LASER SAFETY PROGRAM MANUAL

VANDERBILT
UNIVERSITY

Environmental Health, Safety, and Sustainability (EHSS)

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Revision History Log			
Revision No.	**Date**	**Description**	**Approved by:**
0	4/20/21	Creation of LSM	LSO/LSC
1	6/24/21	New forms added	LSO/LSC
2	8/17/21	Training requirements added	LSO/LSC
3	1/20/22	Appendix on enclosed and interlocked systems added	LSO/LSC
4	8/12/22	UV and LED requirements added	LSO/LSC
5	4/25/2024	Addition of compliance escalation timeline	LSO/LSC
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7	11/10/2025	Updated website links throughout document to reflect new EHS website	LSO

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Vanderbilt University Laser Safety Program

Executive Summary

Lasers and laser systems present a potential safety hazard to students, trainees, staff, and faculty if the devices are not used and/or stored correctly. Safety requirements for lasers and laser systems are listed in this manual and follow the current version of the American National Standards Institute (ANSI) Standard Z136.1, *American National Standard for the Safe Use of Lasers*, and its substandards.

The Vanderbilt University Laser Safety Program (LSP) outlines rules and regulations for the safe operation of lasers and laser systems. It specifies practices to aid laser and laser system users in minimizing their exposure to laser radiation. These measures are taken to comply with ANSI Z136. The LSP can succeed only when each user follows the guidelines in this document.

This LSP was developed to assist Vanderbilt University (VU) personnel in meeting safety and regulatory standard requirements. This manual reviews the responsibilities of laser users, laser classifications, control measures, personal protective equipment, signage/labels, hazards, and additional safety recommendations.

The Vanderbilt University LSP is administered through the Environmental Health, Safety, and Sustainability Department (EHSS) under the authority and guidance of the Laser Safety Committee.

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 beam hazards, such as Laser Generated Air Contaminates (LGAC)
- Determine the following for each laser and/or laser system
    - Nominal Ocular Hazard Zone
    - Required Optical Density (OD) for laser safety eyewear
- Ensure proper labeling of equipment and device locations
    - Including ANSI Z136.1 compliant Laser Safety Door Signs
- Evaluate the hazards associated with each laser and/or laser system
- Provide guidance for the control of these hazards, including engineering controls, administrative (procedural) controls, and personal protective equipment (PPE)
- Outline emergency procedures;
- Outline of organizational responsibilities; and,
- Provide an overview of laser safety through this program and reference materials.

Responsibilities

Laser safety is the responsibility of all faculty, staff, and students who are directly or indirectly involved in the use of lasers and laser systems.

A. Environmental Health, Safety, and Sustainability Office (EHSS)
B. Laser Safety Committee (LSC)
C. Principal Investigator (PI)
D. Laser Safety Officer (LSO)
E. Laser Users (LU)

A. Environmental Health, Safety, and Sustainability Office

- Conducts periodic laser laboratory/facility inspections to ensure that laser safety requirements are being met.
- Assists in evaluating laser hazards and minimizing beam and non-beam hazards.
- Recommends laser safety controls including administrative, engineering, and personal protective equipment (PPE).
- Maintains records of laser locations, class, laser system owners and users.
- Conducts and coordinates general laser safety training for laser operators and incidental personnel.
- Investigates accidents involving lasers and follows up as necessary to preclude recurrence.
- Updates the Vanderbilt University Laser Safety Program as needed.

B. Vanderbilt University Laser Safety Committee (LSC)

- The LSC delegates authority to the Laser Safety Officer to safely manage the use of lasers at Vanderbilt University.
- Approves policies and procedures regarding laser safety within Vanderbilt University.
- In case of serious laser safety use violation, LSC may terminate permission to use Class 3B or 4 laser equipment within the university.
- Outlines the duties of the Laser Safety Officer (LSO).
- Ensures compliance with laser safety standards outlined by the American National Standards Institute (ANSI) Z136 series for laser safety standards.
- Investigates alleged infractions of safety rules or improper use of laser equipment and recommends remedial action.

C. Principal Investigator

The Principal Investigator (PI) has overall responsibility for laser safety in the facilities for which he or she is responsible. In addition to laser safety, the PI is directly responsible for the acquisition, use, and maintenance of all lasers under their authority.
The Principal Investigator is responsible for the following:

Registration and Notification

A PI shall not permit the operation of a new, modified, or manufactured Class 3B or 4 laser under their authority without prior notification to the LSO. The PI must notify the LSO of any changes in operational status, modifications, to any laser equipment that may alter the laser classification. The PI is responsible for registering Class 3B and Class 4 lasers. Click here for the EHS Assist (EHSA) Laser Registration Guide on the VU EHS website.

The PI also needs to:

- Ensure all laser work practices are adequately and safely planned and controlled.
- Maintain an up-to-date laser inventory and list of all laser users in the laboratory.
- Provide, implement, and enforce all safety recommendations and requirements for the safe use of lasers by all laser users in the lab ANSI Standard Z136.
- Provide ongoing annual laser user training in the administrative, alignment, and SOPs for all your lab laser users for both old and new laser or laser-related equipment.
- Notify LSO immediately in the event of being informed of or having knowledge of a laser-related accident, injury, or circumstance that may give rise to a laser-related injury claim due to the use of a Class 3B or 4 lasers.

PIs are responsible for ensuring that all Class 3B and Class 4 open-beam laser users under their authority participate in the medical surveillance program. PIs should submit the names of these users to the Vanderbilt University Laser Safety Officer.

Training

The PI shall ensure that all laser users (LUs) under his/her control, as well as incidental personnel, are properly trained with respect to the safe operation of lasers and are made aware of the associated hazards before they are authorized to operate any Class 3B or 4 lasers or laser systems (see Appendix B: Hazard Classification and Control Measures). PIs shall establish and maintain a list of current LUs that are approved to operate specific types of Class 3B and 4 lasers under their supervision. The PI shall provide “on the job” (OJT) training for each laser system to each laser user of that respective laser system. OJT training completion should be documented.

Principal Investigators must require that their research staff and students complete the VU Laser Safety Video Training module initially and then complete Laser Safety Refresher Training triennially.

Laser Standard Operating Procedures (LSOPs)

The PI is responsible for developing, maintaining, and updating LSOPs for all Class 3B and 4 laser activities, and for giving OJT for each laser system to laser users. The LSOP must be easily accessible, within sight of the laser system, and outline all operating, alignment, and emergency procedures for that particular laser project. Refer to the Standard Operating Procedure Template for guidelines on creating LSOPs.

