ENVIRONMENT, HEALTH & SAFETY
UNIVERSITY OF MICHIGAN

Laser Safety Program

Guideline

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Applies To: Laboratory faculty, staff, students, and visitors at University of Michigan campuses.

The topics in the body of this document pertain to all 3B and Class 4 lasers, and Embedded Class 3B and Class 4 lasers, in labs and other non-clinical University of Michigan facilities whether purchased, borrowed, "homebuilt," or brought in for use by others.

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Laser Safety Policy Statement

All University of Michigan (U-M) personnel who actively use Class 3B, Class 4, and Embedded Class 3B or Class 4 *lasers* in labs and other non-clinical U-M facilities **must** comply with the requirements contained in this document and complete all required training.

The Laser Safety Program practices, policies, and procedures, including an escalation policy, are consistent with SPG 605.01 Safety, Health, and Environment Policy, EHS Academic Laboratory and Research Safety Policy, and *ANSI Z136.1-2022 Appendix A (Laser Safety Programs)*. All personnel who actively use Class 3B, Class 4, and Embedded Class 3B or Class 4 lasers **must** adhere to the roles and responsibilities listed in these documents.

The *Laser Safety Officer* will provide quarterly updates to management regarding the status of the Laser Safety Program and notify EHS management of laser safety issues as a result of laboratory inspections.

Laser Safety Program

The Laser Safety Program is derived from government regulations and the EHS and Office of Research Ethics & Compliance Academic Laboratory and Research Safety Policy. It provides guidance for safe handling of Class 3B and Class 4 lasers and a template for *standard operating procedure*s (SOP) that lab directors and *laser safety supervisors* can customize, then implement in their department.

Related Laser Safety Program Documents

- Laser Requisition Form
- Laser Registration
- Laser Safety Program Standard Operating Procedure Template
- Laser Disposal Guideline

Additional Resources

- Chemical Hygiene Plan
- Chemical Hygiene Plan Document Binder
- Lockout/Tagout – Control of Hazardous Energy Sources
- Personal Protective Equipment, General

Training Requirements

All Lab Directors (LD) and Laser Safety Supervisors (LSS) **must** be trained in the safe use of lasers prior to beginning work with Class 3B, Class 4, or Embedded Class 3B or Class 4 lasers. All laser users (LU) including technicians, engineers, maintenance and service personnel, and any other persons working with or potentially exposed to Class 3B and Class 4 laser radiation, **must** be trained in the safe use of lasers. LUs are recommended but not required to complete Embedded Laser Safety training (EHS_RSS044w) if they are only operating an embedded laser under normal conditions.

Laser safety training is offered by EHS via My LINC. After completing the initial training, a refresher will be required every 2 years. Individuals that are due for refresher training will be notified by e-mail.

- Online Laser Safety Basic Training (EHS_BLS005w) consists of the following topics:
  - Fundamentals of laser operation (physical principles, construction, etc.)
  - Bioeffects of laser radiation (eye and skin hazards)
  - Significance of specular and *diffuse reflections*
  - Non-beam hazards.
  - Laser classification systems
  - Control measures (engineering, administrative, personal protective equipment)
  - Overall responsibilities of management and personnel
  - Medical surveillance
- Online Embedded Laser Safety Training (EHS_RSS044w)
  - Lasers and their dangers
  - Embedded lasers and their advantages
  - Injury response procedures
  - Safety precautions when using equipment containing an embedded laser
- Lab-specific training:
  - This training **must** include reviewing the lab's SOP, other operating procedures, and any other safety information and **must** be given by the LD or LSS. Personnel **must** sign off that this training was completed and the proof-of-training document **must** be maintained in a Laser Safety section of the lab's Chemical Hygiene Plan (CHP, "Blue Binder").

Training for Specific Personnel

- Laser users working with Class 3B and Class 4 laser radiation in the Physics Department at Randall **must** take additional training. Contact Steve Katnik (skatnik@umich.edu) in the Physics Department for this training.
- Laser users at the Center for Ultrafast Optical Science (CUOS) **must** take additional training. Contact John Nees (nees@umich.edu) at CUOS.
- The LD and LSS, in addition to the above mentioned training, **must** also have knowledge of the following topics:
  - Laser terminology.
  - Types of lasers, *power*/*energy*, *wavelengths,* and pulse duration and pulse length, if applicable.
  - Determining the appropriate eyewear for laser users.
- Training Required for Service Personnel. There are significant potential hazards working on lasers with exposed high voltages, the capability of producing potentially lethal electric currents, or both.

- Service personnel **must** know how to shut down all electrical and other power sources before work commences.
- U-M service personnel **must** take Lockout/Tagout – Control of Hazardous Energy Sources training.
- U-M personnel exposed to active Class 3B or Class 4 laser radiation when servicing a Class 1 System **must** have appropriate safety training (EHS_BLS005w). Service personnel from outside U-M **must** have received appropriate laser safety training from their employer before servicing lasers on U-M property.

Additional Training

Additional training is available from commercial vendors. Laser personnel could enroll in a laser safety class for more formal training with the:

- Laser Institute of America (LIA)
- Rockwell Laser Industries
- Kentek

Training Records

All training **must** be documented for record keeping purposes. Departments are responsible for maintaining the Laser Safety Basic Training and lab-specific training records, which may be kept in the Laser Safety Section of the CHP ("Blue Binder").

Hazards

There are biological risks and potential hazards associated with using lasers. In addition to laser *beam* hazards, laser users and service personnel are also potentially exposed to non-beam related hazards.

Laser Hazard Classification

Lasers are classified based on their capabilities to produce injury to personnel. This classification includes seven classes of lasers: 1, 1M, 2, 2M, 3R, 3B, and 4.

