Rev 2: May 2024

Research Laser Safety Program Guideline

Purpose and Scope

The UW – Madison (UW) laser safety program's primary objective is to ensure that no laser radiation more than the maximum permissible exposure (MPE) limit reaches the human eye or skin. This program is also intended to ensure adequate protection against laser-related non-beam hazards.

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 UW-Madison.

To establish safety measures for working with Class 3B and Class 4 lasers and laser systems in the research and instructional laboratories. The laser safety program ensures:

- The use of equipment which produces laser radiation is used in a manner that will minimize risks to health and safety of the faculty, staff, students, and the general public
- The identification of laser hazards
- The prompt investigation of all reported laser radiation over-exposures and the establishment of immediate corrective action(s) to prevent their recurrence
- The maintenance of an accurate inventory for accountability of the hazardous lasers within UW Madison

Laser Safety Program Roles and Responsibilities

The Office of Radiation Safety (ORS): The ORS, within the Environment Health & Safety (EH&S) department at UW, manages the research and medical laser safety programs under the oversight of the Research Laser Safety Committee (RLSC) or Medical Laser Safety Committee (MLSC). A separate safety plan covers medical lasers given the disparate requirements between a laser used for research and a laser used in a medical setting.

Research Laser Safety Committee (RLSC): RLSC is responsible for the oversight of the lasers used on the UW-Madison campus.

RLSC duties and responsibilities:

- Reviews and revises policies and procedures as necessary.
- Establishes requirements based upon applicable regulations and guidance.
- Resolves conflicts or issues identified by the LSO, laser users or other parties.

Medical Laser Safety Committee (MLSC): MLSC is responsible for the oversight of medical lasers at UW Health facilities.

- MLSC duties and responsibilities develops, reviews, and revises policies and procedures as necessary.
- Establishes requirements based upon applicable regulations, guidance, and best practices.

- Resolves conflicts or issues identified by the LSO, laser users or other parties.

Laser Safety Officer (LSO): Is the individual designated by ORS Radiation Safety who has the authority and responsibility to establish, monitor, and enforce the laser safety program at UW-Madison. The LSO reports to the Radiation Safety Officer (RSO). LSO duties and responsibilities (per ANSI Z126.1-2014 Appendix A):

- Administer the day-to-day operation of the Laser Safety Program.
- Maintain a current inventory of Class 3B and 4 lasers.
- Perform laser hazard analyses and audits; ensure, by follow up and additional audits as necessary, that all laser safety deficiencies are addressed and resolved.
- Make recommendations to improve laser safety.
- Restrict or terminate use of lasers that present an imminent danger or excessive hazard.
- Ensure the availability of proper laser safety training.
- Make recommendations for selection of proper personnel protective equipment.
- Investigate laser accidents and near misses.
- Update laser safety policy and procedures as needed.
- Review, approve, and maintain a copy on file of all lasers standard operating procedures (SOPs).
- Review laser user's laser safety training records until that user is no longer involved with laser use at UW.
- Provide reports on the status of laser safety to the RLSC, MLSC and RSO, and promptly inform the RSO of any serious laser safety concerns.

Permit Holder (PH): A Permit Holder is an individual who has overall responsibilities for safe use of lasers and laser systems under their supervision complies with UW-Madison guidelines, University policies, and requirements. PH duties and responsibilities:

- Shall be responsible for the issuance of appropriate instructions and training materials on laser hazards and their control to all personnel who may work with lasers that are operated within the supervisor's jurisdiction.
- Shall not permit the operation of a laser unless there is adequate control of laser hazards to employees, visitors, and the general public.
- Shall submit the names of individuals scheduled to work with lasers to the ORS and shall submit information as requested by the ORS for training completion and medical surveillance.
- When an Approved Laser Worker knows of, or suspects, an incident/accident resulting from a laser operated under his/her authority, he/she shall immediately notify the ORS or LSO and take corrective actions.
- If necessary, the Approved Laser Worker shall assist in obtaining appropriate medical attention for any employee involved in a laser incident/accident.
- Shall not permit operation of a Class 3B or Class 4 laser under his/her authority without prior laser safety certification.
- Shall submit plans for Class 3B and Class 4 lasers installations or modifications of installations to the LSO for review.
- Shall be familiar with the standard operating procedures and ensure that they are provided to users of such lasers.
- Shall register all lasers under his/her authorization to ORS.
- Shall ensure that all lasers under his/her control are properly classified and labeled.
- Ensure the safe and responsible disposition of their unneeded, but potentially hazardous, Class 3B or 4 lasers and laser components.
- Ensure that safety controls are not disabled, removed, or modified and notify LSO immediately of any changes in the status of safety controls.