Accidents and Injuries

The PI shall notify the LSO and the Department Chairperson of all known or suspected laser-related accidents and injuries and report them through Risk and Insurance Management's Origami reporting system. If necessary, the PI will assist in obtaining appropriate medical attention for any employee, trainee, or student involved in a laser accident. During their investigation, the PI shall cooperate with the LSO and the Laser Safety Committee and implement recommendations to prevent recurrence. The PI shall submit a written incident report to the LSO within 5 business days. Also, see section G. Medical Surveillance for more information about actions needed in case of laser irradiation-caused accidents.

Personal Protective Equipment (PPE)

The LSO determines the appropriate eyewear for each laser system. The LSO will calculate the optical density (OD) at the specific wavelength for each laser system. The PI will ensure that personal protective equipment (eyewear and protective clothing) is available, properly maintained, and worn when necessary. Refer to Vanderbilt University **Laser Safety Manual** (See Appendix E: Personal Protective Equipment (PPE)) for more information on personal protective equipment.

D. Laser Safety Officer (LSO)

LSO duties and responsibilities include:

- Operates under delegated authority to manage the safe use of lasers
- Establish and manage daily operations of the VU Laser Safety Program
- Classify or verify the classification of lasers and laser systems
- Develop/coordinate/conduct laser safety training
- Determine the required Optical Density (OD) for laser safety eyewear
- Determine the Nominal Ocular Hazard Zone (NOHZ) and Nominal Hazard Zone (NHZ) for each laser system
- Determines and provides ANSI Z136 compliant Laser Safety Door Signs
- Assist in evaluating, assessing, and controlling hazards
- Review LSP annually and update as necessary to ensure effectiveness in achieving LSP objectives
- Approve LSOPs
- Recommend/approve laser protective equipment
- Review laser installations

- Collaborate on Laser Lab Designs
- Review Medical Examinations checklist
- Maintain records of laser systems, laser safety liaison
- Perform/procure laser safety audits, surveys, and inspections
- Develop a plan to respond to accidental exposures
- Participate in accident investigations involving lasers
- Review non-beam hazards
- Collaborate with EHSS Industrial Hygiene on Laser Generated Air Contaminants (LGAC) such as fumes, nanoparticles, vapors, etc.

E. Laser User (LU)

Personnel who are planning to operate and use Class 3B or 4 lasers are classified as Laser Users (LUs). All LUs must follow the general laser safety requirements outlined in the Vanderbilt University Laser Safety Manual and the LSOP for the specific laser activity they are to perform. LUs are responsible for the following:

Authorization and Training

All users must meet the laser safety training requirement before operating any Class 3B or Class 4 laser. LUs shall only operate Class 3B or 4 lasers after receiving general laser safety training and system-specific OJT from the authorized PI.

Anyone who works within the nominal hazard zone (NHZ) of Class 3B and 4 lasers in Vanderbilt University laboratories, including minors, VUMC researchers, interns/observers, and visitors, needs to complete the laser safety training through the Vanderbilt University Learning Hub. All non-Vanderbilt University persons who do not hold a valid VUNetID can take a publicly available version of the training available on the Vanderbilt University EHS website (https://redcap.link/Training_for_non-VU_persons_in_research).

Compliance

LUs shall ensure they comply with all established safety rules, LSOPs, and other procedural requirements prescribed by the PI and LSO. All laser users are responsible for following the specific hazard controls and notification requirements. Responsibilities include but are not limited to:

- Attend the Vanderbilt University laser safety training class before using any Class 3B and 4 lasers unsupervised.
- Receive appropriate system-specific OJT from the PI.
- Read, understand, sign, and follow lab-specific laser standard operating procedures (LSOPs).
- Wear appropriate Personal Protective Equipment (PPE) in accordance with the campus laser safety program requirements.
- Report any suspected eye or skin exposures to PI, LSO, and Occupational Health/Student Health immediately. Exposures and injuries should also be reported to the Risk and Insurance Management Origami system.

- Follow all other Vanderbilt University or lab-specific safety procedures, requirements, or policies.
- Report any safety concerns to the PI (or designated Lab Contact) or LSO.

All personnel who perform laser beam alignments must have had laser safety training and have received instrument-specific alignment training from the PI or the laser lab supervisor. For more information regarding the Laser Beam Alignment Procedures, please see Appendix C: Laser Beam Alignment Procedures.

Accident Reporting

LUs must inform the PI and the LSO of any apparent safety problems associated with using the laser. All injuries and accidents involving lasers shall be reported to the PI, and medical treatment, if needed, should be sought immediately. The LSO should be informed of the accident immediately after the PI has been notified and medical treatment provided. Injuries and accidents should also be reported to Risk and Insurance Management's reporting system. Refer to Section G, Medical Surveillance, of this manual for more information on emergency procedures resulting from laser irradiation-caused accidents

Laser Safety Program Resources and Forms

- **Laser User Registration**
- **Laser Inventory Registration**
- **Laser Inspection Checklist**
- **Laser Device Disposal and Transfer**
- **Template for Lab-Specific Standard Operating Procedures (SOP)**
- **Warning Signs and Labels**
- **Medical Surveillance**
- **Laser Safety Training**

Laser User Registration

Documentation of laser users and laser inventory are critical elements of an effective laser safety program. Every laser PI **must have a list of** researchers/users who plan to use Class 3B and Class 4 lasers for their research. PIs must register their laser users via the VU EHS Assist platform. Please see https://www.vanderbilt.edu/facilities/ehs/ehsa/ for laser user registration. If a PI cannot find their name in the EHS Assist database as a Laser Permit holder (L-permit), the PI will need to contact the LSO at lasersafety@vanderbilt.edu. EHS Assist automatically informs the VU LSO when a laser PI registers new laser users.

A laser user's registration may be temporarily suspended by order of the LSO or the LSC if they feel that the health or safety of a laser user or the public is in immediate danger.

Laser Inventory Registration

All areas: In research and educational laboratories containing class 3B and class 4 lasers, the Principal Investigator (PI), lead researcher, or supervisor is responsible for registering an accurate and up-to-date laser inventory via EHS Assist. Please see this link for laser inventory registration: https://www.vanderbilt.edu/facilities/ehs/ehsa/

For laser systems comprised of multiple components, each laser in the system must be inventoried separately. Researchers should 1) confirm that their laser inventory in EHS Assist is correct annually, 2) add an additional laser to their inventory in EHS Assist when acquiring a new laser or laser system, and 3) update information when disposing of, decommissioning, or otherwise permanently removing a laser from use. The LSO will provide a due date for the inventory to be completed for new laser-using PIs.

