR DURING THE ALIGNMENT PHASE. IF YOU CANNOT SEE A FAINT IMAGE OF THE BEAM YOU HAVE THE WRONG OPTICAL DENSITY EYEWEAR.

TURN OFF THE LASER AND OBTAIN EYEWEAR WITH THE CORRECT OPTICAL DENSITY.

15. Increase beam power if necessary and complete the assigned task. Always use the lowest beam power necessary for the procedure.

16. Turn off the laser.

17. Remove your laser safety eyewear and place it in their proper storage area.

18. Allow the laser to cool down and then turn off the cooling water.

19. Remove the key from the laser interlock switch

20. Turn off the laboratory interlock system.

21. Return the key to the Permit Holder or Person in Charge.

4.3 FORMS

4.3.1 Permit Application Form

CLASS 3b & CLASS 4 LASERS/LASER SYSTEMS PERMIT APPLICATION

Applicant (Person in Charge): ______________________
Position: ______________________________________
Office Telephone: ______________________________
Office No: _____________________________________
E-mail: ____

Building: ______________________________
Department: ____________________________
Facility Telephone: ______________________
Emergency Telephone: ___________________
Contact Person: _________________________

Experience and Training of the <u>Applicant</u> and/or <u>Contact Person</u>[1] regarding the Lasers/Laser Systems:

(Use separate paper if necessary)

List of Laser Worker[2](s) lasers/laser systems (Class 3b or Class 4) under your supervision

1. ________________________________ e-mail: ____________________________ Ext: __________
2. ________________________________ e-mail: ____________________________ Ext: __________
3. ________________________________ e-mail: ____________________________ Ext: __________
4. ________________________________ e-mail: ____________________________ Ext: __________
5. ________________________________ e-mail: ____________________________ Ext: __________

This application is submitted for the following reason:

☐ New application ☐ Renew application ☐ Relocation of sources
☐ Replacement of old sources ☐ Additional sources ☐ Acquisition of existing facility from:

Lasers/Laser Systems Information:

Room #	Building	Manufacturer	Model #	Serial #	Laser type	Laser Class	Wavelength (nm)	Power (W)	Energy (J)

Note:

[1] Contact Person will be responsible for the lasers/laser systems when Person in Charge is not available.
[2] Laser Worker(s) shall wear appropriate laser safety goggles (where applicable) and receive specific hands-on training from Person in Charge or Contact Person before operating lasers/laser systems.

____
Signed: Applicant Date

____
Signed: Department Chair Date

____
Signed: Radiation Safety Coordinator Date

____
Signed: Radiation Safety Committee Chair Date

Please complete the necessary information and send to:
Hoa Ly, Radiation Safety Coordinator, Room 60, Stevenson-Lawson Building

4.3.2 INSPECTION CHECK LIST

UWO LASER LABORATORY INSPECTION CHECKLIST

Date: ______________________
LSO: ______________________

Permit Holder's Name: ____ Permit #: __________________

Permitted Labs/Department/Building: ____

Lab Phone: ____________ Acknowledge by: _____________________ Signature: ___________________

EQUIPMENT

Laser Type: ______________________________ Laser Class: ______________________________

Model #: ________________________________ Serial #: ________________________________

Other information: ____

Legend: Y-yes N-no N/A-not applicable

Laser Posting, Labeling and Room Control Measures		Deficiency Noted Upon Inspection
Entrances properly labeled and posted	☐ **Y** ☐ **N** ☐ **N/A**	
Room security	☐ **Y** ☐ **N** ☐ **N/A**	
Entryway interlock system	☐ **Y** ☐ **N** ☐ **N/A**	
Entryway interlock system functioning	☐ **Y** ☐ **N** ☐ **N/A**	
A door, blocking barrier, curtain, etc. at entry way	☐ **Y** ☐ **N** ☐ **N/A**	
Laser status indicator outside room	☐ **Y** ☐ **N** ☐ **N/A**	
Equipment Labels	☐ **Y** ☐ **N** ☐ **N/A**	