Laser Worker (LW): Laser worker is an individual who work around hazardous laser beams and has completed the required laser training and eye exam. LW duties and responsibilities:

- Complete the required training before operating a class 3B or 4 laser and again at the interval specified in this guideline.
- Use lasers safely.
- Comply with established policy, SOPs, and other procedural requirements.
- Shall not energize or work with or a near a laser unless authorized to do so by the supervisor for that laser (the Permit Holder).
- Shall comply with safety rules and procedures prescribed by the PH and Office of Radiation Safety and be familiar with all applicable operating procedures.
- Shall immediately inform the supervisor if he knows or suspects that an incident/accident has occurred involving a laser and that such incident/accident has caused or could potentially have caused an injury. If the supervisor is unavailable, the Laser Worker shall notify the ORS promptly.
- Do not disable, remove, or modify any safety controls systems without prior approval from PH.

Other Personnel Responsibilities: Anyone involved in purchasing a Class 3B or Class 4 laser or laser system shall register the device and contact ORS.

Spectators: Is an individual who observes a laser or laser system in operation, and who may lack appropriate laser safety training.

For both indoor and outdoor use, spectators should not be permitted within an LCA that contains Class 3B and Class 4 laser or laser system. Spectators can be allowed in the LCA when the following conditions are met:

a) Appropriate approval from the supervisor has been obtained.
b) The degree of hazard and avoidance procedure has been explained, and
c) Appropriate protective measures are taken.
d) Laser use is restricted solely for demonstration purposes.
e) Spectators understand the hazards and control measures.

Participating visitor: Is an individual requesting to use Class 3B or Class 4 lasers. The individual must be trained in the required laser safety procedure. Participating visitor may use lasers under direct supervision of the PH until completing all-laser safety training requirement. For those staying longer than 30 days, they will need to complete all required training and medical surveillance.

Laser Registration

It is the responsibility of the Permit Holder (PH) to register all Class 3B and Class 4 lasers under his/her authorization, whether constructed, purchased, or otherwise obtained from outside or inside the University with ORS. Class 1, Class 2, and Class 3R lasers or laser systems are not required to be registered.

Laser systems containing embedded Class 3B or Class 4 lasers should be registered with ORS (e.g. confocal microscopes, welder/cutters). If you are unsure if the system may contain a higher-class laser, the LSO or designee can assist in identifying the laser class.

The LSO should be notified when there may be occurrences where protective housings are removed, or interlocks are defeated, outside applications and the possibility for beam hazards to exist. ORS will need to perform a laser hazard evaluation.

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

The registration form(s) is available on ORS website: https://ehs.wisc.edu/labs-research/radiation-safety/lasers/

Research involving exposure of humans to non-ionizing radiation requires additional specific approval. For more information refer to ORS website on Human Investigation with Radiation

Laser Safety Training and Qualifications

All personnel operating Class 3B and Class 4 lasers shall attend and successfully complete the online "General Laser Safety" training before being authorized to work with lasers. This includes the following subject areas:

- Principles and practices of laser safety
- Biological effects of laser radiation on the eye and skin
- Non-Beam hazards
- Control measures

Besides the general training, each operator must be trained by the PH or appropriate designee, on laser specific safety regarding:

- The laser procedure.
- Equipment used.
- Emergency procedures before operating Class 3B, or Class 4 lasers/laser systems.

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

ORS may require the person involved in laser activities to take the online course offered as it is deemed necessary.

LW's shall take the RS 108: The Annual Laser Safety Training with training interval not to exceed 15 months.