This inventory registration process collects information regarding the type of laser(s), specifications of the laser(s), the proposed use, and the location of the laser(s). For newly acquired lasers or laser systems to be used within research or instructional laboratories, a Laser Registration must be completed by the Principal Investigator for each Class 3B and 4 laser system, as well as any Class 1 Laser System with an embedded Class 3B or 4 laser. All other laser class systems are exempt. If the classification is unknown, refer to the label on the device.

Laser Inspections

Before beginning work, the Laser Safety Officer must inspect all Class 3B and Class 4 lasers. A Laser Inspection Checklist Form is located here: Laser Inspection Checklist .

All laser facilities are inspected annually by the LSO to ensure that the lasers are being operated safely. Laser safety inspections will be documented within the EHS Assist system. The PI will get a notification when the inspection is completed in EHS Assist and must confirm the notification and address any findings.

The LSO maintains records of all inspections performed. If there is an imminent hazard, the LSO has the authority to stop the operation and will advise the PI, EHSS Assistant Vice Chancellor, and Chair of the Vanderbilt University Laser Safety Committee of this action. The PI is responsible for promptly correcting unsafe conditions. The LSO will re-inspect the laser facility to verify the correction of the unsafe condition and will notify the EHSS Assistant Vice Chancellor and LSC chair of unsafe conditions and corrective changes that need to be made.

Laser Device Disposal and Transfer

Once the decision has been made to dispose of a laser or laser system, certain actions must be taken to ensure proper disposal.

- Review the manufacturer's laser system manual for 'CAUTION!' statements that list hazardous materials.
- Remove and properly dispose of any hazardous materials such as mercury switches, oils, and other chemicals that are contained in the laser system. Consider the need to dispose of laser dyes and solvent solutions.

- Disable the laser device by either one of the two methods: remove all means of activating the laser (remove the power cord and power switches) or destroy the laser hardware so it cannot be used again.
- Properly dispose of any chemical, biological, or radioactive wastes generated from laser activities.
- Access the EHS Assist program at https://www.vanderbilt.edu/facilities/ehs/ehsa/ to follow the EHS Assist Laser Inventory Transfer and Disposal Guide to dispose or transfer the laser equipment.
- EHS Assist will notify the Laser Safety Officer (LSO) that the Laser has been removed from the Vanderbilt University Laser Inventory List.

In case of relocation of portable small lasers within a research unit (Research Centers, PI's Laboratories), PIs do not need to initiate a laser transfer. In this case, PIs should take care of all the safety measures and procedures for the destination room before the actual move of portable lasers (appropriate eyewear, control measures, etc.) happens. When a portable laser is used in different environments (for example, moved from university educational/research labs to medical rooms at Vanderbilt University Medical Center -VUMC), it is the PI's responsibility to use correct safety measures when changing the environment of the laser. ANSI Standards for Safe Use of Lasers in Health Care - ANSI Z 136.3's guiding principle, in this case, is to use the laser safety measures required for the environment in which the laser is used. In case of a permanent or long-term move of the lasers or laser systems, access EHS Assist at https://www.vanderbilt.edu/facilities/ehs/ehsa/ and complete the transfer information. The PI is responsible for ensuring safety during the laser transfer.

Subsequent registrations for each facility or mobile laser facility are required whenever additional laser devices are installed or whenever previously registered laser devices are disposed of, altered, destroyed, or permanently moved to new locations. Please initiate the laser transfer process in EHS Assist before installation and use. If you have any questions about the laser disposal and transfer process, please contact the VU Laser Safety Officer at 615- 343-2336 or lasersafety@vanderbilt.edu.

Removal from Registration: The Principal Investigator (PI), lead researcher, or supervisor is responsible for permanently rendering the laser inoperative by disassembly or destruction. Transferring the laser to an institution outside of Vanderbilt University also removes it from the University's control. Once the laser has been rendered inoperable or transferred to another institution, it will be removed from the PI's laser inventory.

Laser Standard Operating Procedure

Laser Standard Operating Procedures (LSOPs) must be developed and posted for Class 3B and Class 4 Laser use. A template/format form for Vanderbilt University Standard Operating Procedures can be found here: Template for Lab-Specific Standard Operating Procedures (SOP).

Each Class 3B and Class 4 laser shall have a Laser Safety Standard Operating Procedure

(LSOP) written for its operation and alignment. An LSOP is a laboratory/laser/research-specific protocol that specifies safe use and proceduresfor the laser system. The LSOPs shall be maintained with the laser equipment for reference by the operator and maintenance or service personnel. LSOP's may be stored in a highly visible location next to a laser system, such as, in a binder, clearly displayed in a wall holder). The LSOP shall include, at a minimum, operating instructions, appropriate personal protective equipment, eyewear parameters and instructions for proper use, interlock instructions, as well as safety procedures, which will include the clearing of all non-essential personnel from the Nominal Hazard Zone (NHZ). The LSOP shall include emergency response actions and clear warnings to avoid possible exposure to laser and collateral radiation in excess of the Maximum Permissible Exposure (MPE) (see ANSI 136.1- 2022). The LSOP shall be available for inspection by the LSO.

Warning Signs and Labels

A thorough system of warning signs and labels is in place to provide suitable awareness of laser hazards. This system warns persons of the presence of hazardous laser radiation and related fire, chemical, and electrical hazards. DO NOT remove any hazard identification labels from a laser system.

The LSO shall ensure that any applicable area signage and equipment labels are in place and legible. The purpose of a laser area warning sign is to convey a rapid visual hazard-alerting message.

The four types of signs are: DANGER, WARNING, CAUTION, and NOTICE.

- DANGER signs and labels shall be used for kilowatt-power-level Class 4 lasers.
- WARNING signs and labels shall be used for all other Class 3B and Class 4 laser systems.
- CAUTION signs and labels shall be used for Class 2, 2M, and 3R lasers.
- NOTICE signs shall only be used temporarily to control access to an area where a laser is undergoing service or maintenance. Such signs are not appropriate or allowed on permanent signs warning of a laser hazard or hazardous situation.
- Equipment labels for Class 3B lasers and laser systems shall say, “Laser Radiation – Avoid Direct Exposure to Beam.”
- Equipment labels for Class 4 lasers and laser systems shall say, “Laser Radiation – Avoid Eye or Skin Exposure to Direct or Scattered Radiation.”
- Signage and labels shall be displayed where they best serve to warn laser users and visitors.
- It is the Department’s, PI’s, or laser laboratory supervisor’s responsibility to obtain and install all laser safety signs and labels. See Appendix D: Warning Signs and Labels.

