DEPARTMENT OF HEALTH

DIRECTORATE: RADIATION CONTROL

REQUIREMENTS FOR THE SAFE USE OF

CLASS 3B AND CLASS 4 LASERS OR LASER SYSTEMS

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CONTENTS

1. SCOPE

This document is applicable to users of laser systems classified in risk grouping Class 3b and Class 4.

2. OBJECTIVE

The objective of these requirements is to provide reasonable and adequate guidance for the safe use of laser systems. A practical means for accomplishing this is to use the classification of laser systems (according to their relative hazards) to specify appropriate controls.

The basis of the hazard classification scheme is the ability of the primary laser beam or reflected primary laser beam to cause biological damage to the eye or skin during normal operation. For example, a Class 1 (termed “No-Risk”) laser system is considered to be incapable of producing damaging radiation levels during operation and maintenance and is therefore exempt from any control measures or other forms of surveillance. Class 2 laser systems (termed “Low-power” or “Low-Risk” lasers) emit in the visible portion of the spectrum and eye protection is normally afforded by the aversion response including the blink response. These laser systems would only be hazardous if one purposely overcomes their natural aversion response.

A Class 3 laser system (“low-power” or “medium power” laser) poses a hazard to the eye, since the aversion response is insufficiently fast to limit retinal exposure to a momentarily safe level. Damage to other structures of the eye (e.g., cornea and lens) could also take place. A Class 3 laser system may be hazardous under direct and specular reflection viewing conditions, but the diffuse reflection is usually not a hazard. The laser beam should not be intentionally aimed at people and the use of optical viewing aids (e.g., binoculars) with Class 3 laser systems may be hazardous. Skin hazards normally do not exist for incidental exposure. Class 3 laser systems are divided into two subclasses, Class 3R and 3b. Class 3R is lasers or laser systems, which is normally not hazardous unless viewed intentionally for a long time. For a Class 3b laser system, exposure (including brief accidental exposure) of the eye to the direct beam may cause serious injuries.

A Class 4 laser system (“High-Power” laser) is a hazard to the eye or skin from direct beam and sometimes from a diffuse reflection and they also present a potential fire hazard. Class 4 laser systems may also produce laser generated air contaminants and hazardous plasma radiation.

It must be recognised that the classification scheme used relates specifically to the laser product and its potential hazard, based on operating characteristics.

3. DEFINITIONS

For the purposes of this document, the following definitions apply:

***Aversion response*.** Closure of the eyelid, or movement of the head to avoid an exposure to a noxious stimulant or bright light. In these requirements, the aversion response to an exposure from a bright laser source is assumed to occur within 0.25 s, including the blink reflex time.

***Carcinogen*.** An agent potentially capable of causing cancer

***Controlled area*.** An area where the occupancy and activity of those within it are subject to control and supervision for the purpose of protection from radiation hazards.

***Cryogenics*.** The branch of physical science dealing with very low temperatures.

***Diffuse reflection*.** Change of the spatial distribution of a beam of radiance when it is reflected in many directions by a surface or by a medium.

***Enclosed laser*.** A laser that is contained within a protective housing of itself or of the laser system in which it is incorporated. Opening or removal of the protective housing provides access to laser radiation additional to that, which is possible with the protective housing in place.

***Irradiance*.** Quotient of the radiant flux incident on an element of the surface containing the point at which irradiance is measured, and the area of that element. Unit: watt per square centimeter (W/cm^2).

***Laser*.** A device that produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions. An acronym for Light Amplification by Stimulated Emission of Radiation.

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

***Laser system*.** An assembly of electrical, mechanical, and optical components that includes a laser.

Operation. The performance of the laser system over the full range of its intended functions (normal operation). It does not include maintenance or service.

***Protective housing*.** An enclosure that surrounds the laser system that prevents human access to laser radiation in excess of the prescribed accessible limits. It also limits access to other associated radiant energy emissions and to electrical hazards associated with components and terminals.

