Laser Safety Procedures Manual

Laser Safety Program

THE OHIO STATE UNIVERSITY

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Executive Summary

Lasers devices and laser systems present a potential safety hazard to students, staff and faculty if the equipment is not used and/or stored properly. Safety requirements for lasers and laser systems are listed in this manual and the American National Standards Institute (ANSI) Standard Z136.1-2014, *American National Standard for the Safe Use of Lasers.*

This document outlines The Ohio State University (University) rules and regulations for the safe operation of lasers and laser systems (non-human use) and specifies practices to aid laser and laser system users in minimizing their exposure to laser radiation as well as non-beam hazards. These measures are taken to comply with documented standards and shall succeed only when each user follows the guidelines contained in this document.

Lasers and laser systems may be intended for laboratory or field use with applications in academic settings. Much of this equipment is manufactured commercially, however, custom-built lasers and laser systems are found at the University. Some of the older lasers and/or laser systems may not meet current regulatory safety standards.

This manual was developed to assist University personnel in meeting safety and regulatory standard requirements. Reviewed in this manual are the responsibilities of laser users, laser classifications, control measures, personal protective equipment, warning signs and labels, hazards and additional safety recommendations.

Introduction and Objectives

Introduction

This manual defines the Laser Safety Program for The Ohio State University (University). This program has been developed to provide guidance to faculty, staff, students and visitors for the safe use of lasers and laser systems. This manual also provides essential reference information on non-ionizing optical radiation.

The primary purpose of the University Laser Safety Program (LSP) is to ensure that no laser radiation in excess of the maximum permissible exposure (MPE) limit reaches the human eye or skin. In addition, the LSP is designed to ensure adequate protection against non-beam (collateral) hazards that can be associated with lasers. Non-beam hazards include the risk of electrical shock, explosion, fire and personal exposure to harmful chemical or biological hazards. In order to control these hazards, the University LSP follows the safety guidelines established by the American National Standards Institute (ANSI) Standard Z136.1–2014, *American National Standard for the Safe Use of Lasers*.

The University LSP requirements primarily apply to Class 3B and 4 lasers and laser systems. However, consideration that Class 1 laser devices, such as flow cytometers and cell sorting instrumentation, may become Class 3B laser devices when protective housing panels are removed during laser operation. An overview of the additional laser classes as well as recommendations on safety is found in this document. However, the primary focus of this manual will be the safe use of Class 3B and 4 lasers and laser systems.

This manual is intended to serve as a quick reference guide for University personnel to become familiar with the policies, procedures and safety precautions necessary for the safe use of lasers. It is by no means a complete or all-encompassing source of laser safety.

Objectives

The objectives of the LSP include;

- Identify potential hazards to health and safety associated with lasers, laser systems and laser operations including non-beam hazards.
- Evaluate the classes of lasers and laser systems.
- Evaluate the hazards associated with each laser and/or laser system and provide a means for the control of these hazards.
- Ensure proper labeling of equipment and device locations.
- Outline emergency procedures.
- Outline of organizational responsibilities.
- Provide an overview of laser safety through this manual and reference materials.
- Preview and plan response to emergency situations.

Definitions (ANSI Z136.1-2014)

accessible emission limit (AEL). The maximum accessible emission level permitted within a particular laser hazard class.

accessible laser radiation. Laser radiation emitted from a laser that is compared with the AEL to determine its hazard class. Includes accessible radiant energy and power.

administrative control measure. Control measures incorporating administrative means [e.g., training, safety approvals, LSO designation, and standard operating procedures (SOP)] to mitigate the potential hazards associated with laser use.

aperture. An opening, window, or lens through which optical radiation can pass. The aperture limits the energy or power for measurement or exposure.

authorized personnel. Individuals approved by management to operate, maintain, service, or install laser equipment.

average power. The total energy in an exposure or emission divided by the duration of that exposure or emission.

aversion response. Closure of the eyelid, eye movement, pupillary constriction, or movement of the head to avoid an exposure to a noxious or bright light stimulant. In this manual, the aversion response to an exposure from a bright, visible, laser source is assumed to limit the exposure of a specific retinal area to 0.25 seconds or less.

beam. A collection of light/photonic rays characterized by direction, diameter (or dimensions), and divergence (or convergence).

beam diameter. The distance between diametrically opposed points in that cross-section of a beam where the power or energy is l/e (0.368) times that of the peak power or energy.

beam divergence. For purposes of this manual, divergence is the increase in the diameter of the laser beam with distance from the beam waist, based on the full angle at the point where the irradiance (or radiant exposure for pulsed lasers) is 1/e times the maximum value.

collateral radiation. Any electromagnetic radiation, except laser radiation, emitted by a laser system. This does not include laser target interaction radiation (reradiation).

collecting optics. Lenses or optical instruments having magnification and thereby producing an increase in energy or power density. Such devices may include telescopes, binoculars, microscopes, or loupes.

continuous wave (CW). In this manual, a laser operating with or modeled as having a continuous output for a period > 0.25 s is regarded as a CW laser.

control measure. A means to mitigate potential hazards associated with the use of lasers. Control measures can be divided into three groups: engineering, procedural (administrative), and personal protective equipment (PPE).

controlled area. An area where the occupancy and activity of those within is subject to control and supervision. *See also:* laser controlled area.

cornea. The transparent outer layer of the human eye that covers the iris and the crystalline lens. The cornea is the main refracting element of the eye.

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

electromagnetic radiation. The flow of energy consisting of orthogonally vibrating electric and magnetic fields lying transverse to the direction of propagation. Gamma rays, X-rays, ultraviolet, visible, infrared, and radio waves occupy various portions of the electromagnetic spectrum and differ only in frequency, wavelength, and photon energy.

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

enclosed laser. A laser that is contained within a protective housing of itself or of the laser or laser system in which it is incorporated. Opening or removal of the protective housing provides additional access to laser radiation above the applicable MPE than possible with the protective housing in place.

engineering control measure. Control measures designed or incorporated into the laser or laser system (e.g., interlocks, shutters, watch-dog timer) or its application.

epithelium (of the cornea). The layer of cells forming the outer surface of the cornea.

erythema. For the purposes of this manual, redness of the skin due to exposure from laser radiation.

eye-safe laser. Class 1 laser product. Because of the frequent misuse of the term *eye-safe wavelength* to mean *retina-safe,* (e.g., 1500 nm to 1800 nm) and *eye-safe laser* to refer to a laser emitting at wavelengths outside the retinal-hazard region, the term *eye-safe* can be a misnomer. Hence, the use of *eye-safe laser* is discouraged.

fail-safe interlock. An interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into, or remain in, a safe mode.

infrared (IR). For purposes of this manual, the region of the electromagnetic spectrum between the long-wavelength extreme of the visible spectrum (700 nm) and the shortest microwaves (1000 μm).

intrabeam viewing. The viewing condition whereby the eye is exposed to all or part of a laser beam.

iris. The annular pigmented structure that lies behind the cornea of the human eye. The central opening is the pupil.

laser. A device that produces radiant energy predominantly by stimulated emission. Laser radiation may be highly coherent temporally, or spatially, or both. An acronym for Light Amplification by Stimulated Emission of Radiation.

laser barrier. A device used to block or attenuate incident direct or diffuse laser radiation. Laser barriers are frequently used during times of service to the laser system when it is desirable to establish a boundary for a controlled laser area.

laser classification. An indication of the beam hazard level of a laser or laser system during normal operation, or the determination thereof. The hazard level of a laser or laser system is represented by a number or a numbered capital letter. The laser classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B and Class 4.

laser controlled area (LCA). A laser use area where the occupancy and activity of those within is controlled and supervised. This area may be defined by walls, barriers, or other means. Within this area, potentially hazardous beam exposure is possible.

laser personnel. Persons who routinely work around hazardous laser beams.

laser pointer. A laser or laser system designed or used to specify a discrete point or location, such as those lasers used in classroom lectures or for the aiming of firearms. These products are usually Class 1, Class 2, or Class 3R.

laser product. Any manufactured product or assemblage of components that constitutes, incorporates, or is intended to incorporate a laser or laser system. A laser or laser system intended for use as a component of an electronic product is itself considered a laser product.