Medical Surveillance

Medical Surveillance is recommended for Class 3B and Class 4 laser users in accordance with section 6 of ANSI Z136.1 Standard for the Safe Use of Lasers. All individuals who utilize Class 3B or Class 4 lasers or laser systems should have an eye examination by an ophthalmologist. This

exam should be performed per the following schedule:

- Entrance exam: Should be performed before using such laser systems at Vanderbilt University.
- Within 48 hours of a suspected eye exposure to laser radiation.
- Exit exam: This exam should be performed after completing laser-related research/engineering work at Vanderbilt University.

The purpose of medical surveillance is to establish a baseline against which damage can be measured in the event of an accident and to identify workers who may be at special risk from chronic laser exposures. Users of Class 3B and 4 laser systems should consider an initial medical evaluation by an opthalmologist before using or operating a registered laser.

A VU individual that has a suspected or actual laser-induced injury should immediately visit Occupational Health as medical exams should be performed by a medical professional as soon as practical, preferably within 48 hours. If Occupational Health is closed or cannot perform a medical exam, then the individual should report to the VUMC Emergency Department. For laser-induced eye injury and particularly retinal injury by lasers emitting in the retinal hazard region, an ophthalmologist or an eye care specialist with training and experience with laser-induced eye injuries should perform the examinations. A comprehensive differential diagnosis shall be provided that assesses treatment, prognosis, and causal factors commensurate with the observed symptoms, functional changes, and the exposure situation, that is, wavelength and emission characteristics.

In the event of a laser accident or injury, please see below the list of important information below:

- Shut down the laser system;
- Provide for the safety of personnel as necessary;
- If there is a fire, leave the area, pull the 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, the following actions may be taken:
    - Visit the Vanderbilt Occupational Health Clinic (640 Medical Arts Building: 615-936- 0955).
    - Vanderbilt University Emergency Phone number: **(615) 421-1911** (for after-hours emergencies and/or need of an ambulance)
    - If exposure occurs after hours, report to the **VUMC Emergency Department** and the Occupational Health Clinic for follow-up the next business day.
    - You may also contact **VUMC Eye Institute (VEI)** at **(615) 936 2020**. **At VEI, they have available 24/7 a physician and a nurse**.

- **Students** should report to the **Vanderbilt Student Health Center, Zerfoss Building (615- 322-2427)**. If exposure occurs after hours, a student can report to the VUMC Emergency Department.

A report must be completed in the Risk and Insurance Management's reporting system for issues where medical attention is sought. If online access is unavailable or difficult, call 615-936-0660 to request assistance.

Accident Investigation: Upon notification of an accident involving a laser, the LSO will investigate. Steps of the investigation include:

- LSO, in cooperation with the PI/LSC, interviews injured user(s) and witnesses.
- LSO, in cooperation with the PI/LSC, examines incident location for factors associated with the accident/exposure.
- LSO, in cooperation with the PI/LSC, determines the possible causes of the accident/exposure and provides recommendations to prevent recurrence.
- PI/Lab supervisor takes corrective action to prevent the accident/exposure from recurring. These corrective actions are documented and maintained by the PI and made available to the LSO upon request
- LSO documents the incident and subsequent investigation in an incident report shared with the PI/lab supervisor.

Laser Safety Training

All users of Class 3B and 4 lasers, including those present during open beam laser operation, must complete the online training module available through Oracle Learn entitled "VU Laser Safety Video Training." This includes all VU undergraduate, graduate/professional students, trainees, staff or faculty, and VUMC faculty or staff. The university will not accept training completed elsewhere to meet this requirement. For more information on laser safety training or to have this module assigned to your lab group, please contact the LSO at lasersafety@vanderbilt.edu. For non-VU persons without a VUnetID , the public version available at https://redcap.link/Training_for_non-VU_persons_in_research should be completed.

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

- Read Vanderbilt University Laser Safety Program Manual
- Read all relevant SOPs
- Read all manufacturer-supplied safety instructions for relevant laser systems
- Receive PI training on the specific laser equipment to be used
- View the Vanderbilt University Laser Safety online presentation (or equivalent in-person training)

For non-compliant PIs and users, the LSP has a Laser Safety Training Non-compliance Escalation Process (please see Appendix H).

Overall management and employee responsibilities

Electrical Hazards. Operating any electrical system may give rise to electrical hazards; consequently, proper grounding and insulation are imperative. Protection against accidental contact with energized conductors by means of a barrier system is the primary methodology to prevent electric shock accidents with laser equipment. Additional electrical safety requirements are imposed upon laser devices, systems, and those who work with them, by the US Department of Labor, OSHA, the National Electrical Code (NFPA 70), and related state and local laws and regulations.

Because of the hazard of electrocution, it is recommended that lab personnel who are also Qualified Workers under the OSHA Electrical Safety Standard take online courses (Vanderbilt University OLC) in Basic Rules of Electricity, Electrical Safety Principles, cardiopulmonary resuscitation (CPR)) and be trained in the proper rescue techniques to follow in the event of electrocution. This training type is especially important when lab-built lasers and power supplies are in use, or where lab personnel modify, repair, or maintain laser systems. All laser service personnel, research personnel, and their assistants working with kilovolt-level high voltages should take those courses.

OSHA standards define the "qualified person" who works with electrical systems. A qualified person, according to OSHA standard 1910.399, is "one who has received training in and has demonstrated skills and knowledge in the construction and operation of electric equipment and installations and the hazards involved."

Refresher Training
All Class 3B and 4 laser users must refresh their knowledge of laser safety every three years from initial training. Laser users can fulfill this requirement by completing the general online laser safety training course again or a refresher training module. Refresher or remedial training may also be required of a laser user if they have been observed repeatedly engaging in unsafe practices and/or fail to observe Vanderbilt University Laser Safety Program or LSOP.

Other Training
Labs using amplified multi-watt ultrafast laser systems require additional safety analysis and assessment by the LSO.

Supplementary laser safety training is available from Vanderbilt University EHSS upon request if desired.

VU EHSS thanks you for your cooperation. If you have any questions, please contact the Vanderbilt University Laser Safety Officer at lasersafety@vanderbilt.edu

Additional Information

These are useful links for additional information regarding laser safety products and standards that you might need during the implementation of the laser safety program:

The Laser Institute of America

Kentek Laser Safety Products

Rockwell Laser Industries, Inc.

