University of Idaho
Environmental Health and Safety

Laser Safety Protocol

Environmental Health and Safety
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Contents

1 Introduction

Lasers produce highly-focused and intense beams of non-ionizing electromagnetic radiation that can cause injury to the eyes and skin on direct exposure to the beam or to reflected radiation. Eye injury, including blindness, may occur while using even low-power lasers. Severe burns to the skin may result from exposure to moderate- or high-power laser beams. Lasers can also cause collateral adverse effects associated with the use of laser systems, such as fire or explosion from high heat production, hazardous fumes and particles, and exposure to cryogenics gases or high voltages.

The purpose of this document is to provide an overview of the laser safety program at the University of Idaho and emphasize aspects of laser safety that are of primary importance to personnel on the UI campus. It is not meant to replace either manufacturer laser safety and operation recommendations or the American National Standard for Safe Use of Lasers (ANSI Z136.1-2007). Individuals who will be working with lasers should refer to these resources directly for a more detailed treatment of laser safety. Both the American National Standard for Safe Use of Lasers (ANSI Z136.1-2007)[1] and the American National Standard for Safe Use of Lasers in Educational Institutions (ANSI Z136.5-2009)[2] are available for students, faculty, and staff to reference at the Environmental Health and Safety (EHS) Office. The former is generally applicable to all laser facilities (including those using lasers for research), while the latter applies to teaching facilities only.

Questions regarding the laser safety program at the University of Idaho should be directed toward the Radiation Safety Officer (RSO) in EHS at safety@uidaho.edu or (208)885-6524.

1.1 Intended Audience

This document is intended for use by individuals who will be involved with the normal operation of laser systems, especially moderate- and high-power lasers, at the University of Idaho. These individuals fall into three categories: principal investigators (PIs), authorized personnel, and other personnel.

Principal investigators are UI faculty or staff who are primarily responsible for assuring the safe use of lasers in their possession by all personnel. All PIs should be familiar with the contents of this document and are ultimately responsible for ensuring compliance with its requirements, including the preparation of standard operating procedures (Appendix B), maintenance of appropriate control measures, and ensuring that laser users have been trained.

Authorized personnel include students, faculty, and staff who use Class 3B or 4 lasers under the authority of a PI. Authorized personnel are required to review the UI Laser Safety Protocol, instrument-specific standard operating procedures (SOPs), and instrument-specific manuals prior to laser operation. They must also receive instrument-specific hands-on training, and sign and submit a Laser Safety Training Agreement (Appendix D) indicating their familiarity with laser hazards, emergency measures, and reporting requirements. Authorized personnel are only allowed to operate the specific lasers for which they have received training.

Other personnel are those students, faculty, and staff who use Class 1, 2, 2M, or 3R lasers. These individuals should be familiar with the UI Laser Safety Protocol and the safe use of low- and moderate-power lasers.

This document is not intended for service personnel who may have to bypass the protective housing or safety interlocks of laser systems when performing maintenance and repairs. It is the responsibily of the PI to ensure that all service personnel are appropriately qualified and have adequate laser safety training to perform their duties.

1.2 Overview of Laser Safety Requirements

The major requirements of the laser safety program at the University of Idaho are summarized below for reference:

Laser Registration: All Class 3B and 4 lasers must be registered with the UI RSO. The UI RSO must be notified immediately of any major changes in the configuration or location of Class 3B and 4 lasers, including transfer to surplus or disposal.

Preparation of Standard Operating Procedures: Standard operating procedures must be prepared for all activities performed using Class 3B and 4 lasers. Guidelines for the preparation of laser SOPs are provided in Appendix B.

Authorized Personnel Safety Training and Certification: All authorized personnel must review the UI Laser Safety Protocol, pertinent SOPs, and manuals. They must also receive instrument-specific training prior to using Class 3B or 4 lasers. Authorized personnel who have completed these requirements must fill out the Laser Safety Training Agreement in Appendix D and return a signed copy to the UI RSO within 30 days. It is recommended that other personnel using Class 2, 2M, and 3R lasers also review the UI Laser Safety Protocol.

