ILLINOIS STATE UNIVERSITY

# Laser Safety Manual

*Emergency reference numbers:*

Police, Fire, or Ambulance…….911

Environmental Health and Safety Office…...438-8325

Laser Safety Officer……...438-2663

Radiation Safety Officer…….438-8039

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# Contents

# 1.0 Introduction

This manual describes the Laser Safety Program for Illinois State University. The purpose of this program is to protect personnel, guests, and property from the hazards associated with lasers and laser systems.

The requirements in this manual apply to lasers in classes 3b and 4 only. The hazards from lasers in classes 1, 2 and 3a are less significant than the higher-powered lasers in classes 3b and 4. However, it is important to remember that all lasers, regardless of class, can cause injury if misused.

The State of Illinois regulates the use of class 3b and 4 lasers under Statute 32 (Energy), Part 315 (Standards for Protection Against Laser Radiation). The Illinois Emergency Management Agency (IEMA) is the state agency in charge of supervising compliance by state dependencies.

Illinois State University complies with these regulations via the LSO, who is a member of the Radiation Safety Committee, dependent of ISU Environmental Health and Safety. Thus, this office has direct jurisdiction on all matters related to laser operations within the University.

# 2.0 Registration of Laser Systems

The Illinois Emergency Management Administration (IEMA) requires that all Class 3b or 4 laser systems be registered with the State. The Radiation Safety Officer (RSO), via the Laser Safety Officer (LSO), provides this registration process.

To register a laser, obtain a copy of the Laser Registration form (see Appendix A of this Manual). Provide full and complete responses to the application and submit it to the LSO at Campus Box 1320 or jdriske@ilstu.edu. The LSO will ensure the laser system is registered with IEMA.

# 3.0 Laser Safety Training Requirements

Initial and annual in-service training in laser safety is required for individuals using laser systems to ensure their awareness of the University's laser safety practices and policies. At the beginning of each academic semester, each Principal Investigator/Operator (PI or PO) is shall update the LSO of any new lab workers or returning lab workers who are in need of general laser safety training. These individuals will be granted access to this training on Canvas, the University’s online learning management system.

In addition, PIs/POs are responsible for providing laser safety training to persons using lasers or entering controlled areas under his or her supervision. Other individuals may provide the training under the supervision of the PI. The nature of the training should be commensurate with the potential health protection problems in the area.

# 4.0 Responsibilities

## 4.1 Principal Investigators/Operators

The primary responsibility for ensuring the safe use of lasers belongs to Principal Investigators/Operators (PIs or POs). Specifically, PIs/POs are responsible for ensuring that:

- Only authorized individuals operate lasers or have access to controlled areas during laser operations.
- Individuals authorized to use lasers have received adequate training.
- Appropriate personal protective equipment (PPE) is available and worn when necessary.
- Laser operating procedures include adequate safety measures.
- Lasers manufactured or modified are properly classified, labeled and registered.
- Proper laser warning signs are posted.
- All class 3b and 4 lasers have been registered through the RSO (jlee81@ilstu.edu) and LSO (jdriske@ilstu.edu).

## 4.2 Laser Operators

Persons operating lasers are responsible for:

- Following proper operating and safety procedures.
- Performing only those operations authorized by the PI/PO.
- Restricting access to controlled areas during operations.

## 4.3 LSO

An individual designated by Environmental Health and Safety as the campus LSO has the authority and responsibility to monitor and enforce the control of laser hazards and to effect the knowledgeable evaluation and control of laser hazards. The LSO is responsible for:

- Providing training and/or training materials to PIs/POs and laser operators as necessary.

- Verifying the classification of lasers and providing appropriate signs and labels when required.

- Determining proper protective eyewear and other PPE.

- Conducting bi-annual laser protective eyewear inspections.

- Reviewing operating and safety procedures.

- Registering lasers (class 3b and 4) with IEMA.

### 4.4 RSO (Environmental Health and Safety)

The RSO acts, under Environmental Health and Safety, as an advisory individual (along with the LSO) to the University on matters related to the campus Radiation Safety Manual. The RSO is an individual with the knowledge, training, and expertise to ensure that all radioactive material, x-rays and lasers are appropriately managed and in compliance. As it related directly to laser systems, the RSO will consult with the LSO on all matters regarding laser safety. The President delegates to the RSO, via EHS, the authority to oversee the use of lasers throughout the campus.

The responsibilities of the RSO regarding the use of lasers include the following:

- Review proposals for unusually hazardous uses of lasers and establish criteria for equipment and procedures to ensure employee, student and public safety.

- Review cases which involve repeated infractions of rules and regulations for laser safety.

- Review accidents which may involve injury or serious economic loss and other cases for which reports to outside regulatory authorities are required.

- Review appeals from laser users to modify rules or the decisions of the Radiation Safety Committee.

- Review campus laser safety with the LSO.

- Recommend the establishment or modification of campus laser safety policies and procedures.