Laservision Laser Safety Products

Thorlabs Laser Safety Products

Appendix A: List of links to the Laser Safety Manual and EHS Assist

1 Laser Safety Manual
2 Laser Inspection Checklist
3 Template for Lab-Specific Standard Operating Procedures (SOP)
4 EHS Assist

Appendix B: Hazard Classification and Control Measures

Hazard Classification

Laser hazard classification was developed to aid laser users in assessing the potential hazards of laser systems. ANSI Z-136.1-2022 outlines a simplified method that is used throughout the world. Lasers are divided into classes depending on 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 specific to that class. Understanding laser classification is a fundamental prerequisite for discussing 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.

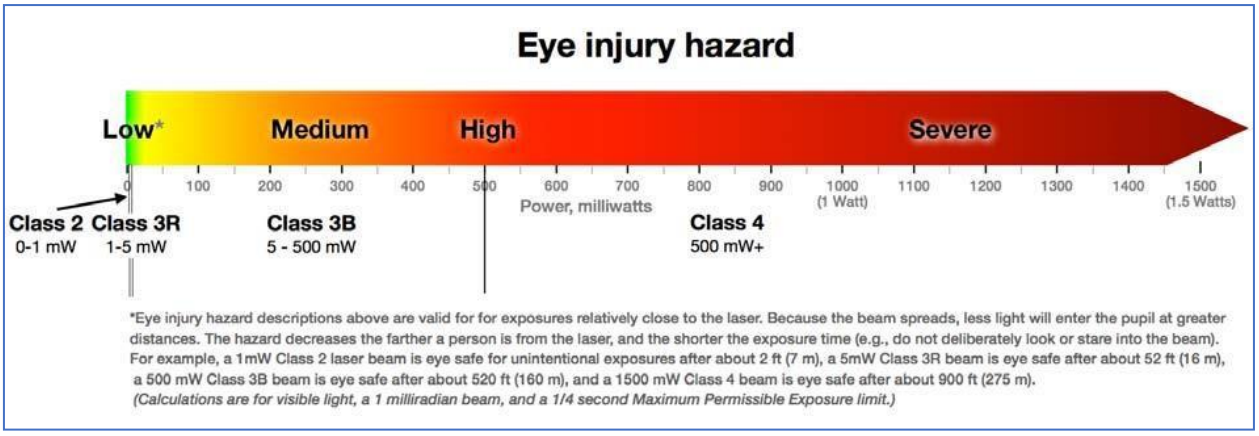
Classification of lasers or laser systems shall be based on the maximum output available for the intended use. The classification of lasers or laser systems capable of emitting numerous wavelengths shall be based on the most hazardous possible operation.

Any completely enclosed laser is classified as a Class 1 laser if emissions from the enclosure does not exceed the maximum permissible exposure (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.

Laser 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 (2022)
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 low-power lasers and laser systems cannot emit radiation levels greater than the maximum permissible exposure (MPE). Class 1 lasers cannot produce 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 from any control measures other than to prevent potentially hazardous optically aided viewing.

Class 2 Laser Systems
Class 2 lasers emit in the visible portion of the spectrum (400 – 700 nm), and eye protection is normally afforded by the human eye aversion response. Prolonged exposure can damage the eye 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. The “M” designates that the laser class is potentially hazardous if viewed through 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 (400 to 700 nm) 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, or laser-generated air contaminant (LGAC) production hazard. Class 3B lasers and laser systems have an accessible output between 5 – 500 mW for continuous wave systems and less than 0.03 Joule (J) for pulsed lasers that have a pulse width of less than 0.25 seconds. Engineering controls are required for Class 3B lasers.

Class 4 Laser Systems
Class 4 lasers produce high- optical powers and can cause damage to the eye and skin from direct viewing, specular, and diffuse reflection; they may also 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/pulse, 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 the normal operation of the laser system. When either maintenance or service is performed, additional control measures are often necessary.

Control measures are classified into engineering control measures and administrative or 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 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 Vanderbilt University	
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, in which case it 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 exposure 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, then 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 laser operation. For pulsed lasers, interlocks shall be designed to prevent unintentional firing of the laser. An example would be 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, using shutters). Service access panels that allow access to the beam during normal operation shall either be interlocked or require a special tool for removal and have an appropriate warning label. All commercially manufactured lasers come equipped with such interlocks and labels.

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

Laser Use without Protective Housing

In the research environment, lasers are often used without a protective housing in place. Optical devices mounted on optical tables are typically employed to manipulate the laser beam. The LSO will evaluate the hazards in this environment 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 allow access to a laser in operation must be 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 door signage. Class 3B and Class 4 laser labs shall have a lighted sign at the doorway indicating the “laser beam 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
An enclosed beam path for a laser is a physical structure or system that contains the laser beam within a controlled, closed environment to prevent accidental exposure to the beam. This path type is used primarily for safety purposes, especially in environments where lasers are used in a laboratory or industrial setting. The enclosed path ensures that no part of the beam is exposed to personnel or the surrounding area, which can reduce the risk of injury from direct or scattered laser radiation.

Temporary Enclosed Beam Path
A provisional or short-term enclosure designed to contain a laser beam for a specific task or project, ususaly for maintenance or service. When the protective housing requirements are temporarily relaxed, 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 if 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 paid 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
Class 3B and 4 lasers should 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 laser classification and identify the aperture(s) when the laser beam is emitted.

Activation Warning Systems – Inside the laser control area, an alarm (for example, an audible sound), a warning light (visible through protective eyewear), or a verbal "countdown" command must be used with Class 3B and 4 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 the operation of Class 3B or 4 lasers, the warning system must be activated at a sufficient time prior to the 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 operation and maintenance conditions.

Window and Door Barriers – All windows and doorways must be either controlled or restricted in such a manner as to prevent the 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 3B or 4 laser system. The written SOP shall be maintained in a visible location near the laser system. Refer to Template for Lab-Specific Standard Operating Procedures for guidelines on creating SOPs.

- *Output Emission Limitations* – The minimum laser radiant energy or laser power level required for the application shall be used. Operate a laser at the minimum power necessary for any operation. Beam shutters and filters can be used to reduce the beam power. Use a lower power or lower class laser when possible during alignment procedures.

- *Education and Training* – All individual users that operate Class 3B or 4 lasers shall have the appropriate general and specific training in laser safety that is commensurate with the level of potential hazard and outlined in this manual.

- *Authorized Personnel* – Class 3B and 4 lasers shall be operated, maintained and serviced only by authorized personnel. The PI of the laser system is responsible for authorizing individual users and maintaining a listing of current individual users.