Compliance with Manufacturer Recommendations and Intended Use: All lasers should be used in accordance with their original intended use, following the safety precautions and protocols described in the documentation and manuals provided by the instrument manufacturer. Manufacturer operation manuals must be reviewed by personnel using Class 3B or 4 lasers, and should be reviewed by personal using Class 2, 2M, or 3R lasers. No alterations to laser systems or other deviations from the intended use should be undertaken without written approval from the UI RSO, following a comprehensive hazard analysis.

Instrument Labels and Area Postings: All equipment containing Class 2, 2M, 3R, 3B, and 4 lasers must be labeled with the laser sunburst logotype symbol, the laser class, and appropriate warning language as described in ANSI Z136.1-2007, Section 4[1]. Areas containing Class 3R, 3B, and 4 lasers must have laser radiation “Notice” or “Danger” signs posted as described in ANSI Z136.1-2007, Section 4[1] and ANSI Z136.5-2009, Section 4[2]. Further details are available in subsection 3.1.11 of this document. Class 2 and 2M laser areas should have warning signs posted if children or people who cannot read may be exposed to laser radiation.

2

Laser Overview and Hazards

The word laser comes from the acronym "light amplification by stimulated emission of radiation," which was coined to describe the mechanism by which lasers produce beams of highly-focused non-ionizing electromagnetic radiation. Laser beams consist of directional electromagnetic waves at discrete frequencies traveling in sync and in parallel. These waves are often highly concentrated over a small transverse area, meaning they are capable of depositing a large amount of energy on a small section of a target. When that target is a human eye or skin, lasers can cause injury through thermal burns or alterations in the biochemistry of the affected area.

Lasers have many applications in teaching and research, including spectroscopy, interferometry, laser ablation for solids sampling, precision materials cutting, and as simple laser pointers. As such, lasers play an important role in the creative and scholarly work performed at the University of Idaho. Awareness of how to safely handle these useful devices is essential to promoting the teaching and research goals central to the UI mission.

2.1 Laser Hazard Classification

Lasers and laser systems are classified according to their potential to cause injury to personnel under normal operating conditions, in a designation known as their "hazard class." If the hazard class of a laser is known, its potential for injury can be identified even if nothing else about it is known. Characteristics affecting the hazard class of a laser include the power and duration of the laser beam produced, the accessibility of the laser beam during normal operation, the potential for user exposure to laser radiation, and the visibility of the laser beam to the human eye. Generally, lasers operate either at a steady output power, referred to as continuous wave (CW) mode, or in pulsed mode, where the output power is maintained for a limited time. The properties of lasers in each hazard class and their potential adverse effects are summarized in Table 2.1. It is important to note that laser systems containing class 3B or 4 lasers may be classified as class 1 or 2 during normal operation if the higher power laser is fully enclosed. These are known as embedded lasers.

Table 2.1: Summary of laser hazard classifications

Hazard Class	**Output Power Range**	**Beam Visibility**	**Potential for Injury**
1	Very low-power laser OR a fully-enclosed higher-power laser	Visible or Invisible	Direct beam exposure cannot cause injury during normal operation
1M	Very low-power laser	Visible or Invisible	Beam may cause injury if viewed with an optical instrument
2	<1 mW (CW) OR a fully-enclosed higher-power laser	Visible Only	Human blink reflex protects again injury on direct beam exposure
2M	<1 mW (CW)	Visible Only	Beam may cause injury if viewed with an optical aid
3R	1–5 mW (CW)	Visible or Invisible	Direct eye exposure may cause injury for invisible beam, or visible beam viewed with optical aid
3B	5–500 mW (CW)	Visible or Invisible	Direct eye exposure will cause injury; skin injury is possible at higher end of power range
4	>500 mW (CW)	Visible or Invisible	Direct or reflected beam exposure can cause eye and skin injury; potential fire hazard

2.2 Primary Laser Beam Hazards

Direct exposure of the human eye or skin to a laser beam poses the greastest overall health risk to users of lasers and laser systems. Fortunately, this type of injury is straightforward to prevent by emphasizing an awareness of beam hazards by authorized and other personnel when placing any parts of their body between the beam source and its target. If such an action becomes necessary, personnel should make absolutely sure that the laser is either off or operating at a sufficiently low power to prevent injury. The human body part most susceptible to injury from laser radiation is the eye.