Engineering Safety Control Measures		Deficiency Noted Upon Inspection
Protective housing in place	☐ **Y** ☐ **N** ☐ **N/A**	
Interlock on housing	☐ **Y** ☐ **N** ☐ **N/A**	
Beam shutter present	☐ **Y** ☐ **N** ☐ **N/A**	
Key control	☐ **Y** ☐ **N** ☐ **N/A**	
Laser activation warning system (with emission delay) in place	☐ **Y** ☐ **N** ☐ **N/A**	
Remote interlock connector (emergency shutoff) available	☐ **Y** ☐ **N** ☐ **N/A**	
Laser secured to table	☐ **Y** ☐ **N** ☐ **N/A**	
Laser optics secured to prevent stray beams	☐ **Y** ☐ **N** ☐ **N/A**	
Enclosed beam path	☐ **Y** ☐ **N** ☐ **N/A**	
Limited open beam path	☐ **Y** ☐ **N** ☐ **N/A**	
Totally open beam path	☐ **Y** ☐ **N** ☐ **N/A**	
Beam barriers in place	☐ **Y** ☐ **N** ☐ **N/A**	
Beam stops in place	☐ **Y** ☐ **N** ☐ **N/A**	
Beam intensity reduced through filtration	☐ **Y** ☐ **N** ☐ **N/A**	
Reflective materials kept out of beam path	☐ **Y** ☐ **N** ☐ **N/A**	

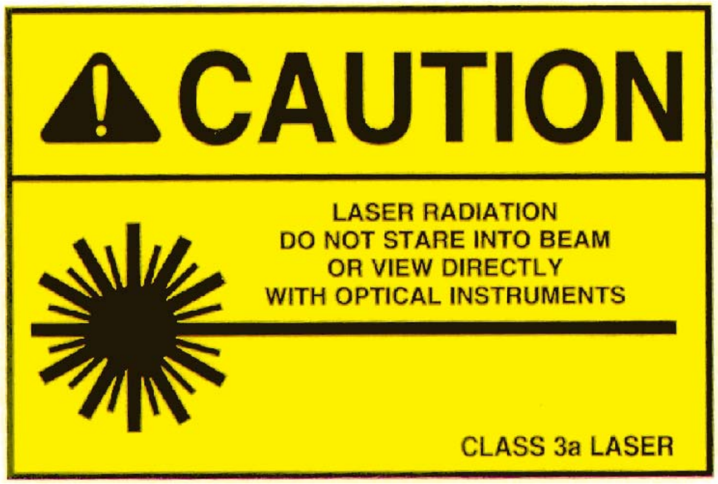
Remote monitoring/viewing devices	☐ **Y** ☐ **N** ☐ **N/A**	

Administrative and Procedural Safety Control Measures		Deficiency Noted Upon Inspection
Standard operating procedures are available	☐ **Y** ☐ **N** ☐ **N/A**	
Alignment procedures are available	☐ **Y** ☐ **N** ☐ **N/A**	
Laser operated, maintained and serviced by authorized personnel	☐ **Y** ☐ **N** ☐ **N/A**	
Spectator procedures are available	☐ **Y** ☐ **N** ☐ **N/A**	
Permit holders/workers' laser safety training requirement	☐ **Y** ☐ **N** ☐ **N/A**	
Has homebuilt/modified laser/laser system been classified	☐ **Y** ☐ **N** ☐ **N/A**	
Proper laser eye protection available	☐ **Y** ☐ **N** ☐ **N/A**	
Proper skin protection available	☐ **Y** ☐ **N** ☐ **N/A**	
Permit holders/workers' medical surveillance requirement	☐ **Y** ☐ **N** ☐ **N/A**	

Non Beam Hazards		Deficiency Noted Upon Inspection
Cryogenic fluids in use	☐ **Y** ☐ **N** ☐ **N/A**	
Compressed gas in use	☐ **Y** ☐ **N** ☐ **N/A**	
Gas cylinders properly restrained	☐ **Y** ☐ **N** ☐ **N/A**	
Laser generated air contaminant (LGAC) production	☐ **Y** ☐ **N** ☐ **N/A**	
Electrical hazards	☐ **Y** ☐ **N** ☐ **N/A**	
Collateral and plasma radiation hazard	☐ **Y** ☐ **N** ☐ **N/A**	
Noise/vibration hazards	☐ **Y** ☐ **N** ☐ **N/A**	
Proper disposal of chemical wastes	☐ **Y** ☐ **N** ☐ **N/A**	

COMMENTS:

4.3.3 Laser Warning Signs



4.3.4 Waiver Form

The University of Western Ontario

Staff / Faculty Health Services

Medical Surveillance Program for UWO Staff and Faculty

Working With Laser Devices

Waiver

I have been informed and understand the potential risks to my vision from direct exposure to laser light. I have been informed and understand that I may participate in a medical examination and surveillance program designed to monitor and protect my vision. I have elected **not** to participate in this program and I release the University of Western Ontario, Staff / Faculty Health Services and its staff for any and all liability for any injury I might sustain in working with a laser device.

