Laser Safety Manual

BALL STATE
UNIVERSITY

Environmental Health and Safety Office

321 N. College Avenue
Muncie, Indiana 47306

September 2023

Table of Contents

Executive Summary

Laser and laser systems present a potential safety hazard to students, staff, and faculty if the device is not used and/or stored properly. Safety requirements for laser 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 Ball State University (BSU, or University) rules and regulations for the safe operation of laser and laser systems (non-human use) and specifies practices to aid laser and laser system users in minimizing their exposure to laser radiation. These measures are taken to comply with documented standards, and shall succeed only when each user follows the actual guidelines contained in this document.

These lasers and laser systems may be intended for laboratory, educational, or field use, with different applications in academic settings. Much of this equipment is manufactured commercially. However, custom-built lasers and laser systems are also found at the University. Some of the older laser 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, signage / labels, hazards, and additional safety recommendations.

Introduction and Objectives

Introduction

This manual defines the Laser Safety Program for Ball State University (BSU, or University). The program has been developed to provide guidance to faculty, staff, students, and visitors for the safe use of lasers and laser systems. The 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 program 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 only apply to Class 3B and 4 laser and laser systems. An overview of the additional laser classes will be discussed as well as recommendations on safety—however, the primary focus of this manual will be on Class 3B and 4 laser and laser systems.

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

The BSU LSP provides guidance to the university community on the safe use of lasers. Principal Investigators (PI) or faculty administering a laser program must be familiar with the following topics covered in the manual:

- Registration of Class 3B and Class 4 lasers
- Training and documentation for all users of Class 3B and Class 4 lasers
- Evaluation of each laser for proper control measures, including required postings and personal protective equipment (PPE)
- Completion of laser hazard evaluations

Objectives

The objectives of the LSP are to:

- Identify potential hazards to health and safety associated with lasers, laser systems, and laser operations including non-laser 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—engineering controls, administrative (procedural) controls, and personal protective equipment (PPE)
- 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

Responsibilities and Program Administration

Laser Safety Officer (LSO)

The LSO is an individual designated by Ball State University with the authority and responsibility to affect 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), faculty or instructors, 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.

Many of these duties are accomplished by the adoption of this LSP and established by the procedures and precautions contained herein.

Principal Investigator (PI)

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

The PI must accept, and maintain, the following specific responsibilities:

- Ensure all Class 3B and 4 lasers and laser systems are registered with the Environmental Health and Safety (EHS) Office (see **Appendix 4**).

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 the *Laser Registration Form* located in Appendix 4.

Please email the completed form(s) to: trhunt@bsu.edu

- Issuance and completion of the 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 as established in this LSP;
- 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 and/or laser systems;

- Procure personal protective equipment, ensure its availability and effectiveness (correct wavelength and optical density) 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, as well as, additional safety systems are installed as needed or applicable;
- Immediately inform the Laser Safety Officer of the Environmental Health and Safety Office of any accidental exposure to direct or indirect laser radiation; and,
- Maintain records to document all of the above.

Individual Users (Laser Personnel/Operators)

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

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

Employee Responsibilities

- Recognize and adhere to the laboratory signage and applicable written safety protocols.
- Attend laser safety awareness training for incidental personnel.
- Do not enter areas that contain unfamiliar equipment.

Training and Qualifications

Individuals who work with or in close proximity to Class 2, 2M, 3, or 3R lasers should complete laser safety training provided by the LSO or PI. Review this *Laser Safety Manual* and complete the Laser Safety Program's Laser Safety Training. The PI is responsible for verifying training status of all operators. Before operating a Class 3B or Class 4 laser, all personnel must review the USF Laser Safety Manual and complete the Laser Safety Program's Laser Safety.

This training covers:

- Fundamentals of laser operation.
- Laser hazards
- Classification of lasers and laser systems.
- Control measures and personal protective equipment.

Individuals who work with or in the same lab area containing a Class 3b or Class 4 lasers shall receive additional training from principal investigator (USF LSO can assist as needed). PI shall maintain training records and the training shall include:

- Operating and emergency procedures for laser(s) in use.
- Relations of specular and diffuse reflections.
- Proper use of protective equipment – (e.g. safety interlocks, eyewear, etc.)
- Maximum personal exposure levels for eye and skin.
- Laser hazard evaluations.
- Review the operating and safety instructions furnished by the manufacturer.

Emergency Procedures

Laser and/or laser 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 responsible PI or faculty member, and the Laser Safety Officer of Environmental Health and Safety.

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, an appropriate extinguisher is convenient, and you have been trained in firefighting techniques;
- Inform the laser or laser system's PI or faculty member as soon as possible;
- Inform the Laser Safety Officer in a timely fashion;
- If injury has occurred, a **written report** must be submitted to the Laser Safety Officer within 3 business days; and,

Call the EHS Office at 765-285-2807 (working hours)
765-285-5081 (work control)
765-289-1241 (BSU Operator)
765-285-1111 (BSU PD)

If you need <u>emergency medical treatment</u>, call 911 or go to the nearest hospital:
IU Health Ball Memorial Hospital is located at 2401 W. University Ave. Muncie, Indiana

<u>**Non-emergency medical attention (Faculty, Researchers, Staff, or Students):**</u>

Ball State Health Clinic: 765-285-8431

Fall/Spring Hours: Monday, Thursday, Friday - 8:00 AM to 4:30 PM
Tuesday and Wednesday - 9:00 AM to 6:30 PM

Summer Hours: Monday through Friday - 7:30 AM to 3:30 PM

Evening, Weekend or Holidays
If you need non-emergency medical care when the Health Center is closed, the local options are:

MedExpress: 1313 W. McGalliard Avenue: 765-287-8460

US Healthworks: 3911 W. Clara Lane: 765-288-8800

Southway Urgent Care: 3807 S. Madison Street: 765-747-1164

Note: Following any laser incident involving injury or fire, operations may not continue until the approval of the Laser Safety Officer has been received.

ANSI Z136.1 "ANSI Standard for Safety User of Lasers", provides guidance for medical referral following suspected or known laser injury. This Standard does not recommend a medical surveillance program for laser users e.g. pre-screening for laser workers (ANSI Z136.1 Appendix F3).

Hazard Classification

Laser hazard classification was developed to aid laser users in assessing the potential hazards of a 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 laser's 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 and immediately identify the laser class. Laser users can then follow the necessary safety precautions that are specific to that class. (See **Appendix 3** for 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 manufactured after August 1976 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 whenever 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.