# 5.0 Laser and Laser System Hazards

### 5.1 Eye
Different structures of the eye can be damaged from laser light depending on the wavelength. Retinal burns, resulting in partial or complete blindness, are possible in the visible (400 - 700 nm) and near-infrared (700 - 1400 nm) regions. At these wavelengths, the eye will focus the beam or a specular reflection on a tiny spot on the retina. This focusing increases the irradiance of the beam by a factor of about 100,000.

Laser emissions in the ultraviolet (< 400 nm) and infrared to far-infrared (> 1400 nm) regions are primarily absorbed by and cause damage to the cornea. In the near-ultraviolet range (315 - 400 nm), some of the radiation reaches the lens of the eye.

### 5.2 Skin
Skin damage can occur from exposure to infrared or ultraviolet light. For infrared exposure, the results can be thermal burns or excessively dry skin depending on the intensity of the radiation. In the 230 - 380 nm range of ultraviolet light, erythema (sunburn), skin cancer, or accelerated skin aging are possible. The most damaging region of ultraviolet is 280 - 315 nm, also known as UV-B.

### 5.3 Electrical
Many lasers contain high-voltage components, which can present a potentially lethal hazard. Proper lockout procedures should be followed when working on high-voltage components.

### 5.4 Fire
Many class 4 lasers are capable of igniting combustible materials. Care should be taken when choosing beam stops and shielding material.

### 5.5 Hazardous Materials
Laser laboratories contain many of the same hazards found in many chemical laboratories; therefore the same precautions should be taken. In addition, most laser dyes are considered to be hazardous materials and should be handled accordingly. Laser interactions with certain materials may produce toxic fumes, which must be properly vented.

# 6.0 Laser Classifications

Lasers and laser systems are classified by potential hazard according to a system described in the American National Standards Institute (ANSI) standard Z136.1, and in 21 CFR part 1040. A laser's classification is based on several factors, including its wavelength, power output, accessible emission level, and emission duration. The level of hazard associated with each class of lasers is listed below.

**Class 1**
Lasers in this class are incapable of causing eye damage. These lasers are exempt from labeling requirements.

**Class 2**
Lasers in this class emit visible light only. They are only capable of producing eye damage if the beam is stared at directly for longer than the normal human aversion response time to bright light (0.25 second). This means a person would naturally turn away from the beam before any damage is done.

**Class 3a**
Lasers in this class are capable of causing eye damage from short-duration (< 0.25 seconds) viewing of the direct beam.

**Class 3b**
Class 3b lasers are capable of causing eye damage from short-duration (<0.25s) viewing of the direct or specularly reflected laser beams. Diffuse reflections from these lasers are generally not hazardous, except for intentional staring at distances close to the diffuser.

**Class 4**
Lasers in this class are high powered and capable of causing severe eye damage with short-duration exposure to the direct, specularly reflected, or diffusely reflected beam. They are also capable of producing severe skin damage. Flammable or combustible materials may ignite if exposed to the direct beam.

**Embedded Lasers**
A laser system of one class may contain a laser of a higher class. For example, a class 3a system might contain a class 4 laser in an interlocked protective housing which incorporates design features to limit the accessible emission level to the class 3a level.

If a laser or laser system has been manufactured by or modified at Illinois State University, the Principal Investigator/Operator is responsible for determining the laser's proper classification and notifying the LSO. This classification may be accomplished using one of the following tables (taken from ANSI Z136.1-2014) depending on if the laser is pulsed or continuous. Refer to ANSI Z136.1 for more details.

## Classification Table for Continuous Wave (CW) Small-Source Lasers

| Wavelength (nm) | Laser type | Wavelength (nm) | Class 1* (W) | Class 2 (W) | Class 3** (W) | Class 4 (W) |
|---|---|---|---|---|---|---|
| Ultraviolet (180 to 280) | Nd:YAG (Quadrupled) | 266 | $\leq 9.6 \times 10^{-9}$ for 8 hours | None | >Class 1 but $\leq$0.5 | >0.5 |
| | Argon | 275 | | | | |
| Ultraviolet (315 to 400) | He-Cd | 325 | $\leq 3.2 \times 10^{-6}$ | None | >Class 1 but $\leq$0.5 | >0.5 |
| | Argon | 351, 363 | | | | |
| | Krypton | 350.7, 356.4 | | | | |
| Visible (400 to 700) | He-Cd | 441.6 only | $\leq 4 \times 10^{-5}$ | > Class 1 but $\leq 1 \times 10^{-3}$ | > Class 2 but $\leq$0.5 | >0.5 |
| | Argon (visible) | 457 | $\leq 5 \times 10^{-5}$ | | | |
| | | 476 | $\leq 1 \times 10^{-4}$ | | | |
| | | 488 | $\leq 2 \times 10^{-4}$ | | | |
| | | 514 | $\leq 4 \times 10^{-4}$ | | | |
| | Krypton | 530 | | | | |
| | Nd:YAG (doubled) | 532 | | | | |
| | He-Ne | 543 | | | | |
| | Dye | 400 - 500 | $\leq 0.4 C_B \times 10^{-4}$ | | | |
| | He-Se | 460 - 500 | | | | |
| | Dye | 550 - 700 | $\leq 4 \times 10^{-4}$ | | | |
| | He-Ne | 632 | | | | |
| | InGaAIP | 670 | | | | |
| | Ti:Sapphire | all | | | | |
| | Krypton | 647.1, 676.4 | | | | |
| Near Infrared (700 to 1400) | GaAlAs | 780 | $\leq 5.6 \times 10^{-4}$ | None | > Class 1 but $\leq$0.5 | >0.5 |
| | GaAlAs | 850 | $\leq 7.7 \times 10^{-4}$ | | | |
| | GaAs | 905 | $\leq 9.9 \times 10^{-4}$ | | | |
| | Nd:YAG | 1064 | $\leq 1.9 \times 10^{-3}$ | | | |
| | He-Ne | 1080 | $\leq 1.9 \times 10^{-3}$ | | | |
| | | 1152 | $\leq 2.1 \times 10^{-3}$ | | | |
| | InGaAsP | 1310 | $\leq 1.5 \times 10^{-2}$ | | | |
| Far Infrared (1400 to 1 x $10^6$) | InGaAsP | 1550 | $\leq 9.6 \times 10^{-3}$ | | | |
| | Holmium | 2100 | | | | |
| | Erbium | 2940 | | | | |
| | Hydrogen Fluoride | 2600 - 3000 | | | | |
| | He-Ne | 3390 only | | | | |
| | Carbon Monoxide | 5000 - 5500 | | | | |
| | Carbon Dioxide | 10600 | | | | |
| | Water Vapor | 118000 | $\leq 9.5 \times 10^{-2}$ | | | |
| | Hydrogen Cyanide | 337000 | | | | |