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

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

limiting exposure duration- An exposure duration that is specifically limited by the design or intended use(s).

macula. The small uniquely pigmented specialized area of the retina of the eye, which, in

normal individuals, is predominantly employed for acute central vision (i.e., area of best visual acuity).

magnified viewing. Viewing an object through an optical system that increases the apparent object size. This type of optical system can make a diverging laser beam more hazardous, (e.g., using a magnifying optic to view the end of an energized optical fiber).

maximum permissible exposure (MPE). The level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin.

nominal hazard zone (NHZ). The space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the applicable MPE.

nominal ocular hazard distance (NOHD). The distance along the axis of the unobstructed beam from a laser, fiber end, or connector to the human eye beyond which the irradiance or radiant exposure does not exceed the applicable MPE.

non-beam hazards (NBH). All hazards arising from the presence of a laser system, excluding direct human exposure to direct or scattered laser radiation.

non-laser radiation (NLR). All radiation arising from the operation of a laser system, excluding laser radiation. This includes collateral radiation and laser target interaction radiation.

optically aided viewing. Viewing with a telescopic (binocular) or magnifying optic. Under certain circumstances, viewing with an optical aid can increase the hazard from a laser beam.

optical density (OD). The logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength.

personal protective equipment (PPE). Personal safety protective devices used to mitigate hazards associated with laser use [e.g., laser eye protection (LEP), protective clothing, and gloves].

photochemical effect. A biological effect produced by a chemical change in molecules resulting from the absorption of photons. The changed molecules fail to function as before.

plasma radiation. Laser target interaction radiation (LTIR) generated by a plasma.

protective housing. An enclosure that surrounds the laser or laser system and prevents access to laser radiation above the applicable MPE. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing limits access to other associated radiant energy emissions and to electrical hazards

associated with components and terminals, and may enclose associated optics and a workstation.

pulse duration. The duration of a laser pulse, usually measured as the time interval between the half-power points on the leading and trailing edges of the pulse.

pulse-repetition frequency (PRF). The number of pulses occurring per second, expressed in hertz.

pulsed laser. A laser that delivers its energy in the form of a single pulse or a train of pulses. For purposes of this manual, the duration of a pulse is less than 0.25 s.

pupil. The variable aperture in the iris through which light travels to the interior of the eye.

Q-switch. A device for producing very short (~10 – 250 ns) intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium, respectively.

Q-switched laser. A laser that emits short (~10 – 250 ns), high-power pulses by means of a Q-switch.

reflectance. The ratio of total reflected radiant power to total incident power.

reflection. Deviation of radiation following incidence on a surface.

refraction. The bending of a beam of light in transmission through an interface between two dissimilar media or in a medium whose refractive index is a continuous function of position (graded index medium).

repetitive pulse laser. A laser with multiple pulses of radiant energy occurring in a sequence.

retina. The sensory tissue that receives the incident image formed by the cornea and lens of the human eye.

retinal hazard region. Optical radiation with wavelengths between 400 nm and 1400 nm, where the principal hazard is usually to the retina.

shall. The word *shall* is to be understood as mandatory.

should. The word *should* is to be understood as advisory.

specular reflection. A mirror-like reflection.

standard operating procedure (SOP). Formal written description of the safety and administrative procedures to be followed in performing a specific task.

thermal effect. For purposes of this manual, an effect brought about by the temperature elevation of a substance due to absorption of laser energy.

ultraviolet radiation (UV). Electromagnetic radiation with wavelengths between 180 nm and 400 nm.

uncontrolled area. An area where the occupancy and activity of those within is not subject to control and supervision for the purpose of protection from radiation hazards.

viewing window. A visually transparent part of an enclosure that contains a laser process. It may be possible to observe the laser processes through the viewing windows.

visible radiation (light). The term is used to describe electromagnetic radiation that can be detected by the human eye. For purposes of this manual, this term is used to describe wavelengths that lie in the range 400 nm to 700 nm. Derivative standards may legitimately use 380 nm to 780 nm for the visible radiation range.

wavelength. The distance in the line of advance of a sinusoidal wave from any one point to the next point of corresponding phase (e.g., the distance from one peak to the next).

Responsibilities

Laser Safety Officer (LSO)

The LSO is an individual designated by the University with the authority and responsibility to effect the knowledgeable evaluation and control of laser hazards and to monitor and enforce the control of such hazards. The LSO provides basic laser safety awareness, hazard analysis and training. It is the ultimate responsibility for the Principal Investigator (PI) and the Individual Users to effect evaluations and safety over his or her laser(s) and/or laser system(s).

The LSO maintains the following specific duties:

- Establish and maintain laser safety policies and procedures.
- Classify or verify the class of lasers or laser systems.
- Perform or delegate the performance of hazard evaluations.
- Ensure control measures are implemented and maintained.
- Approve or delegate the approval of device specific operating procedures.
- Recommend or approve protective equipment.
- Review, approve and implement wording on laser or laser system location signs.
- Review or delegate the review of Class 3B and 4 installations and safety measures.
- Ensure safety training of laser personnel has been completed at a location level.
- Maintain necessary records.
- Conduct inspections and audits of Class 3B and 4 laser or laser systems.
- Develop a plan to respond to accidental exposures.
- Facilitate membership, meetings and discussions of Laser Safety Subcommittee

Principal Investigator (PI)

The primary responsibility of ensuring the safe use of lasers and laser systems belongs to the Principal Investigator associated with the laser(s) and/or laser system(s) for which he or she is responsible.

The PI maintains the following specific responsibilities:

- Ensure all Class 3B and 4 lasers and laser systems are registered with the Radiation Safety Section of Environmental Health and Safety.

  Notification of the acquisition, relocation, transfer, or disposal of any Class 3B and Class 4 laser and/or laser system should be submitted in a timely fashion via form LS-1 "Laser Registration Form," located at:

  Laser Registration Form

  Please email the completed form to radiation.safety@osu.edu.

- Ensure laser operators, technicians, engineers, maintenance and service personnel possess adequate knowledge of the potential hazards, control measures and safety work practices. Training shall include OSU BuckeyeLearn Laser Safety Training, or equivalent, and laser device specific competency based evaluations.
- Issuance and completion of appropriate instructions and training materials for the individual users of the specific laser(s) and/or laser system(s) under the direct responsibility of the PI. Including but not limited to the safe operation of each device and/or system, the use of personal protective equipment and emergency procedures.
- The PI shall not permit the operation of a laser or laser system unless there is adequate control of the laser hazards to staff, visitors and general public.
- Perform hazard evaluations, including MPE and NHZ, for each laser and/or laser system.
- Develop written operating and emergency procedures for all Class 3B and 4 lasers.
- Procure personal protective equipment (PPE), ensure its availability and effectiveness (correct wavelength and optical density of glasses) for all lasers and/or laser systems.
- Lasers or laser systems manufactured or modified are properly classified and labeled.
- Ensure proper laser signs are posted and additional safety systems installed as applicable.
- Immediately inform the Radiation Safety Section of Environmental Health and Safety of any accidental exposure to direct or indirect laser radiation.

Individual Users (Operators)

Individual users and/or operators of lasers and laser systems are responsible for:

- Ensuring proper training has been received on the operation and safety of each laser and/or laser system the user intends to operate.
- Ensure authorization has been granted from the PI for the use of each laser and/or laser system.
- Follow established standard operating, safety and emergency procedures.
- Inform the PI of any departure for the established procedure.
- Immediately inform the PI and/or the Radiation Safety Section of Environmental Health and Safety of any accidental exposure to direct or indirect laser radiation.

Laser Safety Subcommittee

The University Laboratory Safety Committee established the Laser Safety Subcommittee to enhance the safety culture at the University by helping to shape safety programs, review and distribute new regulatory information and provide feedback from the university community regarding current laboratory safety incidents or issues involving laser devices and laser systems used in research. The Laser Safety Subcommittee will consist of members with expertise in laser technology and/or in the assessment of laser hazards representing departments possessing Class 3B or Class 4 lasers.

The Laser Safety Subcommittee serves as a resource for:

- Development and review of laser safety policies and procedures.
- Recommend appropriate laser safety training programs and standard operating procedures.
- Facilitate compliance within their respective departments.
- Review various reports from the laser safety program in Environmental Health and Safety.