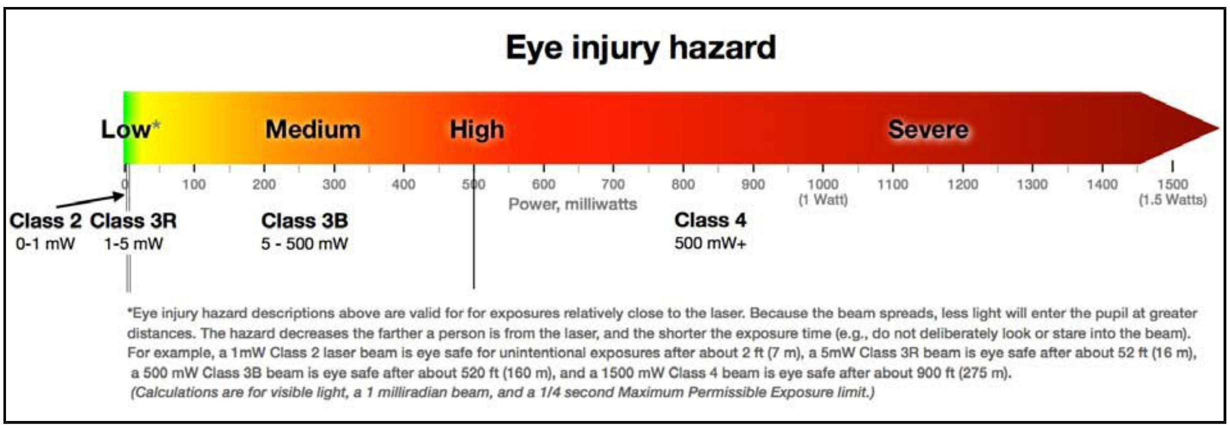
During service procedures, however, the appropriate control measures are temporarily required for the class of laser contained within the enclosure.

Lasers classes are based on the capability of injuring personnel. The manufacturer is responsible for properly classifying lasers using US FDA regulations and ANSI Z136.1 (2014)

Human Aversion Response: Laser light is very bright compared to ordinary light, bright enough to cause an automatic aversion response against the intense light (blinking to close the eyelid, turning the head to avoid the light, automatic constriction of the pupil). The human aversion response of 0.25 seconds can be used to evaluate the potential for injury from visible laser light, such as Class 1, 2 and 3A lasers. Prevent injury to the eye by avoiding intentionally overcoming this aversion response. Note that Class 3B and Class 4 lasers are capable of causing injury before the aversion response has time to protect the eye; Class 3A and 3R have the potential in certain cases to cause injury before the aversion response can protect the eye.

Class 1 Laser Systems

These are low-power lasers and laser systems that cannot emit radiation levels greater than the maximum permissible exposure (MPE). 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. However, as a matter of good practice, unnecessary exposure to Class 1 laser light should still be avoided.



Class 1M Laser Systems

Class 1M lasers produce large-diameter beams, or beams that are divergent. 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. These laser and laser systems are exempt for 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). The 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 (old 3a)

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 (0.4 t0 0.7 μm) have an accessible output between 1 – 5 mW for continuous wave systems.

Class 3B Laser Systems

Class 3B lasers may be hazardous under direct and specular reflection viewing conditions, but are normally not a fire hazard, diffuse reflection hazard, nor 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

Class 4 lasers are high powered and capable of causing damage to the eye and skin from direct viewing, specular, and diffuse reflection; 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. Accidental exposure to high powered Class 4 lasers may result in serious injury or death. 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. Personal Protective Equipment (PPE) is discussed later, as it is a barrier to exposure rather than an exposure "control" measure.

Summary of Required Control Measures at BSU	
Class 1	Exempt from any control measures for laser radiation
Class 1 Embedded Laser Systems	Exempt from any control measures, except for the case when operating with any factory interlocks or other safety features defeated requires hazard evaluation and approval by the LSO
Class 1M	Exempt from any control measures except when using optically aided ("magnified") viewing, and/or the beam is operated unattended into a location where it can be directly viewed by personnel uninformed about the hazards
Class 2	Exempt from any control measures except during intentional direct viewing of the beam.
Class 2M	Exempt from any control measures except during intentional direct viewing of the beam, and/or potential for directly viewing the optically aided ("magnified") beam.
Class 3R *(formerly Class 3A)*	Exempt from any control measures or other forms of surveillance except for conditions when directly viewing the beam or its specular reflection, and/or unattended operation with the beam directed into a location where it can be directly viewed by personnel uninformed about the hazards. Follow the manufacturer's safety instructions.
Class 3B and Class 4	Requires approval of appropriate control measures by the LSO to reduce the risk of hazardous exposure to the eye or skin from the direct and reflected beam. Class 4 lasers may require additional protection from diffusely reflected beams, potential skin hazards, fire hazards and non-beam hazards such as Laser Generated Airborne Contaminates (LGAC) and plasma radiation.

Engineering Controls

Engineering controls are the priority means of minimizing the possibility of accidental exposures to laser hazards. If engineering controls are impractical or inadequate, then safety should be supported through the use of administrative procedures and personnel protective equipment. 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 one or more of the following design features:

Protective Housing and Interlocks

A protective housing is a physical barrier sufficient to contain the beam and laser radiation from exiting the laser system so that the maximum permissible exposure (MPE) is not exceeded on the outside surface. Protective housing must be interlocked so that the laser cannot operate when the housing is opened or removed when the requirements of a protective housing are fulfilled, the laser system is considered a Class 1 laser and no further control measures are required.

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

Laser Use without Protective Housing

In the research environment, lasers are often used without a protective housing in place. The use of optical tables and optical devices are typically employed in order to manipulate the laser beam. In this environment, the LSO will evaluate the hazards and recommend control measures to ensure safe operation. These control measures may include but are not limited to the following:

- Access restriction
- Procedural controls
- Area controls
- Barriers, curtains, and beam stops
- Eye protection
- Training

Access Restriction

For Class 3B and Class 4 laser laboratories, access controls are required to prevent unauthorized personnel from entering the area when the laser is in use. Doors must be kept closed when the laser is in operation. Secondary doors that can allow access to a laser in operation must be either locked or posted similarly to the primary entrance.