- *Alignment Procedures* – Alignment of laser optical systems must be performed in such a manner that the primary beam, or a specular or diffuse reflection of a beam, does not expose the eye to dangerous levels of laser radiation. The alignment procedures shall be outlined in the SOP. The use of low power visible lasers (Class 1 or 2) for path simulation of higher power visible or invisible lasers is recommended. See Appendix C: Laser Beam Alignment Procedures 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. See Appendix E: Personal Protective Equipment (PPE) 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 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

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

The protective enclosure and the laser system must be designed and fabricated so that if a failure occurs, the system will continue to meet the requirements for an enclosed laser.

Attenuated Viewing Windows

Use viewing windows containing a suitable filter material that will attenuate the transmitted laser radiation to levels below the MPE under all conditions of operation.

Warning Signs and Labels

- Label the enclosure with "Caution-Enclosed Laser" signs.
- Attach a label directly to the laser that will display the laser classification in the absence of the enclosure. Make sure that the warning label is immediately visible before enclosure is opened.

Controlled Areas

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

All personnel within the laser controlled area must be provided with appropriate protective equipment and are required to follow all applicable administrative controls. The area designated as a laser controlled area for Class 4 lasers shall meet the requirements of a Class 3B control area and the following additional control measures:

- *Rapid Egress and Emergency Access* – There must be provisions for rapid egress from a laser controlled area under all normal and emergency conditions. Any laser controlled area interlock system must not interfere with emergency egress. In addition, access control measures must not interfere with the ability of emergency response personnel (fire, paramedical, or police) to enter the laser controlled area in the event personnel inside become injured or incapacitated.

- *Laser Activation Warning Systems* – Procedural area or entryway controls must be in place to prevent inadvertent entry into a laser controlled area, or inadvertent exposure to the active laser beam. These measures shall include a visible sign and/or audible warning sign or signal at the entrance to the laser controlled area to indicate when the laser is energized and operating.

- *Limited Access* – Class 4 lasers must have a master switch that is controlled by a key or code. Access to the key or code must only be provided to authorized and trained individual users.

- *Deactivation Switch* – For emergency conditions, a control disconnect switch, panic button or equivalent device must be available for deactivating the laser. The switch shall be clearly marked and readily accessible to all laser personnel. When activated, this button will power down the laser or will reduce the output power of the laser to levels below MPE. The following are acceptable examples of "panic buttons".

    - Key switch to deactivate the laser
    - Master switch on power source to turn off power
    - Red mushroom-type button on control panel or other readily accessible location within the area

- *Entryway Controls* – Never direct a beam toward an entryway. Locking entryway doors as a means of access control is not acceptable because it is contrary to the principle of permitting rapid egress or emergency access. Entryway 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.

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.

Appendix C: Laser Beam Alignment Procedures

The most hazardous activity to perform with a laser is the alignment process; of all the types of activities performed with lasers, the process of aligning a laser beam has caused the most injuries to individuals. The techniques for laser alignment listed below are designed to help prevent incidents or accidents during the alignment of the laser or laser system. All personnel who perform laser beam alignments must have had laser safety training and received direct instrument/setup training from PI or laser lab supervisor.

EHSS offers laser alignment training as a service for VU researchers. Request training by emailing lasersafety@vanderbilt.edu.

Pre-Alignment Preparation

- Review the Safe Operating Procedure (SOP), section on 'Alignment Procedures' for the laser
- or laser system you are going to be working on.
- Have the authorization to conduct the alignment from the Principal Investigator (PI) / supervisor (LS) before starting the alignment.
- Think before you do; have all equipment and materials that will be needed present prior to beginning the alignment, do not forget beam location devices such as sensor cards, viewers, or cell phones, and finally DO NOT FORGET your laser eye protection (LEP)! A check list can be very helpful.
- Remove all potentially reflective items from your person: watches, rings, ID badges,
- necklaces, cell phones, and jewelry before beginning any alignment activities.
- Remove all unnecessary equipment, tools, and combustible materials (if the risk of fire exists) from the work area, to minimize the possibility of stray reflections and non-beam incident or accidents.
- Do not use any tool that is reflective; remember, reflectivity outside of the visible can vary widely. Be proactive to test.
- An alignment notice sign, with the appropriate class warnings (Class 3B or Class 4) must be posted at the entrance to the laser facility or as part of a temporary laser control area, indicating the laser alignment is occurring.
- Limit access to the room or area to authorized personnel alignment personnel only.
- Best practice is to have at least one other person present to help with the alignment process.

Alignment Method Recommendations

- There shall be no intentional intrabeam viewing with the eye.
- Coaxial low-power lasers should be used when practical for alignment of the primary beam path.
- If a low power laser cannot be used to simulate the beam path of a high-power laser, operate the high-power laser at the lowest possible power level needed to accomplish the alignment.
- Reduce primary beam power with ND filters, beam splitters or dumps, or by reducing power at the power supply. Whenever practical, avoid the use of high-power settings during the alignment process.
- Laser protective eyewear shall always be worn during the either alignment, full protection for invisible beams or alignment LEP for visible beams.
- Skin protection should be worn on the face (full shield), hands (gloves), and arms (lab coat) when aligning at high intensity UV wavelengths.
- Keep the laser beam enclosed as much as practical, during alignment and use.
- Keep the shutter closed as much as practical during course adjustments.
- All optics and optics mounts must be secured to the table.
- When adding or removing optics from the beam path close the shutter (turn off the beam) BEFORE removal or addition.
- All beam stops must be secured to the table with screws or strong magnets. All locations or areas where the beam leaves the horizontal plane shall be blocked and labeled.
- Individuals who perform an alignment are responsible for locating and containing ALL stray reflections.
- All stray or unused beams are to be terminated with appropriate beam containment devices.
- Invisible beams are to be viewed with appropriate beam location devices for the laser they are aligning, (IR/UV cards, business cards, card stock, flash paper, IR/UV viewers, shot paper, thermal paper, phosphor cards, Polaroid film, cell phone, Wi-Fi cameras or by a similar technique. Always be aware that some viewing materials may produce specular reflections or may smoke or burn.
- Pulsed lasers are to be aligned by firing single pulses when practical.
- Additional laser alignment controls are encouraged, such as pinholes, fluorescent paper,

and similar methods.

- Place beam blocks behind optics like turning mirrors to terminate beams that might miss the mirror during alignment.
- Walk (place a beam block behind the next optic in a path before removing the beam block from the proceeding optic) beam blocks down a beam path when aligning multiple optics.
- Wear laser goggles instead of glasses when conducting alignment at a location with a lot of protruding objects that might push the glasses up when the person bends over to view the alignment spot. Make all efforts though to keep interfering objects out of the way.
- If your fully protective laser eye protection makes it difficult to see the alignment beam, contact the LSO for assistance selecting alignment laser eye protection.