- Class 1 Lasers - These are incapable of producing damaging radiation levels. Class 1 applies to any laser or laser system appropriately designed to assure that accessible laser radiation levels do **not** exceed the *accessible emission limit* (AEL) for a Class 1 laser under normal use. Examples include an *embedded laser* system with interlocks, laser printers, and CD players.
- Class 1M - The M in Class 1M is used to indicate that the laser may exceed Class 1 AEL if magnifying optics, such as binoculars, are used. An example of a Class 1 M laser would be a fiber optic communication system.
- Class 2 - These are low power (< 1mW) lasers that emit only in the visible spectrum (400-700 nm). They are only hazardous if the viewer overcomes their natural *aversion response* (not blinking or not turning the eyes away from the stimulus) to bright light. An example of a Class 2 laser would be a supermarket barcode scanner.
- Class 2M - The Class 2M designation is the same hazard level as Class 2, but is potentially hazardous when viewing with optical aids. Examples would include levelling instruments and some construction industry lasers.

- Class 3R - Class 3R lasers have a power ranging from 1-5 mW. The laser light is unlikely to be hazardous except when the viewer overcomes their aversion response. Do **not** view a Class 3R beam directly and do **not** point a Class 3R beam into another person's eyes. Many laser pointers are an example of a Class 3R laser.
- Class 3B - Class 3B lasers are in the range 5-500 mW. These lasers can cause injury to the eye from direct and specular reflection viewing within 0.25 seconds (average blinking response). These lasers do **not** pose a significant fire hazard. Examples of Class 3B lasers would be some research lasers.
- Class 4 - Class 4 lasers are lasers with power greater than 500 mW. High-powered lasers pose the greatest risk of injury and can cause combustion of flammable materials. They can cause diffuse and specular reflections that are hazardous to the eyes; and they may cause serious skin injury from direct exposure. Much greater controls are required to ensure the safe operation of this class of laser device.

Systems Containing Embedded Class 3B or 4 Lasers

An embedded laser is a laser designated Class 1, 2, or 3R for normal operation, but contains a Class 3B or Class 4 laser embedded in the system. U-M has many of these lasers, including but not limited to, laser engravers, cutters, and laser confocal microscopy systems.

These embedded systems must have a designated LSS, who must complete EHS_RSS044w (Embedded Laser Safety Training) and be registered in the lab's Equipment Inventory via MI Safety Portal (MISP). Aside from the LSS, laser users who operate an embedded system under normal operating conditions are not required to complete embedded laser safety training.

On-the-job training **must** be provided to all individuals engaging in normal operation of embedded lasers. This training should be documented by the LSS.

During activities outside of normal operation, including maintenance, repair, or other service, exposure to laser radiation above the Maximum Permissible Exposure is possible. As such, laser hazard control measures that are not required for normal operation will be required during these activities. Any individual conducting activities outside of normal operation must receive adequate laser safety training.

Other control measures may include, but are not limited to:

• Written Laser SOP

• Entryway warning signs

• Temporary use of laser barriers

• Use of laser protective eyewear

Contact the LSO (ehs-lasersafety@umich.edu) for guidance prior to maintenance, repair, or other servicing activities.

Potential Biological Hazards from Beam Exposure

- Reflections can cause permanent eye damage: Eye damage is possible from acute and chronic exposure to laser radiation. The extent of the damage is dependent upon the wavelength, power, and duration of the laser. For laser hazard purposes, the important components of the eye are lens, cornea, and retina.
- The lens is sensitive to near ultraviolet radiation (UV-A, wavelengths from 315-390 nm). The lens is also susceptible to high exposure to infrared (IR-A, IR-B, 760-3000 nm). High doses can produce cataracts over time.
- The cornea is more susceptible to damage from exposure to short-wavelength ultraviolet light due to its absorption properties. Prolonged exposure to wavelengths in the UV-C and UV-B region (100-320 nm) can cause photokeratitis, which is a painful burn of the cornea. The cornea is also sensitive and will burn if exposed to high doses of IR-B and IR-C, wavelengths from 1400nm-1 mm.
- Retinal burns causing scotomas (blind spots on the fovea) may occur when the eye is subject to visible light and near infrared (IR-A) with wavelengths from 400-1400 nm. This is known as the retinal hazard region. At these wavelengths the eye will focus the beam or a specular reflection as a tiny spot on the retina. This focusing increases the irradiance of the beam by a factor of about 100,000.

SPECTRUM	LOCATION	EFFECT
UV-C (200-280 nm)	Cornea	Photokeratitis
UV-B (280-315 nm)	Cornea	Photokeratitis
UV-A (315-400 nm)	Lens	Cataract
Visible (400-780 nm)	Retina	Retinal Injury*
IR-A (780-1400)	Retina, Lens	Retinal burn, cataract
IR-B (1400-3000)	Cornea, Lens	Corneal burn, cataract
IR-C (3000-1000000)	Cornea	Corneal burn
*Retinal Injury can be thermal acoustic or photochemical		

- Class 4 beams can potentially cause damage to the skin
  The consequences of skin injury are not usually as severe as eye injuries. Skin absorbs of UV-B, UV-C, IR-B, and IR-C. The ultraviolet wavelengths can cause erythema (reddening of the skin, sunburn) and skin cancer over time. High exposures to *infrared radiation* can cause thermal injury.

SPECTRUM	LOCATION
UV-C (200-280 nm)	Erythema, cancer, accelerated aging
UV-B (280-315 nm)	Erythema, increased pigmentation, cancer, accelerated aging
UV-A (315-400 nm)	Erythema, increased pigmentation, skin burn
Visible (400-780 nm)	Photosensitive reactions, skin burn
IR-A (780-1400)	Skin burn
IR-B (1400-3000)	Skin burn
IR-C (3000-1000000)	Skin burn

Potential Biological Hazards from Non-Beam Exposure

Biological non-beam exposure potential hazards from Class 3B and Class 4 lasers can include exposure to electricity, chemicals, fires, explosions, compressed gases, laser dyes and solvents, noise, laser generated air contaminants (LGACs), and collateral radiation.