Table 1: Laser Safety Training for Operators and Others (Based on Hazard Classification of Laser)

Type of instruction	Laser Class						
	1	1M	2	2 M	3R	3B	4
Manufacturers Operational Manual	X	X	X	X	·	Y	Y
RS 107: General Laser Safety (DOE)	X	X	X	X	·	Y	Y
RS 108: Laser Safety Refresher	X	X	X	X	·	Y	Y
RS 109: Medical Laser Safety (Veterinary Medicine)	X	X	X	X	·	Y	Y
RS 110: Medical Laser Refresher Training	X	X	X	X	·	Y	Y
PH Laboratory – Specific training	X	X	X	X	·	Y	Y

Y - Required
· - Recommended
X - Not Required

Medical Surveillance

A baseline eye exam is required before use of Class 3B and/or Class 4 lasers and laser systems. Occupational Medicine at UW-Madison provides baseline eye examinations. Occupational Medicine is located at 333 East Campus Mall, floors 5-8.

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

Please see the ORS website for more information on Medical Clearance instructions: https://ehs.wisc.edu/labs-research/radiation-safety/lasers/

Audits/Site Monitoring/Enforcement

The LSO, under the authority of the Radiation Safety Office, has the responsibility for monitoring all locations where lasers or laser systems are used or stored. The audits specified time period for labs shall not to exceed annually with a 60-day grace period; prior notification for such audits will be sent out to PH or designee.

The audits include, but are not limited to:

- Laser and eyewear inventory verification.
- Inspection of eyewear for damage.
- Inspection of laser system for required engineering and administrative controls.
- Training record review.
- Review of SOP's.

Corrective recommendations will be sent in writing to the approved PH or appropriate designee regarding any deficiencies identified during audits. Because unsafe use of lasers may lead to serious injuries, any deficiencies, or unsafe conditions identified by the LSO or designee and communicated to the PH shall be made in the required timeline. If not corrected, additional enforcement action may be necessary.

Laser Classification

All lasers and laser systems are categorized into one of the hazard classes described below. The manufacturer provides the classification for most lasers. For custom-built and modified lasers, the LSO can assist with classification.

A **continuous wave (CW)** laser according to ANSI Z136.5 (2020) is a laser operating with or modeled as having a continuous output for a period greater than or equal to 0.25 seconds.

A **pulse laser** according to ANSI Z136.5 (2020) is a laser that delivers its energy in the form of a single pulse or a train of pulses. The ANSI standard defines pulse lasers as having a pulse duration less than 0.25 seconds.

Class 1

- Visible lasers with wavelengths longer than 500 nm have a class 1 limit of 0.4 mW. The class 1 limit for visible lasers with wavelengths shorter than 450 nm is 40 µW.
- Do not emit harmful levels of radiation during normal operation.
- Also includes higher class lasers completely enclosed and interlocked to prevent beam access, allowing a Class 1 laser system designation; any time the higher-class laser is accessible (e.g. during alignment or servicing), the higher laser class controls must be observed.
- Can be used without restriction in the manner intended by the manufacturer and without special operator training or qualification.

Class 2

- Emit accessible laser light in the visible wavelength region.
- Capable of creating eye damage through chronic exposure.
- In general, the human eye will blink within 0.25 second when exposed to Class 2 laser light; this blink reflex provides adequate protection.
- Can be used without restriction in the manner intended by the manufacturer and without special operator training or qualification.

Class 3R

- Power output between 1-5 milliwatt (mW).
- Normally not hazardous when viewed momentarily with the unaided eye but may pose severe eye hazards when viewed through collecting optics (e.g., microscopes and binoculars).

- Same controls as Class 1 and Class 2 lasers for normal operations; if viewed through optical instruments (e.g., binoculars, telescopes, or microscopes), contact the LSO for a hazard review to determine if further control measures will need to be put in place.

Class 3B

- Power output 5-500 mW if CW, or less than 0.03 joule (J) per pulse for a pulsed system (i.e. pulse width less than 0.25 second).
- Will cause injury upon direct viewing of the beam and specular reflections.
- Must implement specific control measures described in the Control Measures section of this policy.

Class 4

- Includes all laser systems with power levels greater than 500 mW CW or greater than 0.03 J per pulse for a pulsed system.
- Pose eye hazards, skin hazards, and fire hazards. Viewing the beam, specular reflections, or exposure to diffuse reflections can cause eye and skin injuries.
- All control measures for class 4 lasers must be implemented as described in the Control Measures section of this policy.

