

# University of Wisconsin

## *Laser Safety Handbook*

*For*

*Academic and Research Laboratories*

**Environment, Health and Safety Department**

a unit of Facilities Planning and Management

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## **I. Purpose and Scope**

The purpose of this guide is to establish safety measures for working with Class 3B and Class 4 lasers and laser systems in the research and instructional laboratories. This document is developed based on ANSI Z136.1 Standard “The Safe Use of Lasers” and serves as a guidance document for all faculty, staff, and students working with Class 3B and Class 4 lasers at the University of Wisconsin- Madison. (UW – Madison)

## **II. Roles and Responsibility**

The Office of Radiation Safety (ORS), within the Environmental Health & Safety (EH&S) department at UW-Madison, manages the research and medical laser safety programs under the oversight of the Laser Safety Committee (LSC). A separate safety plan covers medical lasers given disparate requirements.

A member of the ORS staff serves as the Laser Safety Officer (LSO) and works closely with the laser labs, EH&S departments, and the LSC to establish and maintain adequate policies and programs for the control of laser hazards.

## **III. Procedures**

### **i. Laser Registration**

It is the responsibility of the Principle Investigator (PI) to register all Class 3B and Class 4 Lasers under his/her authorization with the ORS. The [registration form](#) is available online on the ORS website.

Laser systems containing embedded Class 3B or Class 4 lasers are exempt from registration. However, the LSO should be notified when such a system is acquired to perform a laser hazard evaluation, as there may be the situations where protective housings are removed or interlocks are defeated and the possibility for beam hazards exists.

Once the lasers are registered, the LSO will contact the PI and work together to have all laser safety requirements and control measures in place. The PI, lab, and laser details are then entered into Environmental Health and Safety Assistant (EHSA) database system.

### **ii. Laser Safety Training and Qualifications**

All staff and students operating Class 3B and Class 4 Lasers shall attend the online “General Laser Safety” training prior to any laser use. The [training](#) details are available at ORS website.

Besides the general training, each operator must be trained on laser specific safety regarding the procedure, equipment used, and emergency procedure before operating class 3B, or Class 4 lasers/laser devices by the PI or appropriate designee.

The laser specific safety training should be included as the part of the standard operating procedure.

### **iii. Medical Surveillance**

A baseline eye exam is required before use of Class 3B and/or Class 4 Lasers/Laser systems. University Health Services (UHS) at UW-Madison provides baseline eye examinations. UHS is located at 333 East Campus Mall, floors 5-8.

Please see [laser baseline eye exam instructions](#) on the ORS website for details.

Once the individuals complete the “General Laser Safety” training and baseline eye exam, a laser safety certificate will be provided for your record.

Eye examinations are also required for laser workers in the event of any accidental or suspected eye exposure to laser radiation.

### **iv. Laser Disposal**

Disposal of the Class 3B and Class 4 Lasers must go through ORS. Complete the [Online Laser Disposal Form](#). The LSO will contact you and work together to guide you through the disposal process.

See [Appendix A](#) for instructions for laser disposal.

## **IV. Hazard Evaluation/ Standard Operating Procedure**

An assessment should be performed for every laser lab to identify hazards that could arise from the laser system used and laser-use settings. The following aspects should be taken into consideration while conducting an evaluation.

- The laser or laser systems capability for causing injuries
- The environment where the laser is manipulated
- The people who may use or be exposed to laser beam

The ORS can assist in performing the hazard evaluation.

See [Appendix B](#) for the sample assessment form.

A written Standard Operating Procedure (SOP) is required for all Class 3B and Class 4 lasers or laser system. The SOP must include description on following:

- Laser details
- Laser system set-up
- Intended laser application

- Operating procedures
- Control measures
- Maintenance procedure
- Beam and Non-beam hazards
- Personal protective equipment requirements

The SOP should be reviewed and followed by all users and must be available in the lab for access. The manufacturer's operating manual can be included in the SOP but is not a substitute for an SOP.

See [Appendix C](#) for a sample SOP

## **V. Laser Classification, Warning Signs and Labels**

### **i. Laser Classification**

Lasers are classified based on the capability of the laser or laser system to produce injury to personnel. The class of laser reflects the potential for eye and skin damage. Higher-class numbers mean greater potential hazards.