Emergency Procedures

Laser and/or laser system suspected injuries may require immediate medical attention. For injuries to the eye, the injured individual should lay face down to prevent further eye damage. Notification of injury should be made in a timely fashion to the Radiation Safety Section of Environmental Health and Safety at (614) 561-7969 (24-hour emergency cell phone).

In the event of a laser accident or injury, perform the following:

- Shut down the laser system.
- Provide for the safety of personnel as necessary.
- If there is a fire, leave the area, pull nearest fire alarm and/or contact the fire department. Do not attempt to fight the fire unless it is very small and you have been trained in firefighting techniques.
- Inform the Laser Safety Officer or Radiation Safety Officer in a timely fashion.
    - Laser Safety Officer – (614) 457-6403
    - Radiation Safety Officer – (614) 688-2599
- Inform the PI of the laser or laser system as soon as possible.
- If injury has occurred, a written report must be submitted to the Laser Safety Officer within 3 business days.
- Following any laser incident involving injury or fire, operations may not continue until the approval of the Laser Safety Officer has been received.

If a **MEDICAL EMERGENCY** occurs in which the extent or nature of the injury precludes the employee going to Employee Health Services, **call 911 and request assistance.** If medical attention is required, you are expected to call for help. Under no circumstances should you transport an injured person to the health center or suggest a seriously injured person go to the health center alone. A true medical emergency requires a medical professional to determine the appropriate follow-up care needed by the injured person.

Hazard Classification

Laser hazard classification was developed to aid laser users in assessing the potential hazards of a laser or laser system. ANSI Z-136.1-2014 outlines a simplified method that is used throughout the world. Lasers are divided into classes depending upon the power or energy of the beam, the wavelength of the emitted radiation and the exposure duration. Laser classification is based on the potential for causing biological damage to the eye or skin and the potential for causing fires, either from direct exposure to the beam or from diffuse or specular reflections. Corresponding labels are affixed to the laser to positively identify the laser class. Laser users can then follow the necessary safety precautions that are specific to that class. (Additional information found in Appendix 3 includes a table of safety precautions based on the class of laser. Understanding the laser classification is a fundamental prerequisite for any discussion of laser safety.

Commercial lasers and laser systems are classified in accordance with the *Federal Laser Product Performance Standard* (*21 CFR Part 1040)* and are appropriately labeled by the manufacturer. However, the classification may change if the laser or laser system is modified to accomplish a given task.

Classification of lasers or laser systems shall be based on the maximum output available for the intended use. The classification of lasers or laser systems that are capable of emitting numerous wavelengths shall be based on the most hazardous possible operation.

Any completely enclosed laser is classified as a Class 1 laser if emissions from the enclosure do not exceed the MPE values under any conditions inherent in the laser design. However, during service procedures or if the enclosure panels are opened during laser operation, the appropriate control measures are temporarily required for the class of laser contained within the enclosure.

Class 1 Laser Systems

Class 1 lasers are incapable of producing damaging radiation levels during operation and are exempt from any control measures and training. Class 1 lasers and laser systems cannot cause eye damage as the MPE cannot be exceeded, as a matter of good practice, unnecessary exposure to Class 1 laser light should be avoided.

Class 1M Laser Systems

Class 1M lasers are considered incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with collecting optics such as microscopes and telescopes. Class 1M lasers and laser systems are exempt from any control measures other than to prevent potentially hazardous optically aided viewing.

Class 2 Laser Systems

Class 2 lasers emit in the visible portion of the spectrum (400 – 700 nm) and eye protection is normally afforded by the human eye aversion response. Prolonged exposure can result in eye damage if the beam is stared at directly for longer than the normal aversion response time to bright light (0.25 seconds). Upper limit for continuous wave lasers is one (1) milliwatt (mW). Class 2 lasers are commonly used in alignment procedures.

Class 2M Laser Systems

Class 2M lasers emit in the visible portion of the spectrum (400 – 700 nm) and eye protection is normally afforded by the human eye aversion response. However like Class 1M, Class 2M lasers are potentially hazardous if viewed with collecting optics.

Class 3R Laser Systems

Class 3R lasers have a reduced control requirement and are potentially hazardous under some direct and specular reflection viewing conditions if the eye is focused and stable. The probability of an actual injury is small and the laser will not pose either a fire hazard or diffuse reflection hazard. Class 3R lasers and laser systems have an accessible output between 1 – 5 mW for continuous wave systems.

Class 3B Laser Systems

Medium-powered lasers (visible or invisible regions) that present a potential eye hazard for intrabeam (direct) or specular (mirror-like) conditions. Normally not a fire hazard, diffuse reflection hazard or laser generated air contaminant (LGAC) production hazard. Class 3B lasers and laser systems have an accessible output between 5 – 500 mW for continuous wave systems and less than 0.03 Joule (J) for pulsed lasers that have a pulse width of less than 0.25 seconds. Engineering controls are required for Class 3B lasers.

Class 4 Laser Systems

High-powered lasers (visible or invisible regions) considered to present potential acute hazard to the eye and skin for both direct (intrabeam) and scatter (diffused) conditions. They may pose a fire hazard and many also produce LGAC and hazardous plasma radiation. Class 4 lasers and laser systems have an accessible output of greater than 500 mW for continuous wave systems and greater than 0.03 J for pulsed laser systems. Significant engineering controls are required for all Class 4 lasers.

Embedded Laser Systems

An enclosed laser or laser system is defined as a higher classification than the laser system in which it is incorporated, where the system's lower classification is appropriate due to the engineering controls limiting accessible emission.

Control Measures

Control measures for Class 3B and Class 4 lasers and laser systems are designed to reduce the possibility of eye and skin exposure to hazardous levels of radiation and to other hazards associated with laser systems.

Laser control measures are designed to ensure that skin and eye exposures do not exceed the applicable maximum permissible exposure (MPE) limit. The MPE defines the maximum safe exposure without hazardous effects or adverse biological changes in the eye or skin. The MPE depends on the wavelength and exposure duration.

An important consideration when implementing control measures is to distinguish between operation, maintenance and service. Control measures are based on normal operation of the laser system. When either maintenance or service is performed, it is often necessary to implement additional control measures.

Control measures are classified into two groups; engineering control measures and administrative and procedural control measures. Engineering control measures are incorporated into the laser system and the laser laboratory. Administrative and procedural controls are methods or instructions that specify rules and work practices to supplement engineering controls. When feasible, engineering controls are always the preferred method to provide for safety in a laser laboratory.

Engineering Controls

Engineering controls for Class 3B and 4 lasers are listed below. Unless otherwise approved by the LSO, all Class 3B and 4 lasers at the University must have the following design features:

- *Beam Enclosures (Control)* – Beam enclosures (controls) should be used whenever practical. Use of enclosures will significantly reduce the need for other engineering or administrative controls.
    - Laser beam height should be maintained at a level other than the normal position of the eye of a person in a standing or sitting position. Special attention should be given to lasers at eye level when an individual is in the seated position based on seat/bench height.
    - Position the laser system so that the beam is not directed toward doorways, windows, aisles and open portals.
    - The laser system should be mounted securely to ensure the beam is maintained in a fixed position during operation.
- *Protective Housings* – A protective housing shall be provided for each laser system.
- *Safety Interlocks* – The protective housing shall be interlocked such that removal of the protective housing will prevent exposure to laser radiation greater than the MPE. Interlocks shall not be defeated or overridden during normal operation of the laser. For pulsed lasers, interlocks shall be designed to prevent unintentional firing of the laser.

An example of this would be by dumping the stored energy into a dummy load. For continuous wave (CW) lasers, the interlocks shall turn off the power supply or interrupt the beam (for example, by means of shutters). Service access panels that allow access to the beam during normal operation shall either be interlocked or require a special tool for removal and have an appropriate warning label. All commercially manufactured lasers come equipped with such interlocks and labels.

Class 3B lasers should be provided with a remote interlock connector. Class 4 lasers shall have a remote interlock connector. The remote interlock connector will decrease the laser beam power to a safe level when activated.