Name (print) ________________________________ Date __________________

Signature ___________________________________

Supervisor Name ______________________________ Date ___________________

Supervisor Signature __________________________

Please FAX a copy of this completed form to Staff / Faculty Health Services at 661-2016

Prepared by Dr. Macfarlane
Director, Student and Staff/Faculty Health Services
September 12, 2003

4.4 Typical Laser Classification (ANSI Z136.1)

4.4.1 Continuous Wave (CW) Small-Source Lasers (ANSI Z136.1)

Wavelength (µm)	Laser Type	Wavelength (µm)	Class 1 * (W)	Class 2 (W)	Class 3 ** (W)	Class 4 (W)
Ultraviolet 0.180 to 0.280	Neodymium: YAG (Quadrupled)	0.266	≤ 9.6 x 10 -9 for 8 hours	None	> Class 1 but ≤ 0.5	> 0.5
	Argon	0.275				
Ultraviolet 0.315 to 0.400	Helium-Cadmium	0.325	≤ 3.2 x 10 -6	None	> Class 1 but ≤ 0.5	> 0.5
	Argon	0.351, 0.363,				
	Krypton	0.3507, 0.3564				
Visible 0.400 to 0.700	Helium-Cadmium	0.4416 only	$\leq 4 \times 10^{-5}$	> Class 1 but ≤ 1 x 10 -3	> Class 2 but ≤ 0.5	> 0.5
	Argon (Visible)	0.457	$\leq 5 \times 10^{-5}$			
		0.476	$\leq 1 \times 10^{-4}$			
		0.488	$\leq 2 \times 10^{-4}$			
		0.514	$\leq 4 \times 10^{-4}$			
	Krypton	0.530				
	Neodymium: YAG (Doubled)	0.532				
		0.543				
	Helium-Neon					
		0.400 – 0.500	$\leq 0.4\ C_B \times 10^{-4}$			
	Dye	0.460 – 0.500				
	Helium-Selenium					
		0.550 – 0.700	$\leq 4 \times 10^{-4}$			
	Dye	0.632				
	Helium-Neon	0.670				
	InGaA1P					
	Ti: Sapphire	0.6471, 0.6764				
	Krypton					
Near Infrared 0.700 to 1.400	GaA1As	0.780	$\leq 5.6 \times 10^{-4}$	None	> Class 1 but ≤ 0.5	> 0.5
	GaA1As	0.850	$\leq 7.7 \times 10^{-4}$			
	GaAs	0.905	$\leq 9.9 \times 10^{-4}$			
	Neodymium:	1.064	$\leq 1.9 \times 10^{-3}$			
	YAG	1.080	$\leq 1.9 \times 10^{-3}$			
	Helium – Neon	1.152	$\leq 2.1 \times 10^{-3}$			
		1.310	$\leq 1.5 \times 10^{-2}$			
	InGaAsP					
Far Infrared 1.400 to 10^3	InGaAsP	1.550	$\leq 9.6 \times 10^{-3}$			
	Holmium	2.100				
	Erbium	2.940				
	Hydrogen	2.600 – 3.00				
	Fluoride	3.390 only				
	Helium-Neon	5.000 – 5.500				
	Carbon Monoxide	10.6				
	Carbon Dioxide					
		118	$\leq 9.5 \times 10^{-2}$			
	Water Vapor	337				
	Hydrogen Cyanide					

* Assumes no mechanical or electrical design incorporated into laser system to prevent exposures from lasting to Tmax = 8 hours (one workday); otherwise the Class 1 AEL could be larger than tabulated