* Assumes no mechanical or electrical design incorporated into laser system to prevent exposures from lasting to $T_{max}$ = 8 hours (one workday); otherwise the Class AEL could be larger than tabulated.

** Class 3a lasers and laser systems include lasers and laser systems which have an accessible output between 1 and 5 times the Class 1 AEL for wavelengths shorter than 400 nm or longer than 700 nm, or less than 5 times the Class 2 AEL for wavelengths between 400 and 700 nm.

## Classification Table for Single Pulse Small-Source Lasers

| Wavelength (nm) | Laser type | Wavelength (nm) | Pulse Duration (s) | Class 1 (J) | Class 3b (J) | Class 4 (J) |
|---|---|---|---|---|---|---|
| Ultraviolet (180 to 400) | Excimer (ArF) | 193 | $20 \times 10^{-9}$ | $\leq 2.4 \times 10^{-5}$ | > Class 1 but $\leq$0.125 | > 0.125 |
| | Excimer (KrF) | 248 | $20 \times 10^{-9}$ | $\leq 2.4 \times 10^{-5}$ | | |
| | Nd:YAG Q-switched (quadrupled) | 266 | $20 \times 10^{-9}$ | $\leq 2.4 \times 10^{-5}$ | | |
| | Excimer (XeCl) | 308 | $20 \times 10^{-9}$ | $\leq 5.3 \times 10^{-5}$ | | |
| | Nitrogen | 337 | $20 \times 10^{-9}$ | $\leq 5.3 \times 10^{-5}$ | | |
| | Excimer (XeF) | 351 | $20 \times 10^{-9}$ | $\leq 5.3 \times 10^{-5}$ | | |
| Visible (400 to 700) | Rhodamine 6G (Dye laser) | 450 - 650 | $1 \times 10^{-6}$ | $\leq 1.9 \times 10^{-7}$ | > Class 1 but $\leq$0.03 | > 0.03 |
| | Copper vapor | 510, 578 | $2.5 \times 10^{-9}$ | | | |
| | Nd:YAG (doubled) (Q-switched) | 532 | $20 \times 10^{-9}$ | | | |
| | Ruby (Q-switched) | 694.3 | $20 \times 10^{-9}$ | | | |
| | Ruby (Long pulse) | 694.3 | $1 \times 10^{-3}$ | $\leq 3.9 \times 10^{-6}$ | | |
| Near Infrared (700 to 1400) | Ti:Sapphire | 700 - 1000 | $6 \times 10^{-6}$ | $\leq 1.9 \times 10^{-7}$ | | |
| | Alexandrite | 720 - 800 | $1 \times 10^{-4}$ | $\leq 7.6 \times 10^{-7}$ | > Class 1 but $\leq$0.033 | > 0.033** |
| | Nd:YAG (Q-switched) | 1064 | $20 \times 10^{-9}$ | $\leq 1.9 \times 10^{-6}$ | > Class 1 but $\leq$0.125 | >0.125 |
| Far Infrared (1400 to $1 \times 10^{6}$) | Erbium:Glass | 1540 | $10 \times 10^{-9}$ | $\leq 7.9 \times 10^{-3}$ | > Class 1 but $\leq$0.125 | > 0.125 |
| | Co:Mg-Fl | 1800 - 2500 | $80 \times 10^{-6}$ | $\leq 7.9 \times 10^{-4}$ | | |
| | Holmium | 2100 | $250 \times 10^{-6}$ | $\leq 7.9 \times 10^{-4}$ | | |
| | Hydrogen Fluoride | 2600 - 3000 | $0.4 \times 10^{-6}$ | $\leq 1.1 \times 10^{-4}$ | | |
| | Erbium:Glass | 2940 | $250 \times 10^{-6}$ | $\leq 5.6 \times 10^{-4}$ | | |
| | Carbon Dioxide | 10600 | $100 \times 10^{-9}$ | $\leq 7.9 \times 10^{-5}$ | | |
| | Carbon Dioxide | 10600 | $1 \times 10^{-3}$ | $\leq 7.9 \times 10^{-4}$ | | |