***Radiant energy*.** Energy emitted, transferred or received in the form of radiation. Unit: joule (J).

***Radiant exposure*.** Surface density of the radiant energy received. Unit: joules per centimeter squared (J/ cm^2).

***Reflection*.** Deviation of the direction of radiation following incidence on a surface.

***Shall*.** The word “shall” is to be understood as mandatory.

***Should*.** The word “should” is to be understood as a recommendation.

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

***Specular reflection*.** A mirrorlike reflection.

***Ultraviolet radiation*.** Electromagnetic radiation with wavelengths smaller than those of visible radiation; for the purpose of these requirements, 180 to 400 nm.

***Visible radiation (light*).** Electromagnetic radiation that can be detected by the human eye. The term is commonly used to describe wavelengths that lie in the range 400 to 700 nm.

***Wavelength*.** The distance between two successive points on a periodic wave which have the same phase.

4. LASER SAFETY OFFICER (LSO)

4.1 General

An individual shall be designated the Laser Safety Officer (LSO) with the authority and responsibility to monitor and enforce the control of laser hazards for the operation, maintenance and service of a Class 3b or Class 4 laser system. The LSO may be designated from among such personnel as the radiation protection officer, industrial hygienist, safety engineer, laser specialist, laser operator, etc.

4.2 Classification

The LSO shall verify classification of lasers and laser systems used under his or her jurisdiction.

4.3 Hazard Evaluation

The LSO shall be responsible for hazard evaluation of laser work areas.

4.4 Control Measures

The LSO shall be responsible for assuring that the prescribed control measures are in effect, recommending or approving substitute or alternate control measures when the primary ones are not feasible or practical, and periodically auditing the functionality of those control measures in use (see Section 5).

4.5 Procedure Approvals

The LSO shall approve standard operating procedures, alignment procedures, and other procedures that may be part of the requirements for administrative and procedural control measures.

4.6 Protective Equipment

The LSO shall recommend or approve protective equipment i.e., eyewear, clothing, barriers, screens, etc., as may be required to assure personnel safety. The LSO shall assure that protective equipment is audited periodically to ensure proper working order.

4.7 Signs and Labels

The LSO shall approve the wording on area signs and labels.

4.8 Facility and Equipment

The LSO shall approve laser installation facilities and laser equipment prior to use. This also applies to modification of existing facilities or equipment.

4.9 Safety Features Audits

The LSO shall ensure that the safety features of the laser installation facilities and laser equipment are audited periodically to assure proper operation.

4.10 Training

The LSO shall assure that adequate safety education and training is provided to laser area personnel.

4.11 Medical Surveillance

The LSO shall determine the medical surveillance requirements for personnel working in a laser environment (see Section 7).

4.12 Additional

The LSO will have the authority to suspend, restrict, or terminate the operation of a laser system if he or she deems that laser hazard controls are inadequate.

5. CONTROL MEASURES

5.1 General Considerations

Control measures are devised to reduce the possibility of exposure of the eye and skin to hazardous levels of laser radiation and to other hazards associated with the operation of laser devices during operation and maintenance.

The LSO has the authority to monitor and enforce the control of laser hazards. For all uses of lasers and laser systems, it is recommended that the minimum laser radiation required for the application be used. It is also recommended that the beam height be maintained at a level other than the normal position of the eyes of a person in the standing or seated position.

Engineering controls items incorporated into the laser system or designed into the installation by the user shall be given primary consideration in instituting a control measure program for limiting access to laser radiation. If engineering controls are impractical or inadequate, administrative and procedural controls and personnel protective equipment shall be used. The limits of any type of control measure for example, failure modes of enclosures and eye protection, or the inability of some personnel to understand written warnings, shall be considered in developing a laser hazard control program.

5.2 Protective Housings

A protective housing that surrounds the laser system shall be provided to limit access to associated radiant energy emissions and to electrical hazards associated with components and terminals. In some circumstances, such as research and development, operation of laser systems without a protective housing may become necessary. In such cases the LSO shall perform a hazard analysis and ensure that control measures are instituted to assure safe operation. These controls may include, but not be limited to:

(1) access restriction
(2) eye protection
(3) area control
(4) barriers, shrouds, beam stops etc.
(5) administrative and procedural controls
(6) education and training

Lasers or laser systems which contain protective housing enclosures which are of sufficient size to allow personnel within the enclosure (walk-in protective housing) shall be provided with an area warning system (floor mats, IR sensors, etc.) which is activated upon entry by personnel into the protective housing. Only authorised (service) personnel shall be provided with means to override the sensors for alignment or testing procedures if beam access is required for beam diagnostic purposes. If overridden, the interlock circuit shall activate an appropriate warning (light, electronic tone, etc.) indicating the condition of sensor override.