Embedded Lasers

Lasers are often embedded in laser products or systems with a lower hazard class. When the laser system is used as intended, the controls for the system's class apply. When the system is opened (e.g., for service or alignment) and the embedded laser beam is accessible, a temporary control area must be established. The controls for the temporary control area must be based on the classification of the embedded laser.

Hazard Evaluation

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.

ORS can assist in performing the hazard evaluation.

Laser Hazard Control Measures

Control measures are established in the Z136.1 standard as a means of reducing the possibility of skin and eye exposure to laser radiation, during normal operation and maintenance, above their respective maximum permissible exposure (MPE). MPE is the level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin (ANSI Z136.1 2014). Hazard control measures can be grouped into three general categories:

- Engineering (e.g., enclosures, interlocks, beam stops)
- Administrative (e.g., policies, laser safety procedures, training)
- Personal Protective Equipment (e.g., eyewear, clothing)

Maximum emphasis should be placed on engineering control measures. However, if engineering controls are impractical or inadequate, warning devices, personal protective equipment, or administrative controls must be used.

Laser Controlled Areas (LCA)

Class 3B and Class 4 lasers may be operated only in designated laser control areas. The purpose of laser control areas is to confine laser hazards to well-defined spaces that are under the control of the laser worker, thereby preventing injury to those visiting and working near the controlled area. This area may be defined by walls, barriers, or other means. All personnel

authorized to enter a Class 3B or Class 4 laser-controlled area shall be appropriately trained and must follow all applicable administrative and operational controls.

- Spectators should be prevented from entering the controlled area during operation, maintenance, or service of the laser.
- Personnel authorized to enter controlled areas shall be properly trained and must adhere to all applicable administrative, procedural, and operational controls.
- All personnel potentially exposed to hazardous levels of laser radiation shall wear appropriate protective eyewear.
- The entrances to an LCA shall be posted with appropriate laser warning signs.

Temporary Laser Controlled Areas

Temporary laser-controlled areas can be created for the servicing and alignment of embedded lasers, enclosed lasers, and in special cases where permanent laser control areas cannot be provided. The exterior boundary of a temporary Laser Controlled Area shall be posted in accordance with ANSI Z136.1(2014), for appropriate warning signs and wording. The laser safety "Notice" signage (see Appendix A) shall be used on signs posted outside a temporary LCA during periods of service.

Outdoor Laser Operation

For any outdoor space using lasers or laser systems, they shall meet the requirements in ANSI Z136.1 and Z136.6. The operation of Class 4 lasers during rain, snowfall, fog, or dusty atmospheres may produce hazardous scattering near the beam. In such conditions, the LSO shall evaluate the need for, and specify the use of, appropriate PPE.

Laser experiments or programs that will involve the use of lasers or laser systems in outdoor settings or navigable airspace shall be coordinated with the Federal Aviation Administration (FAA) and ORS.

Access Control

For any Class 3B or Class 4 laser lab, 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 MPE. If the same lab is used for other functions by other researchers, then the laser within the lab must be secured with a key switch only accessible by authorized personnel.

Emergency Stop

Within Class 3B and Class 4 LCAs, there must be a clearly marked "Emergency Stop" or other appropriately marked device for the intended purpose of deactivating the laser or reducing the output to levels at or below the applicable maximum permissible exposure (MPE). Do not block the emergency stop button in any way. It is important to have fast and easy access to it in case of emergency.

Warning Device

The entrance to laser labs with open beam Class 3B and Class 4 lasers shall have a lighted warning sign or device on when the laser is operating. A visible warning device may be in the form of a single red light or an illuminated laser warning sign that flashes when the laser is operating and is clearly visible through the laser protective eyewear and is also viewable within the area.

For any new laser lab, installing the warning sign that lights up will be 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.

Written Warning Signs and Labels

The warning sign notifies users of the presence of a potential laser hazard inside the lab or space. Appropriate warning signs conveying the severity of hazards pertinent to the class of laser shall be posted at all entrances to the laser lab.

ORS will provide the appropriate warnings signs for the lab entrance posting after the lasers are registered. Reference Appendix A for warning signage.