* Assuming that both eye and skin may be exposed, i.e., 1.0 mm beam (area of limiting aperture = $7.9 \times 10^{-3}$ $cm^2$)

** Class 3b AEL varies from 0.033 to 0.480 J corresponding to wavelengths that carry between 0.720 and 0.800 um.

# 7.0 Control Measures

This section describes administrative, procedural and engineering measures, which can reduce the chance of a laser-related incident. These measures should be considered when evaluating a class 3b or 4 laser facility. Although some items are appropriate for all facilities (e.g. posting proper warning signs), others may not be practical for some operations. Primary control measures are *italicized* for emphasis. In most cases, implementing these measures will provide the most effective safety considerations.

### 7.1 Beam Control

*Enclosure of the laser equipment or beam path is the preferred method of control, since the enclosure will isolate or minimize the hazard.* At a minimum, beam stops must be used to ensure no direct or specularly reflected laser light leaves the experiment area.

*Laser beam height should be maintained at a level other than the normal position of the eye of a person in the standing or seated position.* Securely fasten the laser and all optics on a level, firm, and stable surface.

### 7.2 Reflections

Remove unnecessary reflective items from the vicinity of the beam path. Do not wear reflective jewelry, such as rings or watches, while working near the beam path.

Be aware that lenses and other optical devices may reflect a portion of the beam from their front or rear surfaces.

Avoid placing unprotected eyes along or near the beam axis. The probability of a hazardous specular reflection is greatest in this area.

### 7.3 Power Level

*The minimum laser radiation required for the application should be used.* Operate a laser at the minimum power necessary for any operation. Beam shutters and filters can be used to reduce the beam power. Use a lower power laser when possible during alignment procedures.

### 7.4 Signs and Labels

The entrance to a class 3b or 4 laser facility must be posted with the appropriate warning sign. Each laser must be labeled as required by 21 CFR part 1040. These labels show the classification of the laser and identify the aperture(s) where the laser beam is emitted. Signs and labels may be obtained through the LSO.

### 7.5 Warning Devices

Class 4 laser facilities where the beam is not fully enclosed should have a visible warning device (e.g. flashing red light, warning sign) at the outside of the entrance, which indicates when a laser is in operation. Access to the laser room must be restricted to the room while the laser is in operation.

### 7.6 Control of Area
Except for fully enclosed and interlocked systems, an authorized user must be present or the room kept locked during laser operations.

### 7.7 Interlocks
Many laser systems have interlocked protective housings which prevent access to high-voltage components or laser radiation levels higher than those accessible through the aperture. These interlocks should not be bypassed without the specific authorization of the Principal Investigator/Operator. Additional control measures must be taken to prevent exposure to the higher radiation levels or high voltage while the interlock is bypassed.

### 7.8 Personal Protective Equipment
Eye protection designed for the specific wavelength of laser light should be available and worn when there is a chance that the beam or a hazardous reflection could reach the eye. The manufacturer should mark protective eyewear with the wavelength range over which protection is afforded and the minimum optical density within that range. Eyewear should be examined prior to each use and discarded if there is damage which could reduce its effectiveness.

Protective eyewear generally will not provide adequate protection against viewing the direct beam of a high-powered laser. Direct viewing of the laser beam must be avoided even if proper eyewear is being used. Wearing protective eyewear should not be used as an excuse for performing an unsafe procedure.

### 7.9 Training
All operators must receive training in the safe and proper use of lasers by the PI/PO (or a person designated by the PI/PO) before being allowed to operate a laser. A standard operating procedure (SOP) or manual shall be available for consultation.

Initial and annual in-service training in laser safety is required for individuals using laser systems outside the supervision of the Principal Investigator/Operator (PI/PO) to ensure their awareness of the University's laser safety practices and policies. Students working under the direct supervision of the PI/PO do not need the in-service training, but still require laser safety training provided by the PI/PO. At the beginning of each academic semester, each PI/PO shall update the LSO of any new lab workers or returning lab workers who are in need of in-service laser safety training. These individuals will be granted access to this training on Canvas, the University’s online learning management system.

### 7.10 Standard Operating Procedures (SOP)
Written operating procedures shall be available, which can include the manufacturer operations manual.

### 7.11 Maintenance and Service
Only a knowledgeable person who has been specifically authorized by the PI/PO should perform maintenance, servicing, or repair of a laser. Whenever such work involves accessing an embedded laser of a higher class, the controls appropriate to the higher class must be applied. Any laser which is significantly modified must be re-evaluated to determine its classification.

The following table provides general laser safety guidelines for all classes of lasers.