5.3 Key Control

A Class 3b laser system should be provided with a master switch. A Class 4 laser system shall be provided with a master switch. This master switch shall be operated by a key, or by a coded access (such as a computer code).

The authority for access to the master switch shall be vested in the appropriate supervisory personnel. The master switch shall be disabled when the laser system is not intended to be used.

A single master switch on a main control unit shall be acceptable for multiple laser installations where the operational controls have been integrated.

5.4 Beam stop or attenuator

The inadvertent exposure of bystanders shall be prevented by the use of a permanently attached beam attenuator, filter or beam stop. Important in the selection of window and display screen material, are the flammability and the decomposition products of the material. It is essential that the material used for viewing portals and display screens does not support combustion or release toxic airborne contaminants following exposure to laser radiation.

5.5 Beam Paths

The LSO shall assure that consideration is given to direct, reflected and scattered radiation in the establishment of boundaries for the laser controlled area as furnished by the manufacturer. If the operators or maintenance personnel are required to be within this controlled area, appropriate control measures shall be established. In some cases, the total hazard assessment may be dependent upon the nature of the environment, the geometry of the application or the spatial limitations of other hazards associated with the laser use. This may include, for example, localised fume or radiant exposure hazards produced during laser material processing or surgery, robotic working envelopes, location of walls, barriers, or other equipment in the laser environment.

5.6 Remote Interlock

A Class 3b laser system remote interlock should be connected to an emergency master disconnect interlock. A Class 4 laser system remote interlock shall be connected to an emergency master interlock.

The interlock connector facilitates electrical connections to the emergency master interlock or to a room, entrance, floor, or area interlock. The person in charge may be permitted momentary override of the remote interlock connector to allow access to other authorised persons if it is clearly evident that there is no optical radiation hazard at the time and point of entry.

When medical procedures requiring operation without interruption is required, interlocks may be inappropriate. In these instances the control measures specified in section 5.9 shall be used.

5.7 Laser Activation Warning System

An alarm (for example, an audible sound such as a bell or chime), a warning light (visible through protective eyewear), or a verbal “countdown” command for single pulse or intermittent operations should be used with Class 3b, and shall be used with Class 4 lasers or laser systems during activation or startup.

For single pulsed lasers or laser systems, an audible system may commence operation when the laser power supply is charged for operation, for example, during the charging of capacitor banks. In this case the warning should sound intermittently during the charging procedure and continuously when fully charged.

When warning lights are employed, one form of warning light could indicate conditions of enabled laser (high voltage on), laser on (beam on) and area clear (no high voltage or beam on).

For Class 4 lasers or laser systems, the warning system shall be activated a sufficient time prior to emission of laser radiation to allow appropriate action to be taken to avoid exposure to the laser radiation.

5.8 Class 3b Laser Controlled Area

The Class 3b laser controlled area shall:

- Be posted with the appropriate warning signs (see 5.15). An appropriate warning sign shall be posted at the entrance(s) and, if deemed necessary by the LSO, should be posted within the laser controlled area
- Be operated only by authorised personnel
- Be operated or attended by personnel who have been appropriately trained
- Be operated in a manner such that the path is limited when the laser beam must extend beyond an indoor controlled area, particularly to the outdoors under adverse atmospheric conditions, i.e. fog, snow, etc. (see 5.10).