** See 3.3.3.1 for definition of Class 3a

4.4.2 Single-Pulse Small-Source Lasers (ANSI Z136.1)

Wavelength (μm)	Laser Type	Wavelength (μm)	Pulse Duration (s)	Class 1 (J)	Class 3b (J)	Class 4 (J)
Ultraviolet 0.180 to 0.400	Excimer (ArF) Excimer (KrF) Neodymium: YAG Q-switched (Quadrupled) Excimer (XeCl) Nitrogen Excimer (XeF)	0.193 0.248 0.266 0.308 0.337 0.351	20 x 10-9 20 x 10-9 20 x 10-9 20 x 10-9 20 x 10-9 20 x 10-9	≤ 2.4 x 10-5 ≤ 2.4 x 10-5 ≤ 2.4 x 10-5 ≤ 5.3 x 10-5 ≤ 5.3 x 10-5 ≤ 5.3 x 10-5	> Class 1 but ≤ 0.125	> 0.125
Visible 0.400 to 0.700	Rhodamine 6G (Dye Laser) Copper Vapor Neodymium: YAG (Doubled) (Q-switched) Ruby (Q-switched) Ruby (Long Pulse)	0.450-0.650 0.510, 0.578 0.532 0.6943 0.6943	1 x 10-6 2.5 x 10-9 20x 10-9 20 x 10-9 1 x 10-3	≤ 1.9 x 10-7 ≤ 3.9 x 10-6	> Class 1 but ≤ 0.03	> 0.03
Near Infrared 0.700 to 1.400	Ti: Sapphire Alexandrite Neodymium: YAG (Q-switched)	0.700-1.000 0.720-0.800 1.064	6 x 10-6 1 x 10-4 20 x 10-9	≤ 1.9 x 10-7 ≤ 7.6 x 10-7 ≤ 1.9 x 10-6	> Class 1 but ≤ 0.033 > Class 1 but ≤ 0.125	> 0.033 ** > 0.125
Far Infrared 1.400 to 10^3	Erbium: Glass Co: Magnesium-Fluoride Holmium Hydrogen Fluoride Erbium Carbon Dioxide Carbon Dioxide	1.540 1.8-2.5 2.100 2.600-3.000 2.940 10.6 10.6	10 x 10-9 80 x 10-6 250 x 10-6 0.4 x 10-6 250 x 10-6 100 x 10-9 1 x 10-3	≤ 7.9 x 10-3 ≤ 7.9 x 10-4 ≤ 7.9 x 10-4 ≤ 1.1 x 10-4 ≤ 5.6 x 10-4 ≤ 7.9 x 10-5 ≤ 7.9 x 10-4	> Class 1 but ≤ 0.125	> 0.125

4.4.3 Typical Class 3b and Class 4 Lasers at UWO

Manufacturer	Model #	Serial #	Laser Type	Laser Class	Wavelength (nm)	Power	Energy
Coherent	Imnova	7-651	Ar - Ion	4	488	12 W	-
Spectra Physics	GCR-Y	N21523	Nd-Yag	4	1064	10^9 W/pulse	1 J/pulse
Lumonics	HD-500	0016	DYE	4	tunable	10^6 W/pulse	20 mJ/pulse
Spectra Physics	PRO-250	2097FR	Nd-Yag	4	1064	10^6 W/pulse	50 mJ/pulse
Spectra Physics	MOPO-HF	1205 HF	OPO	4	tunable	10^9 W/pulse	1 mJ/pulse
Lumonics	TE861-4	4195	excimer	4	308	10^7 W/pulse	150 mJ/pulse
Coherent	ANTARES 76-5-ML-SHG20	HD #1124	Nd-Yag	4	1064	10^9 W/pulse	10 mJ/pulse
Lumonics	HD-500	531280	DYE	4	tunable	10^6 W/pulse	20 mJ/pulse
Siemens	LGK-7628	SIN 8135 AQ	He Ne	3b	632	10 mW	-
Siemens	LGK-7628	SIN 4557	He Ne	3b	632	40 mW	-
Siemens	LGK-7628	SIN 0475	He Ne	3b	632	15 mW	-
Melles-Griot	T543R-A-A03	1820-T	Ar - Ion	3b	488-514	300 mW	-
Coherent	370C-4	010540369	Ar - Ion	4	476-514	4 W	-
Melles-Griot	T543-TSIA01	2236T	Ar - Ion	4	488-514	300 mW	-
New Wave	Genumi 15	10358	Nd-Yag	4	532	-	120 mJ
Melles Griot	56DIF106P1	9J018	Diode	3b	780	17 mW	-
Melles Griot	56DIF106P1	9J016	Diode	3b	780	17 mW	-
Melles Griot	56DIF106P1	9J031	Diode	3b	780	17 mW	-
Melles Griot	56DFB108P	NA1	Diode	3b	830	0.02	-
Melles Griot	56DFB108P	NA2	Diode	3b	830	0.02	-
Coherent	Innova 20	902	Argon	4	337-529	30	-
Coherent	699-21	NA	Dye	4	350-1400	500 mW	-
Coherent	899-29	90481077	Dye	4	250-1400	3 W	-
Renishaw	HeNe	G93077	He Ne	3b	633	50 mW	-
Coherent	Innova 70	7-596	Argon-Ion	4	514	12 W	-

For more information, contact Hoa Ly, Radiation Safety Coordinator at 661-2111 ext. 84746.