- Electricity
  Most serious injuries and fatalities are associated with the electrical/high voltage components of lasers. High voltage power supplies required for pulsed and *continuous wave* lasers present the most significant high voltage electrical hazard. The U-M Lockout/Tagout, Control of Hazardous Energy Sources Program Guideline **must** be followed whenever servicing or maintaining a laser.

- Chemical Hazards
  Media used to stimulate laser radiation (excimer, dye, chemical lasers) may be toxic or hazardous substances. In addition, the generation of harmful gases, vapors or particles as by-products associated with burning metals and polymers may present significant health hazard.

  Hazardous chemical and gas use is common within laser laboratories. In compliance with the EHS lab safety program, all personnel **must** be trained on correct safety practices when handling potentially hazardous chemicals and gases.

  The proper handling and storage of gas cylinders is necessary to prevent serious physical injury. Examples of chemicals and gases known to be hazardous include chlorine gas, fluorine gas, and some laser dyes. Some gases such as argon and carbon dioxide may not be as toxic as others used, but can displace oxygen in enclosed areas. Additionally, chemicals and materials that are used as lasing mediums may require the installation of special controls due to the generation of hazardous off gassing components. Contact EHS (EHSLabSafety@umich.edu) for assistance in evaluating chemical hazards.

- Fire
  Use of flammable materials in conjunction with high-powered lasers increases the potential of a fire hazard. Class 4 lasers by definition are considered fire hazards. Flammable and combustible materials and substances within an area containing a Class 4 laser **must** be placed outside the *Nominal Hazard Zone* (NHZ). Reflective surfaces are to be painted with non-reflective paint in order to avoid a fire hazard due to unintended beam reflections.

- Explosion
  High-pressure arc lamps, filament lamps, and capacitor banks are potential explosion hazards. These items **must** be enclosed in housing that can withstand the high pressure resulting from exploding components.

- Compressed Gases
  Many lasers are used that incorporate hazardous gases such as chlorine and fluorine. Be sure all compressed gas cylinders are properly secured. Gas cylinders **must** be labeled.

- Laser Dyes and Solvents
  There are some lasers on campus that use dyes as a laser medium. These dyes are complex organic compounds that are mixed in solution with certain solvents. Great care **must** be taken when handling these dyes. A Safety Data Sheet **must** be available to anyone working with these dyes.

- Noise
  Some lasers, such as an excimer, create an intensity of noise that may require controls to be instituted. Contact EHS at (734) 647-1143 to set up a noise hazard evaluation.

- Laser Generated Air Contaminants (LGACs)
  This is a term that refers to contaminants in air associated with the use of Class 3B or Class 4 lasers. LGACs are created when there is an interaction between the laser beam and the target matter. LGACs may include metallic fumes, dust, chemical fumes, and aerosols containing biological materials. Local or area ventilation **must** be adequate to keep airborne contaminant levels below worker permissible exposure limits. High power CO_2 lasers with wavelength 10,600 nm are commonly used as laser cutters and often generate LGACs that require proper ventilation. Contact EHS for help in determining whether or not the contaminants generated by a particular application will pose a health hazard.

- Collateral Radiation
  Some lasers create collateral radiation. This is radiation other than that associated with the primary laser beam. Examples include plasma and ionizing radiation (X-rays). X-rays are electromagnetic in nature and arises from atomic transitions when electrons are stopped in materials.

Control Measures

Control measures are established in *ANSI Z136.1-2022* as a means of reducing the possibility of eye and skin exposure to laser radiation. Hazard control measures are grouped by the following categories: engineering, administrative, personal protection equipment, and signage.

An important consideration when implementing control measures is to distinguish between operation, maintenance, and service of the laser. When either maintenance or service is performed, it is often necessary to implement additional control measures. This often applies to the maintenance or service of embedded lasers.

Requirements by Laser Class

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

Engineering Controls

The following table outlines the engineering control measures for each laser classification.

Table 10a. Control Measures for the Seven Laser Classes

Legend:

X	Shall
•	Should
-----	No requirement
▽	Shall if enclosed Class 3B or Class 4
NHZ	Nominal Hazard Zone analysis required

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 Panels (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 (4.4.3.10.3)	-----	-----	-----	-----	-----	-----	X
Protective Barriers and Curtains (4.4.2.5)	-----	-----	-----	-----	-----	•	•

Laser Curtains

Laser curtains are a type of protective barrier used in conjunction with Class 3B and Class 4 lasers to block direct and diffused laser radiation in excess of the *maximum permissible exposure* (MPE) limits. Laser curtains are used at entryways to laser labs, to cover windows, as a perimeter guard around all or part of an optics table, during laser service and alignment, or a combination of any of these uses.

Laser curtains provide protection by preventing the laser radiation from exiting the laser control area. Thus, they are intended to protect persons outside the laser control area from accidental exposure. Laser curtains are **not** intended to serve as long-term beam blocks – they are rated by their ability withstand short term exposures (i.e., 100 seconds).

- Determining the Effectiveness of Laser Curtains: The effectiveness of a laser curtain is a function of its ability to withstand damaging radiant exposures. This is evaluated by determining the burn-through time (penetration threshold level or PTL), which is a function of the incident power, material thickness, and material type. In addition, the laser curtain material **must** be fire-resistant. Class 4 lasers beams can result in potential fire hazards. Under some situations where flammable compounds or substances exist it is possible that fires can be initiated by Class 3B lasers. All curtains hung in laboratories **must** meet the flame propagation performance criteria of NFPA 701 or be noncombustible.
- Testing the Quality of Laser Curtains: The *ANSI Z136.7-2020* American National Standard for Testing and Labeling of Laser Protective Equipment provides recommendations to the manufacturer for testing and labeling of laser curtains. The testing protocol is based on the ability of a barrier to withstand beam penetration when exposed for 100 seconds at a maximum incident irradiance level. In addition, *laser barriers* should **not** support combustion or LGACs following an exposure. Barriers are tested over a range of beam diameters (3-10 mm) under standardized conditions. Evaluation is based on first appearance of visible damage, power level at which the beam breaks through the material (penetration threshold level), and analysis of LGACs if flame and thermal distortion or air contamination are observed.
- Documenting and Labeling Laser Curtains: Regardless of which laser supplier is chosen, the curtains should have the following documentation and labeling (provided by the supplier):
    - Documentation that the materials were tested according to *ANSI Z136.7-2020* and that the penetration threshold level is appropriate for the proposed laser use.
    - Labeled according to *ANSI Z136.7-2020.*
    - Documentation affirming that the curtain material meets the flame resistant performance criteria of NFPA 701.