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.

Laser Protective Eyewear

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 PH 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 for 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. The LSO can assist in selecting the proper laser-protective eyewear.

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 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

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 purposes in labs with multiple lasers.

Inspection and Cleaning of Laser Eyewear

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

For laser eyewear inspection, check for:

- Pitting, grazing, cracking, discoloration of the attenuation material
- Mechanical integrity of the frame
- Light leaks and coating damage

Standard Operating Procedure

A written SOP is required for all Class 3B and Class 4 lasers or laser systems. The SOP must include a description of the following:

- Laser details (e.g. Laser class, mode, max output power/energy, pulse length, pulse repetition frequency)
- Laser system set-up
- Intended laser application.
- Operating procedures
- Routine alignment procedures
- Schematics of laser set-up
- Control measures
- Maintenance procedure
- Beam and non-beam hazards
- Personal protective equipment requirements
- Emergency procedure

The SOP shall 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.

All SOPs should be reviewed annually by personnel working with lasers to ensure the accuracy of the procedure(s). If new hazards have been added to the experiment, a review by the LSO may be necessary to assure all applicable safeguards have been implemented. The SOP should be sent for review before they start the experiment.

See Appendix D for a sample SOP. A template is provided on ORS website.

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

Any substitute on the control measures, (engineering controls) specified in the standard for Class 3B and Class 4 lasers with administrative or other alternative controls measures shall 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.

Perimeter guards, barriers, barrier covers, beam tubes and smaller enclosures the material should be compatible with the laser wavelength and beam power.

Materials that are flammable such as cardboard, foam boards and foam core boards are not acceptable materials, especially with high power Class 3B and Class 4 lasers.

Laser Transfer and Disposal

ORS shall be notified of any Class 3B, or 4 lasers or laser systems relocated, transferred to another PH or institution, or sent offsite as surplus equipment.

Permit holders or designees have an obligation to ensure safe and responsible disposition of their Class 3B or 4 lasers and laser components. Appropriate means of laser disposal includes:

- Transfer the laser to another lab that would have need for such a device.
- Return the laser to the manufacturer or to a vendor specializing in re-selling or disposing of used laser equipment.
- Eliminate the possibility of activating the laser by removing all means by which it can be electrically activated. Once this has happened the laser could then be cleared by ORS for disposal.

- Proper disposal of any hazardous materials found inside the laser components, such as mercury switches, oils, dyes, etc.
- Chemical Safety can help assist with the proper disposal of oils, mercury switches, dyes and other chemicals if used in lasers.
- Biological Safety can help assist with the proper disposal of sharps for fiber lasers.

Permit holders or designees should contact the proper safety department if they need further information or assistance with proper disposal.

See Appendix C for laser disposal instructions.

A laser disposal and transfer form are available on ORS Laser safety website: https://ehs.wisc.edu/laser-device-disposal-form/

Laser Permit Deactivation

Permit holders are responsible for contacting ORS when:

1. They wish to deactivate their laser permit.
2. Are leaving the University.

ORS will assist in the proper steps for laser lab close out.

Laser Related Injury and Reports

Laser workers must report all laser accidents on site, no matter how minimal, to the PH responsible for the laser system involved. The PH must report any accidents causing injury or property damage to the LSO.

In the event of the suspected laser related injury:

1. Stop all laser work.
2. Seek medical attention asap.

Eye Exposure

- **During business hours:** Contact UW Occupational Medicine (609) 265-5610. They will assist in setting up an eye exam at Davis Duehr Dean.
- **After business hours:** Seek care at the nearest Urgent Care or Emergency Department.
- **In case of an emergency:** Dial 911
  Laser eye exposures should be evaluated by an ophthalmologist as soon as possible.