Injury may also occur upon exposure to a reflected laser beam. There are two types of reflections to consider when using lasers: specular and diffuse. Specular reflections are those which result from the reflectance of a laser beam from a highly-polished or mirror-like surface. These are the most dangerous types of reflections because the power of the reflected beam may be similar to that of the direct beam. Diffuse reflections occur when a laser beam hits a rough surface, dispersing the laser radiation in many directions. Diffuse reflections are generally only of concern for very high-power lasers.

Injury to the eyes and skin following either direct exposure to a laser beam or to a laser beam reflection occurs through two different mechanisms. The first and most common mechanism is direct heating of the targeted area. These photothermal effects can cause burns to the cornea or retina of the eye, or skin burns. The second mechanism, which is less common, is the inducement of changes in the biochemical environment of the eye or skin. Such photochemical effects are caused by the cleavage of chemical bonds to form new or reactive species, and can result in diseases such as cataracts (eye effect) or cancer (eye or skin effect) following chronic exposure to low levels of laser radiation.

The maximum permissible exposure (MPE) for a laser describes the threshold level of laser radiation (in units of power per area, ususally W/cm^2) below which there is no risk of eye or skin injury. A table of MPEs for different types of commonly-encountered lasers is provided in Appendix E. Maximum Permissible Exposures can be calculated for both eye and skin exposures following the procedures described in ANSI 136.1-2007, Appendix B[1].

2.3 Non-Beam Laser Hazards

The equipment required to generate a beam of laser radiation may pose health and safety hazards in addition to those associated with direct beam exposure. The following are the major non-beam hazards associated with laser use:

- *Electrical hazards* are associated with the high-voltage sources required for the operation of many lasers and laser systems, and may result in electrical shock to users or act as an ignition source for flammable and explosive materials.
- *Plasma and other radiation* can be generated by the interaction of a laser beam and a (ususally metallic) target, resulting in possible exposures to ultraviolet, X-ray, or radiofrequency radiation.
- *Noise* levels may be excessive for certain types of lasers.
- *Laser generated airborne contaminants* can be produced by the interaction of a sufficiently powerful laser beam with most types of targets. The resulting gases, vapors, or aersols may require additional ventilation to avoid personnel exposure.
- *Compressed gases* required for some lasers may be inert, flammable, toxic, corrosive or oxidizing and appropriate control measures and personal protective equipment (PPE) should be used depending on the specific hazards posed.

- *Laser dyes and solvents* include many compounds known to be toxic or flammable. The least hazardous dye and solvent should be used for a given application.
- *Infectious materials* may become airborne upon acting as a laser target, requiring additional ventilation and air filtration.

2.4 Awareness of Hazardous Conditions and Mitigation

The American National Standard for Safe Use of Lasers (ANSI Z136.1-2007, Section 4) lists the following as the most common conditions contributing to accidents involving lasers:

1. Unanticipated eye exposure during alignment
2. Misaligned optics and upwardly directed beams
3. Available eye protection not used
4. Equipment malfunction
5. Improper methods of handling high voltage
6. Intentional exposure of unprotected personnel
7. Operators unfamiliar with laser equipment
8. Lack of protection for non-beam hazards
9. Improper restoration of equipment following service
10. Eyewear worn not appropriate for laser in use
11. Unanticipated eye/skin exposure during laser usage
12. Inhalation of laser generated air contaminants and/or viewing laser generated plasmas
13. Fires resulting from ignition of materials
14. Eye or skin injury of photochemical origin
15. Failure to follow standard operating procedures (SOPs)[1]

This list includes conditions increasing the risk of adverse health impacts resulting from both beam and non-beam hazards. Such primary and secondary hazards associated with laser use can be mitigated through a combination of positive personnel action and safety measures implemented in the design of laser systems. Personnel working with lasers should leverage an awareness of laser hazards and common conditions contributing to laser injuries to prevent accidents involving themselves and others. For example, an individual who knows that the process of laser alignment has a high potential for injury should exercise a greater level of care when completing this action. Furthermore, individuals who have only a conceptual understanding of laser operation may be not be familiar with non-beam laser hazards. Awareness of non-beam hazards and how they originate is developed through laser safety training and exposure to resources such as this document.