  ANSI Z136.7-2020 specifies the minimum information to be provided on the barrier label by the manufacturer as the (1) threshold limit and exposure time for which the limit applies and the exposure conditions under which protection is afforded and (2) manufacturer and model number or barrier material. The barrier should be accompanied by information on intended use, exposure limitations, conditions for which protection is specified, and cleaning, storage and inspection instructions.

- Installing Laser Curtains: Curtains should be hung 18 inches below the ceiling when the room has sprinklers and 24 inches when no sprinklers are present. Curtains should **not** be hung from ceiling to floor unless it is required for the lighting conditions of the application.

When curtains are used as entryway protection and a split is present, the curtain parts should overlap each other by at least 6 inches (15 cm).

The laser and optics should be configured so that personnel will **not** experience any radiation exposure above the MPE immediately upon entry. The appropriate threshold limit (e.g., 100 W/cm^2, 250 W/cm^2, etc.) is based on the laser characteristics. Typically, the laser curtain supplier calculates this limit using the laser specifications provided by the purchaser.

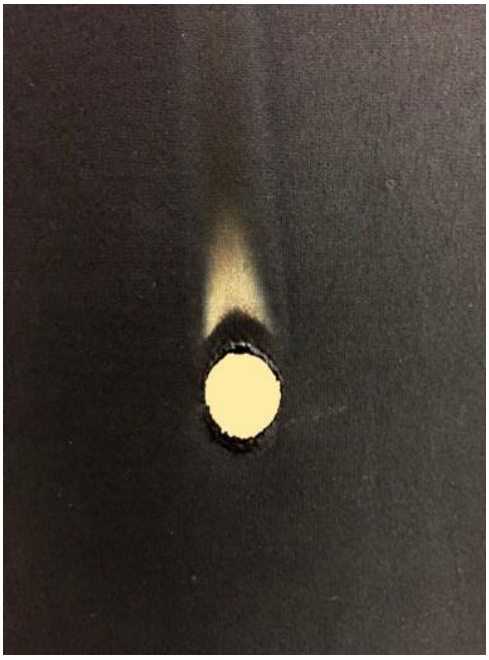
Blackout Curtains

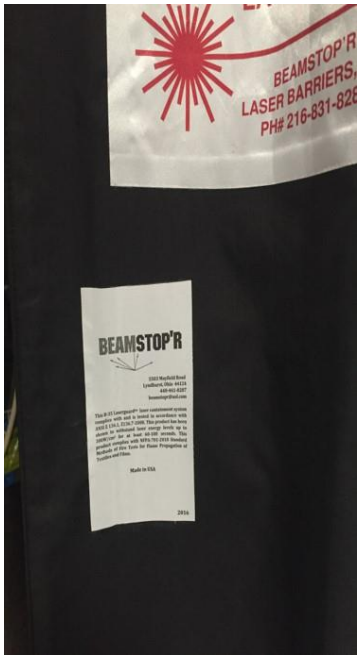
The purpose of blackout curtains is to exclude light from an area, **not** to provide protection. In addition to research laboratories, they are used in a variety of applications such as in theatre, photography, and hotels. There is no standard definition of a blackout curtain and **not** all commercial blackout curtains block 100% of the light.

In laser applications, blackout curtains are most commonly used to block room light from impinging upon the laser beam, area, sample, or a combination of these. This is for the purpose of the experiment or application, **not** for human or fire protective purposes. Laser curtains can be used as blackout curtains (in addition to serving as protective barriers), **but blackout curtains that are not certified as providing laser protection are not laser curtains**.

Blackout curtains may be used in conjunction with non-laser light and Class 1-3R lasers. Class 1-3R lasers do not represent an ignition hazard and *ANSI Z136.1-2014* does not require the use of laser rated protective barriers for these lase classes.

As with laser curtains, blackout curtains hung in laboratories **must** meet the flame propagation performance criteria of NFPA 701 or be noncombustible.





Administrative Controls

The following table outlines the administrative control measures for each laser classification.

Table 10b. Control Measures for the Seven Laser Classes (cont.)

Legend:

X	Shall
•	Should
-----	No requirement
▽	Shall if enclosed Class 3B or Class 4
MPE	Shall if MPE exceeded
NHZ	Nominal Hazard Zone analysis required
◯	May apply with use of optical aids

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						

Alignment and Beam Control Guidelines for Class 3B and Class 4 Lasers

In the research setting, over 60% of all laser accidents occur during the alignment process. Therefore, alignment procedures are very important and should be strictly adhered to. Written alignment procedures are required for all Class 3B and Class 4 laser labs and are required to be filed in each lab's CHP ("Blue Binder"). The Laser Safety Program SOP provides work practice controls for alignment procedures for Class 3B and Class 4 laser systems. LDs can include these controls in their Laser Safety Program SOP.

Alignments **must** be done only by those who have received laser safety training and appropriate on-the-job training and are aware of any hazards that may arise.

