Standard Operating Procedure for Use of Lasers in Research

|  |  |
| --- | --- |
| Department: | Choose a department.  Enter department here if not listed. |
| Principal Investigator: | PI name. |
| Group Safety Coordinator/Lab Manager: | Name of safety contact. |
| SOP written by: | College of Engineering SOP Committee  engrsafety@illinois.edu |
| Date SOP was approved by PI/lab supervisor: | Click here to enter date SOP was approved. |
| Lab Phone: | Enter the lab phone number |
| PI’s Phone: | Enter the PI office or mobile phone number |
| Location(s) covered by this SOP: | Enter the building and room number |
| Emergency contact information for this location: | Enter contact information of lab personnel to be notified in case of emergency. |

|  |  |  |  |
| --- | --- | --- | --- |
| Type of SOP: (check one) | Hazardous material  (SOP describes a specific hazardous chemical) | Hazardous class  (SOP describes a group of hazardous materials ) | Hazardous Process  (SOP describes a hazardous process or equipment) |

**NOTE**: This SOP is intended as an initial resource and as a general reference regarding the topic discussed. It is not a substitute for hands-on training and supervision by experienced laboratory personnel. The Principal Investigator must review and approve of all information in this document for the SOP to be valid and useable.

This SOP is not complete until: 1) Clear and detailed instructions are written that will ensure safe handling of the material or safe performance of the procedure, and 2) SOP has been approved and dated by the PI or laboratory supervisor.

Print a hardcopy and insert into your *Laboratory Safety Manual* and *Chemical Hygiene Plan*.

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# Purpose

This SOP is designed to assist groups in establishing a procedure for their daily (or regular) operations with an experimental apparatus that requires the use of lasers, especially class 3 and 4 lasers. This SOP covers procedures for the safe operation of lasers, not system design.

**NOTE**: These guidelines are intended to function as an initial resource and as a general reference for research involving the use of lasers. They are not a replacement for personal hands-on training and supervision by experienced laboratory personnel, nor are they a replacement for ascertaining specific details concerning the safe operation of lasers. The primary responsibility of establishing this SOP lies with the Principal Investigator (PI). The PI or research personnel should make lab-specific changes to this SOP. The edited document should then be placed in the research group’s laboratory safety manual and training should be documented. The PI must approve of modifications before they are accepted into this document. Approval sometimes requires departmental (and beyond) involvement.

# Key Points

* Lasers are devices that concentrate high energy into a small area. They are capable of causing minor to severe burns to the eye and skin in a very short amount of time.
* Appropriate PPE must be worn when working with lasers. The vast majority of laser accidents with serious consequences occur when the operator does not wear proper eye or skin protective equipment.
* Researchers operating class 3 and 4 lasers should have a thorough understanding of safe operation of such devices and should have acquired (through a combination of training and experience) the knowledge, skill, and discipline to consistently execute safe laboratory practices and have a track record of doing so.
* Researchers should know the risks associated with the use of the particular lasers that they operate. Such risks go beyond the direct beam exposure hazards and may include chemical and electrical hazards present during the laser operation. Vapors and fumes may be generated by the interaction of the beam with different materials.
* Whenever possible, all beams should be enclosed in a manner that ensures that the operators are not exposed. The enclosures should be made of a material resistant to direct interaction with the laser beam.
* Any changes or upgrades to the lasers used in an apparatus covered by this SOP should trigger a review of this SOP to determine if updates are necessary.
* Define and mark the area where the laser’s direct, reflected, or scattered radiation could pose a hazard. This Nominal Hazard Zone (NHZ), should be recognized by everyone in the laboratory or building/institution as a location where special training, precautions, laboratory skill, and safety discipline are required. Only trained personnel should be admitted in this area.

# Important considerations

## **Prior approval from PI required?** Answer Yes or No

If the answer above is Yes, consent must be obtained from the PI before performing the experiment or procedure. Describe the approval process here.

## Consultation of other reference material, documents or knowledgeable persons

Is this document sufficient or are other reference materials required? Examples include equipment operating manuals, SDS documents for chemicals such as laser dyes, or specimen materials, checklists to ensure that daily start-up or termination of work is completed without missing details, or other background information.