- *Reflections* – Remove unnecessary reflective items from the vicinity of the beam path. Do not wear reflective jewelry such as rings or watches while working near the beam path. Special attention should be given to the location of lenses and other optical devices as they may create a reflection from any surface.
- *Controlled Access* – A Class 3B laser should have a key controlled master switch. A Class 4 laser must have a key controlled master switch. The authority for key access is vested in the PI. All lasers shall be disabled by removing the key when not in use.
- *Signs and Labels* – The entrance to Class 3B and 4 laser systems area/room must be posted with the appropriate sign(s). Each laser must be labeled as required in 21 CFR 1040. These labels show the classification of the laser and identify the aperture(s) when the laser beam is emitted.
- *Activation Warning Systems* – Inside the laser control area, an alarm (for example, an audible sound), a warning light (visible through protective eyewear), or a verbal "countdown" command must be used with Class 3B and 4 lasers or laser systems during activation or startup. Distinctive and clearly identifiable sounds that arise from auxiliary equipment (such as a vacuum pump or fan) that are uniquely associated with the emission of laser radiation are acceptable as an audible warning. A warning light outside the control area must be used with Class 3B and 4 lasers.
- *Emission Delay* – For operation of Class 3B or 4 lasers, the warning system must be activated at a sufficient time prior to emission of laser radiation to allow appropriate action to be taken to avoid exposure to the laser.
- *Viewing/Collecting Optics* – All viewing/collecting optics (lenses, telescopes, microscopes and eye loupes) that integrate the use of a laser or laser system shall incorporate suitable means, such as interlocks, filters and attenuators, to maintain the laser radiation transmitted through the collecting optics to levels at or below the applicable MPE for all conditions of operation and maintenance.
- *Window and Door Barriers* – All windows and doorways must be either controlled or restricted in such a manner as to prevent escape of potentially hazardous laser radiation. Typically, laser safety curtains at doorways and window coverings are required for Class 3B and 4 lasers that have open beam configurations.
- *Controlled Areas* – A controlled area shall be designated for all open beam paths. The controlled area is defined as the area where laser radiation is in excess of the MPE.

Appropriate control measures must be implemented in laser controlled areas.

- *Beam Stops* – Class 3B lasers should have a permanent beam stop in place. Class 4 lasers shall have a permanent beam stop in place. Most laser heads come equipped with a permanently attached beam stop or attenuator that will lower the beam power to MPE at the aperture from the housing. Additional beam stops may be needed in the beam path to keep the useful beam confined to the experimental area.
- *Remote Operations* – Whenever possible, Class 4 lasers should be operated and fired from a remote location.

Administrative and Procedural Controls

Administrative and procedural controls are methods that specify rules and work practices that implement or supplement engineering controls. The specified engineering control measures for Class 3B and 4 laser systems may be replaced by procedural, administrative or other alternate engineering controls that will provide equivalent protection.

- *Standard Operating Procedures (SOPs)* – A written SOP is required for each Class 3B or 4 laser system. The written SOP shall be maintained in a visible location near the laser system. Refer to Appendix 1 for guidelines on creating SOPs.
- *Output Emission Limitations* – The minimum laser radiant energy or laser power level required for the application shall be used. Operate a laser at the minimum power necessary for any operation. Beam shutters and filters can be used to reduce the beam power. Use a lower power or lower class laser when possible during alignment procedures.
- *Education and Training* – All individual users that operate Class 3B or 4 lasers shall have the appropriate training in laser safety that is commensurate with the level of potential hazard.
- *Authorized Personnel* – Class 3B and 4 lasers shall be operated, maintained and serviced only by authorized personnel. The PI of the laser system is responsible for authorizing individual users and maintaining a listing of current individual users.
- *Alignment Procedures* – Alignment of laser optical systems must be performed in such a manner that the primary beam, or a specular or diffuse reflection of a beam, does not expose the eye to dangerous levels of laser radiation. The alignment procedures shall be outlined in the SOP. The use of low power visible lasers (Class I or II) for path simulation of higher power visible or invisible lasers is recommended. Refer to Appendix 2 for beam alignment safety guidelines.
- *Personal Protective Equipment* – Personal protective equipment (such as eyewear, barriers, clothing and gloves) may be required to eliminate potential exposure in excess of the applicable MPE when other control measures are inadequate. Refer to the Personal Protective Equipment section of this document for more information.

- *Service Personnel* – During periods of service or maintenance, control measures appropriate to the class of the embedded laser shall be implemented when the beam enclosures are removed and access to the beam is possible. The PI shall require that service personnel have the education and training commensurate with the class of the laser or laser system contained within the protective housing. A temporary laser controlled area shall be established by service personnel that provides the safety requirements for all personnel both within and outside the area appropriate to the laser or laser system. A notice sign shall be posted outside the temporary laser controlled area to warn of the potential hazards.
- *Visitors and Spectators* – Visitors and spectators shall not be permitted within a laser controlled area during operation of a Class 3B or 4 laser or laser system unless:
    - Specific protective measures for visitors and spectators have been approved by the LSO.
    - The degree of hazard and avoidance procedure has been explained to the spectators.
    - Appropriate protective measures have been taken.

Converting to a Class 1 Laser System

Any laser or laser system can be converted to a Class 1 enclosed laser by incorporating all of the following controls in the laser system design. These controls will effectively enclose the laser, thus preventing personnel from contact with any laser radiation while permitting unrestricted access into the area.

- *Protective Housing*
    - House the laser system within a protective enclosure to prevent escape of laser radiation above the MPE.
    - The protective housing must prevent personnel access to the laser system during normal operations.
    - Personnel entering the enclosure to perform maintenance or adjustment tasks must be made aware of the higher risks and comply with the control measures for the higher risk laser class.
- *Safety Interlocks*
    - Install safety interlocks wherever the protective enclosure can be opened, removed or displaced.
    - When activated, safety interlocks must prevent a beam with a radiant energy above the MPE from leaving the laser or laser system.
    - Service adjustments or maintenance work completed on the laser system must not render the interlocks inoperative or cause exposure levels outside the enclosure to exceed the MPE, unless the work is performed in a laser controlled area with limited access and appropriate safeguards, supervision and control.
- *Fail-Safe Design*
    - The protective enclosure and the laser system must be designed and fabricated so that if a failure occurs, the system will continue to meet the requirements for an enclosed laser.
- *Attenuated Viewing Windows*
    - Use viewing windows containing a suitable filter material that will attenuate the transmitted laser radiation to levels below the MPE under all conditions of operation.
- *Warning Signs and Labels*
    - Label the enclosure with “Caution-Enclosed Laser” signs.
    - Attach a label directly to the laser that will display the laser classification in the absence of the enclosure. Make sure that the warning label is immediately visible before enclosure is opened.

Controlled Areas

If the beam of a Class 3B or 4 laser is completely enclosed, the laser will meet the standard of a Class 1 laser (all areas below MPE), and no further restrictions will be required. If the beam path is not fully enclosed, then a Nominal Hazard Zone (NHZ) needs to be accessed and a controlled area established.

Class 3B Controlled Areas

Class 3B lasers with an open beam configuration may only be operated in designated laser controlled areas. The purpose of a laser controlled area is to confine laser hazards to well-defined spaces that are under the control of the individual user. This is an attempt to prevent injury to those visiting and working near the laser controlled area. All personnel who require entry into a Class 3B laser controlled area shall be appropriately trained. They are required to follow all applicable administrative and operational controls. The area designated as a laser controlled area for Class 3B lasers shall have the following adequate control measures:

- *Posting* – The area must be posted with appropriate warning signs that indicate the nature of the hazard and conform to the ANSI Z136.1 guidelines. Such signs must be posted at all entrances to the laser controlled area during the time a procedure utilizing the active beam is in progress, and shall be removed when the procedure is completed.
- *Authorization* – Only personnel who have been authorized by the responsible PI may operate the laser.
- *Beam Stops* – All laser beams must be terminated at the end of their useful paths by a material that is non-reflective and fire resistant.
- *Eye Protection* – Lasers should be mounted so that the beam path is not at eye level for standing or seated personnel. Laser protective eyewear of adequate optical density and threshold limit for the beams under manipulation must be provided and worn at any point where laser exposure could exceed the MPE. Procedures and practices must ensure that optical systems and power levels are not adjusted upstream during critical open beam operations (during beam alignment). It is the responsibility of the PI to obtain and provide appropriate laser protective eyewear.
- *Laser Light Containment* – Laser light levels in excess of the MPE must not pass the boundaries of a laser controlled area. All windows, doorways, open portals and other openings through which light might escape from a laser controlled area must be covered or shielded in such a manner as to preclude the transmission of laser light.