3 Control Measures

Control measures are actions, procedures, and physical barriers that protect personnel from exposure to hazards. Control measures are categorized based on their effectiveness and potential for failure. There are two major types of control measures that may be encountered while using existing laser equipment: engineering controls, and administrative and procedural controls.

3.1 Engineering Controls

Engineering controls are designed to isolate personnel from exposure to hazard sources through the use of physical barriers. Engineering controls used in laser operations are described in the following sections.

3.1.1 Protective Housing

All lasers must be equipped with a protective housing that prevents access to laser radiation above the MPE.

3.1.2 Safety Interlocks (Class 3B or 4)

If removable, the protective housing enclosing class 3B or 4 lasers (including embedded lasers) must be equipped with fail-safe interlocks to prevent access to laser radiation above the MPE if the housing is removed during normal operation..

3.1.3 Key Control (Class 3B or 4)

All class 3B or 4 lasers must be equipped with a key- or code-controlled master switch capable of terminating the laser beam or turning off the laser system.

Figure 3.1: Example "Notice" sign for designating temporary laser controlled areas

3.1.4 Viewing Optics and Windows

When viewing optics or windows are used with lasers, suitable measures such as filters or attenuators must be used to maintain personnel exposures below the MPE.

3.1.5 Beam Paths

If the beam path of a class 3B or 4 laser is fully open or only partially enclosed, a hazard evaluation must be completed by the RSO to ensure that appropriate control measures have been implemented to prevent personnel exposures above the MPE. This includes defining a Nominal Hazard Zone (NHZ) within which the MPE is exceeded, and may include additional measures such as ventilation ducts or additional room partitions.

If the beam path of a normally-enclosed laser is made accessible, additional controls should be implemented as necessary. This may include the designation of a temporary laser controlled area, requiring a "Notice" sign (Figure 3.1), entry limitations, additional PPE, and other protective features. The information required on a "Notice" sign is provided in ANSI 136.1-2007, Chapter 4[1].

3.1.6 Remote Interlock Connector (Class 3B or 4)

Class 3B lasers should have a remote interlock connector that will reduce the laser radiation level below the MPE when activated. A remote interlock connector is required for class 4 lasers.

Figure 3.2: Example "Caution" sign for laser areas with class 2 or 2M lasers (for class 2, as shown)

3.1.7 Beam Stop or Attenuator (Class 3B or 4)

Class 3B lasers should be equipped with a beam stop or attenuator to limit accessible laser radiation when not needed. Class 4 lasers must be equipped with these devices.

3.1.8 Laser Area Warning Signs and Activation Warnings (Class 2, 3, or 4)

An area with a class 2 or 2M laser that is accessible by children or people who cannot read or understand warning labels must have "Caution" signs (Figure 3.2) with required safety information posted at all access points.

Areas with class 3R, 3B, or 4 lasers must have "Danger" signs (Figure 3.3) with required safety information posted at all access points. A detailed description of required safety information can be found in ANSI 136.1-2007, Chapter 4[1].

Warning signs for non-beam hazards (as described in section 2.3) should be posted where appropriate.

Class 3B lasers should be equipped with an audible alarm or warning light to notify personnel in the area of laser activation or startup. Class 4 lasers must be equipped with an activation warning system.

3.1.9 Laser Controlled Areas (Class 3B or 4)

Class 3B and 4 Laser Controlled Area Requirements

The following control measures must be implemented in class 3B or 4 laser controlled areas:

Figure 3.3: Example "Danger" sign for laser controlled areas with class 3R, 3B, or 4 lasers (for class 3B, as shown

1. Only authorized personnel with documented laser training are allowed to operate class 3B or 4 lasers (see subsection 3.2.3 for more information).

2. "Danger" signs must be posted at all access points (subsection 3.1.8).