## Pre-requisite training or skill

[Laser safety training](http://www.drs.illinois.edu/Training?section=LaserSafety#GeneralLaserSafety) of all personnel operating a class 3B or 4 laser system is required by law and must be renewed yearly.

Is any other prerequisite training necessary before work is to begin? Examples include basic laboratory safety, chemical safety, equipment training, etc.

# Hazard Awareness

## Introduction

Operations involving the use of lasers will include hazards from several sources other than laser beams. The risks are varied, and will depend on the implementation of the experimental apparatus using the lasers as well as the laser beam characteristics. Some are obvious and some are less so. A comprehensive hazard identification and analysis is necessary to ensure the safety of all personnel in proximity to the apparatus. The relationship of the identified hazards and their potential effects on the experimenter, bystanders, property, and the environment should also be analyzed.

## **Hazards and pertinent regulati**ons

The research group should perform a comprehensive [**risk assessment**](#_Tools_and_resources) based on all elements of their proposed operation to determine their risk of exposure to the hazards presented by the lasers that they intend to use. The list below identifies some hazards. It is not intended to be an all-inclusive list. The group must discuss the hazards below as well as others not mentioned here.

Possible hazards when working with lasers include:

**Laser beam exposure hazards:** The primary means of exposure is likely to be from stray reflections or inappropriate beam steering. Each of the optical elements in the beam path may generate a specular or diffuse reflection or change the beam path. This poses an eye and skin exposure hazard. If inappropriate PPE is worn, these risks increase. Risks of beam exposure are greater during construction of a new experimental apparatus, modification of an existing apparatus, and during alignment procedures.

The type and severity of injury caused by a laser beam exposure will vary with:

1. Wavelength: *UV-B and UV-C light (100 to 315 nm)* will be absorbed by the surface of the cornea, causing a painful condition known as photokeratitis (welder’s flash). This is a temporary condition; the tissue of the cornea regenerate relatively quickly. *UV-A light (315 to 400 nm)* will pass through the cornea, lens, and the vitreous body, being mostly absorbed by the lens, where it will promote the formation of cataracts. *Visible and infrared-A light (400 to 1400 nm)* will be focused by the lens onto the retina, were the light irradiance can increase by up to 100,000 times. Damage to the retina can cause partial to total permanent blindness.
2. Pulse duration: Pulsed lasers can deliver a larger amount of energy in a shorter period of time than a continuous wave laser with the same average power. Thus the determination of the maximum permitted exposure (MPE) must take the pulse duration into account. When using pulsed lasers, pulse energy is a more appropriate measure of the laser beam intensity than average power.

**Electrical hazards:** Laser power supplies often operate at high electrical potentials and currents that could be lethal.

**Exposure to chemicals hazards:** Some lasers operate using hazardous chemicals such as laser dyes or toxic gases. These present a potentially serious threat to health and/or life in case a leak or spill occurs. Another hazard due to chemical exposure is the interaction of the laser beam with samples and other materials in its beam path.

**Fire hazards:** Laser beams carry high energy concentrated into a relatively small area. This can cause combustible materials exposed to the beam to ignite or explode*.*

**Personnel behavior:** Personnel without demonstrated discipline to follow procedures completely, without fail, pose a risk when working with or around lasers.

## Experimental Risk Assessment

Summarize the results of the risk assessment in this section, or provide a link to the risk assessment documentation here. For guidance on risk assessments, consult the [Tools and Resources](#_Tools_for_Performing) section.

## Means to control the hazards

In response to the [**risk assessment**](#_Tools_and_resources), the group can plan how to minimize the risks of working with lasers, especially those specific to their setups. This includes the development of specific steps in the SOP, the use of engineering controls, the development of specific alignment procedures, etc. The goal is to reduce the likelihood of exposure and/or injury when something goes wrong. It is desirable to have a minimum set of procedures that reduces uncertainty in operational details and that ensures the operation of devices that are designed to protect and warn you. Addressing the list in the previous section yields the following suggestions.