Class 4 Controlled Areas

Only appropriately trained personnel may enter a Class 4 laser controlled area during the time a procedure utilizing the active beam is in progress. All personnel within the laser controlled area must be provided with appropriate protective equipment and are required to

follow all applicable administrative controls. The area designated as a laser controlled area for Class 4 lasers shall meet the requirements of a Class 3B control area and the following additional control measures:

- *Rapid Egress and Emergency Access* – There must be provisions for rapid egress from a laser controlled area under all normal and emergency conditions. Any laser controlled area interlock system must not interfere with emergency egress. In addition, access control measures must not interfere with the ability of emergency response personnel (fire, paramedical, or police) to enter the laser controlled area in the event personnel inside become injured or incapacitated.
- *Laser Activation Warning Systems* – Procedural area or entryway controls must be in place to prevent inadvertent entry into a laser controlled area, or inadvertent exposure to the active laser beam. These measures shall include a visible sign and/or audible warning sign or signal at the entrance to the laser controlled area to indicate when the laser is energized and operating.
- *Limited Access* – Class 4 lasers must have a master switch that is controlled by a key or code. Access to the key or code must only be provided to authorized and trained individual users.
- *Deactivation Switch* – For emergency conditions, a control disconnect switch, panic button or equivalent device must be available for deactivating the laser. The switch shall be clearly marked and readily accessible to all laser personnel. When activated, this button will power down the laser or will reduce the output power of the laser to levels below MPE. The following are acceptable examples of "panic buttons".
    - Key switch to deactivate the laser
    - Master switch on power source to turn off power
    - Red mushroom-type button on control panel or other readily accessible location within the area
- *Entryway Controls* – Never direct a beam toward an entryway. Locking entryway doors as a means of access control is not acceptable because it is contrary to the principle of permitting rapid egress or emergency access. Entry to rooms containing Class 4 lasers and laser systems must be interlocked with the laser to prevent unexpected entry of personnel while the laser is in operation. The PI shall implement one of the following three mechanisms to protect personnel:
    - Non-Defeatable Entryway – Non-defeatable entryway controls (safety latches and entryway or area interlocks such as electrical switches, pressure sensitive floor mats, or motion detectors) shall be used to deactivate the laser or reduce the output levels to less than MPE should unauthorized entry into the laser area occur.
    - Defeatable Entryway – Defeatable entryway controls (safety latches and entryway or area interlocks) shall be used if the controls in the previous paragraph adversely affect the intended use of the laser or laser system. If there

is no laser light hazard at the entry point, the interlock may be bypassed to allow access to authorized personnel provided they have been adequately trained and provided with adequate personal protective equipment.

- Procedural entryway safety controls – Where the above entryway safety controls are not practical or are inappropriate, the following shall apply:
  - All authorized personnel shall be trained and proper personal protective equipment shall be available upon entry.
  - A secondary barrier (laser curtain, wall or partition) shall be used to block the laser radiation at the entryway. This secondary barrier will intercept a beam or scatter so that a person entering the room cannot be exposed above MPE limits.
  - At the entryway there should be a visible or audible indication that the laser is in operation. Existing installed laser-warning signs or flashing lights may satisfy this requirement.

Temporary Controlled Areas

Temporary laser controlled areas can be created for the servicing and alignment of embedded lasers, enclosed lasers, and in special cases where permanent laser control areas cannot be provided.

Personal Protective Equipment (PPE)

Enclosure of the laser equipment or beam path is the preferred method of control. However, it may be necessary to use PPE when other control measures do not provide adequate means to prevent access to direct or reflected beams at levels above the MPE.

Protective Eyewear

Even if you are wearing protective eyewear, never look directly into any laser beam. Always use engineering controls whenever possible to eliminate the need for laser protective eyewear. Wear approved laser protective eyewear specifically designed for the type of laser to be used whenever working with a Class 3R, 3B or 4 lasers. Even when the accessible radiation levels are considered safe, it is good practice for individual users to wear eye protection at all times when operating lasers.

Laser eyewear should not be subjected to high-intensity beams. High average intensity and high peak intensity beams can physically damage the lenses, resulting in loss of eye protection.

Protective eyewear devices shall meet the following requirements:

- Provide a comfortable fit all around the area of the eye.
- Provide adequate visibility (luminous transmission).
- Be in proper condition to ensure the optical filters and holder provide the required optical density (OD) or greater at the desired wavelengths and retain all protective properties during its use.
- All protective eyewear must be clearly labeled with the OD and wavelength for which the protection is afforded.

Care and Maintenance

The proper care and maintenance is essential to ensure that the equipment remains in good condition. Eyewear can represent a significant investment and will last longer and give better service if it is kept clean and properly stored. Eyewear should be stored in a clean and sanitary condition in an area away from dust, dirt and other contaminants. If the eyewear needs to be cleaned, follow the recommendations of the manufacturer. Generally, a mild soap solution is fine for polycarbonate eyewear. Special care may be needed for coated or laminated eyewear.

Inspection

Eyewear inspections shall be conducted periodically. Inspect the filter material for pitting or cracking and inspect the goggle frame for mechanical integrity and light leaks. Straps should be inspected as well and replaced if they have been stretched or are frayed.

Skin Protection

When there is a possibility of exposure to laser radiation greater than the MPE for skin, individual users are required to use protective gloves, clothing and shields.

Other Personal Protective Equipment

As a temporary control measure, respirators and other PPE shall be required whenever engineering controls are unable to provide protection from laser generated air contaminants (LGAC) and other hazards. Collateral ultraviolet (UV) radiation emitted from laser discharge tubes and pump lamps, as well as plasma emissions created during laser-material interaction processes, may contain sufficient UV and blue light to pose a long-term ocular viewing hazard unless appropriate eye protection is worn. High levels of shorter wavelength UV radiation can produce significant amounts of ozone, which will need to be exhausted if concentrations approach recognized exposure limits.

Signs and Labels

Areas where Class 3B and 4 lasers are used must be secured against persons accidentally being exposed to beams and must provide a proper warning indication. It is the responsibility of the PI/laboratory to purchase and maintain the proper signage.

Laser Caution / Warning / Danger Signs

A sign must be posted near all entrances to any area or laboratory that contains a Class 2, 2M, 3R, 3B or 4 laser or laser system. The sign and the wording must be commensurate with the highest-class laser contained within the area or laboratory. Laser controlled areas must be indicated with the appropriate warning signs. The term "proper warning indication" generally means that an illuminated warning sign is outside of the area. The light should be flashing and lit only when the laser is on. When a Class 3B or 4 laser is left on and all personnel leave the room, the door shall always be locked. Lights alone do not suffice as adequate warning unless the light is clearly posted as to its meaning. A well-designed warning light should have redundancy (two lights), a "safe" light when the laser is off, and two lamps, wired in parallel, in the "laser on" signal. Non-English speaking personnel who may need to enter areas where lasers are used must be given appropriate instruction as to the meaning of the warning signs and labels.