- Exclude unnecessary personnel from the laser area during alignment and only allow trained personnel to be present.
- Notify everyone in the lab yourself that you are doing a beam alignment.
- Post additional warning signs on door and entryways to lab as appropriate.
- Review all alignment procedures before attempting the alignment. Make sure all warning signs, lights, and locks are operating.
- Pay attention to housekeeping. Be sure the work area and optical table are free of objects or surfaces that could reflect light. Removes watches and jewelry including objects in a shirt pocket. Tape over rings so they don't reflect a beam. Make sure that any reflective surfaces in the area are covered.
- Wear protective eyewear at all times during the alignment.
- Wear a lab coat or a long-sleeved shirt to protect from UV lasers.
- Do **not** look directly into the beam!
- Whenever possible, use a low-power (Class 2 or Class 3R) visible laser for path simulation of higher-power visible or invisible light lasers. If not, operate laser at lowest power setting possible for alignment.
- Make sure beam paths are at a safe height (**not** at eye level when sitting or standing).
- Use image converters or phosphor cards to locate beams.
- Perform alignments that use high-power lasers at the lowest possible power level.
- Whenever possible, the use of remote viewing devices and automated devices should be considered.
- Enclose the beam as much as possible.
- Use a shutter or beam block to block high-power beams at their source except when they are actually needed during the alignment process.
- Use a laser-rated beam block to terminate high-power down range of the optics being aligned.
- Where feasible, terminate laser beams and specular reflections on diffuse reflecting beam blocks.
- Use beam blocks and/or laser protective barriers in conditions where alignment beams could stray into areas with uninvolved personnel.
- Place beam blocks behind optics to terminate beams that might miss mirrors during alignment.
- Locate and block all specular reflections before proceeding to the next optical component or section.
- Be sure all beams and reflections are properly terminated prior to high power operation.
- Replace any enclosures of beam stops removed as part of the alignment process.
- Be sure to communicate with everyone in the lab at all times (especially before removing eyewear.)

Personal Protective Equipment

Table 10c. Control Measures for the Seven Laser Classes (cont.)

Legend:

X	Shall
•	Should
-----	No requirement

PERSONNEL PROTECTIVE EQUIPMENT	CLASSIFICATION						
	1	1M	2	2M	3R	3B	4
Laser Eye Protection (4.4.4.1)	-----	-----	-----	-----	-----	X	X
Skin Protection (4.4.4.3)	-----	-----	-----	-----	-----	•	•
Protective Clothing (4.4.4.1 and 4.4.4.3.1)	-----	-----	-----	-----	-----	•	•
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Laser Protective Eyewear

Laser protective eyewear (laser eyewear) is required to be available and worn when using Class 3B and Class 4 lasers and associated equipment.

Laser eyewear is designed to protect the eyes from laser radiation by attenuating laser light within the MPE for eye exposures while allowing enough ambient light to be transmitted as not to pose a safety hazard. This characteristic of the laser eyewear lens is called *optical density* (OD). The OD varies for all types of lasers, and is not only based on the type of laser, but also on the laser user's use of the eyewear. The OD of the laser eyewear **must** be specific to the laser being used and should **not** be interchanged with different types of lasers unless approved.

The LD or LSS determines the appropriate Personal Protective Equipment to be used with the laser system. Manufacturer recommendations on the type of laser eyewear to be used are to be followed if no modification or change to the laser system is performed by the operators. The LSO is available to verify proper laser eyewear is used.

Under *ANSI Z136.1-2022 4.4.4.2.6,* it is a requirement that the wavelength and OD be printed on the laser eyewear. If this information is **not** legible, then the laser eyewear **must** be replaced.

Treat laser eyewear with care. Laser eyewear is expensive in most cases and the manufacturer's instructions and recommendations should be followed carefully in order to ensure they last as long as possible. With good care, they should last for years. Care and maintenance is a matter of keeping them clean and protected from damage.

Do **not** pile unprotected laser eyewear in a drawer. They get scratched and when scratched, they lose their ability to protect your eyes as they were designed. Here are a few guidelines for laser eyewear care:

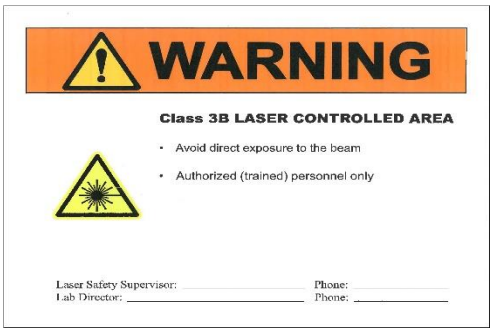
- Keep the laser eyewear organized in protective cases and readily available outside the laser controlled area (LCA) in an area behind an approved laser curtain.
- Label the laser eyewear protective cases with the wavelength of the glasses.
- Replaced scratched eyewear.

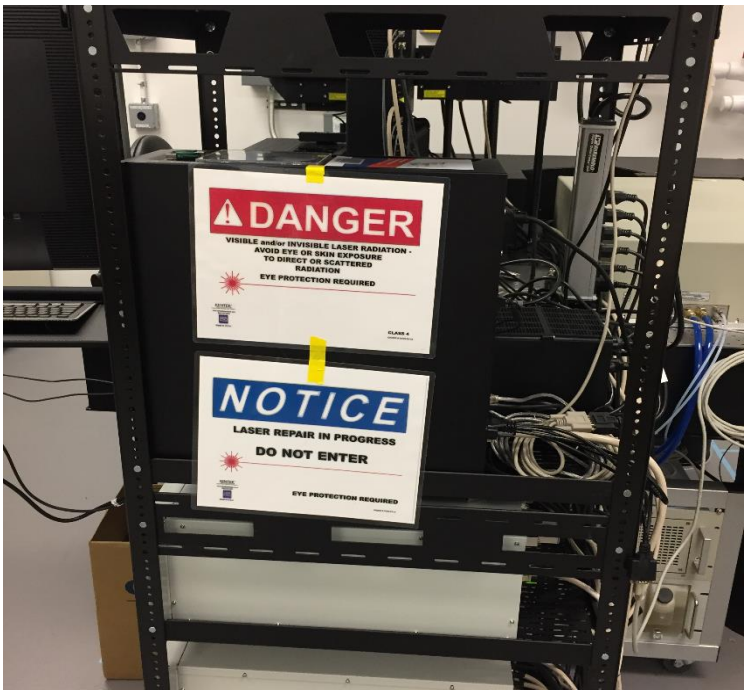
Signage and Labeling

Signage is required per the *ANSI Z136.1-2022* at entryways and to mark the NHZ.