In addition to the above, a Class 3b controlled area should:

- Be under the direct supervision of an individual knowledgeable in laser safety
- Be so located that access to the area by spectators is limited and requires approval
- Have any potentially hazardous beam terminated in a beam stop of an appropriate material
- Have only diffusely reflecting material in or near the beam path, where feasible
- Provide personnel within the laser controlled area with the appropriate eye protection
- Have the laser secured such that the exposed beam path is above or below eye level of a person in any standing or seated position, except as required for medical use
- Have all windows, doorways, open portals, etc. from an indoor facility be either covered or restricted in such a manner as to prevent the transmission of laser radiation
- Require storage or disabling (e.g., removal of the key) of the laser system when not in use to prevent unauthorised use

5.9 Class 4 Laser Controlled Area

All personnel who regularly require entry into a Class 4 laser-controlled area shall be appropriately trained, provided with appropriate protective equipment, and follow all applicable administrative procedural controls.

All Class 4 area or entrance safety controls shall be designed to allow both rapid egress by laser personnel at all times and admittance to the laser controlled area under emergency conditions.

For emergency conditions there shall be a clearly marked “Panic Button” (remote controlled connector or equivalent device) available for deactivating the laser

The Class 4 laser controlled area shall be designed to fulfill all items of 5.8, and in addition shall incorporate one of the following alternatives:

- Non-Defeatable (non-override) Area or Entrance Safety Controls

Non-defeatable safety latches, entrance or area interlocks (e.g., electrical switches, pressure sensitive floor mats, infrared or sonic detectors) shall be used to deactivate the laser in the event of unexpected entry into the laser controlled area.

- Defeatable Area or Entrance Safety Controls

Defeatable safety latches, entrance or area interlocks shall be used if non-defeatable area/entrance safety controls limit the intended use of the laser system. For example, during normal usage requiring operation without interruption e.g., long term testing, medical procedures, surgery), if it is clearly evident that there is no laser radiation hazard at the point of entry, override of the safety controls shall be permitted to allow access to authorised personnel provided that they have been adequately trained and provided with adequate personal protective equipment.

- Procedural Area or Entrance Safety Controls

Where safety latches or interlocks are not feasible or inappropriate, for example during medical procedures, surgery, etc., the following shall apply:

All authorised personnel shall be adequately trained and adequate personal protective equipment shall be provided upon entry.

A door, blocking barrier, screen, curtains, etc. shall be used to block, screen or attenuate the laser radiation at the entrance.

At the entrance there shall be a visible or audible signal indicating that the laser is energised and operating at Class 4 level. A lighted laser warning sign or flashing light (visible through laser protective eyewear) are two of the appropriate methods to accomplish this requirement. Alternatively, an entrance warning light assembly may be interfaced to the laser in such a manner that one light will indicate when the laser is powered up (high voltage applied – but no laser emission) *and* by an additional (flashing optional) light that activates when the laser is operating.

5.10 Outdoor Control Measures for Class 3b or Class 4 laser systems

A Class 3b or Class 4 laser system used outdoors shall meet the following requirements:

- Laser warning signs shall be posted at the demarcated laser-controlled area (see 5.12)
- All personnel authorised to enter the area shall be appropriately trained (see 6.2)
- Only authorised personnel shall operate a laser system
- Appropriate combinations of physical barriers, screening, personnel protective equipment shall be provided and used by authorised personnel
- Appropriate administrative controls shall be used
- Directing the laser beam at motor-vehicles, aircraft or other manned structures shall be prohibited
- The exposed laser beam path shall not be maintained at or near personnel eye level without specific authorisation of the LSO
- The beam path shall be confined and terminated wherever possible
- When the laser is not being used, it shall be disabled in a manner that prevents unauthorised use
- The operation of Class 4 lasers or laser systems during rain or snowfall or in a foggy or dusty atmosphere may produce hazardous reflections near the beam. In such conditions, the LSO shall evaluate the need for, and specify the use of, appropriate personal protective equipment.

5.11 Equipment Labels

The LSO shall apply advisory protective housing labeling to long distance (› 3 m) beam conduits. Such labeling shall be placed on the outside of the conduit at appropriate intervals (approximately 3 meters), to provide warning of the relative hazards of laser radiation contained within the conduit. The laser sunburst logotype symbol is not required on such advisory labels. See 5.15.3 for suggested wording. Additional wording for non-laser hazards may be required.