See [Appendix D](#) for the Laser Classification

### **ii. Lighted Warning Sign**

The entrance to laser labs with open beam Class 3B and Class 4 lasers shall have a lighted warning sign on when the laser is operating. For any new laser lab, installing the lighted warning sign will be the part of the lab remodeling process. For existing labs, the LSO will work together with the lab, department, and FP&M electric shop to initiate the process.

### **iii. Written Warning Signs and Labels**

The warning sign warns the presence of a laser hazard inside the lab or space. Appropriate warning signs conveying the severity of hazards pertinent to the class of laser should be posted at the entrance of the laser lab.

The LSO will provide the appropriate warnings signs for the lab entrance posting after the lasers are registered.

Except for class 1 lasers, all other lasers/laser systems should have appropriate warning labels. The labels shall be affixed to a conspicuous place on the laser housing or control panel.

The labels shall indicate the class of laser/laser system, wavelength, maximum power output, pulse duration (if applicable), and the precautionary instructions or protection action required for using the system.

## **VI. Safety Precautions**

### **i. Controls for Class 3B and Class 4 Lasers**

#### **➤ Access control**

For any Class 3B or Class 4 laser lab, the access to the lab should be limited to only authorized personnel. It can be maintained through room interlocks or entryway controls. For entryway controls, a key control door, blocking barriers, screen, laser curtain, etc. can be used to prevent the laser radiation from exiting the area at levels above the applicable Maximum Permissible Exposure (MPE). If the same lab is used for other functions by other researchers, then the laser within the lab has to be secured with a key switch only accessible by authorized personnel.

#### **➤ Substitution of alternate control measures (Class 3B and 4)**

The ANSI Z136.1 establishes the LSO's authority to substitute the control measures, (engineering controls) specified in the standard for Class 3B and Class 4 lasers with administrative or other alternative controls measures that provide the equivalent protection.

Each research laser lab is unique and designed for a specific purpose. As such, not all the engineering control measures specified in the standard may be feasible to implement. The LSO will view controls used in a laser lab and may approve alternate controls.

#### **➤ General safety procedures for working with Class 3B and Class 4 lasers**

- Only trained and authorized individuals should be permitted to operate the laser.
- Post an appropriate laser hazard warning signs at each entrance to laser use areas.
- Secure the laser from operation by unauthorized personnel. A key switch should be used if unauthorized personnel may gain access to the laser. Entrance controls (e.g. warning lights, interlocks, key door, laser barriers) are required.
- Remove unnecessary optics from the beam path.
- Always keep the beam path below the eye level for either sitting or standing position.
- Enclose as much of the beam as is practical.
- Never look directly into laser beam with optical instruments without an adequate filter.
- Use proper laser eyewear if applicable MPE may be exceeded.
- Use remote firing of the Class 4 laser, video monitoring, or remote viewing whenever feasible.
- Have all windows, doorways, and open portals in an indoor facility covered if they are part of the nominal hazard zone.

- Use beam blocks, which absorb the beam area diffusely reflecting and composed of fire-resistant materials, to stop unwanted beams.

**ii. Techniques for Safe Laser Alignment Procedures**

The most likely time for laser accidents to occur is during beam alignment. Only trained personnel should perform a beam alignment.

The ANSI Z136.1 standard suggests the following techniques to prevent accidents during laser beam alignment:

- Exclude unnecessary personnel from the laser-controlled areas during alignment.
- Perform alignment at the lowest possible power level.
- When possible, use low-power visible lasers for path simulation of high-power visible or invisible lasers.
- Wear laser protective eyewear and protective clothing as required based on MPE.
- Use beam display devices (image converter viewers phosphor cards, or liquid crystal paper) to locate beams when aligning invisible lasers.
- When inserting any alignment device in the beam, angle the device so that any reflections are directed away from you.
- Use appropriately rated laser shutters or beam blocks to block high-power beams at their source except when needed during the alignment process.
- Use a laser - rated beam block to terminate high power beams down range of the optics being aligned.
- Use appropriately rated laser beam blocks and/or laser protective barriers in conditions where alignment beams could stray into areas with uninvolved personnel.
- Place beam blocks behind optics; for example, turning mirrors to terminate beams that may miss the mirrors during alignment.
- Locate and block all stray reflections before proceeding to the next optical component or section.
- Make sure that all beams and reflections are terminated before resuming high-power operation.

