ENVIRONMENT, HEALTH & SAFETY
UNIVERSITY OF MICHIGAN

# Laser Safety Program

## Guideline

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**Applies To**: Laboratory faculty, staff, students, and visitors at the Ann Arbor campus.

The topics in the body of this document pertain to all 3B or 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 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 the EHS and Office of Research Ethic & Compliance Academic Laboratory and Research Safety Policy, SPG 605.01 Safety, Health, and Environment Policy, and the *ANSI Z136.1- Appendix A (Laser Safety Programs)*. All personnel who actively use Class 3B and 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 Ethic & 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*

- Request to Purchase a Class 3B or Class 4 Laser
- 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 laser users 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** take the:

- Online Laser Safety Basic Training (EHS BLS005w) before operating a laser. The training 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
- 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 lab director (LD) or lab safety supervisor (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 Chemical Hygiene Plan 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*, *wavelength*s, 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.

### *Additional Training*

Additional training is available outside the U-M. 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. 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 mW - 500mW. 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.

## *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 1400-1mm.
- 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 bun |

## *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 EHS's 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 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 for an 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 CO2 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 x-rays, plasma, and ionizing radiation. X-radiation is electromagnetic in nature and arises from atomic transitions when electrons are stopped in materials.

## Control Measures

Control measures are established in the ANSI Z136.1-2014 Standard 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

### *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 Control Measures*

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

### Table 10a. Control Measures for the Seven Laser Classes

Table 10a, 10b, and 10c—Control Measures for the Seven Laser Classes, reproduced with permission from ANSI Z136.1 (2014) American National Standard for Safe Use of Lasers. Copyright 2014, Laser Institute of America, Orlando, Florida. The Laser Institute of America disclaims any responsibility of liability resulting from the placement and use in the described manner.

**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 (i.e. 100 sec) exposures.

- 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 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 barrier*s 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 and that the penetration threshold level is appropriate for the proposed laser use.
  - Labeled according to the ANSI Standard.
  - Documentation affirming that the curtain material meets the flame resistant performance criteria of NFPA 701.

  The ANSI Standard 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/cm2, 250 W/cm2, 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 are 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 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 needed for each laser classification.

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

Table 10a, 10b, and 10c—Control Measures for the Seven Laser Classes, reproduced with permission from ANSI Z136.1 (2014) American National Standard for Safe Use of Lasers. Copyright 2014, Laser Institute of America, Orlando, Florida. The Laser Institute of America disclaims any responsibility of liability resulting from the placement and use in the described manner.

**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 Blue Binder. The Laser Safety Program Standard Operating Procedure 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.)

Table 10a, 10b, and 10c—Control Measures for the Seven Laser Classes, reproduced with permission from ANSI Z136.1 (2014) American National Standard for Safe Use of Lasers. Copyright 2014, Laser Institute of America, Orlando, Florida. The Laser Institute of America disclaims any responsibility of liability resulting from the placement and use in the described manner.

**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) | ----- | ----- | ----- | ----- | ----- | • | • |

### 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 PPE 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.

It is an ANSI 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 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 Standard 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”

## 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.

## Periodic Inspection Requirements

Laser Safety inspectors periodically inspect active Class 3B and Class 4 laser labs to verify the lab is compliant with *ANSI Z136.1-2014*.

Attachment 2 C, Laser Safety Program Laboratory Audit Form 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.

## Medical Surveillance

Baseline eye examinations have been determined by the U-M Department of Ophthalmology not to be 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, call Occupational Health Services at (734) 764-8021 during regular business hours. After hours, go to the U-M Hospital emergency room.

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 on the Work Connections website Where to go for treatment to obtain proper medical treatment and 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 through EHS (734) 647-1142 and on the EHS website.

# Appendix A: 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-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.<br>• Maintain and verify the inventory of all Class 3B and Class 4 lasers on campus.<br>• Ensure that the campus use of lasers is in compliance with regulations, ANSI Standards, and requirements outlined in this guideline.<br>• Approve all Class 3B and Class 4 laser purchases.<br>• Review Class 3B and Class 4 SOPs including written alignment procedures.<br>• 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.<br>• Review the wording on area warning signs to verify they are appropriate for lasers used in a particular lab.<br>• Provide baseline laser safety training to each laser user.<br>• Inspect laser safety control measures and operations including engineering and administrative controls, PPE, and signage and labeling.<br>• Maintain records related to the Laser Safety Program including inventory, laser safety training, laser approvals, and inspections.<br>• Suspend, restrict, or terminate the operation of a laser system as decided in consultation with the Executive Director of EHS.<br>• Investigate incidents resulting from a laser operation and initiating corrective action.<br>• 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.<br>• 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 Chemical Hygiene Plan Document Binder (Blue Binder). Written alignment procedures **must** be included in the SOP.<br>• 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.<br>• Conduct on the job training as necessary.<br>• Document training for all personnel. Maintain training records for all individual laser users in the Laser Safety Section of the Blue Binder.<br>• 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.<br>• Implement procedures in accordance with this Guideline.<br>• Evaluate hazards of laser work areas and institute appropriate control measures. |