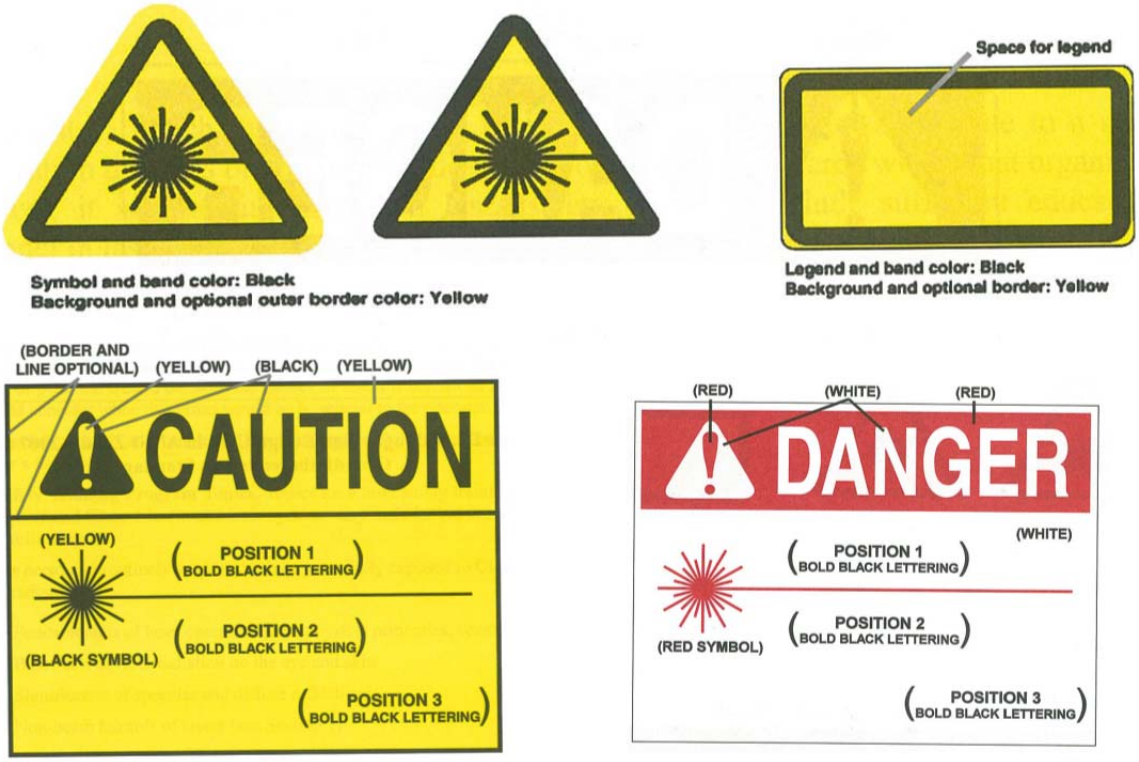
In accordance with ANSI Z136.1-2014, an area which contains a Class 2 or 2M laser or laser system shall be posted with an appropriate yellow "Caution" sign.

In accordance with ANSI Z136.1-2014, an area which contains a Class 3R, 3B and 4 laser or laser system shall be posted with an appropriate orange "Warning" sign. "Warning" should be used on all Class 3B and 4 lasers where the exposure "could result in death or serious injury."

In accordance with ANSI Z136.1-2014, an area which contains a Class 4 (multi-kilowatt) laser or laser system shall be posted with an appropriate red "Danger" sign. "Danger" should be used with lasers where the exposure "will result in death or serious injury.

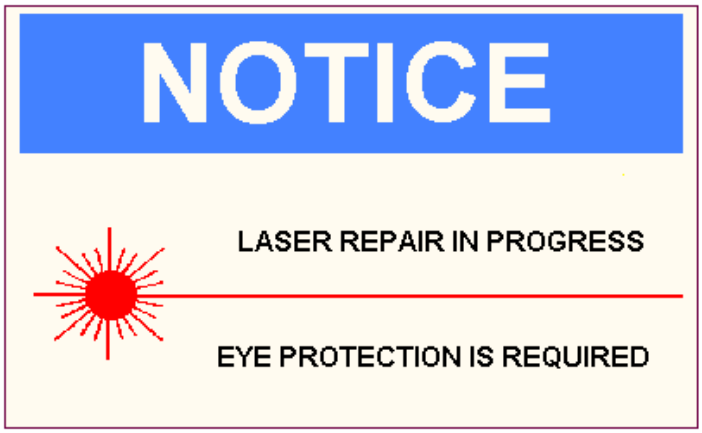
Grandfathered Postings

The following signs have been grandfathered into the ANSI Z136.1-2014 standard.



Temporary Laser Control Area Signs

Post a notice sign outside any area or laboratory designated as a temporary laser control area. Temporary laser control areas are required when accessible laser radiation exceeds the acceptable MPE. Use wording that describes the required precautionary procedures.



Equipment Labels

All lasers, except Class I, are required to contain warning labels in accordance with the Federal Laser Product Performance Standard. Labels shall contain:

- Manufacturer's identification including contact means.
- Certification statement – "This product complies with 21 CFR 1040 as applicable."
- Protective housing warning labels detailing interlocks and access panels that may lead to over exposure if removed or the interlock is defeated.
- The laser sunburst logo.
- Laser class description.
- Hazard designation words, caution, warning, danger, and/or biological hazard (eye or skin damage).
- Aperture label.

Manufacturers place these labels on laser equipment and it is important that they are not removed. Modified or constructed laser systems at the University shall be provided with labels that are clearly visible during operation and be affixed to the laser housing or control panel. Labels must be placed on both the laser housing and the control panel when they are separated by more than two meters. Ancillary hazards shall also be appropriately labeled.

Training

The primary responsibility of ensuring the safe use of lasers and laser systems belongs to the Principal Investigator associated with the laser(s) and/or laser system(s) for which he or she is responsible. The PI is responsible for providing laser safety training to persons using lasers or entering controlled areas under his or her supervision.

Laser users who operate a Class 3B or 4 laser or laser system must:

- Read this Laser Safety Procedures Manual
- Complete Fundamentals of Laser Safety training (available at BuckeyeLearn website)
- Read all relevant Standard Operating and Emergency Procedures
- Read all manufacturer supplied safety instructions for relevant laser systems
- Receive PI training on the specific laser equipment to be used

The Fundamentals of Laser Safety training should include the following:

- Fundamentals of laser operation
- Potential biological effects of laser radiation to the eye and skin
- Specular and diffuse reflections
- Non-beam hazards
- Laser and laser system classifications
- Control measures
- Personal protective equipment
- Emergency procedures and what to do in the event of an accident

Eye and Skin Hazards

The most prominent safety concern with lasers is the possibility of eye damage from exposure to the laser beam. The nature of the damage and the threshold level at which each type of injury can occur depends on the beam parameters. The beam parameters include wavelength, output power, beam divergence, beam diameter and exposure duration. The wavelength of the laser will determine which part of the eye absorbs the laser radiation. For pulsed lasers, additional parameters include pulse duration and pulse repetition frequency.

Retina

The retinal hazard region involves optical radiation in the visible regions (wavelength 400 nm - 700 nm) and near infrared (700 nm - 1400 nm) where the principal hazard is to the retina. Retinal injuries can occur instantaneously with Class 3B and 4 lasers and the damage may be irreparable. This can result in the following types of retinal damage:

- *Thermal Burn* – Normal focusing by the eye results in an irradiance amplification of approximately 100,000. Therefore, a 1 mW/cm^2 beam entering the eye will result in a 100 W/cm^2 exposure at the retina and permanent damage.
- *Acoustic Damage* – Laser pulses of duration less than 10 microseconds (μs) induce a shock wave in the retinal tissue that can cause a rupture of the tissue. Like thermal retinal burns, this damage is permanent. Acoustic damage is potentially more destructive than a thermal burn. Acoustic damage usually affects a greater area of the retina and the threshold energy for this effect is substantially lower.
- *Photochemical Damage* – Laser light with wavelengths less than 400 nm do not focus on the retina. UV radiation can damage the cornea and/or lens. Wavelengths from 400 to 600 nm can result in photochemical effects to the retina. Photochemical effects can be additive over time.

Cornea

The cornea and the conjunctiva tissue surrounding the eye can also be damaged by exposure to laser light. Damage to the cornea and conjunctiva tissue usually occurs at greater power levels. Therefore, these issues only become a concern for those wavelengths that do not penetrate through to the retina, such as UV (< 315 nm) and far infrared (> 1,400 nm) laser light. For UV or far infrared laser light entering the eye, much of the light is absorbed at the cornea and in the lens. Depending on the level of exposure, this may cause immediate thermal burns or the development of cataracts over a period of years.

Skin

Skin has the greatest risk of coming into contact with a laser beam. If the beam is of sufficient energy, the skin can experience thermal burns, acoustic lesions and photochemical changes from laser exposure. The wavelength of the beam determines the layer of the skin

that will be affected. Personnel should observe common-sense safety practices when working with lasers that have the potential to cause skin damage. PPE including gloves and long sleeves are recommended if laser damage to the skin is possible.