Post Alignment

- Check once again for any stray beams or reflections and block them.
- Return optical path to its normal operational state; remove alignment optics, coaxial laser, beam blocks, tools and other items that were used during the alignment process.
- Make sure all optics are properly secured.
- Restore all normal laser hazard controls when the alignment is completed, these can include replacing all enclosures, covers, beam blocks, barriers and resetting affected interlocks to proper operation.
- Test interlock system to insure it has been restored to full operational condition.
- Check to insure nothing obstructs in the beam path and all lose items have been removed
- Notify all laboratory personnel that alignment process is complete and full power operation are ready to start.
- Remove the alignment notice sign.

Appendix D: Warning Signs and Labels

Signs and Labels

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

Laser Caution / Warning / Danger Signs

A sign must be posted near all entrances to any area or laboratory that contains a Class 2, 2M, 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 3B 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.

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

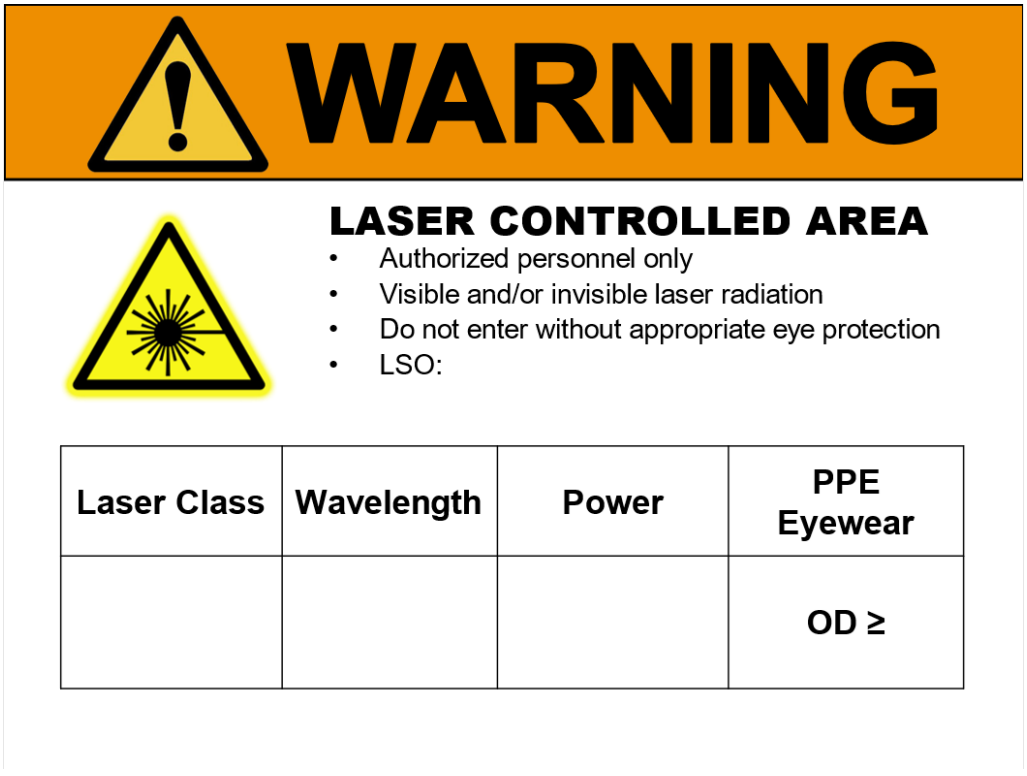
- **“CAUTION”** indicates a hazardous situation that, if not avoided, could result in minor or moderate injury. The signal word “CAUTION” shall be used with all signs and labels associated with Class 2, 2M and 3R lasers. “CAUTION” should be printed in black letters on a yellow background.

- **“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.

- 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.

- 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 Z136.1-2022, 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 Z136.1-2022, an area which contains a Class 3R, 3B and 4 lasers 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.”

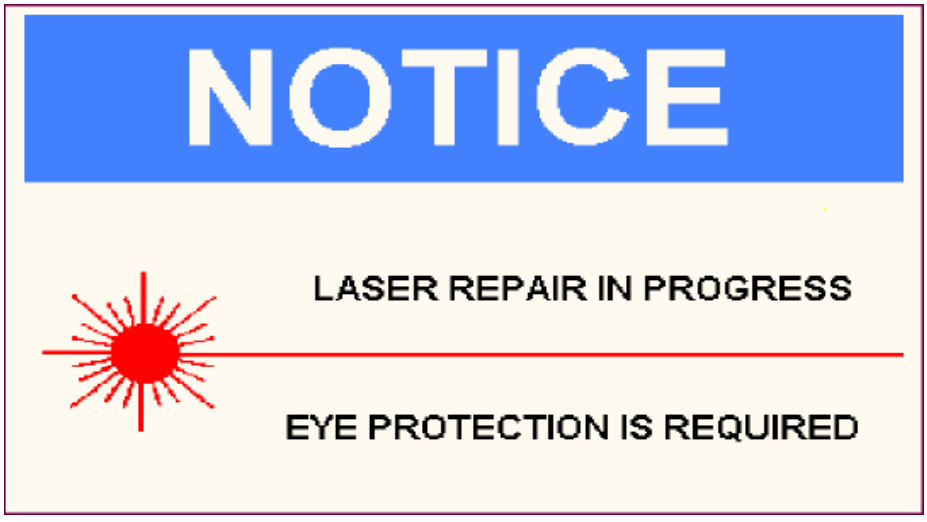
In accordance with ANSI Z136.1-2022, an area which contains a Class 4 (multi-kilowatt) laser or laser system shall be posted with an appropriate red “Danger” sign. “Danger” should be used with lasers where the exposure “will result in death or serious injury.

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

- The hazard class of the laser controlled area
- Name and contact information for PI and LSO

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 1, 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.

Appendix E: Personal Protective Equipment (PPE)

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 shall be documented in the laser SOP.

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

Protective Eyewear
Notice: Even if you are wearing protective eyewear, never look directly into any laser beam. [See ANSI Z136.1-2022, 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.

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:

- Wavelength(s)
- Mode of operation (continuous wave or pulsed)
- Maximum exposure duration (assume worst case scenario)
- Maximum irradiance (W/cm2 for CW) or radiant exposure (J/cm2 for pulsed)
- Maximum permissible exposure (MPE)

- 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:

- Visible light transmission (VLT)
- Effect on color vision
- Field of view provided by the design of the eyewear
- Reversible bleaching of absorbing media
- Need for prescription lenses
- Fit and comfort
- 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) requirement.