## Laser Safety Guidelines

| Class | User Precautions |
|---|---|
| **General Safety for All Classes** | ✓ Ensure that personnel have had safety training appropriate to the level of expected hazard.<br>✓ Do not aim laser beam at people or objects not involved in the research.<br>✓ Protect against non-beam hazards.<br>✓ Use the minimum energy or power required for the experiment.<br>✓ Develop and follow standard operating procedures, alignment procedures, etc. |
| **1** | ✓ No user-specific rules necessary in normal usage. |
| **2** | ✓ Do not stare directly into laser beam. |
| **3a** | ✓ Permit only properly trained personnel to operate the laser.<br>✓ Do not view the beam or its specular reflection with collecting optics. |
| **3b** | ✓ Establish a Nominal Hazard Zone (NHZ) for the laser.<br>✓ Post appropriate laser hazard signs.<br>✓ Permit only properly trained personnel to enter the NHZ and operate the laser.<br>✓ Do not view the laser beam or its specular reflection.<br>✓ Enclose as much of the beam path as possible.<br>✓ Use beam stops to terminate beams at the end of useful beam paths.<br>✓ Ensure that the beam path is above or below the eye level of sitting and standing personnel.<br>✓ Mount the laser, its associated optics and other equipment firmly to a stable surface to ensure that the beam travels along its intended path.<br>✓ Wear appropriate laser eyewear within the NHZ.<br>✓ Practice good laboratory hygiene. In particular, remove unnecessary reflective surfaces from the vicinity of the beam path. |
| **4** | ✓ Establish a Nominal Hazard Zone (NHZ) for the laser.<br>✓ Post appropriate laser hazard signs.<br>✓ Permit only properly trained personnel to enter the NHZ and operate the laser.<br>✓ Do not view the laser beam, its specular reflection or in some cases, its diffuse reflection.<br>✓ Enclose as much of the beam path as possible.<br>✓ Use non-flammable beam stops to terminate beams at the end of useful beam paths.<br>✓ Ensure that the beam path is above or below the eye level of sitting and standing personnel.<br>✓ Mount the laser, its associated optics and other equipment firmly to a stable surface to ensure that the beam travels along its intended path.<br>✓ Wear appropriate laser eyewear within the NHZ.<br>✓ Practice good laboratory hygiene. In particular, remove unnecessary reflective surfaces from the vicinity of the beam path.<br>✓ Install appropriate shielding to protect personnel from beam.<br>✓ Operate laser in a room with door interlocks, if possible.<br>✓ Use remote firing and/or remote monitoring systems, if possible. |

# 8.0 Emergency and Incident Report Procedures

**Emergencies**

- For any emergency requiring police, fire or ambulance assistance, call 911.

**Emergencies or Incidents Involving Lasers**

- In the event of an accident or unusual incident involving a laser: TURN OFF THE LASER or UNPLUG IT FROM THE POWER LINE.
- If there is a serious injury or fire, call 911 and request paramedics or the fire department. *Note: If a laser eye injury is suspected, have the injured person keep their head upright and motionless to restrict bleeding in the eye. A physician should evaluate laser eye injuries as soon as possible.*
- Notify Environmental Health and Safety (438-8325). If after working hours, contact the University Police Department (438-8631) and have the operator contact the EHS Safety Officer On-Call. The Safety Officer On-Call will contact the RSO whom will inform the LSO.
- Notify the Principal Investigator/Operator. If there is an injury, the PI/PO needs to submit an online accident report to Environmental Health and Safety. Provide as many details as possible. Only PIs/POs can submit an online accident report.

**Notifications and Reports**

Under most circumstances, the LSO will make formal notifications and reports to the Illinois Emergency Management Agency (IEMA). Completion of these reports may require additional consultation with laboratory personnel. The PI/PO should provide the details of the incident (who/when/how) to the LSO for preparation of reports within the time frames specified below. The LSO will need to notify the RSO of any exposures on campus as soon as they are reported.

***Immediate notification***

Illinois state regulations require the immediate notification to the IEMA of any incident involving exposure to laser radiation that has or may have caused accidental injury to an individual in the course of use, handling, operation, manufacture, or discharge of a laser system, including:

- Exposure of an individual to greater than 100 times the MPE
- Exposure that involves the partial or total loss of sight in either eye
- An exposure that involves perforation of the skin or other serious injury exclusive of the eye

***24-hour notification***

Notification to IEMA within 24 hours is required for any incident involving exposure to laser radiation that has or may have caused:

- An individual's exposure of greater than five times the MPE
- An exposure that involves second or third degree burns to the skin

## Appendix A: Illinois State University - Laser Registration Form

**ILLINOIS STATE UNIVERSITY**
**LASER REGISTRATION FORM**

I. Principal Operator/Investigator: _____
Phone: 8-_____ ULID: _____
Department: _____ Date: _____

II. Authorized User Information:

| Name | ULID | Status (faculty/staff/student) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