Summary of Basic Biological Effects

Wavelength	**Eye**	**Skin**
UV-C (100 – 280 nm)	Photokeratitis Photochemical cataract	Erythema (sunburn) Skin cancer
UV-B (280 – 320 nm)		Accelerated skin aging Skin cancer
UV-A (320 – 400 nm)		Pigment darkening Photosensitive reactions Skin burn
Visible (400 – 700 nm)	Photochemical Thermal retinal injury	Photosensitive reactions Skin burn
IR-A (700 – 1,400 nm)	Retinal burns Cataract	Skin burn
IR-B (1,400 – 3,000 nm)	Corneal burn Aqueous flare Cataract	Skin burn
IR-C (3,000 – 10^6 mm)	Corneal burn only	Skin burn

Non-Beam Hazards

Non-beam hazards are a class of hazards that result from factors other than exposure to the direct or scattered laser beam. While beam hazards are the most prominent laser hazard, other hazards pose equal or possibly greater risk of injury or death. These hazards must be addressed where applicable.

Electrical

Accidental electrocution while working with high voltage sections of laser systems can be lethal. Electrical hazards are not normally present during laser operation, but are present during installation, maintenance and service. Follow safety procedures, including but not limited to, lockout/tagout (29 CFR 1910.147) procedures, enclosing high voltage sources, ensuring power is disconnected before access is granted, ensuring capacitors are properly discharged and grounded and not wearing rings, watches, or other jewelry when working with electrical equipment.

Chemicals

In some laser systems, dyes are used as the optically active medium. Laser dyes are often toxic, carcinogenic and/or corrosive chemicals that are dissolved in flammable solvents. This creates the potential for personal chemical exposures, fires and hazardous spills. A safety data sheet (SDS) should accompany any chemical handled in the laser laboratory.

Collateral Radiation

Gamma and x-ray radiation may be generated from three main sources: high voltage vacuum tubes of laser power supplies, electric discharge lasers and high intensity laser/matter interactions.

Fire and Explosions

Class 4 lasers represent a fire hazard. Depending on the construction materials used, beam enclosures, barriers, beam stops and wiring are all potentially flammable if exposed to high beam irradiance for more than a few seconds. Use of non-combustible materials, removing unnecessary items from laser area and storing flammable, combustible solvents and material away from laser beams is recommended.

Laser Generated Air Contaminants (LGAC)

Air contaminants may be generated when certain Class 3B and Class 4 laser beams interact with matter. Target materials (including plastics, composites, metals and tissues) may liberate toxic, noxious airborne contaminants and infectious contaminants. Hazardous fumes or vapors need to be captured or exhausted.

Compressed and Toxic Gases

Hazardous gases may be used in laser applications including chlorine, fluorine, hydrogen chloride and hydrogen fluoride. Laser laboratories with compressed gasses are required to have an SOP when applicable to the specific compressed gas.

Cryogenic Fluids

Cryogenic fluids are used in cooling systems of certain lasers and can create hazardous situations. As these materials evaporate, they can replace the oxygen in the air, thereby creating oxygen deficient atmospheres (asphyxiation hazard). Adequate ventilation must be provided. Cryogenic fluids are potentially explosive when ice collects in valves or connectors that are not specifically designed for use with cryogenic fluids. Condensation of oxygen in liquid nitrogen presents a serious explosion hazard if the liquid oxygen comes in contact with any organic material.

Plasma Radiation

Interactions between very high power laser beams and target materials may produce plasma radiation (the complete dissociation of nuclei and orbital electrons). The plasma generated may contain hazardous "blue light" and UV emissions which can be an eye and/or skin hazard. When targets are heated to very high temperatures (example, laser welding and cutting) an intense light is emitted. This light often contains large amounts of short wavelength, or blue light, which may cause conjunctivitis, photochemical damage to the retina or erythema (sunburn-like reactions) to the skin.

Appendix 1 – Standard Operating Procedure Preparation Guide

These guidelines are intended to aid PIs and individual laser users in preparing standard operating procedures (SOPs) for lasers and laser systems. The information should be used as a guide to allow you to develop a SOP that is specific to your laser system. The SOP should include all lasers in a given laser system including alignment and pumping lasers.

1) **Introduction**

    a. Laser location
    b. Laser type, manufacturer, model, serial number, classification and technical specifications [continuous (CW), pulsed, Q-switched, wavelength, power/energy, pulse length, repetition rate, beam diameter and divergence].
    c. Briefly describe the purpose of the operation.

2) **Hazards**

    a. Identify and analyze the specific hazards associated with the laser operation
        i. Beam hazards
        ii. Electrical
        iii. Chemical
        iv. LGAC
        v. Other non-beam hazards

3) **Hazard Controls**

    a. Engineering Controls
    b. Administrative Controls
    c. Personal Protective Equipment

4) **Training Requirements**

    a. Describe the training requirements for the laser users and incidental personnel.
    b. Laser or laser system specific training.
    c. Laser safety during operation.
    d. Maintenance and repair as necessary.

5) **Operating Procedures**

    a. List the sequential events that describe the complete operation, including when to implement the hazard control measures. The procedures shall be written for the benefit of the laser user who must read and understand them to perform the operation safely.
        i. Equipment preparation
        ii. Personal Protective Equipment preparation
        iii. Step-by-step protocol on laser system operation
        iv. Shutdown procedures
        v. Emergency shutdown procedures

6) **Alignment Procedures (See Appendix 2)**

   a. List the steps used to perform beam alignment on the laser or laser system. Special attention should be given to control measures that can reduce the potential for exposure. Examples for control measures are shutting down the main laser and using an alignment laser, reducing the power/energy of the laser, use of beam dumps for the primary beam, etc.
   NOTE: Most laser accidents from the beam occur during the alignment operation.

7) **Emergency Procedures**

   a. Describe planned actions in case of an accident, injury, fire, or other emergency. Include names and phone numbers of those that must be contacted in case of an emergency.

8) **Responsibility and Registration**

   a. State the name, title, office location and phone number of the principal investigator responsible for ensuring that the operation is carried out in accordance with the SOP.
   b. All laser systems must be registered with the LSO using the online registration form.

9) **Miscellaneous**

   a. Rules for visitors
   b. Rules for building and facility workers as necessary

Appendix 2 – Safety Guidelines for Beam Alignment

Most laser accidents in research settings occur during the alignment process. If an alignment procedure is recommended or required, use the following as a guide for items that may need to be considered in your particular application.

- **Access.** To avoid injuries, make sure that unauthorized people are not present and are not able to enter the lab at any time an alignment is being conducted.

- **Buddy System.** When working with Class 4 lasers, be sure to use the buddy system.

- **Preparation.** To reduce accidental reflections, watches, rings, badges and reflective jewelry should be removes before alignment activities begin. To make alignment as quick and easy as possible, locate all equipment and materials needed prior to beginning the alignment.

- **Reduced Beam Power.** During alignments, use a Class I or II laser when possible or use the laser at the lowest useful power. Avoid going to full power as much as possible during alignments.

- **Personal Protective Equipment (PPE).** Identify and use the correct PPE.

- **Beam Control.** The individual who moves or places an optical component on an optical table is responsible for identifying and terminating each and every stray beam coming from that component. Close the laser shutter while conducting crude adjustments of optics or when entering the beam path. Make sure that the optics and beam blocks are secure prior to opening the shutter. Clearly mark beams that leave the horizontal plane. Have beam paths at a safe height, below eye level when standing or sitting.

- **Invisible Beams.** Use viewing aids (IR cards and viewers) or fluorescent materials (colored pieces of paper). Note that IR cards may be specular reflectors. Avoid alignment using invisible lasers.

- **Pulsed Lasers.** Align by firing pulses one at a time, if practical.

- **Intrabeam Viewing.** Avoid intrabeam viewing. If intrabeam viewing is required, use a remote viewing camera.

- **Restoring Normal Controls.** When alignment is complete, make sure that all beam blocks, barriers, interlocks, and enclosures are replaced and working.