Laser Use Area Control

Class 3B and Class 4 laser area control measures are used to minimize laser radiation hazards. The area must be posted with the appropriate signage and include a lighted sign at the doorway indicating the "on" status of a laser system. Only authorized personnel who have been appropriately trained will be allowed to operate the laser. Control of the laser beam path shall be accomplished in the following manner:

Totally Unenclosed Beam Path

Where the entire beam path is unenclosed, a laser hazard analysis shall be performed by the LSO and PI to establish the nominal hazard zone (NHZ) if not furnished by the manufacturer or available as part of the classification.

Limited Open Beam Path

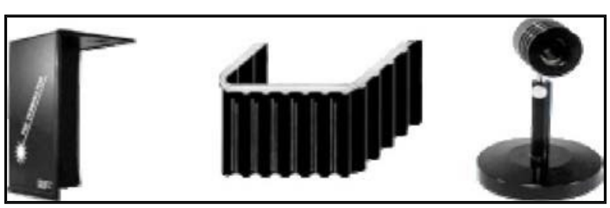
Where the beam path is confined to significantly limit the degree of accessibility of the open beam, a hazard analysis shall be performed by the LSO to establish the NHZ.

Enclosed Beam Path

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

Laser Use Barriers, Enclosures and Beam Stops

Beam barriers, enclosures, and stops are used to prevent beam propagation outside of the controlled access area in excess of the Maximum Permissible Exposure (MPE). It is always desirable to enclose as much of the beam path as possible.



As with a protective housing, the proper enclosure of the entire beam path may change the laser system to a Class 1 laser. When the beam needs to be directed to another area such as between optical tables, enclosure of the beam is recommended. Physical barriers are used to prevent laser radiation from exiting the controlled area. Laser curtains and partitions are routinely used as laser containment systems. Rail curtains can be used to completely enclose an optical table or part of the laser system.

Due to the power density of Class 4 lasers, the combustible properties of the barrier material must be evaluated. Beam stops are used to prevent the beam from leaving the optical table and to terminate the beam path. Beam stops are to be used behind optical devices in the event that the beam becomes misaligned.

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 made 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, widows, aisles, and open portals
- The laser system should be mounted securely to ensure the beam is maintained in a fixed position during operation.

Controlled Access and Operation

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 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 3 B 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 3 B 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 Optics – All viewing portals, display screens, and collecting optics shall be designed to prevent exposure to the laser beam above 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 (Procedural) Controls

Administrative and procedural controls are methods that specify rules and work practices that support 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 are demonstrated to provide equivalent protection.

- *Standard Operating Procedures (SOPs)* – A written SOP is required for each Class 3 B 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 3 B or 4 lasers shall have the appropriate training in laser safety that is commensurate with the level of potential hazard.
- *Authorized Personnel* – Class 3 B 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 of 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 class of laser or laser system (including 3B and 4) 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

- o Install safety interlocks wherever the protective enclosure can be opened, removed, or displaced.
- o When activated, these interlocks must prevent a beam with a radiant energy above the MPE from leaving the laser or laser system.
- o Service adjustments or maintenance work performed 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

- o 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

- o 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

- o Label the enclosure with "Caution-Enclosed Laser" signs.
- o 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 3 B 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. <u>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:</u>

- *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:
    - <u>Non-Defeatable Entryway</u> – 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.
    - <u>Defeatable Entryway</u> – 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 thereis 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.
    - <u>Procedural entryway safety controls</u> – 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)

Engineering controls shall be given primary consideration in instituting a control measure program for limiting access to laser radiation. Enclosure of the laser equipment and the beam path, or remote viewing and operation are the preferred methods of control to isolate or minimize the hazard. When engineering controls are impractical or inadequate, administrative and procedural controls and PPE shall be used, and requirements documented in the laser SOP.

The Principal Investigator or responsible faculty member is responsible for ensuring that the appropriate PPE is available and worn. Laser operators are responsible for properly using all required protective equipment.