III. Laser System Information:

1. System location (Building and Room Number): _____
2. Laser warning sign on door? Yes / No
3. Do users wear safety goggles? Yes / No
4. Are safety goggles available for visitors? Yes / No
5. Is there a written SOP/operation manual available? Yes / No
6. Please complete the table below:

| | **Laser Description** |
|---|---|
| Manufacturer | |
| Model # | |
| Serial # | |
| Class (1, 2, 3a, 3b, or 4) | |
| Type (CW or Pulsed) | |
| Lasing Medium (He-Ne, Nd:YAG, etc.) | |
| Wavelength(s) | |
| Average Output Power (W) | |
| Peak Power (W) or Peak Pulse Energy (J) | |
| Pulse Duration (s) | |
| Repetition Rate (Hz) | |
| Emerging Beam Divergence (mrads) | |
| Emerging Beam Dimensions (mm x mm) | |
| Primary Function (holography, alignment, etc.) | |

# Appendix B: SOP Preparation Guide

This outline is intended to aid in the preparation of laser standard operating procedures (SOP). The SOP should include all lasers in a given laser system, including alignment and pumping lasers. The SOP should be reviewed every two years and revised as needed. The LSO will be responsible for ensuring the SOPs are reviewed as needed.

I. Introduction
- A. Location of laser/laser system (building, room)
- B. Map of area
- C. Description of each laser:
  1. Classification
     - a. Class 1, 2, 3a, 3b or 4
     - b. Continuous wave, pulsed, Q-switched
  2. Lasing medium
  3. Beam characteristics (as applicable):
     - a. Divergence
     - b. Aperture diameter
     - c. Pulse duration
     - d. Pulse frequency
     - e. Maximum energy or power output
- D. Purpose/application of laser(s)

II. Hazards
- A. Identify hazards present:
  1. Laser beam(s)
  2. Electrical
  3. Chemical
  4. Fire/explosion
  5. UV light
- B. Hazard analysis

III. Controls
- A. Engineering controls, e.g., interlocks, beam stops, etc.
- B. Administrative controls, e.g., signs, LSOP, etc.
- C. Personnel Protective Equipment, e.g., laser eye protection, gloves, etc.

IV. Operating Procedures
- A. Equipment preparation
- B. Personnel Protective Equipment preparation
- C. Step-by-step protocol for laser system operation
- D. Shutdown procedures

E. Special procedures:
    1. Alignment
    2. Safety checks
    3. Emergency
    4. Maintenance

V. User Training
A. Initial orientation/basic laser safety principles
B. Laser safety during operations
C. Maintenance and repair training, if applicable

VI. Responsibility
A. Supervisor (include emergency contact)
B. Users and auxiliary personnel

VII. Miscellaneous
A. Rules for visitors
B. Rules for building service workers
C. Other

# Appendix C: Samples for SOPs

The following was taken from the Illinois Administrative Code, Title 32: Energy, Chapter II: Division of Nuclear Safety, Subchapter b: Radiation Protection, Part 315 "Standards for Protection against Laser Radiation", Appendix A.

Standard Operating Procedures (SOPs) are governed by institutional policy and are developed, modified and maintained in accordance with the needs of individual facilities. Information relative to safety incorporated into these SOPs is gathered from a wide range of resources, including, but not limited to, the laser system manufacturer or distributor. This appendix contains examples of SOPs for issues associated with the use of laser systems. It is recognized that the safety needs of installations with multiple laser systems may be different from those facilities with a single laser system. The samples that follow cannot cover all situations or procedures; they are only intended as models that should be used to accommodate specific requirements.

It is reasonable to expect that the manufacturer of the laser system shall supply safety information that can serve as the cornerstone for the generation of the SOPs. It is incumbent upon the operator to demand the information from the manufacturer. The availability of safety related information is facilitated by the FDA requirement that the manufacturer of laser products provide the user with adequate instructions for the safe operation and maintenance of all laser products.

**SAMPLE 1: Controlled Access to the Laser Room**

**Purpose:** To define the area in which control measures shall be applied and to describe the control measures necessary in order to maintain a safe environment for use of the laser system.

**Policy:** Class 3b and Class 4 lasers shall be operated in areas where traffic flow and compliance with all safety procedures can be monitored.

**Procedure:**

1) Appropriate warning signs shall be posted at eye level on all doors that access a room where a laser is to be operated. These signs shall state all required information and shall be removed when the laser is not in use.

2) Safety goggles labeled with the appropriate wavelength and optical density shall be available at the entry where each door sign is posted.

3) Glass windows shall be covered with shades or filters of appropriate optical density whenever a fiberoptic laser system is operational.

4) All safety procedures shall be followed during service, maintenance and demonstrations.

5) No one shall be allowed into a laser room unless properly authorized and protected.

6) The laser shall not be activated when it is necessary to open the door, if the controlled area extends to the doorway.

7) Laser keys shall be kept in a secured area and signed out only by those authorized to do so.

**SAMPLE 2: Ocular Safety**

**Purpose:** To prevent ocular injuries to personnel working with Class 3b and Class 4 lasers.

**Policy:** Within the controlled area, all personnel shall adhere to appropriate eye protection procedures during all laser applications.