3. Laser use must not take place without PI knowledge and approval.

4. Spectators must be aware of laser hazards and obtain PI consent before entry into a controlled area to observe laser operation.

5. Laser beamstop(s) must be made of an appropriate material to absorb the laser beam.

6. Only diffusely reflecting material is allowed in or near the beam path.

7. All personnel must be provided with appropriate PPE in laser controlled areas (subsection 3.2.5).

8. The path of an exposed laser beam must be located either above or below eye-level for seated or standing personnel.

9. Windows and doors must be covered to prevent laser radiation above the MPE from escaping the laser controlled area.

10. Measures must be taken to prevent unauthorized laser access when not in use, such as removing the master switch key.

Class 4 Laser Controlled Area Requirements

In addition to those described in section 3.1.9, the following control measures must be implemented in class 4 laser controlled areas:

1. Doorways and other access points must be designed to allow for rapid entry and exit under emergency conditions.

2. The controlled area must be equipped with an obvious “Emergency Stop” device to deactivate the laser or reduce its power below the MPE.

3. Access to the controlled area must be limited by one of the following (in order of preference):

    a) A non-defeatable automated system for deactivating the laser or reducing its power below the MPE upon the unexpected entry of personnel into the controlled area.

    b) A defeatable automated system for deactivating the laser or reducing its power below the MPE upon the unexpected entry of personnel into the controlled area. Authorized personnel may override the automated system to allow the entry of other authorized personnel during laser operation when necessary.

    c) Procedural controls allowing entry of only authorized personnel with appropriate PPE to the area, where a barrier is used to shield the laser radiation at the point of entry, and there is a warning system at the point of entry indicating when the laser is in use.

3.1.10 Controlled Operation (Class 4)

Personnel operating class 4 lasers and lasers systems should be located as far away as possible from the laser, preferably in a separate area or room.

3.1.11 Equipment Labels (Class 2, 3, and 4)

Class 2, 2M, 3R, 3B, and 4 lasers must have appropriate “Notice,” “Caution,” or “Danger” labels on a highly visible part of the laser housing or control panel. A detailed description of label requirements can be found in ANSI 136.1-2007, Chapter 4[1].

3.2 Administrative and Procedural Controls

Administrative and procedural controls are actions and procedures undertaken by personnel to prevent their exposure to hazards. Administrative and procedural controls (including PPE) used in laser operations are described in the following sections.

3.2.1 Laser Registration

All class 3B or 4 lasers or laser systems must be registered with the UI RSO. The RSO must be notified when new lasers are acquired, and if any major changes are made to the location or configuration of existing lasers.

3.2.2 Standard Operating Procedures

Standard operating procedures must be developed for all class 3B or 4 lasers or laser systems. Guidelines for preparing laser SOPs are provided in Appendix B. Where possible, SOPs should follow manufacturer instructions. If a class 3B or 4 laser is modified or used in a way not recommended by its manufacturer, the UI RSO must be notified so a hazard evaluation of the new operating conditions can be performed.

3.2.3 Training and Authorized Personnel

Only authorized personnel may operate a class 3B or 4 laser. Students, faculty, or staff may be designated as authorized personnel upon completing all of the following:

1. Review of the UI Laser Safety Protocol
2. Review of laser manufacturer operation and safety recommentations
3. Review of instrument-specific SOPs
4. Instrument-specific hands-on training
5. Signed Laser Safety Training Agreement returned to UI RSO (Appendix D)

Authorized personnel are only allowed to operate lasers for which they have received instrument-specific training.

3.2.4 Alignment Procedures

Because most direct-beam laser injuries occur during beam alignment, the procedures for performing this task must be carefully defined. Specific procedures for laser alignment should be included in the laser SOP. Guidelines for preparing laser SOPs are provided in Appendix B.

3.2.5 Personal Protective Equipment (Class 3B and 4)

Protective eyewear is required for PIs or authorized personnel operating a class 3B or 4 laser. The type of protective device should be appropriate for the type of laser being used. Guidelines for choosing appropriate PPE are provided in ANSI 136.1-2007, Chapter 4[1].