5.12 Area Posting Signs

An area that contains a Class 3b or Class 4 laser system shall be posted with the appropriate sign as described in 5.15.

5.13 Administrative and Procedural Controls

Administrative and procedural controls are methods or instructions that specify rules, or work practices, or both, which implement or supplement engineering controls and which may specify the use of personal protective equipment.

5.13.1 Standard Operating Procedures

The LSO should require approved written standard operating, maintenance and service procedures (SOP) for Class 3b lasers or laser systems. The LSO shall require and approve written SOP for Class 4 lasers or laser systems. These written SOP's shall be maintained with the laser equipment for reference by the operator and maintenance or service personnel (see 5.13.5).

5.13.2 Output Emission Limitations

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

5.13.3 Education and Training

Education and training shall be provided for operators, maintenance or service personnel of lasers or laser systems. The level of training shall be equal to the level of the potential hazard (see Section 6).

5.13.4 Authorised Personnel

The lasers or laser systems shall be operated, maintained or serviced only by authorised personnel.

5.13.5 Alignment Procedures

Laser incident reports have repeatedly shown that an ocular hazard may exist during beam alignment procedures.

Written Standard Operating Procedures (SOP) outlining alignment methods should be approved for Class 3b and shall be approved for Class 4 lasers or laser systems. The use of low power (Class 1 or Class 2) visible lasers for path simulation of higher power lasers is recommended for alignment of higher power Class 3b or Class 4 visible or invisible lasers and laser systems.

5.13.6 Protective Equipment

Protective equipment (eye protection in the form of goggles or spectacles, barriers, windows, clothing and gloves, and other devices) that has been specifically selected for suitable protection against laser radiation may be required when other control measures are inadequate to eliminate potential exposure (see 5.14).

5.13.7 Spectators

Spectators should not be permitted within a laser-controlled area (see 3.8, 3.9 and 3.10) that contains a Class 3b laser system and spectators shall not be permitted within a laser-controlled area that contains a Class 4 laser system 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

5.13.8 Service Personnel

Personnel who require access to Class 3b or 4 lasers or laser systems enclosed within a protective housing or protective area enclosure shall comply with the appropriate control measures of the enclosed laser system. The LSO shall require that service personnel shall have the education and safety training equal with the class of the laser system contained within the protective housing.

5.14 Protective Equipment

5.14.1 General

Enclosure of the laser equipment or beam path is the preferred method of control, since the enclosure will eliminate or minimize the hazard.

When other control measures do not provide adequate means to prevent access to direct or reflected beams it may be necessary to use personal protective equipment. It should be noted that personal protective equipment may have serious limitations when used as the only control measure with higher-power Class 4 lasers or laser systems; the protective equipment may not adequately reduce or eliminate the hazard, and may be damaged by the incident laser radiation.

5.14.2 Eye protection

Eye protection devices, which are specifically designed for protection against radiation from Class 3b lasers or laser systems should be administratively required and their use enforced when engineering or other procedural and administrative controls are inadequate to eliminate potential exposure.

Eye protection devices, which are specifically designed for protection against radiation from Class 4 lasers or laser systems shall be administratively required and their use enforced when engineering or other procedural and administrative controls are inadequate to eliminate potential exposure

Laser protective eyewear may include goggles, face shields, spectacles or prescription eyewear using special filter material or reflective coatings (or a combination of both) to reduce the potential ocular exposure.

Laser protective eyewear shall be specifically selected to withstand either direct or diffusely scattered beams. In this case, the protective filter shall exhibit a damage threshold for a specified exposure time (typical 10 seconds). The eyewear shall be used in a manner so that the damage threshold is not exceeded in the “worst case” exposure scenario.

5.14.3 Laser Protective Windows

Facility windows (exterior or interior) shall be provided with appropriate absorbing filter, scattering filter, blocking barrier or screen, which reduces any transmitted laser radiation to save levels. Such laser windows shall be specifically selected to withstand direct and diffusely scattered beams. In this case, the window barrier shall exhibit a damage threshold for beam penetration for a specified exposure time equal to the total hazard evaluation for the facility and specific application. Important in the selection of the window are the factors of flammability and decomposition products of the window material. It is essential that the window not support combustion or release toxic airborne contaminants following a laser exposure.