NOTE: Under some conditions, the controlled area may include the entire room in which the laser procedure is performed. Under those conditions, the ocular safety procedures listed in this Sample 2 apply to the entire room. In health care facilities, ocular safety procedures shall also apply to the patient receiving laser treatment.

All personnel involved in maintenance and demonstrations of laser systems shall follow all ocular safety procedures whenever a laser is in operation in the facility.

**Procedure:**

1) Appropriate eyewear shall be worn by everyone in the controlled area while the laser is in operation. Appropriate eyewear consists of glasses or goggles of sufficient optical density to prevent ocular damage at the laser wavelength in use. Exception to this is the operator looking through an attached microscope with a lens that has the appropriate optical density for the laser in use.

2) Prior to use, the operator and ancillary personnel shall be responsible for selecting and examining eyewear for comfort, proper fit, and presence of labels describing both wavelength and proper optical density.

3) If eyewear is damaged, it shall not be worn and a report shall be made to the LSO.

4) Contact lenses are not acceptable as protective eyewear. Prescription lens wearers shall use appropriate laser safety eyewear.

5) All goggles shall have side shields to protect from peripheral injury and impact.

6) Any articulated arm that is not shuttered shall be capped when not connected to the hand piece or the operating microscope.

7) The laser system shall be placed in standby mode when delivery optics are moved away from the target.

8) In health care facilities, patients shall be fitted with appropriately labeled eyewear, or have their eyes covered with wet cloth pads or towels. Metal or dry materials shall be placed on the patient's face or eyes only when indicated.

**SAMPLE 3: Handling of Laser Fiber Delivery Systems in Health Care Facilities**

**Purpose:** To promote safe and proper handling of laser fiber delivery systems and to limit the potential for fiber breakage, damage and reduced efficiency during clinical laser procedures.

**Policy:** Personnel handling laser fibers shall assure compliance with all safety procedures and shall consider the fiber an extension of the laser system, governed by applicable standards and regulations.

**Procedure:**

1) Appropriate eye safety filters shall be used with endo/microscopes.

2) Laser room windows shall be covered completely with appropriate filters, if necessary.

3) Fibers and associated equipment shall be positioned to allow for safe traffic patterns in the room.

4) The fiber shall be examined for breaks or damage of the distal tip, the proximal connector and the catheter sheath. Fiber shall be calibrated in accordance with manufacturer's directions. If deficiencies or damage are noted, another fiber shall be obtained.

5) Do not use clamps or other instruments to secure fiber in the operative site.

6) Always use coaxial cooling that is appropriate to the procedure. Never use gas to purge a fiber in the intrauterine cavity.

7) Never operate the laser unless the aiming beam (if used) and the tip of the fiber beyond the end of the endoscope are both visible.

8) Monitor the fiber for distortion of the beam, decreased power transmission and accumulation of debris on the tip.

9) Never reuse a disposable fiber without manufacturer's directions.

10) Always put the laser in standby when not aimed at a target.

**SAMPLE 4: Non-Beam Hazards in Health Care Facilities**

**Purpose:** To recognize and effectively deal with a variety of potential non-beam hazards that may be present during laser procedures.

**Policy:** Non-beam hazards are the purview of safety and industrial hygiene personnel, who will effect the appropriate hazard evaluation and control.

**Procedure:**

I. Fire

1) Never use alcohol in the operative field. Fibers may be rinsed in hydrogen peroxide or saline intraoperatively.

2) Never place a hot fiber directly on paper drapes. Wait until tip is cool before contact is made with flammable material.

3) Use fire-retardant drapes, damp packs or pads. Fill pelvic cavity with Ringer's, saline or other appropriate solution during surgery.

4) Put laser system in standby mode when procedure is interrupted or terminated.

5) Avoid high levels of oxygen in the operative field.

6) Avoid laser beam exposure of the sheaths of flexible fiber endoscopes, since many of the sheaths are flammable.

II. Plume Management

1) Remove laser generated airborne contaminants from the laser target area to reduce the transmission of potentially hazardous particles.

2) Position smoke evacuator in the operating room whenever a plume is anticipated.

3) Check operation of the plume management system prior to the beginning of a procedure.

4) Check the plume filter monitor and, if needed, install a clean filter.

5) In-line filters with minimum 0.3 micrometers filtration shall be placed between wall suction and the fluid canister for:

a) Suction line not connected to evacuator

b) Procedures producing minimal plume

c) Failure of evacuator before or during operation

6) Distal collection port shall be no more than 2 cm from impact site when practical.

7) All tubing, connectors, adaptors and wands will be changed between patients and disposed of according to biohazard procedures.

III. Electrical Shock

1) During service or maintenance, precautions shall be taken against electrical shock that may be fatal.

2) Medical lasers shall be installed and operated in conformity with the National Electrical Code.

**SAMPLE 5: Work Practices for Optical Fiber Communications Systems (OFCS)**

**Purpose:** To recognize and effectively deal with a variety of potential hazards that may be present when working on an OFCS.

**Policy:** Engineering controls shall not take the place of good work practices. Good work practices are essential to operating, servicing and maintaining OFCS, especially with higher power systems that utilize Class 3b and Class 4 lasers.