All lasers, manufactured or homebuilt, require specific labeling. Lasers and laser systems **must** have an equipment label that includes the following information:

- Class of laser or laser system
- Emitted wavelength, pulse duration (if appropriate), and maximum output power
- A precautionary statement for laser users such as:
- For Class 3B lasers and laser systems, “Laser Radiation—Avoid Eye Exposure to Beam”
- For Class 4 lasers and laser systems, “Laser Radiation—Avoid Eye Exposure to Direct or Scattered Radiation; Avoid Skin Exposure to Direct Radiation”
- For Class 1 laser system when access to an embedded Class 3B or 4 laser during service or maintenance is required, “Notice—Laser Repair in Progress” **and** appropriate laser class warning.





Safety Precautions

Class 3B and Class 4 Lasers

- Post laser hazard warning signs at entrances to laser use areas.
- Mount the laser on a firm support to ensure the beam travels along its intended path.
- Remove unnecessary specular (i.e., mirror-like) reflecting objects from the beam path.
- Keep the beam path above or below eye level for one seated or standing.
- Only trained and authorized individuals are permitted to operate the laser.
- Secure the laser from operation by unauthorized personnel. A key switch should be used if unauthorized personnel may gain access to the laser.

Class 3B (eye and specular reflection hazard)

- Never aim the laser at a person's eye or stare at the laser.
- Wear laser eyewear if MPE may be exceeded.
- Use a protective filter when directly viewing a beam with optical instruments.
- Enclose as much of the beam path as practical
- Operate the laser in a controlled access area.
- During alignment, avoid placing one's eyes near the axis of the beam path where specular reflections are most likely to occur. Alignment eyewear should be considered.

Class 4 (fire, eye, skin, and diffuse reflection hazard)

- Review your laser safety procedure prior to laser operation.
- A controlled access area is required. Entrance controls (e.g., warning lights/signs, interlocks, protective eyewear, etc.) are required.
- Assure that protective laser eyewear is available and worn by all personnel within the controlled area.
- Use appropriate shielding between the beam area and personnel when the beam is a serious fire or skin hazard.
- Use remote firing of the laser, video monitoring, or remote viewing through a laser safety shield whenever feasible.
- If full laser power is not required, laser output filters and shutters which reduce the laser beam output to less than hazardous levels should be used.
- Assure that the laser has a key switch master control and that only authorized and properly trained individuals operate the laser.
- Install appropriate laser warning signs at entrances to the laser controlled area.
- Shield optical pump systems that may be hazardous to view.
- Use beam blocks that are diffusely reflecting and composed of fire-resistant material.

Initial and Periodic Inspection Requirements

University of Michigan labs acquiring a Class 3B or Class 4 laser for the first time must meet all safety requirements by the Environmental Health and Safety Department and set up an initial laser safety inspection with the Laser Safety Officer (LSO) before use.

Laser Safety inspectors periodically inspect active Class 3B and Class 4 labs to verify the lab is compliant with *ANSI Z136.1-2022*.

Attachment 1 (Laser Safety Program Laboratory Audit) can be used as a guide for LD and LSS to use when setting up their labs and when preparing for inspections.

Laser and Associated Equipment Servicing

The U-M Lockout/Tagout – Control of Hazardous Energy Sources Guideline **must** be followed whenever servicing or maintenance of a laser occurs. Only authorized personnel that have received adequate laser training may service Class 3B, Class 4, and Embedded Class 3B or Class 4 lasers/systems.

Acquiring a Class 3B, Class 4, or Embedded Class 3B or 4 Laser

Class 3B, Class 4, and Embedded Class 3B or Class 4 Lasers (including but not limited to Laser Cutters, Laser Confocal Microscopes, and 3D Printers) are Restricted Commodities under Procurement Services and require approval by the LSO.

Please submit a completed Laser Requisition Form via MI Safety Portal (MISP).

Registering a Class 3B, Class 4, or Embedded Class 3B or 4 Laser

After acquiring a Class 3B, Class 4, or Embedded Class 3B or Class 4 Laser it must be registered in the laboratory's Equipment Inventory via MI Safety Portal (MISP). Primary Investigators, Lab Directors, and Lab Managers have access to the MISP Equipment Icon. Embedded Systems containing multiple lasers may be registered as one piece of equipment where multiple wavelengths are listed in the Laser Registration Properties.

Disposing of a Laser

The LSS must notify the LSO of a laser disposal, lab transfer, or donation within 15 days of the action. Please refer to the Laser Disposal Guideline attached in the Related Laser Safety Program Documents section for guidance.

Lasers in good condition may also be donated to UofM's Lab Reuse Program.

Medical Surveillance

The U-M Department of Ophthalmology has determined that baseline eye examinations are not necessary in order to later evaluate an acute laser eye injury. Therefore, there is no pre-assignment medical requirement for laser users.

Injury

In the event of an injury related to laser use, call Occupational Health Services at (734) 764-8021 during regular business hours. After hours, go to the Michigan Medicine Emergency Department at University Hospital.

A follow-up evaluation, when necessary, will be conducted by an ophthalmologist.

Reporting a Work-Related Incident

Report all work related accidents, injuries, illnesses, or exposures to Work Connections within 24 hours by completing and submitting the Illness and Injury Report Form. Follow the directions at the Where to go for treatment page to obtain proper medical treatment/follow-up.