5.14.4 Laser Protective Barriers and Curtains

A blocking barrier, or screen, or curtain which can block or filter the laser beam at the entrance should be used inside the controlled area to prevent the laser light from exiting the area at hazardous levels.

Such laser barriers shall be specifically selected to withstand direct and diffusely scattered beams. In this case, the barrier shall exhibit a damage threshold for beam penetration for a specified exposure time equal to the total hazard evaluation for the facility and specific application.

Important in the selection of the barrier are the factors of flammability and decomposition products of the barrier material. It is essential that the barrier not support combustion or release toxic fumes following a laser exposure.

5.14.5 Skin Protection

In some laser applications, such as use of excimer lasers operating in the ultraviolet region, the use of a skin cover shall be employed if chronic (repeated) exposures are anticipated at levels at or near the applicable limits for skin exposure.

Skin protection can best be achieved through engineering controls. If the potential exists for damaging skin exposure, particularly for ultraviolet lasers (180 – 400 nm), then skin covers and or “sun screen” creams are recommended. Most gloves will provide some protection against laser radiation. Tightly woven fabrics and opaque gloves provide protection. A laboratory jacket or coat can provide protection for the arms. For Class 4 lasers, consideration shall be given to flame-retardant materials.

5.14.6 Other Personnel 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 (see Section 8).

5.15 Warning Signs and Labels

5.15.1 Design of Signs

Sign dimensions and color, etc., shall be in accordance with Figure 1. The minimum length for the legs of the equilateral triangle shall be 150 mm.

5.15.2 Symbols

The laser hazard symbol shall be a sunburst pattern consisting of two sets of radial spokes of different lengths and one long spoke, radiating from a common center.

5.15.3 Warning Labels

The minimum size of the label shall be 150 mm x 100 mm. The minimum height of the lettering shall be 5 mm.

The word “DANGER” shall be used with Class 3b and Class 4 lasers and laser systems and shall be located at the top of the panel (see Figure 1).

Adequate space shall be left on all labels to allow the inclusion of pertinent information. Such information may be included during the printing of the sign or label or may be handwritten in a legible manner, and shall include the following:

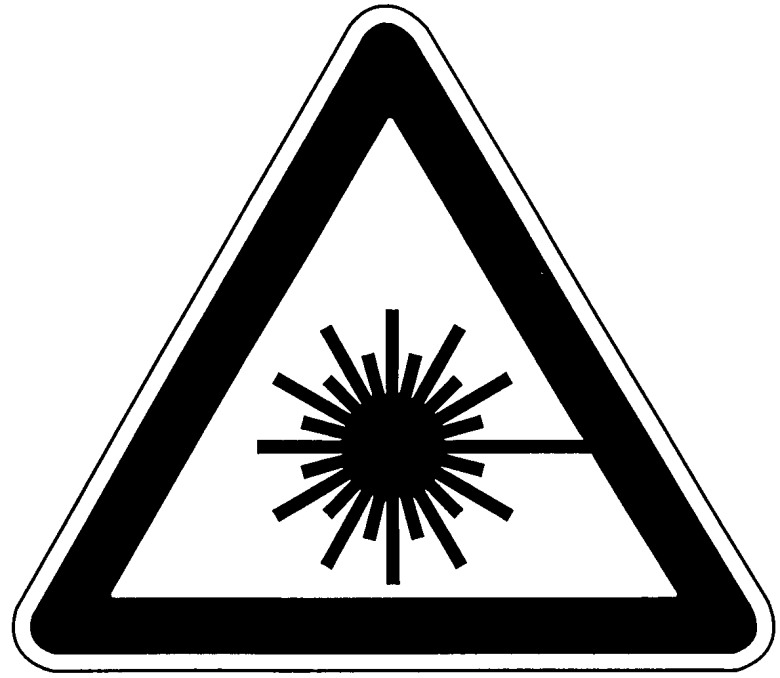
For all Class 3b lasers and laser systems, “Laser radiation – Avoid Direct Eye Exposure to Beam”