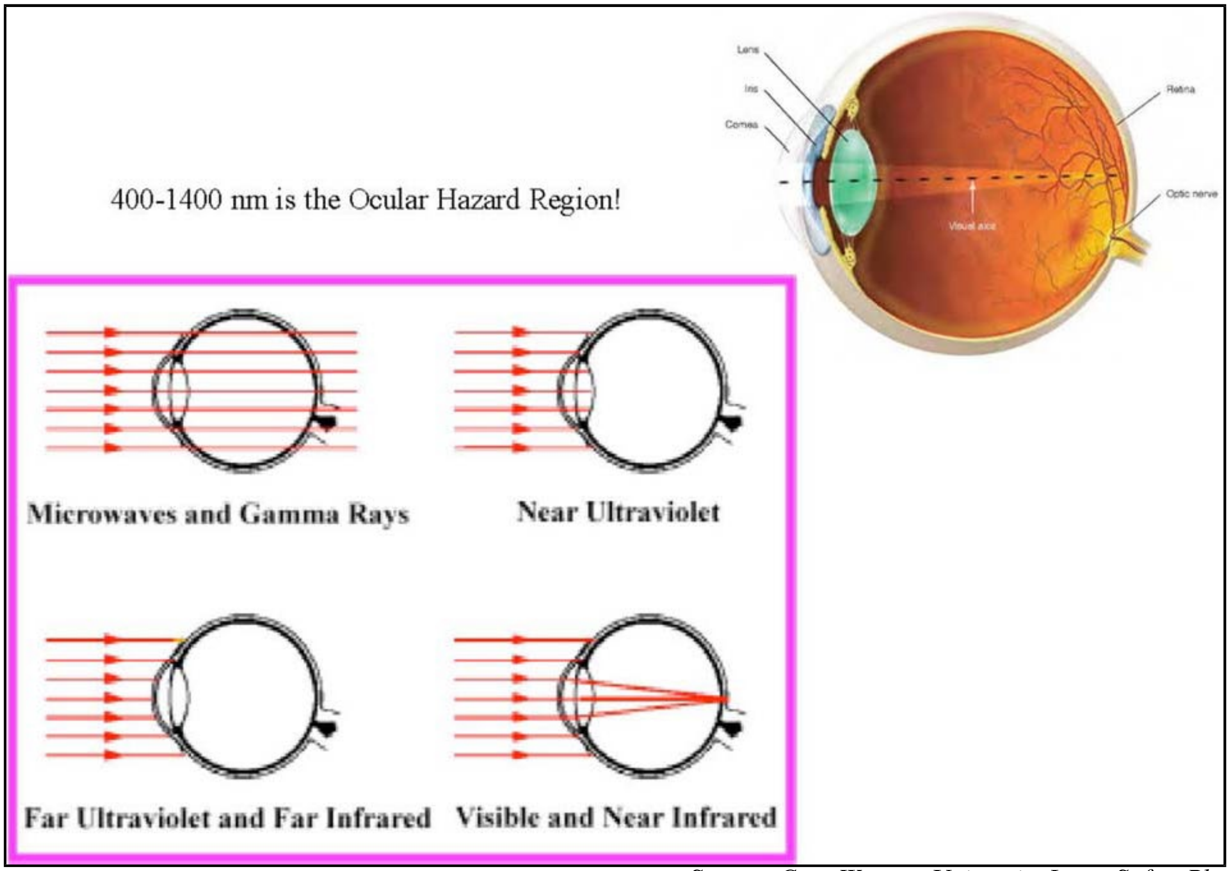
Protective Eyewear

<u>Even if you are wearing protective eyewear, never look directly into any laser beam.</u>

[See ANSI Z136.1-2014, Appendix B, Calculations for Hazard Evaluation and Classification]

Availability and Use of Laser Safety Eyewear

Laser safety eyewear shall be available and worn by laser operators, attendants and visitors in laboratories where a Class 3B or Class 4 laser is present and there is a potential exposure to the beam or reflected beams at levels above the MPE. The use of laser protective eyewear is especially important during alignment procedures since most laser accidents occur during this process. Protective eyewear must be labeled with the absorption wavelength and optical density (OD) rating at that wavelength. Laser eyewear must comply with ANSI Z136.1 requirements.



Source: Case Western University Laser Safety Plan

Laser safety eyewear is not required for Class 2, Class 2M or Class 3R/3A lasers unless intentional long-term (>0.25 seconds) direct viewing is required. The LSO or PI shall approve any lasers operations that require intentional long-term viewing.

Laser safety eyewear shall be chosen based on the level of protection needed to protect the eyes from a worst-case scenario. The LSO or PI can assist with selection of proper laser eyewear for the research or application. The following information is needed when selecting appropriate laser safety eyewear:

1. Wavelength(s)
2. Mode of operation (continuous wave or pulsed)
3. Maximum exposure duration (assume worst case scenario)
4. Maximum irradiance (W/cm2 for CW) or radiant exposure (J/cm2 for pulsed)
5. Maximum permissible exposure (MPE)
6. Optical density (OD)

One pair of laser safety eyewear may not be sufficient when working with tunable or multiple wavelength lasers. Always check the OD and wavelength prior to use. Eyewear with multiband filters and flip-up eyewear are available for some applications.

For ultra-fast (femtosecond) lasers, temporary bleaching may occur from high peak irradiances from ultra-fast laser pulses. Contact the manufacturer of the laser safety eyewear for test data to determine if the eyewear will provide adequate protection before using them.

Other considerations for laser safety eyewear:

1. Visible light transmission (VLT)
2. Effect on color vision
3. Field of view provided by the design of the eyewear
4. Reversible bleaching of absorbing media
5. Need for prescription lenses
6. Fit and comfort
7. Impact resistance

Glass laser eyewear is heavier and more costly than plastic, but it provides better visible light transmittance. There are two types of glass lenses, those with absorptive glass filters and those with reflective coatings. Reflective coatings can create specular reflections and the coating can scratch, minimizing the protection level of the eyewear.

Polycarbonate: Polycarbonate laser eyewear is lighter, less expensive and offers higher impact resistance than glass, but allows less visible light transmittance.

Diffuse Viewing Only (DVO): As the name implies, DVO eyewear is to be used when there is a potential for exposure to diffuse reflections only. DVO eyewear may not provide protection from the direct beam or specular reflections.

Alignment Eyewear: Alignment eyewear may be used when aligning low power visible laser beams. Alignment eyewear transmits enough of the specified wavelength to be seen for alignment purposes, but not enough to cause damage to the eyes. Alignment eyewear cannot be used during operation of high power or invisible beams and cannot be used with pulsed lasers.

Labeling of Laser Safety Eyewear - Laser safety eyewear shall be labeled with the optical density and the wavelength(s) the eyewear provides protection for. Additional labeling may be added for quick identification of eyewear in multiple laser laboratories. Must be labeled to meet ANSI Z136.1 (4.4.4.2.6) requirements

The following guidelines are suggested for maximum eye protection.

- Whenever possible, confine (enclose) the beam (e.g., use beam pipes) and provide non-reflective beam stops to minimize the risk of accidental exposure or fire.
- Use fluorescent screens or similar "targets" to align the beam.
- Avoid direct intrabeam exposure to the eyes. Direct viewing must not be used to align laser optical systems.
- Use the lowest laser power possible for beam alignment procedures.
- Whenever possible, use Class 2 lasers for preliminary alignment procedures.
- Keep optical benches free of unnecessary reflective items.
- Confine the beam to the optical bench unless necessary for an experiment.
- Whenever possible, keep the beam in a single plane on the bench.
- Use barriers at the sides of benches or other enclosures.

- Do not use room walls to align Class 3b or 4 laser beams.
- Use non-reflective tools. Remember that some tools that seem to be non-reflective for visible light may be very reflective for the non-visible spectrum.
- Do not wear reflective jewelry when working with lasers. Metallic jewelry also increases shock hazards.

Care and Maintenance

The proper care and maintenance are 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. Inspecting laser safety eyewear, check for:

- Pitting, crazing, cracking and discoloration of the attenuation material.
- Mechanical integrity of the frame.
- Light leaks.
- Damage to the lens coating.
- Use care when cleaning eyewear and follow manufacturers' instructions to avoid damage to absorbing filters or reflecting surface.

Ultraviolet (UV) Laser Protection

Particular care shall be taken when using UV lasers due to the potential for significant photochemical bio-effects and the high level of scattering of UV radiation by air molecules. UV radiation may produce undesirable reactions, for example formation of skin sensitizing agents, ozone and other Laser Generated Airborne Contaminates (LGAC). Chronic eye and skin exposure to UV radiation may have long term adverse health effects which are not fully understood.