Incidents relating to research **must** also be reported to EHS. Complete the Laboratory Incident and Near Miss Report Form for research-related incidents involving:

- Near misses
- Fires/Explosions
- Property damage
- Injuries
- Illnesses

Technical Support

All reference guidelines, regulations, and other documents are available on the EHS website or by calling EHS at (734) 647-1142.

Roles and Responsibilities

The following table describes additional responsibilities for laser users, researchers, and administrators specific to implementing this guideline. The elements in this section are based on *ANSI Z136.1-2022, Appendix A (Laser Safety Programs)*.

POSITION	ROLES AND RESPONSIBILITIES
Laser Safety Officer (LSO)	• Provide consultation and evaluation of laser hazards for a particular laser system. • Maintain and verify the inventory of all Class 3B and Class 4 lasers on campus. • Ensure that the campus use of lasers is in compliance with regulations, ANSI Standards, and requirements outlined in this guideline. • Approve all Class 3B and Class 4 laser purchases. • Review Class 3B and Class 4 SOPs including written alignment procedures. • Recommend personal protective equipment (PPE) such as eyewear, clothing, and barriers that may be required to ensure personnel safety. The LSO **must** ensure that protective equipment is audited periodically. • Review the wording on area warning signs to verify they are appropriate for lasers used in a particular lab. • Provide baseline laser safety training to each laser user. • Inspect laser safety control measures and operations including engineering and administrative controls, PPE, and signage and labeling.

POSITION	ROLES AND RESPONSIBILITIES
	• Maintain records related to the Laser Safety Program including inventory, laser safety training, laser approvals, and inspections. • Suspend, restrict, or terminate the operation of a laser system as decided in consultation with the Executive Director of EHS. • Investigate incidents resulting from a laser operation and initiating corrective action. • Provide quarterly updates to management, including a statement reiterating the established escalation policy and any specific details relevant to laser safety. These updates will discuss the status of the Laser Safety Program and inform EHS management of laser safety issues as a result of laboratory inspections.
Laboratory Director (LD)	• Notify the LSO whenever acquiring, fabricating, transferring a laser to a different laboratory, or changing the hazard classification of a laser system. • Register all Class 3B, Class 4, or Embedded Class 3B or Class 4 Lasers in the laboratory's Equipment Inventory via MI Safety Portal (MISP) • Develop written laser safety procedures to include with the SOP and ensuring that laser operations are carried out in accordance with those procedures. The SOP **must** be filed in the Laser Safety Section of the CHP ("Blue Binder"). Written alignment procedures **must** be included in the SOP. • Ensure that laser users and laboratory personnel are properly instructed and trained in laser safety and are familiar with the laser safety procedure for their laser system prior to initial operation. • Complete required laser safety training and refresher training. • Conduct on the job training as necessary. • Document training for all personnel. Maintain training records for all individual laser users in the Laser Safety Section of the CHP ("Blue Binder"). • Inform visitors to areas or laboratories where lasers are present of the hazards and control measures associated with these systems and give proper eyewear, as appropriate, to the visitors. • Implement procedures in accordance with this Guideline. • Evaluate hazards of laser work areas and institute appropriate control measures.
Laboratory Director (LD) (cont'd)	• Ensure that laser maintenance and repairs are performed by qualified, trained individuals and conducted in a safe manner. • Promptly notify the LSO in the event of a suspected incident involving the laser and discontinuing operation. Report laser related injuries to Work Connections by completing the Illness or Injury Report Form. • Contact the LSO for technical assistance. • Report near misses and incidents to EHS in the Laboratory Incident and Near Miss Report Form.
Laser Safety Supervisor (LSS)	• Complete required laser safety training and refresher training. • Issue of appropriate instructions and training material on laser hazards. • Maintain training records in the Laser Safety Section of the CHP ("Blue Binder"). • Conduct on-the-job training for individual laser users. • Permit the operation of a laser only when there is adequate control of laser hazards to personnel, visitors, and the general public.

POSITION	ROLES AND RESPONSIBILITIES
	• Immediately notify the LD and the LSO in the event of a suspected laser incident. All incidents and near misses should be reported at once by using the Laboratory Incident and Near Miss Report Form. • Report all work-related injuries and illnesses to Work Connections by completing the Illness or Injury Report Form • If necessary, the LSS **must** assist in obtaining appropriate medical attention for any employee involved in a laser accident. • Assist in writing the SOP for their lab and review it at least once annually with the LD.
Laser User	• Take and pass EHS's Laser Safety Program Online Training located on My LINC (EHS_BLS005w) if working with Class 3B or Class 4 lasers. • Attend a Laser Safety Training class in your department, if available. • Review, understand, and comply with the laser safety rules and procedures within this Guideline, the SOP, and any further safety recommendations initiated by the LSS, LD, or LSO prior to operating a laser or laser system. **NOTE**: All individual laser users **must** sign the SOP to indicate they read and understand the SOP and will follow it. • Maintain engineering controls on the laser system as designed, specified, and approved by the laser manufacturer or LD in consultation with the LSO. • Only energize or work with or near a laser when authorized to do so by the LD and LSS for that laser. • Conduct assigned tasks in a safe manner and wear appropriate personal protective equipment such as approved eyewear and protective clothing. • Only operate lasers and associated equipment for which they have been formally trained. • Report any disabled, broken, or bypassed safety features are reported to the LD or LSS. • Promptly report the details of incidents or near misses involving a laser to the LD, LSS, or both. Complete the Laboratory Incident and Near Miss Report Form. • Consult the LD or LSO whenever there are any questions regarding laser use. • Contact EHS to evaluate health and safety conditions within their unit.