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

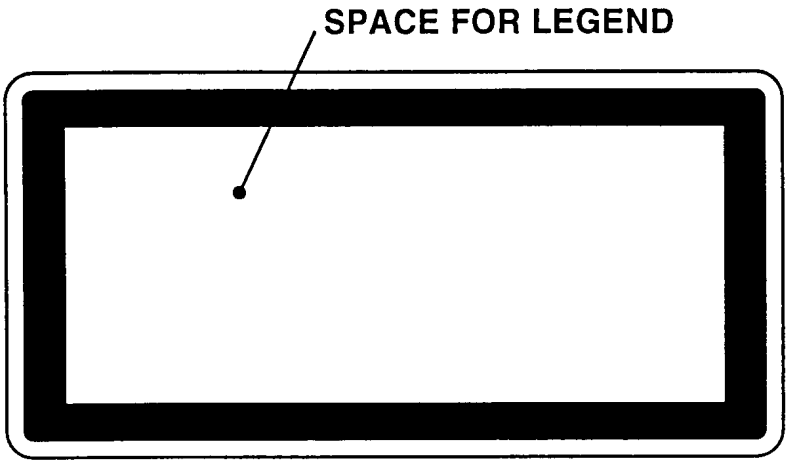
The word “Radiation” on labels may be replaced by the word “Light” for lasers operating in the visible range of wavelengths greater than 400 nm and equal to or less than 700 nm. For lasers operating outside of this visible range the word “invisible” shall be placed prior to the word “radiation”.

Special precautionary instructions or protective action shall be included that may be applicable such as, Invisible Laser Radiation; Knock Before Entering; Do Not Enter When Light is On; Restricted Area; etc.

All signs and labels shall be conspicuously displayed in locations where they will best serve to warn of the laser hazard.



SYMBOL AND BORDER : BLACK
BACKGROUND : YELLOW



LEGEND AND BORDER : BLACK
BACKGROUND : YELLOW

Figure 1: Laser Warning Sign and Label

5.16 Modification of Laser Systems

Where deliberate modifications are made which could change a laser system's class and affect its output power or operating characteristics so as to make it potentially more hazardous, the LSO shall ascertain whether any additional or modified control measures are required.

6 LASER SAFETY AND TRAINING PROGRAMS

6.1 Organisation

The management (employer) shall establish and maintain an adequate program for the control of laser hazards. Safety and training programs shall be required for lasers and laser systems. The program shall include provisions for the following:

(1) Delegation of authority and responsibility to the LSO for the monitoring and enforcement of hazard evaluation and control of laser hazards.
(2) Education of authorised personnel (LSO, operators, service personnel and others) in the assessment and control of laser hazards. This may be accomplished through training programs.
(3) Application of adequate protective measures for the control of laser hazards as required in Section 5.
(4) Incident investigation, including reporting of alleged incidents and preparation of action plans for the future prevention of incidents following a known or suspected incident.
(5) Provide an appropriate medical surveillance program in accordance with Section 7.

6.2 Education

The management shall provide training to the LSO on the potential hazards, control measures, medical surveillance and other pertinent information pertaining to laser safety or provide to the LSO adequate consultative services. Safety training program(s) shall be provided to the users, which shall include operators, technicians, engineers, maintenance and service personnel, etc., working with or around lasers. The training shall ensure that the users are knowledgeable about the potential hazards and the control measures for the laser equipment they may have occasion to use.

7 MEDICAL EXAMINATIONS

The basic reasons for performing medical surveillance of personnel working in a laser environment are the same as for other potential health hazards. Although chronic injury from laser radiation in the ultraviolet, blue portion of the visible, and near infrared regions is theoretically possible, risks to workers using laser devices are primarily from accidental acute injuries.

Except for examinations following suspected injury, preassignment medical examinations are the only examination required. The purpose is to establish a baseline against which damage (primarily ocular) can be measured in the event of an accidental injury. Examinations should be performed by, or under the supervision of, an ophthalmologist or optometrist or other qualified physician. Although chronic skin damage from laser radiation has not been reported, and indeed seems unlikely, this area has not been adequately studied.