Skin Exposure

- **During business hours:** Contact UW Occupational Medicine (608) 265-5610
- **After business hours:** Seek care at the nearest Urgent Care or Emergency Department
- **In case of an emergency:** Dail 911

After any accidental exposure or possible radiation injury:

1. Notify your supervisor immediately.
2. Notify the Office of Radiation Safety: radiationsafety@wisc.edu or (608) 262-3600
3. Contact UHS to arrange for medical evaluation.
4. Fill out the injury reporting forms and submit them through your department's human resources representative within 24 hours. https://businessservices.wisc.edu/managing-risk/workers-compensation/

5. The Office of Radiation Safety will investigate any suspected exposure and prepare the incident report.

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 can be a major concern and may require more control measures. When concerning Non-Laser Radiation (NLR), Radiation Safety can help address the hazards below associated with ionizing and non-ionizing radiation:

Collateral Radiation: Any electromagnetic radiation, except laser radiation, emitted by a laser system. This does not include laser target interaction radiation (reradiation).

Laser Target Interaction Radiation (LTIR): Non-laser radiation, including ionizing radiation, emitted by a material because of that material's exposure to laser radiation.

Optical Radiation: Collateral ultraviolet light (UV) radiation emitted from laser discharge tubes and pump lamps as well as plasma emissions.

These hazards must be reviewed by the ORS and addressed by the PH in the SOP for the laser operation, where applicable. Seek assistance from Chemical, Fire, Biological safety personnel or industrial hygiene personnel to address some of the non-beam hazards listed below.

Table 2: Non-beam hazards associated with laser use.

1. Physical Hazard	**Possible Source**
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
2. Chemical Hazard	**Possible Source**
Toxic substance	Laser dyes
Carcinogenic substances	Solvents
Irritant substances	Samples
Dust and particulates	Cracked optics
Fire	From ignition
3. Biological Hazards	**Possible Source**
Microbiological organism	Released from target interaction
Viruses	Released from target interactions
4. Mechanical Hazards	**Possible Source**
Trailing cables and pipes	Housekeeping
Sharp edges	Razor blades

Moving parts	Robotic arm or piston
High-pressure water	Cooling lines
5. Ergonomic Hazard (Human Factors)	**Possible Source**
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.

Safety Precautions

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 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 eye level for either sitting or standing position.
- Enclose as much of the beam as is practical.
- Never look directly into the laser beam path 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.

Techniques for Safe Laser Alignment Procedures

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

ORS, in conjunction with 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.

Resources

- Laser Cutter Safety
- Laser Pointer Safety
- Emergency Poster for Laser Users
- Laser Institute of America
- Rockwell Laser Institute
- Sam's Laser FAQ

Laser Safety Eyewear Resources

- Kentek
- Laservision
- NoIR Laser
- Thorlabs

Laser Safety Free Calculators

- LIA Free Optical Density Calculator
- Kentek Easy Haz Basic Web Version Hazard Software

References

Standards

The American National Standards Institute (ANSI) currently has three standards applicable to UW laser use.

1. ANSI Z136.1-2014, titled “American National Standard for Safe Use of Lasers”.
2. ANSI Z136.5-2020, titled “American National Standard for Safe Use of Lasers in Educational Institutions”.
3. ANSI Z136.8 2021, titled “American National Standard for Safe Use of Lasers in Research, Development, or Testing”.

Regulations

1. WI Statutes 941.299 Restrictions on the use of laser pointers

Other

- 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

Further Information

For further information on laser surveys or the proper implementation, please contact the ORS at RadiationSafety@wisc.edu or LaserSafety@wisc.edu (608) 262-3600.

Laser Safety Program information is available on the ORS website: https://ehs.wisc.edu/labs-research/radiation-safety/lasers/

Appendix A: Laser Warning Signage

Danger Signage: The “DANGER” sign is to denote an imminently hazardous situation which, if not avoided, will result in death or serious injury.

Caution Signage: The “CAUTION” sign is used with the safety alert symbol to denote a potential hazardous situation, which, if not avoided, may result in minor or moderate injury.

Notice Signage: The “NOTICE” sign is used without the safety alert symbol to advise of temporary or non-standard situations, such as a laser service. Can be used in combination with other hazard signs to provide appropriate warning and safety information.