**iii. Non-beam Hazards**

In addition to the hazards of the laser beam, other hazards associated with the operation of the laser can be present in the lab. Some of the non-beam hazards and possible sources are listed below.

<b>1. Physical Hazard</b>	<b>Possible Source</b>
Noise	Constant pinging of pulse laser
Pressure	Vacuum chamber, gas cylinders
Incoherent radiation	Broadband light source
X-rays	Target interaction
High temperature	Ovens in the lab

Low temperature	Cryogenic use
Electricity	Power supplies
<b>2. Chemical Hazard</b>	<b>Possible Source</b>
Toxic substance	Laser dyes
Carcinogenic substances	Solvents
Irritant substances	Samples
Dust and particulates	Cracked optics
Fire	From ignition
<b>3. Biological Hazards</b>	<b>Possible Source</b>
Microbiological organism	Released from target interaction
Viruses	Released from target interactions
<b>4. Mechanical Hazards</b>	<b>Possible Source</b>
Trailing cables and pipes	Housekeeping
Sharp edges	Razor blades
Moving parts	Robotic arm or piston
High-pressure water	Cooling lines
<b>5. Ergonomic Hazard (Human Factors)</b>	<b>Possible Source</b>
Workstation layout	Hitting head on table shelves
Manual handling	Lifting of lasers
Person-machine interface	Robotic work
Shift patterns	Working too many hours (fatigue, inattention)

**Note: The LSO should be contacted to evaluate any non-beam hazard conditions and implement control measures to mitigate the hazards.**

## VII. Laser Protective Eyewear

An enclosure of the laser beam path or laser equipment is the preferred method of control. However, when complete enclosure is not feasible, and other controls are inadequate to eliminate potential exposure, laser-protective eyewear should be used.

The purpose of laser-protective eyewear is to attenuate any laser radiation reaching one's eye to a level below which it will cause injury.

The PI must ensure that the appropriate eyewear is available for use and worn in the laser lab where Class 3B and Class 4 laser are present and there is a potential exposure to the beam or reflected beams at levels above the MPE.



The laser protective eyewear should be selected based on the level of protection required to protect the eyes from a worst-case scenario.

Consider following factors for selecting appropriate eyewear. Contact the LSO if you need assistance in selecting the eyewear.

**i. Factors in Selecting Appropriate Eyewear**

- Laser wavelength
- Laser power and/ or pulse energy
- Mode of operation (continuous wave or pulsed)
- Maximum exposure duration (assume worst case scenario)
- Maximum permissible exposure (MPE)
- Maximum Radiant exposure ( $J/cm^2$ ) or Irradiance ( $W/cm^2$ ) for which the protection is required
- Optical density (OD) requirement of eyewear filters at the specific laser output wavelengths
- For ultra-fast lasers, non-uniform bleaching may cause degradation of the rated OD of laser eyewear. Check with the manufacturer of the eyewear for the testing results to determine if the eyewear will provide the adequate protection before using them.

**Other considerations:**

- Visible light transmission (VLT)
- Anti-fogging design or coatings
- Comfort and fit
- Impact resistance
- Side shields protection
- Prescription glasses

**ii. Labeling Eyewear**

All laser safety eyewear shall be clearly labeled with the optical density and wavelength for which protection is afforded. Additional labeling may be added for identification purpose in labs with multiple lasers.

**iii. Inspection and Cleaning of Laser Eyewear**

Periodic cleaning and inspection shall be performed to ensure eyewear are maintained in satisfactory condition. Use care when cleaning them and follow manufacturer instruction to avoid damage to the absorbing and reflecting surfaces.

For laser eyewear inspection, check for:

- Pitting, crazing, cracking, discoloration of the attenuation material

- Mechanical integrity of the frame
- Light leaks and coating damage

### **VIII. Inspection**

The LSO will conduct annual inspections of the laser labs to ensure compliance with the ANSI Z136.1 Standard.

### **IX. Laser Related Injury and Reports**

In the event of the suspected laser related injury

- Notify your supervisor immediately
- Notify the LSO immediately
- Fill out the injury reporting forms and submit through your department's human resources representative; [Employees Work Injury and Illness Report](#), Supervisor and Safety Coordinator Investigation Report for Injury or Illness  
<https://businessservices.wisc.edu/wp-content/uploads/sites/546/2019/04/Employee-Work-Injury-and-Illness-Report.pdf>
- Contact UHS to arrange for the medical evaluation.