The primary purpose of termination examinations is for the legal protection of the employer against unwarranted claims for damage that might occur after an employee leaves a particular job. The decision about whether to offer or require such examinations is left to individual employers.

8 NON-BEAM HAZARDS

8.1 General

In addition to direct hazards to the eyes and skin associated with exposure to the laser beam, it is also important to address other hazards associated with the use of lasers. The non-beam hazards, in some cases, can be life threatening, e.g., electrocution. As a result, the special considerations discussed in this section require use of control measures different from those discussed in Section 5. Because of the diversity of these potential hazards, the LSO may employ safety personnel to perform the hazard evaluations for special considerations.

8.2 Electrical Hazards

The use of lasers or laser systems can present an electric shock hazard. This may occur from contact with exposed utility power utilisation, device control, and power supply conductors.

8.3 Laser Generated Air Contaminants (LGAC)

Air contaminants may be generated when certain laser beams interact with matter. The quantity, composition, and chemical complexity of the LGAC depend greatly upon the beam irradiance. While it is difficult to predict what LGAC may be released in any given interaction situation, it is known that contaminants, including new compounds, can be produced with many types of lasers. When the target irradiance reaches a given threshold, target materials including plastics, composites, metals, and tissues may liberate toxic and noxious airborne contaminants. LGAC include metallic fumes and dust, metallic oxide fumes, chemical and gaseous vapors, and biological fragments from human and animal tissues (bio-aerosols, dead and live cellular material, bacteria, fungi, and viruses).

The LSO shall ensure that appropriate industrial hygiene characterisation of exposure to LGAC are performed and appropriately controlled through exhaust ventilation, respiratory protection and isolation.

8.4 Fire Hazards

Class 4 laser systems represent a fire hazard. The use of flame retardant materials should be encouraged.

Opaque laser barriers e.g., curtains, can be used to block the laser beam from exiting the work area during certain operations (see 5.14). While these barriers can be designed to offer a range of protection, they normally cannot withstand high irradiance levels for more than a few seconds without some damage, e.g., production of smoke, open fire or penetration. Users of commercially available laser barriers should obtain appropriate fire prevention information from the manufacturer.

Operators of Class 4 lasers should be aware of the ability of unprotected wire insulation and plastic tubing to catch on fire from intense reflected or scattered beams, particularly from lasers operating at invisible wavelengths.

8.5 Explosion Hazards

The laser target, which may shatter during laser operation, shall be enclosed or equivalently protected to prevent injury to operators and observers.

8.6 Compressed Gases

Presently many hazardous gases are used in laser applications including chlorine, fluorine, hydrogen chloride, and hydrogen fluorite. Standard operating procedures should be developed for safely handling compressed gases. Typical safety problems that often arise when using compressed gases are:

(1) Working with free-standing cylinders not separated from personnel
(2) Inability to protect open cylinders (regulator disconnected) from atmosphere and contaminants
(3) No remote shutoff valve or provisions for purging gas before disconnect or reconnect
(4) Labeled hazardous gas cylinders not maintained in appropriately exhausted enclosures
(5) Gases of different categories (toxics, corrosives, flammable, oxidisers, inerts, high pressure, and cryogenics) not stored separately.

8.7 Laser Dyes

Laser dyes are complex fluorescent organic compounds that, when in solution with certain solvents, form a lasing medium for dye lasers. Certain dyes are highly toxic or carcinogenic. Since these dyes frequently need to be changed, special care must be taken when handling, preparing solutions, and operating lasers.

8.8 Noise

Noise levels from certain lasers, such as eximer lasers, may be of such intensity that noise control may be necessary.

8.9 Waste Disposal

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

8.10 Confining Space and Ergonomics

There must be sufficient room for personnel to turn around and maneuver freely. If LGAC's are present when laser systems are used in a confined space, local exhaust and mechanical ventilation shall be provided and respiratory protection shall be used.

Ergonomic problems can exist in certain laser operations that can cause unique arm, hand, and wrist deviations. If such repetitive deviations occur for long periods of time medical problems can arise. The LSO should be aware of this problem and become familiar with appropriate user control measures.