Exposure to UV radiation shall be minimized by using beam shields and clothing that attenuate the radiation to levels below the MPE for the specific UV wavelengths. For example, for an excimer laser operating in the UV, the use of a skin cover shall be employed if chronic (repeated) exposures are anticipated at exposure levels at or near the applicable MPE's for skin.

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. Skin effects can be of significant importance with the use of lasers emitting in the Ultraviolet spectral region. The potential for skin injury from the use of high-power lasers can present a potential hazard. For laser systems using an open beam, skin protection may be necessary. Covering exposed skin by using lab coats, gloves and an UV face shield will protect against UV scattered radiation.

Adequate skin protection may be required for certain applications using high power laser systems.

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.

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 the all entrances to any area or laboratory that contains a Class 2, 2M, 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. When a Class 3 B or 4 laser is left on and all personnel leave the room, the door must always be locked to prevent unauthorized entry.

Required laser hazard signs shall be conspicuously displayed in locations where they will best serve to warn onlookers. All access doors to rooms that contain Class 3B or 4 lasers are to be posted with a laser hazard sign.

B. Signal words “Caution”, “Warning” and “Danger” for hazard signs are assigned as follows:

1. **“CAUTION”** indicates a hazardous situation that, if not avoided, could result in minor or moderate injury. The signal word “CAUTION” shall be used with all signs and labels associated with Class 2, 2M and 3R lasers. “CAUTION” should be printed in black letters on a yellow background.

2. **“WARNING”** indicates an imminently hazardous situation that, if not avoided, could result in death or serious injury. The signal word “WARNING” shall be used on laser area warning signs associated with lasers and laser systems whose output exceed the MPE for irradiance, including all Class 3B and Class 4 lasers and laser systems. “WARNING” should be printed in black letters on an orange background.

3. Note: the **"DANGER"** signal word is restricted to Class 4 lasers with high (multi-kW) output power or pulse energies with exposed beams, and indicates an imminently hazardous situation that, if not avoided, will result in death or serious injury.

4. The signal word ***“NOTICE”*** is not appropriate or allowed on signs warning of a laser hazard

or hazardous situation, instead use “CAUTION” or “WARNING” in these situations.

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.

Examples of signs

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.”

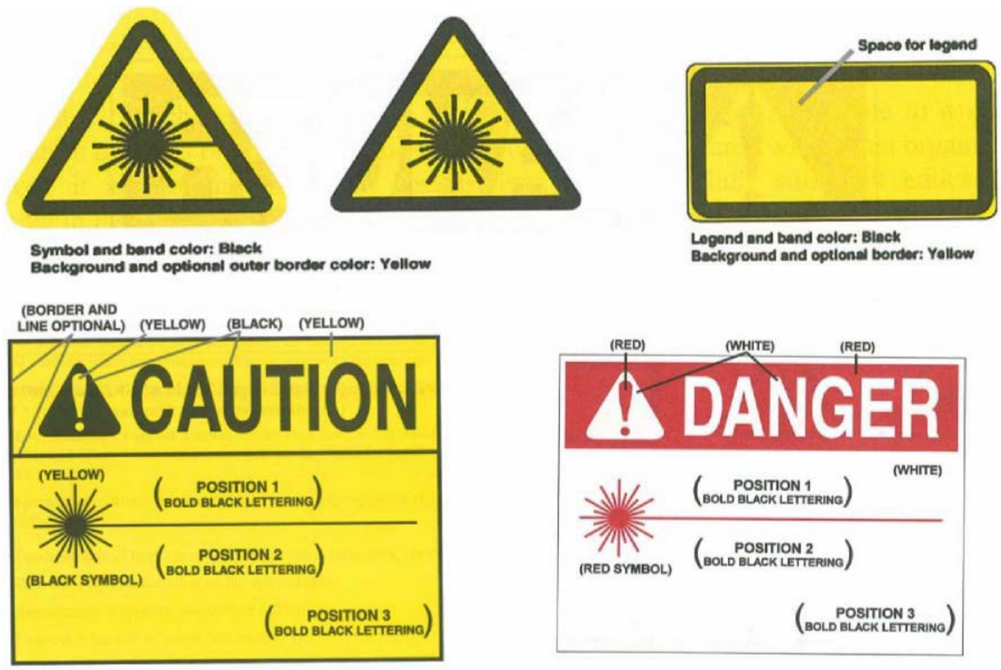
In accordance with ANSI Z136.1-2014, an area which contains a Class 4 (multi-kilowatt) laser or laser system shall be posted with an appropriate red "Danger" sign. "Danger" should be used with lasers where the exposure "will result in death or serious injury.

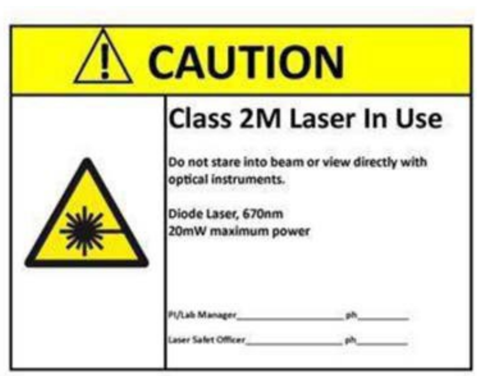
Required warning signs shall include the following information, as applicable:

1. The hazard class of the laser controlled area
2. Name and contact information for PI and LSO

Grandfathered Postings

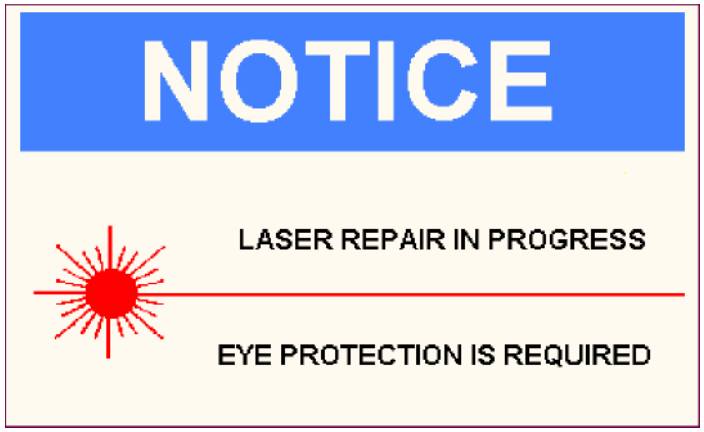
The following signs have been grandfathered into the ANSI Z136.1-2014 standard and may remain in use under this program, but should be replaced with the above signage as soon as practicable, but definitely when the outdated signs are replaced.