4

Emergency Procedures

4.1 Emergency Measures and Reporting Requirements

IN CASE OF EMERGENCY:

1. Immediately turn off the laser and remove the interlock key, if possible. If not possible, alert others in the area and tell them to exit the room. Exit the room yourself.
2. In the event of a fire, evacuate the area and activate a fire alarm.
3. If exposure to laser radiation is known or suspected, seek medical attention immediately. Ensure that medical personnel are aware of the nature of the laser exposure (eye and/or skin).
4. As soon as possible following the incident, notify the PI.
5. Contact the UI RSO at (208)885-6524 to report the incident. All incidents involving laser malfunctions, or actual or potential personnel injury must be reported to the RSO.

4.2 Medical Examinations

The Unversity of Idaho does not have a medical surveillance program for personnel working with lasers. Personnel who have been exposed to laser radiation should be referred to an ophthalmologist for eye exposures, and a physician for skin exposures.

A

Personnel Responsibilites

Principal Investigator(PI) Responsibilities

- PIs are faculty or staff who bear primary responsibility for the safe use of lasers under their control
- Must be familiar with the hazards associated with the lasers under their control
- Are responsible for the preparation of standard operating procedures for their lasers
- Must only allow properly-trained authorized personnel to operate class 3B and 4 lasers
- Must register all class 3B and 4 lasers with the UI RSO
- Must notify the UI RSO of all major changes to the location or configuration of class 3B and 4 lasers
- Must notify the UI RSO of all accidents or potential injuries resulting from laser operation
- Must obtain the approval of the UI RSO before operating new or modified class 3B or 4 lasers

Authorized Personnel Responsibilities

- Authorized personnel are students, faculty, or staff who are authorized to operate a class 3B or 4 laser under the authority of a PI
- Must be familiar with the hazards associated with the lasers they are authorized to use
- Must only operate the specific lasers for which they have received training
  - A record of this training in the form of the Laser Safety Training Agreement in Appendix D must be submitted to the UI RSO within 30 days of completing the required training

- Must be familiar with the SOPs governing the lasers they are authorized to use
- Must notify the PI of all accidents or potential injuries resulting from laser operation
  - If the PI is not available, authorized personnel should notify the UI RSO directly

Other Personnel Responsibilities

- Other personnel are students, faculty, or staff who use class 1, 2, 2M, or 3R lasers
- Should be familiar with the hazards associated with the lasers they use, and appropriate precautions

B

Guidelines for Preparing a Laser Standard Operating Procedure

Standard operating procedures are required for all class 3B and 4 lasers at the University of Idaho. Laser SOPs must include the following information:

1. **Lab-Specific Information**
    a) Laser location & specifications (type, manufacturer, model, hazard class, etc.)
    b) PI name and contact information
    c) Brief summary of laser intended use
2. **Hazards**
    a) Description of all beam and non-beam hazards associated with the laser or laser system
3. **Control Measures and Personal Protective Equipment (PPE)**
    a) Description of the control measures used to mitigate beam and non-beam hazards
    b) List of PPE required for laser operation
4. **Training Requirements**
    a) Description of the type of instrument-specific training that is required to operate the laser
        i. Include specific tasks and information covered
5. **Operating Procedures**
    a) Step-by-step description of the actions taken to operate the laser
        i. Include reminders of relevant hazards at high-risk points in the procedure

6. **Alignment Procedures**
    a) Step-by-step description of the actions taken to align the laser beam
        i. Include reminders of relevant hazards at high-risk points in the alignment process
7. **Emergency Procedures**
    a) Describe procedures to be followed in case of injury, fire, or other emergency
        i. Specific emergencies addressed will be impacted by the hazards of the specific laser
8. **Laser Registration**
    a) Attach a signed, completed copy of the UI Laser Registration Form to the SOP

C

Laser Registration Form

The University of Idaho Laser Registration Form is reproduced on the following page, and is also available on the EHS website.