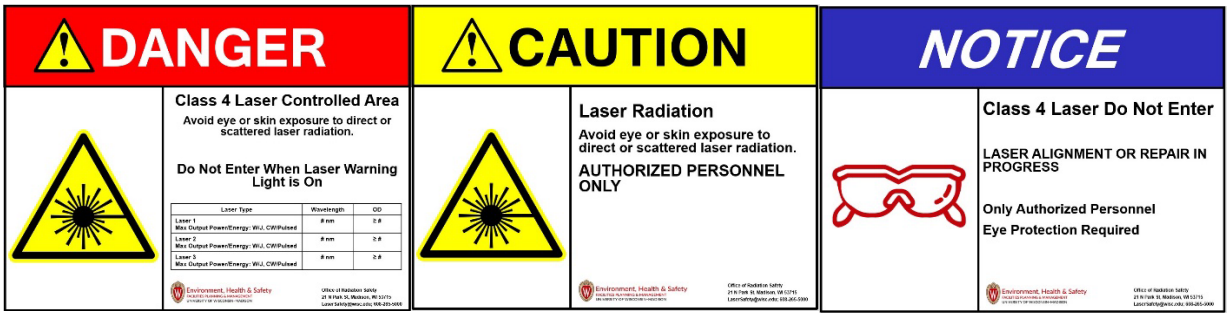

Figure 1: Sample laser controlled area warning signs.

Appendix B: Research Laser Disposal Instructions

For Class 3B and Class 4 Laser (s) and Laser System (s):

- Follow UW- Madison equipment disposition guidelines and receive written approval from property control for all lasers intended for disposal. The guidelines can be found as follows:

  https://businessservices.wisc.edu/documents/3008-7-equipment-disposition-procedure/

  The UW Property tag should be removed prior to disposal.

- Complete Online Laser Disposal form. Once Office of Radiation Safety (ORS) receives the Laser Disposal form, we will contact you and work together to guide you through disposal process.

- Laser can be returned to the manufacturer or transferred/donated to another institution. The transfer/donation must be approved by the ORS.

- Lasers can be listed for resale at UW- SWAP (Surplus with a Purpose) auction website. This should be done in coordination with ORS and SWAP. Lasers intended for disposal shall not be moved anywhere from the original location without ORS approval.

- For disposal as Metal Scrap

  a. Remove any hazardous materials contained in the laser system and properly dispose of them in accordance with appropriate federal, state and local guidelines.

  b. Remove all means by which the laser can be electrically activated or make it inoperable (remove power cord and switches).

  c. Receive a clearance sticker from ORS and contact Campus Waste and Recycling group for pick up.

Appendix C: Laser Safety Standard Operating Procedures Template

WISCONSIN
UW Health

Environment, Health and Safety Program
Office of Radiation Safety
Class 3B & 4 Laser Standard Operation Procedure
30 East Campus Mall Madison, WI 53715
Phone: 608-265-5000 | Fax: 608-262-6767 | www.ehs.wisc.edu/

Permit Holder: _____

Laser Class:	☐ Class 3B ☐ Class 4
Manufacturer	
Model	

LASER SAFETY CONTACT FOR YOUR LAB

Name	
Phone	
Email	

1. LASER SAFETY GENERAL CAMPUS POLICIES

Responsibilities of the laser operator(s):

Operator will ensure the safety of any personnel that might enter the room and will advise same of the status of the lasers and optics. This includes ensuring use of protective protective eye wear where necessary.
The laser user is responsible for the safe of the laser(s) at all times.
Incidents/accidents will be reported promptly to EH&S @ (608) 265-5000. Emergency response: 9-1-1

Laser Training Requirements: Part 1 of the training involves review the EH&S online Laser Safety Training. The Principal Investigator is responsible for providing instruction in the safe and appropriate use of the laser related to the specific research project, which constitutes Part 2 of the training.

Laser Registration Requirements: EH&S must be notified after the purchase any class 3B or 4 lasers through the online Laser Registration Form.

Device label(s), door placard(s) and exterior light installed.

Personnel Protective Equipment Requirements: EHS will review the laser application/SOP. Typically, protective eyewear will be required. Other protective equipment may also be needed. This will be evaluated on a case by case basis. Users are responsible for purchasing and using prescribed protective equipment.

Disposal Requirements: EHS requires proper disposal of all class 3B and 4 lasers. The laser may contain toxic or hazardous materials which require proper disposal. Use the EHS Laser Disposal Form to begin the disposal process.

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 ≥ 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 τ_λ is the transmittance at the wavelength of interest. Symbol: D (λ), D_λ 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).