Appendix 3 – Additional Information

Requirements by Laser Class (ANSI Z136.1-2014)

Class	Control Measures	Training	LSO	Engineering Controls
1	Not Required	Not Required	Not Required	Not Required
1M	Required	Application Dependent [a]	Application Dependent [a]	Application Dependent [a]
2	Not Required [b]	Not Required [b]	Not Required	Not Required [b]
2M	Required	Application Dependent [a]	Application Dependent [a]	Application Dependent [a]
3R	Not Required [b]	Not Required [b]	Not Required [b]	Not Required [b]
3B	Required	Required	Required	Required
4	Required	Required	Required	Required
NOTE—During maintenance and service, the classification associated with the maximum level of accessible laser radiation shall be used to determine the applicable control measures.				

[a] Certain uses of Class 1M or Class 2M lasers or laser systems that exceed Class 1 or Class 2 because they do not satisfy measurement Condition 1 may require hazard evaluation and/or manufacturer's information (see 4.1).

[b] Not required except for conditions of intentional intrabeam exposure applications.

Appendix 3 – Additional Information (cont'd)

Control Measures by Laser Class (ANSI Z136.1-2014)

Engineering Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Protective Housing (4.4.2.1)	X	X	X	X	X	X	X
Without Protective Housing (4.4.2.1.1)	LSO shall establish Alternative Controls						
Interlocks on Removable Protective Housings (4.4.2.1.3)	∇	∇	∇	∇	∇	X	X
Service Access Panel (4.4.2.1.4)	∇	∇	∇	∇	∇	X	X
Key Control (4.4.2.2)	—	—	—	—	—	•	•
Viewing Windows, Display Screens and Diffuse Display Screens (4.4.2.3)	Ensure viewing limited < MPE						
Collecting Optics (4.4.2.6)	X	X	X	X	X	X	X
Fully Open Beam Path (4.4.2.7.1)	—	—	—	—	—	X NHZ	X NHZ
Limited Open Beam Path (4.4.2.7.2)	—	—	—	—	—	X NHZ	X NHZ
Enclosed Beam Path (4.4.2.7.3)	Further controls not required if 4.4.2.1 and 4.4.2.1.3 fulfilled						
Area Warning Device (4.4.2.8)	—	—	—	—	—	•	X
Laser Radiation Emission Warning (4.4.2.9)	—	—	—	—	—	•	X
Class 4 Laser Controlled Area (4.4.2.10 and 4.4.3.5)	—	—	—	—	—	—	X
Entryway Controls (4.4.2.10.3)	—	—	—	—	—	—	X
Protective Barriers and Curtains (4.4.2.5)	—	—	—	—	—	•	•

Administrative (and Procedural) Control Measures	Classification						
	1	1M	2	2M	3R	3B	4
Standard Operating Procedures (4.4.3.1)	—	—	—	—	—	•	X
Output Emission Limitations (4.4.3.2)	—	—	—	—	LSO Determination		
Education and Training (4.4.3.3)	—	•	•	•	•	X	X
Authorized Personnel (4.4.3.4)	—	—	—	—	—	X	X
Indoor Laser Controlled Area (4.4.3.5)	—	◦	—	◦	—	X NHZ	X NHZ
Class 4 Laser Controlled Area (4.4.2.9 and 4.4.3.5)	—	—	—	—	—	—	X
Temporary Laser Controlled Area (4.4.3.5)	∇ MPE	∇ MPE	∇ MPE	∇ MPE	∇ MPE	—	—
Controlled Operation (4.4.3.5.2.1)	—	—	—	—	—	—	•
Outdoor Control Measures (4.4.3.6)	X	◦ NHZ	X NHZ	◦ NHZ	X NHZ	X NHZ	X NHZ
Laser in Navigable Airspace (4.4.3.6.2)	•	•	•	•	•	•	•
Alignment Procedures (4.4.3.8)	∇	X	X	X	X	X	X
Spectators (4.4.3.7)	—	◦	—	◦	—	•	X
Service Personnel (4.4.3.9)	LSO Determination						

LEGEND:
- X — Shall
- • — Should
- — — No requirement
- ∇ — Shall if enclosed Class 3B or Class 4
- MPE — Shall if MPE is exceeded
- NHZ — Nominal Hazard Zone analysis required
- ◦ — May apply with use of optical aids

Appendix 3 – Additional Information (cont'd)

Summary of Area Warning Signs (ANSI Z136.1-2014)

Clause	Title	Classification					Required Statement or Comment
		2	2M	3R	3B	4	
3.5.1	Personnel	✓	✓	✓	✓	✓	Some individuals may be unable to read or understand signs
4.4.2.8.1	Visible Warning Devices	-	-	-	✓	✓	Visible warning should be required for Class 3B and shall for Class 4
4.4.2.8.2	Audible Warning Devices	-	-	-	✓	✓	Audible warning should be required for Class 3B and shall for Class 4
4.6.1	Design of Signs	✓	✓	✓	✓	✓	Per ANSI Z535 requirements
4.6.1.1	Safety Alert Symbol	✓	✓	✓	✓	✓	The alert symbol is required on all Caution, Warning & Danger Signs
4.6.1.2	Laser Radiation Hazard Safety Symbol	✓	✓	✓	✓	✓	Laser sun burst required on all signs per ANSI Z535
4.6.1.3	Area Warning Sign Signal Words	✓	✓	✓	✓	✓	Specifies which sign required: Danger, Warning, Caution
4.6.1.4	Area Warning Sign Purpose	-	-	-	✓	✓	States the four purposes of area warning signs
4.6.2.1	Signal Word "Danger"	-	-	-	-	✓	Specifies when to use "Danger" word and format
4.6.2.2	Signal Word "Warning"	-	-	-	✓	✓	Specifies when to use "Warning" word and format
4.6.2.3	Signal Word "Caution"	✓	✓	✓	-	-	Specifies when to use "Caution" word and format
4.6.3	Pertinent Sign Information	✓	✓	✓	✓	✓	Specifies the format of signs
4.6.3.4	Message Panel Information	✓	✓	✓	✓	✓	Specifies wording of message panel
4.6.4	Location of Signs	✓	✓	✓	✓	✓	Specifies location of signs
NOTE—Area warning signs prepared in accordance with previous revisions of this standard are considered to fulfill the requirement of the standard.							

LEGEND:

✓ denotes that the section applies to laser hazard classification

- denotes that the section does not apply to the laser hazard classification

Appendix 3 – Additional Information (cont'd)

Summary of Labeling Requirement and PPE Labeling (ANSI Z136.1-2014)

Clause	Title	Classification					Required Statement or Comment
		1	2	3R	3B	4	
3.5.1	Personnel	✓	✓	✓	✓	✓	Some individuals may be unable to read or understand labels
4.6.6	Warning Label	-	✓	✓	✓	✓	Class label with symbols & specific words
4.4.2.1	Protective Housing	✓	✓	✓	✓	✓	Specific word depending on internal laser (See 4.6.6 for suggested words)
4.4.2.1	Conduit Label	-	✓	✓	✓	✓	
4.4.2.1.4	Service Access Panel	✓	✓	✓	✓	✓	Label required if removal permits access to laser
4.4.2.1	Optical Fiber Transmission	-	-	✓	✓	✓	Words required if disconnect not in a laser controlled area
4.4.2.1.5	Equipment Label Information	✓	✓	✓	✓	✓	Specifies specific wording by class
NOTE 1—Labeling of laser equipment in accordance with the Federal Laser Product Performance Standard (FLPPS) or IEC 60825-1 may be used to satisfy the equipment labeling requirements in this standard. NOTE 2—Labels prepared in accordance with previous revisions of this standard are considered to fulfill the requirement of the standard.							

LEGEND:

✓ denotes that the section applies to laser hazard classification

- denotes that the section does not apply to the laser hazard classification

Table 11c. Summary of Protective Equipment Labeling

Clause	Title	Summary
4.4.4.2	Protective Eyewear	OD and wavelength marking required
4.4.2.3	Viewing Windows and Display Screens	OD, wavelength and exposure time marking recommended
4.4.2.4	Facility Windows	OD, wavelength and exposure time marking required
4.4.2.6	Collecting Optics Filters	OD, wavelength and threshold limit marking required
4.4.2.5	Protective Barrier	Threshold limit and exposure time marking required, see Appendix C2.4.
NOTE 1— Signs and labels prepared in accordance with previous revisions of this standard are considered to fulfill the requirement of the standard. NOTE 2—Labeling is only required when windows, filters or barriers are not sold as an integral part of the product.		