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 may exceed the acceptable MPE such as during servicing. 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.
- Wavelength, pulse duration, and maximum output power.
- 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 (or responsible faculty member) 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 Manual;*
- Complete *Fundamentals of Laser Safety* training;

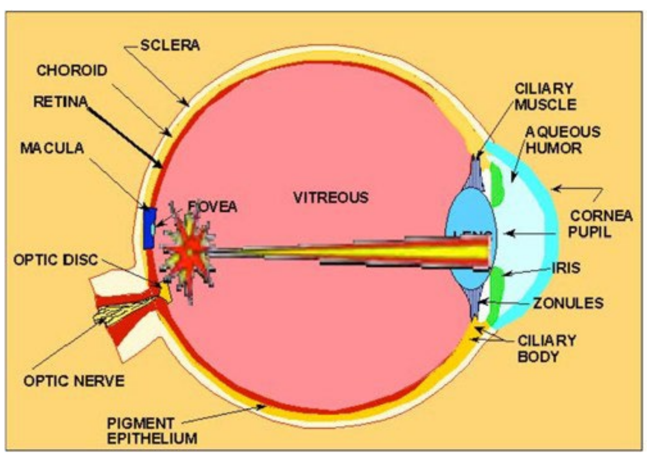
- Read all relevant *Standard Operating* and *Emergency Procedures;*
- Read all manufacturer supplied safety instructions for relevant laser systems; and,
- Receive PI training on the specific laser equipment to be used,

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; and,
- 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 eye is easily injured by laser beams. Incoherent light can be viewed safely because the light reaching the eye is but a fraction of the output energy and is spread over the entire retina. Laser radiation is coherent light. 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

Retinal injuries can occur instantaneously with Class 3 B and 4 lasers and the damage may be irreparable. In the retinal hazard region, visible (400 nm - 700 nm) and near infrared (700 nm - 1400 nm) regions, laser radiation that enters the eye is focused on the retina. This can result in the following types of retinal damage:

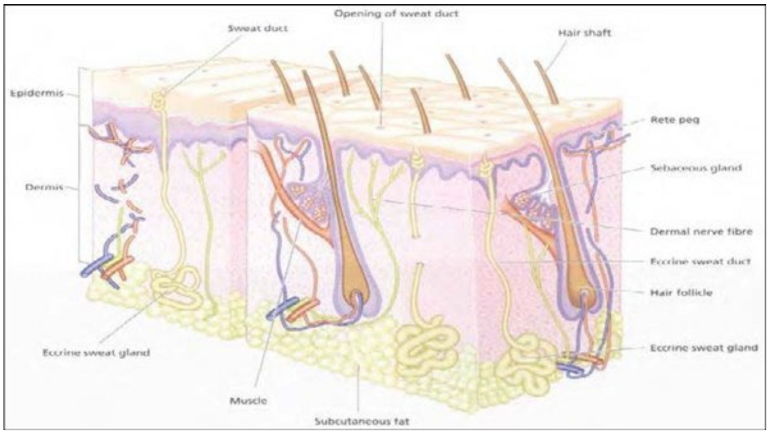
- *Thermal Burn* – Normal focusing by the eye results in an irradiance amplification of approximately 100,000. Therefore, a 1 mW/cm^2 beam entering the eye will result in a 100 W/cm^2 exposure at the retina.
- *Acoustic Damage* – Laser pulses of duration less than 10 microseconds (μs) induce a shock 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 to 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. 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

Since the skin is the largest organ of the body, it 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. Unlike injury to the eye, acute damage to the skin is usually repairable.



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

Some high-powered mode-locked short pulsed lasers can mechanically disrupt the retina causing hemorrhage (Nd-YAG Lasers). XeCl lasers (308 nm) emit UV in the ultraviolet acute cataract action spectrum and require special precautions. Please give these lasers additional focus for laser safety.

Other Beam Exposures

There are a variety of types of beam exposures that are not limited to intrabeam viewing. For high powered lasers, the specular or diffuse reflection may be equally as damaging. Quartz discharge tubes may emit collateral UV radiation. Broadband irradiance (400-550nm) from welding arcs may create potential point source overexposures in 10-20 min. (blue-light region).

Intrabeam Exposures

The skin or eye is exposed directly to all or part of the laser beam resulting in a full exposure to the irradiance of the beam.

Specular Reflections

The reflection from a smooth or mirrored surface when the roughness is l.t. the wavelength of incident light. Items such as jewelry or wrist watch cover glass produce specular reflections. These items should be removed prior to operating a laser. Exposure to specular reflections can be as equally dangerous as intrabeam viewing and reflections from Class 4 lasers may cause a fire (at 0.5 w/cm2 CW).

Beam Alignment and Elevation

It is highly recommended that laser users and PIs document, prior to use, that laser alignment is correct and the search for unwarranted dangerous reflections or errant beams was negative. As a precaution, beams are not to be elevated anywhere on the optical bench.

Diffuse Reflections

A non-uniform reflection from a rough surface whose roughness is g.t. the wavelength of incident light. Diffuse reflections scatter the beam and do not carry the full power of an intrabeam. Diffuse beams have a maximum upward vertical irradiant component perpendicular to the source impact.

Note: In tuning a laser from one wavelength to another, one may be moving from diffuse to specular reflections or vice versa. Know your surfaces and how they reflect!

Non-Beam Hazards

In addition to the beam hazards of a laser, other hazards may be associated with laser operations. These non-beam hazards include electrical shocks, explosions, flammable liquids, compressed gases, noise, UV radiation, dyes and solutions, and laser generated air contaminants. Safety considerations that may go into the assessment and evaluation of laser hazards include electrical skin exposure, chemical and associated gas hazards. Some other special considerations include whether the laser is enclosed in an engineered system of protection, the beam is invisible, maintenance, repair, and if modifications will be necessary on a routine basis or whether there is a potential for explosion, fire, or hazardous fumes.

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/or 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

X-ray and gamma rays may be produced from three main sources: high voltage vacuum tubes of laser power supplies, electric discharge lasers, and heavy metal target 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 and combustible solvents and material away from laser beams is recommended.