**Laser beam exposure hazards:** To control or minimize the risk of a laser beam exposure there are several procedures and tools available. These are generally divided into [engineering controls, administrative controls, and personal protective equipment (PPE)](#_Safe_Work_Practices:). These measures should be employed in response to the hazard assessment performed for a particular experimental setup. Areas where class 3B and 4 lasers are used should be segregated and access to these areas must be controlled when the risk of exposure exists. These NHZ must be appropriately labeled with standard warning signs. Examples of such signs are given in the [appendix](#_Appendix). An illuminated warning sign installed at the lab entrance is another excellent administrative control if well designed. The message must be clear and the sign located where it will be noticed by anyone it is designed to warn. A simple red light at the door does not carry a clear message.

Eyewear is arguably the most important PPE for operators because the majority of laser related accidents involve eye exposure. PPE can protect the operator when engineering controls (such as shutters and beam stops) fail.

**Electrical hazards:** Electrical hazards will typically be present only during repair and installation of laser power supplies. These tasks should always be done by individuals trained to service those units who understand high voltage electrical circuitry and possess adequate knowledge about the equipment to be serviced or installed. Whenever possible, the equipment being repaired should be not energized while work is being performed. Signage and physical barriers should be in place to avoid accidental contact with equipment being serviced.

**Exposure to chemicals hazards:** When preparing laser dyes or performing work with hazardous chemicals, specific procedures should be followed. It is the responsibility of each research group to prepare these SOPs, train personnel, and keep a training record.

**Fire:** Lasers concentrate a large amount of energy into a small area. This can start fires in combustible materials such as paper and cardboard. Lab occupants should be thoroughly versed in their preparation for what to do in case of a fire.

**Failure of warning signs and interlocks:** Lab operators must ensure the operation of illuminated warning signs daily before beginning work. Interlock systems may also require periodic testing to assure that they’re operational.

**Personnel behavior:** Personnel must have a track record of reliability and discipline to ensure that steps aren’t skipped when performing the numerous operations described here. The many details involved means that regular review of the procedures further reduces this risk. This practice should be required. Any accident or near miss should be investigated and should trigger a review of the SOP to prevent recurrence.

## Examples of hazardous materials or processes

Use this section to include examples that are more likely in your environment. Examples include apparatus alignment, modification, maintenance, and laser dye preparation. The SOP author should add examples that are pertinent to their lab.

# Safe Work Practices: Engineering Controls, Administrative Controls, and PPE

## Introduction to engineering controls, administrative controls, and PPE

**Safe work practices** describe known safe and prudent policies and required practices used when performing the experiment or procedure or when handling materials. Some chemicals are acutely toxic or carcinogenic and require a **designated area** to work with them. A designated area may be the entire laboratory, an area of the lab, or a containment device such as a fume hood. Safe work practices may require the use of **engineering controls, administrative controls** and **personal protective equipment** (PPE). **Engineering controls** are part of the equipment or process designed to reduce or eliminate hazards. **Administrative controls** are changes to work procedures with the goal of reducing the duration, frequency, and severity of exposure to hazardous materials or situations. **PPE** refers to clothing or specialized equipment such as goggles that are worn to protect the wearer’s body from injury or exposure. In general, if the hazard cannot be eliminated or substituted with a lesser hazard, engineering controls are favored over administrative controls and PPE because well-designed engineering controls can be highly effective while not requiring effort on the part of the researcher to follow certain work policies or remembering to wear the correct PPE.

For the SOP author: Describe relevant safe work practices, designated areas (if present), engineering and administrative controls and select the PPE that are needed to protect the experimenter from hazards.

## Recommended work practices

Certain practices, when performed safely and consistently ensure operational success and personal safety and help ensure quality results.

For a laser system or experimental apparatus, operations that involve the most risk include alignment or other beam manipulation activities. Clear instructions for those operations should be in the SOP. The SOP must restrict these operations to individuals that are specifically authorized. Alignment procedures should include the following steps:

* Exclude unnecessary personnel from the laser area during alignment.
* Whenever possible, use low-power visible lasers for path simulation of higher-power visible or invisible lasers.
* Wear laser protective eyewear during alignment. Use special alignment eyewear when circumstances (e.g., wavelength, power, etc.) permit their use.
* When aligning invisible (e.g., ultraviolet or infrared) beams, use beam display devices such as image converter viewers or phosphor cards to locate beams.
* Perform alignment tasks using high-power lasers at the lowest possible power level.
* Use a shutter or beam block to block high-power beams at their source except when those beams are needed during the alignment process.
* Use an appropriately rated beam block to terminate high-power beams downstream of the optics being aligned.
* Use beam blocks and laser protective barriers in conditions where alignment beams could stray into areas where uninvolved personnel are working.
* Place beam blocks behind optics to terminate the beam during alignment in case the beam misses the optic (e.g., when adjusting mirrors or repositioning optics).
* Locate and block all stray reflections before proceeding to the next optical component or section.
* Be sure all beams and reflections are properly terminated before high power operation.
* Post appropriate area warning signs during alignment procedures to warn of increased risks.
* Remove all unnecessary tools, objects, and optics from the work area. Remove jewelry.

## Designated area to work with the material or process

Areas where class 3B and 4 lasers are used should be segregated and access to these areas must be controlled when the risk of exposure exists. These nominal hazard zones must be appropriately labeled with standard warning signs. Examples of such signs are given in the [appendix](#_Appendix). Signs should clearly state the type of lasers used in the NHZ, including wavelength range, power or pulse energy and laser classification. An illuminated warning sign installed at the lab entrance is another excellent administrative control if well designed. The message must be clear and the sign located where it will be noticed by anyone it is designed to warn. A simple red light at the door does not carry a clear message.

## **Necessary engineering or administrative controls**

Engineering controls are measures that are engineered into the apparatus to protect the operators and anyone who could be put at risk by the apparatus. They include shutters, interlocks, beam blocks, key locks and switches, beam enclosures, etc. The characteristic of an engineering control is that it removes the human factor. Engineering controls should be used in a laser laboratory as much as possible. The proper operation and maintenance of engineering controls must be part of the SOP.

Administrative controls are measures that are not engineered into the setup to protect the user, nor are PPE. These include warning signs, proper training, operating instructions, and policies for the use of the experimental setup. An important aspect of administrative controls is that they are only effective if people act on them in a predictable way. One of the most important administrative controls is the SOP.

## **Required Personal Protective Equipment.**

Personal Protective Equipment is equipment worn to protect personnel. PPE includes protective eyewear, gloves, and appropriate clothing. Of these, eyewear is the most important to laser operators because most laser-related accidents involve eye exposure. One very important aspect to consider about PPE is that it should never be your first line of defense against beam exposure. It exists to protect you when other forms of beam-containment engineering controls, such as beam enclosures and shutters fail. PPE should be selected based on the characteristics of the beam or beams present and the task to be performed. Laser protective eyewear can be partial attenuation (for alignment of visible beams) or, more commonly, full attenuation. Only full attenuation eyewear offers protection against intra-beam exposure (direct beam exposure). For non-visible wavelengths, only full attenuation eyewear should be worn. If you can’t see the beam, there is no reason to partially attenuate the laser light. For visible wavelengths, full attenuation eyewear should be used unless visualization of the beam termination points is required and other methods of visualization, such as cameras and viewers are not feasible.

See the Division of Research Safety guidance document [Personal Protective Equipment](https://www.drs.illinois.edu/SafetyLibrary/PersonalProtectiveEquipment) for more information.

# Detailed procedures or techniques

## Introduction

Successful experiments require adherence to correct procedure, correct sequence of operation, observation of experimental parameters and possibly making adjustments to certain variables to ensure safe operation. After completion of the experiment, all waste material should be collected in properly labeled containers.

The procedures for operation of specific laser equipment will vary widely due to the variety of lasers available to the researcher. That’s beyond the scope of this document, so editing this document to suit your laboratory is essential. A common sequence of steps will often resemble those described in the procedures below.

For the SOP author: Describe detailed procedures for performing the experiment or handling the materials in the step-by-step procedures section below. Whenever possible, point out critical steps, and describe any observations or indicators that the experiment is proceeding in a satisfactory manner. Describe any criteria that would indicate that something is amiss, as well as actions to be taken in those cases to avoid mishap. Upon conclusion of the experiment, describe the procedures for a safe shutdown, and properly deal with any waste generated. If a waste stream has already been established with a UI#, include that to aid the researcher in collection container labelling, waste segregation and disposal.