**Procedure:** The following presents some basic guidelines when working on any OFCS.

1) Trained Personnel. Only authorized, trained personnel shall be permitted to install or perform service on OFCS containing Class 3b or Class 4 lasers.

2) Unterminated Fibers

a) Do not view the end of a fiber with unprotected eye. Fiber should only be viewed with an indirect image converter or with a filtered optical instrument or optical density (OD) sufficient to reduce the exposure to levels below the appropriate MPE.

b) Always cover the ends of unterminated fibers with a splice protector, tape or end caps.

3) Splicing. Splicing on ribbon cables, fixed array cables or OFCS containing Class 3b or Class 4 lasers shall be de-energized or viewing systems incorporating personal protection shall be employed.

4) Installation and Testing. The laser source shall be first to be disconnected and last to be connected when installing and/or testing an OFCS.

5) Modifications. No modifications shall be made to the OFCS or associated equipment without management or supervision authorizations. Such modifications may alter the service group classification of the OFCS.

6) Labels. Any damaged or missing optical safety labels shall be reported immediately to the supervisor.

7) Other Hazards

a) Use of protective guards or shields shall be used during splicing and cleaving operation to prevent direct injury from small lengths or particles of fiber. Proper disposal of fiber pieces avoids subsequent embedding in clothing or skin.

b) Optical photocuring may present a UV or light source hazard. Protective filter lenses of the appropriate optical density shall be worn if viewing of the light source is probable.

# Appendix D: Glossary of terms related to Laser Systems

Accessible Emission Level (AEL)
The magnitude of laser radiation to which human access is possible. Usually measured in watts for continuous wave lasers and in joules for pulsed lasers.

Accessible Emission Limit
The maximum accessible emission level permitted within a particular class.

Aperture
An opening through which laser radiation can pass. This term usually refers to the opening on the laser (or a protective housing) where the beam is emitted.

Aversion Response
Movement of the eyelid or the head to avoid exposure to a bright light. For laser light, this response is assumed to occur within 0.25 second.

Continuous Wave (CW) Laser
A laser which has a continuous output for greater than or equal to 0.25 second.

Controlled Area
An area where the occupancy and activity of those within are subject to control and supervision for the purpose of protection from hazards.

Diffuse Reflection
A reflection where different parts of the beam are reflected over a wide range of angles, such as when hitting a matted surface.

Embedded Laser
A laser with an assigned class number higher than the classification of the laser system in which it is incorporated, where the system's lower classification is appropriate because of the engineering features limiting accessible emission.

Enclosed Laser System
Any laser or laser system located within an enclosure which does not permit hazardous optical radiation emission from the enclosure.

Erythema
Redness of the skin due to congestion of the capillaries.

Fiber Optics
A system of flexible quartz or glass fibers with internal reflective surfaces that passes light through thousands of glancing (total internal) reflections.

Fluorescence

The emission of light of a particular wavelength resulting from absorption of energy typically from light of shorter wavelengths.

Infrared Radiation (IR)
Invisible Electromagnetic radiation with wavelengths which lie within the range of 0.70 to 1000 micrometers.

Irradiance or Intensity
The optical power per unit area reaching a surface ($W/cm^2$).

Laser
A device which produces an intense, coherent, directional beam of light. Also an acronym for Light Amplification by Stimulated Emission of Radiation.

Laser System
An assembly of electrical, mechanical, and optical components which includes a laser.

Optical Density (OD)
A logarithmic expression for the attenuation produced by an attenuating medium, such as an eye protection filter. $OD = \log10 (I_i/I_t)$ where $I_i$ is the incident irradiance and $I_t$ is the transmitted irradiance.

Protective Housing
A device designed to prevent access to radiant power or energy.

Pulsed Laser
A laser that delivers its energy in the form of a single pulse or a train of pulses, with a pulse duration of less than 0.25 s.

Scanning Laser
A laser having a time-varying direction, origin or pattern of propagation with respect to a stationary frame of reference.

Specular Reflection
A mirror-like reflection. The exact definition of a specular surface is one in which the surface roughness is smaller than the wavelengths of the incident light

Tunable Laser
A laser system that can be "tuned" to emit laser light over a continuous range of wavelengths or frequencies.

Ultraviolet (UV) Radiation
Electromagnetic radiation with wavelengths between soft X-rays and visible violet light, often broken down into UV-A (315-400 nm), UV-B (280-315 nm), and UV-C (100-280 nm).

Visible Radiation (light)
Electromagnetic radiation which can be detected by the human eye. It is commonly used to describe wavelengths which lie in the range between 400 nm and 700 nm.

Wavelength
The length of the light wave, usually measured from crest to crest, which determines its color. Common units of measurement are the micrometer (micron, μm) and the nanometer (nm).

# Appendix E: References

American National Standards Institute for Safe Use of Lasers, ANSI Z136.1 - 2014

Code of Federal Regulations, Title 21, Part 1040, Performance Standards for Light-emitting Products

Illinois Administrative Code, Title 32 Energy, Part 315 Standards for Protection Against Laser Radiation

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