Laser Generated Air Contaminants (LGAC)

Air contaminants may be generated when certain Class 3 B and Class 4 laser beams interact with matter. Target materials (including plastics, composites, metals and tissues) may liberate toxic, noxious airborne contaminants, and/or 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. Inert gases may create asphyxiation or low oxygen conditions in the event of a release.

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.

Bibliography

American National Standards Institute (ANSI) Standard Z136.1-2014, *American National Standard for the Safe Use of Lasers; and,* the ANSI Laser Hazards and related standards include the following references:

ANSI Z87.1-1989: Practice for Occupational and Educational Eye and face Protection
ANSI Z136.1-2014 American National Standard for the Safe Use of Lasers
ANSI Z136.2-1988 American National Standard for the Safe Use of Optical Fiber Communications
Systems Utilizing Laser Diodes and LEDs
ANSI Z136.3-1996 American National Standard for the Safe Use of Lasers in the Health Care Environment
ANSI Z136.5-2000 Safe Use of Lasers in Educational Institution
ANSI Z136.6-2000 Safe Use of Lasers Outdoors
FAA 7400.2D Guidelines for Use of Lasers Outdoors (this is not a title)
FDA, 21 CFR Subchapter J: Federal Laser Product Performance Standard
OSHA Technical Manual (TED 1-0.15A), Section 111- Chapter 6, (January 1999)
CDRH: Federal Laser Product Performance Standard 1976

Laser Safety Procedures Manual, Laser Safety Program, The Ohio State University, November 2014 (from which much of this program is derived).

Laser Registration Form, Emory University

Laser Safety Manual, and *Basic Laser Safety Training*, University of South Florida, December 1, 2016.

Laser Safety Manual, Case Western Reserve University, November 14, 2016.

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, etc.)
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
b. Temporary (Servicing)

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

iv. Step-by-step protocol on laser system operation
v. Shutdown procedures
vi. 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.

9) **Miscellaneous**

a. Rules for visitors
b. Rules for building and facility workers as necessary
c. Rules for servicing: Controls, signage, and access restrictions when servicing the laser (enclosure and/or interlocks bypassed to allow access for servicing of laser components). Identification and qualifications and training requirements of the service person and firm.

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.** With Class 4 lasers, be sure to use the buddy system.
- **Preparation.** To reduce accidental reflections, watches and reflective jewelry should be taken off 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 and not at a level that temps one to bend down and look at the beam
- **Invisible Beams.** Use viewing aids (IR cards and viewers) or fluorescent materials (colored pieces of paper or Polaroid sheets). Note that IR cards and Polaroid sheets 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.		

Appendix 4 – Laser Registration Form

(Next 2 pages)

BALL STATE UNIVERSITY	**Environmental Health and Safety Office**	321 N. College Ave. 765-285-2807 trhunt@bsu.edu

Laser Registration Form

NOTE: All lasers of Class 3B and Class 4 must be registered with the Environmental Health and Safety (EHS) Office (see page 2 for Class 3B and Class 4 laser criteria before completing this form).

INSTRUCTIONS: Please complete this form for each laser in either of the aforementioned laser classes and email to trhunt@bsu.edu *Be sure to sign this Registration where shown.*

Section A: Registration Information			
Principal Investigator:			
Office Phone No:		Email address:	
Laser Operator(s):			
Laser Manufacturer:			
Model Number:		Serial number	
Laser Equipment Type:			

Section B: Location of Laser					
Fixed or Mobile Laser?	☐ Fixed facility		☐ Mobile Laser		
Department:		Building:		Room Number:	
Power Output:		Laser Embedded:	☐ Yes	☐ No	
Laser Classification (check one)	☐ Class 3B		☐ Class 4		
Active Medium (ex: Argon, Ruby, Nd: YAG, Dye):					
Tunable Laser (check one)	☐ Yes		☐ No		
Operational Wavelength (nm);					
Beam Divergence) (milirads):					
Beam Diameter (millimeters):					
Use Frequency:					
Beam Type:	☐ Continuous Wave	Average Power:			
	☐ Pulsed	J per Pulse:		Repetition Frequency (Hz)	
	☐ Q-Switched	Pulse Width:		Joules per Pulse	
	☐ Other				
Describe purpose of laser use and *nominal hazard zone*					
Laser Servicing Performed:	☐ **In House**	☐ **Contracted Out To: ______________________**			
Comments:					

Laser Registration Form

Section C: Criteria for Class 3B and Class 4 Lasers
Criteria for Class 3B Lasers

1. The device is capable of emitting laser radiation that is <u>accessible</u> for any duration inherent in its design;
2. For operation in the ultraviolet (180 nm-400 nm) and the infrared (1400 nm-1mm) areas of the electromagnetic spectrum:
   a. The device cannot produce accessible laser radiation exceeding an average radiant power of 0.5 W (500 milliwatts) for ≥ 0.25 seconds (normal aversion response); or,
   b. The device cannot produce accessible laser radiation exceeding a radiant energy of 0.125 J within an exposure time of <0.25 seconds;
3. For operation in the visible (400 nm – 700 nm) or near-infrared (700 nm – 1400 nm) areas of the electromagnetic spectrum:
   a. The device cannot produce accessible laser radiation exceeding an average radiant power of 0.5 W (500 milliwatts) for ≥ 0.25 seconds, and
   b. The device cannot produce accessible laser radiation exceeding an average radiant power of 0.03 J per pulse.

Criteria for Class 4 Lasers

1. The device is capable of emitting laser radiation that is <u>accessible</u> for any duration inherent in its design;
2. For operation in all areas of the electromagnetic spectrum, the device produces accessible laser radiation exceeding an average radiant power of 0.5 W (500 milliwatts) for ≥0.25 seconds.

Attestation:

My signature below attests to the following:

1. The use of lasers as described in this Registration will adhere to the guidelines described in the Ball State University *Laser Safety Manual*.
2. I will inform the EHS of any real or suspected injury that occurs as a result of the use of lasers under my responsibility;
3. I will inform the EHS prior to transferring, re-locating, or disposal of any laser or laser-related component.

SIGN BELOW:

PI or Faculty Signature:	
Date:	

Appendix 5 – Glossary

[A few common terms – for more information contact the LSO]

Administrative Control Measures

Procedures, training and warning signs designed to inform personnel to safety work near laser radiation.

ANSI Z136.1 (2014) and ANSI Z136.8 (2012)

American National Standard for Safe Use of Lasers Series - These documents are the regulatory laser protection standard in the US. The USF Laser Safety Manual is based on these standards.