The following guidelines are suggested for maximum eye protection.

- Whenever possible, confine (enclose) the beam (e.g., use beam pipes) and provide

- nonreflective 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

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

Skin injuries from lasers primarily fall into two categories: thermal injury (burns) from acute exposure to high power laser beams and photo-chemically induced injury from chronic exposure to scattered ultraviolet laser radiation. Effects can be minor to severe sunburn, increased risk of skin cancer.

Skin protection can best be achieved through engineering controls, easily prevented through proper beam management and hazard awareness. If potential skin damaging exposures exist, skin covers are recommended. Minimize exposure to UV radiation by using beam shields and clothing (opaque gloves, tightly woven fabrics, laboratory jacket or coat) which attenuate the radiation to levels below the MPE for specific UV wavelengths. Consider flame-retardant materials for Class 4 lasers. Special attention must be given to the possibility of producing undesirable reactions in the presence of UV radiation (formation of skin sensitizing agents, ozone, etc.). Window drapes should be used to prevent skin exposure to persons outside of the laser laboratory.

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.

List of Laser Protective Eyewear Manufacturers or Vendors:

- Rockwell Laser Industries
- Kentek Corporation
- Thorlabs
- Edmund Scientific Co.
- Ealing Electro- Optics, Inc.
- Laser Vision

Appendix F: Facilities with enclosed and interlocked Class 3B and Class 4 lasers

VU facilities that house optical imaging/scanning microscopes with attached Class 3B and Class 4 lasers and laser cutters with enclosed/interlocked Class 3B or Class 4 lasers have to follow the guideline described below.

Please see the manual of your device for the laser hazard class. If your manual describes your system as Class 2M then your system doesn't does not require the typical control measures for the Class 3B and Class 4 lasers, because class 3B and 4 lasers used with the microscope and laser cutters are considered "enclosed", and laser beam paths are enclosed within tubes, covers, and protected with interlocks. Microscopy laboratory managers or laboratory staff members should caution the microscope users not to disconnect lasers and not to open laser beam covers and tubes. Regular users of these devices don't need to take the Laser Safety Training. Only the laboratory managers and staff members are required to complete the Laser Safety Training.

For laser cutters it is very important to have good air ventilation of the device to avoid Laser Generated Air Contaminants (LGAC).

When a microscope or a laser cutter is maintained/serviced or aligned by a VU personnel, then the person needs to meet the laser safety requirements for operating a Class 3B or Class 4 lasers. The laboratory needs to have appropriate eyewear for the lasers in case the lasers are in process of being maintained or aligned by a campus personnel.

Appendix G: LED Device Policy

In recent years there have been significant improvements in the power and efficiency of light-emitting diodes (LED). Along with “white” LEDs, significant progress has also been made in production of ultraviolet (UV) and infrared (IR) LEDs. These improvements have raised concerns for the safety of the radiation emissions from handheld LEDs.

Safety requirements for UV emitting LEDs are currently being developed by American National Standards Institute (ANSI); thus, there is currently no single source of guidance. As soon ANSI publishes their guidance, Vanderbilt will implement it in the Laser Safety Program and Manual.

The Laser Safety Committee has approved the following requirements for LED emitters:

- Research laboratories using any LED device (UV, IR “white light” and visible) with an emitting power of more than 500 mW, must report the device to the VU Laser Safety Officer at lasersafety@vanderbilt.edu.
- Laboratories must take necessary safety measures while working with the LED emitters as discussed below.

Safety measures necessary for working with LEDs

Limiting Irradiation Exposure

Control measures to limit exposure to eyes and skin and to prevent cumulative exposure must be in place and documented in a Standard Operating Procedure (SOP). The precautions needed will depend on the risk assessment. Control measures designed to eliminate the risk of exposure to UV, IR and visible irradiation at its source, such as engineering and administrative controls and personal protective equipment (PPE), must be implemented wherever possible. A key element in achieving the goal of reduced radiation exposure is worker training and awareness.

A Standard Operating Procedures Template is available at VU EHS website: www.vanderbilt.edu/facilities/ehs/radiation-laser-safety/ to help users to adept it for their use.

Engineering Controls

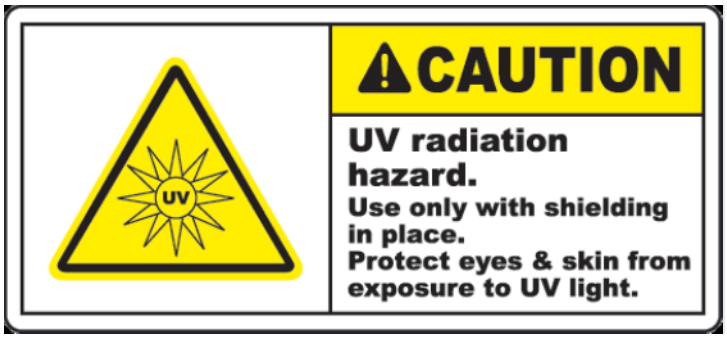
- Having equipment located in a separate room, alcove, or low-traffic area of a lab is ideal. To avoid exposure to other personnel, avoid placing equipment in the vicinity of desk areas or other equipment.
- The use of enclosures is the preferred means of preventing irradiation exposure. Where it is not practicable to fully enclose the UV source, use screens, shields, and barriers, such as the following:
    - Metal sheet (e.g., aluminum or steel that has been coated black or is black anodized) that is used to minimize the researcher's exposure to reflected UV, IR and visible light.
    - Rigid plastic film (transparent, UV-blocking plastics, typically polycarbonate or acrylic) that is commonly used to create shielding yet maintain transparency.
    - Flexible film (UV-blocking flexible urethane film) that is used to quickly create work-station shielding.

Administrative Controls

Typical administrative controls include limiting access, ensuring that people are aware of the potential hazards, and providing training and safe working instructions for users.

Hazard Warning Signs

Warning signs are necessary to inform about the risk of exposure during use and maintenance. Warning signs should be used where applicable to indicate the presence of potential UV radiation hazards, access restrictions, and the need for PPE.


UV
CAUTION
UV radiation hazard.
Use only with shielding in place.
Protect eyes & skin from exposure to UV light.

Appendix H: Laser Safety Training Non-compliance Escalation Process

If a Laser PI or Laser User does not comply with safety training requirements, EHSS will follow the escalation process outlined in the figure below. If the PI or user is still not compliant after the extensions and notifications outlined in this process (LSC chair, department chair, and then Dean's office), their laser privileges will be revoked.