The LSO will investigate any suspected exposure and prepare the incident report.

## **X. Resources**

American National Standards Institute (ANSI) [www.ansi.org](http://www.ansi.org)

Laser Institute of America [www.laserinstitute.org](http://www.laserinstitute.org)

Rockwell Laser Institute [www.rli.com](http://www.rli.com)

### ➤ **Laser Safety Eyewear Resources**

Kentek [www.kenteklaserstore.com](http://www.kenteklaserstore.com)

Laservision [www.lasersafety.com](http://www.lasersafety.com)

NoIR Laser [www.noirlaser.com](http://www.noirlaser.com)

Thorlabs - [https://www.thorlabs.com/newgrouppage9.cfm?objectgroup\\_id=762](https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=762)

### ➤ **LIA Free Optical Density Calculator**

Click <https://www.lia.org/evaluator/od.php> link to open resource.

### ➤ **Kentek Easy Haz Basic Web Version Hazard Software**

<http://lasersafetyu.kentek.com/easy-haz-laser-hazard-software-basic-web-version/>

### ➤ **Sam's Laser FAQ**

Click <http://www.repairfaq.org/sam/lasersam.htm> link to open resource.

## **XI. References**

ANSI Z136.1, American National Standard for Safe Use of Lasers

Ken Barat, Laser Safety in the Lab

Laser Safety Guide, Tenth Edition, Laser Institute of America

CLSOs' Best Practices in Laser Safety, First Edition, Laser Institute of America

OSHA Technical Manual, available at:

[https://www.osha.gov/dts/osta/otm/otm\\_iii/otm\\_iii\\_6.html](https://www.osha.gov/dts/osta/otm/otm_iii/otm_iii_6.html)

## **XII. Appendix**

- i.** Appendix A: [Research Laser Disposal Instruction](#)
- ii.** Appendix B: [Laser Hazard Evaluation](#)
- iii.** Appendix C: [Laser Safety Standard Operating Procedures Template](#)
- iv.** Appendix D: [Laser Hazard Classification](#)

## XIV. Glossary

**Authorized Personnel** – Individuals approved by management to operate, maintain, service, or install laser equipment.

**Continuous wave (CW) Laser**– A laser operating with a continuous output for a period  $\geq 0.25$  s

**Controlled area (laser)** – An area where the occupancy and activity of those within is subjected to control and supervision for the purpose of protection from laser radiation hazard.

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

**Laser Energy** – Total work done by the light, usually measured in joules (i.e., watts \* seconds).

**Laser Power** – Energy per unit time, usually measured in watts (joules per second).

**Laser Safety Committee (LSC)** – The Committee that oversees the laser safety program at UW-Madison and UW-Health. The LSC reviews and revises policies and procedures, establish requirements based on the ANSI and other applicable regulations.

**Laser Safety Officer (LSO)** – An individual designated by management who has authority and responsibility to manage the overall laser safety program.

**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.

**Maximum Radiant Exposure** – Is the radiant energy received by a surface per unit area

**Maximum Radiant Energy** – Energy of electromagnetic and gravitational radiation. This radiation may be visible and invisible to the human eye.

**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.

**Nominal Ocular Hazard Distance (NOHD)** – The distance along the axis of the unobstructed beam from a laser, fiber end, or connector to the human eye beyond which the laser exposure is not expected to exceed the applicable MPE.

**Optical Density (OD)** – The logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength:  $D_{\lambda} = \log_{10} (1/\tau_{\lambda})$  – where  $\tau_{\lambda}$  is the transmittance at the wavelength of interest. Symbol: D ( $\lambda$ ),  $D_{\lambda}$  or OD.

**Protective Housing** – An enclosure that surrounds the laser or laser system and prevents access to laser radiation above the applicable MPE.

**Pulsed laser** – A laser that delivers its energy in the form of a single pulse or a train of pulses. In this standard, the duration of a pulse is less than 0.25 s.

**Standard Operating Procedure (SOP)** – Formal written description of the safety and administrative procedures to be followed in performing a specific task.

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

**Visible Light Transmission (VLT)** – The percentage of visible light transmitted through a lens, filter, or other optical element.

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