Aversion Response (Blink 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. The aversion response to an exposure from a bright, visible, laser source is assumed to limit exposure of a specific retinal area to 0.25s or less.

Collecting Optics

Lenses or optical instruments having magnification and that may produce an increase in energy or power density of laser. Such devices may include telescopes, binoculars, microscopes, or loupes. Collecting optics is a hazard in laser labs, and requires particular attention when used around Class 1M or 2M lasers.

Continuous Wave (CW)

A laser operating with 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, administrative (procedural), or personal protective equipment (PPE).

Cornea

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

Critical Frequency

The pulse repetition frequency above which the laser output is considered continuous wave

(CW). For example, for a short unintentional exposure (0.25 s to 10 s) to nanosecond (or longer) pulses, the critical frequency is 55 kHz for wavelengths between 0.40 and 1.05 µm, and 20 kHz for wavelengths between 1.05 and 1.40 µm.

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. A diffuse reflector will cause the reflected laser radiation to be spread over a wider area, and have a significantly reduced hazard level compared to the direct laser beam (see “Specular Reflection”)

Divergence

The divergence is the increase in the diameter of the laser beam with distance from the exit aperture, based on the full angle at the point where the irradiance (or radiant exposure for pulsed lasers) is 1/e times the maximum value. Symbol: φ

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. Many laser cutters are Class 4 lasers in a Class 1 laser enclosure, and require no special laser safety precautions as long as the factory installed safety features remain intact.

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 removing of the protective housing provides additional access to laser radiation above the applicable MPE than possible with the protective housing in place (an embedded laser is an example of one type of enclosed laser).

Engineering Control Measure

Key controls, interlocks, beam housings, shutters, etc. designed to prevent exposure to hazardous levels of laser radiation. Engineering controls are considered the most effective laser safety control measures.

Erythema

Redness of the skin due to exposure from laser radiation

Eye-safe Laser

A Class 1 laser product. Because of the frequent misuse of the term “eye-safe wavelength” to mean “retina-safe,” (e.g., at 1.5-1.6 μm) 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.

Intrabeam Viewing

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

Iris

The circular pigmented structure which lies behind the cornea of the human eye. The iris is perforated by the pupil.

Irradiance

Radiant power incident per unit area upon a surface, expressed in watts-per- centimeter-squared (W/cm-2). Symbol: E

Laser

Light **A**mplification by **S**timulated **E**mission of **R**adiation. A laser produces an intense, coherent (temporally, or spatially, or both), directional beam of light by stimulating electronic or molecular transitions to lower energy levels.

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

Laser Controlled Area (LCA)

An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser radiation hazards. The Nominal Hazard Zone (NHZ) is within the LCA.

Laser-Generated Air Contaminants (LGAC)

Air contaminants generated when Class 4 and some Class 3b laser beams interact with matter. The quantity, composition and chemical complexity of the LGAC depend on the target material, cover gas and beam irradiance. Materials such as plastics, composites, metals and tissues may release carcinogenic, toxic and noxious air contaminants. Ozone is produced around flash lamps and can build up with high repetition rate lasers. Special optical materials used for far infrared windows and lenses may also release hazardous air contaminants.

Laser personnel

USF personal that operates or works around hazardous laser beams.

Laser Pointer

A laser product that is usually hand held that emits a low-divergence visible beam and is intended for designating specific objects or images during discussions, lectures or presentations.

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 which includes a laser

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 a small 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 an optical fiber with a laser beam emitted).

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. The MPE is useful in laser safety calculations, such as determining the nominal hazard zone (NHZ).

Nominal Hazard Zone (NHZ)

Exposure within the boundary of the NHZ to direct, reflected, or scattered laser radiation has the potential to exceed the MPE and thus cause injury. Exposures beyond the boundary of the NHZ are below the MPE, and unprotected exposure will not cause damage to the eye or skin.

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 is not expected to exceed the applicable MPE.

Non-beam Hazard

A class of hazards that result from factors other than direct human exposure to a laser beam. Examples include electrical hazards, compressed gases, chemical hazards from dyes or solvents, sharp objects and fire hazards.

Ocular Fundus

The interior posterior surface of the eye (the retina), as seen upon ophthalmoscope examination.

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 OD is the measure of the laser radiation permitted to pass through a filter. Laser protective eyewear will always specify an OD for specific wavelengths of laser light.

Personal Protective Equipment (PPE)

Equipment worn to minimize exposure to laser radiation. The most common PPE is laser protective eyewear. Skin covering may be required for certain applications work around UV laser radiation.

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 which delivers its energy in the form of a single pulse or a train of pulses. In this standard, 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-switched Laser

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

Repetitive Pulse Laser

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

Retinal Hazard Region

Optical radiation with wavelengths between 0.4 and 1.4 µm, where the principal hazard is usually to the retina.

Safety Latch

A mechanical device designed to require a conscious decision to override the latch to gain entry into a controlled area.

Secured Enclosure

An enclosure to which casual access is impeded by an appropriate means, e.g., a door secured by a magnetically or electrically operated lock or latch, or by fasteners that need a tool to remove.

Spectator

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

Specular Reflection

A mirror-like reflection. The specular reflection of the laser can be as hazardous as the primary laser beam

Standard Operating Procedure (SOP)

Formal written description of the safety and administrative procedures to be followed in performing a specific task/operation.

Threshold Limit (TL)

The TL is an expression of the "resistance factor" for beam penetration of a laser protective device (such as eyewear filters, protective windows, and barriers). The Threshold Limit (TL) of the protective device is generally expressed in W·cm-2 or J·cm-2. It is the maximum average irradiance or radiant exposure at a given beam diameter for which a laser protective device provides adequate beam resistance. Thus, laser exposures delivered on the protective device at or below the TL will limit beam penetration to levels at or below the applicable MPE.

Ultraviolet Radiation

Electromagnetic radiation with wavelengths between 0.18 and 0.40 µm (shorter than those of visible radiation)

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 Light Transmission (VLT)

The percent of visible light transmitted through laser protective eyewear.

Visible Radiation (light)

The term is used to describe electromagnetic radiation which can be detected by the human eye. This term is used to describe wavelengths which lie in the range 0.4 to 0.7 μm. Derivative standards may legitimately use 0.38 – 0.78 μm for the visible radiation range.