Attachment 1: Laser Safety Program Laboratory Audit

ENVIRONMENT, HEALTH & SAFETY
UNIVERSITY OF MICHIGAN

Laser Safety Program Laboratory Audit Form

IDENTIFICATION INFORMATION	
Lab Director (LD):	Date:
Laser Safety Supervisor (LSS):	
Building:	Room number:

	Y	N	N/A	Comments
Lab Entrances- Posted Signs, Security				
All doors posted with ANSI laser signs appropriate for laser Class				
Lab doors closed				
Visible warning device operational				
Entryway controls				

INVENTORY				
Lasers adequately labeled:				
Certification label, Class, Output, Wavelength, Aperture				

Engineering Controls				
Are laser curtains/barriers in place				
Are laser curtains rated appropriately for the power of the laser(s)				
Non-reflective and flame retardant curtains label				
Lab windows covered (including on doors) with non-reflective curtains				
Any burn holes in curtains or on walls				
Are reflective surfaces in room controlled				
No tools that could reflect the beam on the table				
No jewelry while working with laser, especially during alignment				
Good housekeeping				
Eye level not equal with standing or sitting position				
Are there beam stops present at the end of all beam paths				
Housing in place and in good condition				
Laser secured to table				

Laser optics secured to prevent stray beams				
Does laser have remote viewing capability				
Key control for power supply				
Emergency OFF switch clearly marked				

Personal Protective Equipment (PPE)				
Sufficient number or eyewear available				
All eyewear is good condition (free of cracks and scratches)				
Is each pair of eyewear labeled from the manufacturer with optical density and wavelength for which protection is provided				
Laser eyewear cover all wavelengths				
Are the ODs adequate				
Does eyewear have side shields				

Non-Beam Hazards				
Is there any exposed wiring				
High voltage equipment grounded properly				
High voltage equipment located away from wet surfaces or water sources				
Combustible materials in area				
Compressed gas cylinders secured				
LGAC addressed, if present				
Collateral radiation hazards addressed, if present				

Administrative Controls				
SOP complete and filed in Blue Binder				
All users listed in SOP				
LSS identified				
Have all Laser Users completed EHS's Laser Safety Program online training				
Have Laser Users taken other Laser Safety training at UM				
Have all Laser Users received lab-specific laser safety training specific to the laser operation in the lab and documented				
Alignment procedures available				
Alignments performed by trained personnel (eyewear??)				
Maintenance/Service performed by trained/authorized personnel				

Glossary of Terms

TERM	DEFINITION
Accessible Emission Limit (AEL)	The maximum accessible emission level permitted within a particular laser hazard class.
Aversion Response	Closure of the eyelid, eye movement, pupillary constriction, or movement of the head to avoid exposure to a noxious or bright light stimulant. The aversion response is assumed to limit the exposure of a specific retinal area to 0.25 seconds or less
Beam	A collection of light/photonic rays characterized by direction, diameter (or dimensions), and divergence (or convergence).
Continuous Wave (CW)	A laser operating with a continuous output for a period ≥ 0.25 seconds is regarded as a CW laser.
Diffuse Reflection	Change of the spatial distribution or "scattering" of a beam of radiation when reflected in many directions by a surface or by a medium.
Embedded Laser	An enclosed laser with an assigned class number higher than the inherent capability of the laser system in which it is incorporated, where the system's lower classification is appropriate due to the engineering features limiting accessible emission.
Energy	The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers, generally expressed in joules (J). Symbol: Q
Infrared Radiation (IR)	Electromagnetic radiation with wavelengths between 700 nm and 1 mm. The region is often broken up into near or far IR (dependent on the wavelength).
Laboratory Director	Individual responsible for assuring that the use of lasers under their supervision complies with the U-M Laser Safety Program and ANSI Standards as outlined in the guidelines and procedures.
Laser	A device that produces radiant energy predominantly by stimulated emission. Laser Radiation may be highly coherent temporally, spatially, or both. An acronym for Light Amplification by Stimulated Emission of Radiation.
Laser Barrier	A device used to block or attenuate incident direct of 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 Controlled Area (LCA)	A laser use area where the occupancy and activity of those within is controlled and supervised. This area may be defined by walls, barriers, or other means. Within this area, potentially hazardous beam exposure is possible,
Laser Safety Officer (LSO)	The LSO is an individual designated by the Executive Director of EHS and has the authority and responsibility to effect the knowledgeable evaluation of control of laser hazards and to monitor and enforce the control of those hazards. The LSO shall have the authority to suspend, monitor, or terminate the operation of a laser system (in consultation with the Executive Director of EHS) if deemed that the laser hazard controls are inadequate.

TERM	DEFINITION
Laser Safety Supervisor (LSS)	Individual who is the main person responsible for the safety of all individual laser users in a laboratory. This person is designated by the LD or may be the LD. The LSS oversees all activities of individuals with the potential to receive exposure to Class 3B or Class 4 laser radiation. The LSS should have a basic overall knowledge of laser safety requirements for those lasers.
Laser User	Any U-M employee working with a laser or laser system.
Maximum Permissible Exposure (MPE)	The level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin.
Nominal Hazard Zone (NHZ)	The space within which the level of the direct, reflected or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.
Optical Density (OD)	Ability of a filter to attenuate optical radiation at a particular wavelength. The OD of eyewear has to be at least equal to or greater than the required OD. The OD can be calculated based on formulas in *ANSI Z136.1-2022* or can typically be found in the laser manufacturer's operations manual.
Power (Φ)	The rate at which energy is emitted, transferred, or received. Unit: watt (W) (1 W = 1 J/s)
Pulsed laser	A laser that delivers its energy in the form of a single pulse or a train of pulses. The duration of a pulse is less than 0.25 seconds.
Standard Operating Procedure (SOP)	Formal written description of the safety and administrative procedures specific to the laser and associated equipment.
Wavelength	The distance in the line of advance of a sinusoidal wave from any one point to the next point of corresponding phase (distance from peak to peak).

Revision History as of 1/7/2015

REVISION #	DATE	REVISION #	DATE	REVISION #	DATE	REVISION #	DATE
12	06/05/17	15	09/28/23				
13	09/26/17	16	08/06/24				
14	10/4/17	17	1/05/25				