| POSITION | ROLES AND RESPONSIBILITIES |
|---|---|
| Laboratory Director (LD) (cont'd) | • Classify and verify classes of lasers in laboratories.<br>• Ensure that laser maintenance and repairs are performed by qualified, trained individuals and conducted in a safe manner.<br>• 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.<br>• Contact the LSO for technical assistance.<br>• Report near misses and incidents to EHS in the Laboratory Incident and Near Miss Report Form. |
| Laser Safety Supervisor (LSS) | • Issue of appropriate instructions and training material on laser hazards.<br>• Maintain training records in the Laser Safety Section of the Blue Binder<br>• Conduct on-the-job training for individual laser users.<br>• Permit the operation of a laser only when there is adequate control of laser hazards to personnel, visitors, and the general public.<br>• 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.<br>• Report all work-related injuries and illnesses to Work Connections by completing the Illness or Injury Report Form<br>• If necessary, the LSS **must** assist in obtaining appropriate medical attention for any employee involved in a laser accident.<br>• Classify or verify classes of lasers in their laboratories.<br>• 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).<br>• Attend a Laser Safety Training class in your department, if available.<br>• 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.<br>**NOTE**: All individual laser users **must** sign the SOP to indicate they read and understand the SOP and will follow it.<br>• Maintain engineering controls on the laser system as designed, specified, and approved by the laser manufacturer or LD in consultation with the LSO.<br>• Only energize or work with or near a laser when authorized to do so by the LD and LSS for that laser.<br>• Conduct assigned tasks in a safe manner and wear appropriate personal protective equipment such as approved eyewear and protective clothing.<br>• Only operate lasers and associated equipment for which they have been formally trained.<br>• Report any disabled, broken, or bypassed safety features are reported to the LD or LSS.<br>• 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.<br>• Consult the LD or LSO whenever there are any questions regarding laser use.<br>• Contact EHS to evaluate health and safety conditions within their unit. |

# Attachment 1: Laser Safety Program Laboratory Audit

| IDENTIFICATION INFORMATION | |
|---|---|
| Lab Director: | 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 locked when unattended | | | | |
| Lab door locked when laser in use | | | | |
| Visible warning device operational | | | | |
| Other warning indicators used when laser is 'On' | | | | |
| Access to laser restricted to Authorized Users only | | | | |
| Warning for unattended operations | | | | |
| Entryway controls | | | | |
| Through traffic restricted | | | | |
| **INVENTORY** | | | | |
| Lasers adequately labeled: | | | | |
| Certification label | | | | |
| Class designation label | | | | |
| Radiation output information on label | | | | |
| Wavelength | | | | |
| Aperture Label | | | | |
| All Lasers included in inventory | | | | |
| **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 | | | | |
| Open beam | | | | |
| 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 | | | | |
| Is the power 'ON' clearly visible | | | | |
| Key control for power supply | | | | |

| | | | | |
|---|---|---|---|---|
| Emergency OFF switch clearly marked | | | | |
| **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 | | | | |
| Maintenance/Service performed by trained/authorized personnel | | | | |
| Laser Safety Program (EHS) notified of laser move or acquisition | | | | |
| **PERSONNEL 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 | | | | |
| Protective clothing, barrier, screens, skin protection available and adequate (particularly when operating in the UV region) | | | | |
| **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 | | | | |
| Explosion/fire hazard addressed, if present | | | | |
| Compressed gas cylinders secured | | | | |
| Toxic gas safety measures addressed, If cryogens in use, PPE adequate if in use | | | | |
| LGAC addressed, if present | | | | |
| Noise exposure addressed, if present | | | | |
| Collateral radiation hazards addressed, if present | | | | |
| Other laser safety issues? | | | | |

Comments:

_____

_____

Laser Safety Inspector: _____ Date : _____

## 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 in the 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 or can typically be found in the laser manufacturer's operations manual. |
| Power ($\Phi$) | The rate at which energy is emitted, transferred, or received. Unit: watt (W) (1 W = 1 J.s-1) |
| 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 | 14 | 10/4/17 | | | | |
| 13 | 09/26/17 | 15 | 6/29/18 | | | | |