Laser Registration Form

Owner Information

Principal Investigator:

Department:

Phone:

E-mail:

Laser Location (Building & Room):

Laser Information

Manufacturer:

Model:

Serial No.:

UI Property No.:

Laser Type (Nd:YAG, etc.):

Hazard Class (3B or 4):

Beam Diameter (mm):

Beam Divergence (mrad):

☐ **Continuous Wave Laser**

Wavelength (nm):

Max. Operating Power (W):

Average Operating Power (W):

☐ **Pulsed Laser**

Wavelength (nm):

Min. Pulse Duration (s):

Max. Pulse Frequency (Hz):

Max. Operating Energy (J):

Average Operating Energy (J):

Other Information

☐ Use of Cryogens

☐ Use of High Voltage

☐ Tunable Laser

☐ Home-Fabricated or Modified Laser

☐ Use of Compressed Gases

☐ Use of Beam Focusing Optics

☐ Exposed Beam Path

Laser Intended Use:

PI Signature & Date

RSO Signature & Date

D

Laser Safety Training Agreement for Authorized Personnel

The University of Idaho Laser Safety Training Agreement form is available on the following page. Please sign and return this form to the UI RSO following completion of all requirements. The form may be e-mailed to safety@uidaho.edu or returned directly via inter-campus mail.

University of Idaho
Environmental Health and Safety

Laser Safety Training Agreement for Authorized Personnel

I certify that I have read and am familiar with the following laser safety resources:

- The UI Laser Safety Protocol
- The manufacturer laser safety and operation recommendations and
- The standard operating procedure(s) specific to the following laser:

______________________________	______________________________
Laser Description	Laser Location (Building/Room)

I also certify that I have been provided instrument-specific hands-on training for the above laser.

______________________________	______________________________
Trainer Signature	Training Date

I agree to abide by the following rules regarding laser operation:

1. Do not look directly into the laser beam.
2. Do not look at specular reflections of the laser beam.
3. Operate the above laser only in the approved location and setup, wearing appropriate PPE.
4. Beware of high voltage when the case or enclosure of an operating laser is open.
5. Do not leave an operating laser unattended.
6. Deactivate the laser when not in use.

______________________________	______________________________
First & Last Name (Printed)	Vandal Number
______________________________	______________________________
Signature	Date

E

Selected Ocular MPEs

Table E.1: Point source MPEs for the eye for commonly used lasers[2]

	Wavelength (µm)	**MPE (W/cm^2)**		
		*** *t*=0.25 s**	***t*=10 s**	***t*=3 × 10^4 s**
Carbon Dioxide (CO_2)	10.6	—	0.1	0.1
Nd:YAG (CW)[a]	1.33	—	40 × 10^{-3}	40 × 10^{-3}
Nd:YAG (CW)	1.064	—	5 × 10^{-3}	5 × 10^{-3}
Nd:YAG Q-switched[b]	1.064	—	17 × 10^{-6}	17 × 10^{-6}
Nd:YAG (freq. doubled)	0.532	2.5 × 10^{-3}	—	1 × 10^{-3}
GaAs (diode)	0.840	—	1.9 × 10^{-3}	1.9 × 10^{-3}
InGa AIP (diode)	0.670	2.5 × 10^{-3}	—	1 × 10^{-3}
HeNe	0.633	2.5 × 10^{-3}	—	1 × 10^{-3}
Krypton	0.647	2.5 × 10^{-3}	—	1 × 10^{-3}
	0.568	2.5 × 10^{-3}	—	1 × 10^{-3}
	0.530	2.5 × 10^{-3}	—	1 × 10^{-3}
Argon	0.514	2.5 × 10^{-3}	—	1 × 10^{-3}
XeF[c]	0.351	—	—	33.3 × 10^{-6}
XeCl[c]	0.308	—	—	1.3 × 10^{-6}

* *t* is the exposure duration in seconds

[a] Less commonly used wavelength

[b] Operating in repetitive pulse duration mode at 11 Hz, 12-ns pulse, 20 mJ/pulse

[c] When repeated exposure levels on successive days are anticipated to approach the MPE, the MPE must be reduced by a factor of 2.5

Bibliography

[1] American National Standard for Safe Use of Lasers. *ANSI Z136.1-2007*, 2007.

[2] American National Standard for Safe Use of Lasers in Educational Institutions. *ANSI Z136.5-2009*, 2009.