## Step-by-step procedures

## Regular usage

### Preparation

* Ensure that the laser shutter is closed or the beam path is blocked.
* Turn on warning lights and illuminated signs.
* Don proper PPE (e.g. eyewear) for operating the instrument.
* Verify that the apparatus is properly aligned using the [pilot laser](#_Definition_of_terms).

### Experiment

* Follow your procedure for energizing the laser.
* Open shutter to expose sample to the beam.
* Acquire and save the data.

### Finishing the experiment

* Close the shutter to block the beam.
* Follow your procedure for shutting down the laser.
* Turn off warning lights and illuminated signs.
* Store eyewear in the proper storage place.

## Alignment or modification

### Preparation

* To reduce accidental reflections, watches, rings, dangling badges, necklaces, reflective jewelry must be removed before any alignment activities begin.
* Use of non-reflective tools should be considered.
* Access to the room or area should be limited to authorized personnel only.
* Consider having at least one other person present to help with the alignment.
* Ensure that all necessary equipment and materials are present before beginning.
* All unnecessary equipment, tools, etc. must be removed to minimize the possibility of stray reflections and non-beam accidents.
* Only individuals that have been authorized by the Responsible Individual may perform the alignment.
* A NOTICE sign shall be posted at entrances when temporary laser control areas are set up or when unusual conditions warrant that additional hazard information be available to personnel who may enter the area.

### Alignment

* Whoever moves or places an optical component on an optical table (or in a beam path) is responsible for identifying and terminating every stray beam coming from that component (meaning reflections, diffuse or specular). There shall be no intentional intra-beam viewing by eye. When necessary, use a camera or suitable equipment.
* Pilot lasers should be used when practical for alignment of the primary beam.
* Reduce beam power with neutral density (ND) filters, beam splitters, or dumps, or by reducing the output of the power supply. Whenever practical, avoid the use of high-power settings during alignment.
* The laser protective eyewear specified by the Responsible Individual shall be worn at all times during the alignment.
* Beam blocks must be secured and labeled.
* Design the system so that beam paths are at a safe height, generally below eye level when standing or sitting.
* If the Responsible Individual has authorized the use of eyewear with reduced optical density (OD) to allow the beam spot to be seen, measures shall be taken and documented to ensure that no stray hazardous specular reflections are present before the lower-OD eyewear is worn. Maximum-OD eyewear shall be worn again once alignment is complete. The reduced-OD eyewear shall be labeled as alignment eyewear and shall be stored in a different location than the maximum-OD laser eyewear.
* Skin protection should be worn on the face, hands, and arms when aligning sources that emit UV wavelengths.
* The beam shall be enclosed as much as practical. The shutter shall be closed as much as practical during coarse adjustments. Optics and optical mounts shall be secured to the table as much as practical. Beam stops shall be secured to the table or optical mounts.
* Areas where the beam is diverted from the horizontal plane shall be labeled to inform personnel of the change in the conventional beam path.
* Any stray or unused beams shall be terminated.
* Invisible beams shall be viewed with IR/UV cards, business cards, card stock, viewers, thermal paper, or by a similar technique. Operators should be aware that such materials may produce specular reflections or may smoke or burn.
* Pulsed lasers shall be aligned by firing single pulses when practical.
* Intra-beam viewing shall be not allowed unless specifically evaluated and approved by a certified Laser Safety Officer (LSO). Intra-beam viewing by eye is to be avoided by using cameras or fluorescent devices.

### Completion

* Normal laser hazard controls shall be restored when the alignment is completed. Controls include replacing all enclosures, covers, beam blocks, and barriers and checking affected interlocks for proper operation.

## Waste disposal procedure.

If the experiment or regular maintenance of the experimental apparatus generate waste materials, these should be handled in the following manner:

* Handle/prepare all waste materials according to their hazard class.
* Place materials into an appropriately constructed container.
* Clearly label the container with the contents and appropriate UI#.
* Clearly and properly complete the [chemical waste pickup request form](https://www.drs.illinois.edu/chemicalwastepickup).
* Once the request is reviewed by DRS and you have received notification that your request has been accepted, print the labels for the waste container and await the scheduled pickup

# **Emergency response**

## Introduction to emergency response

While prevention of lab accidents is preferred, preparation for emergency situations is an essential part of good lab practice. A laboratory and/or process-specific plan of action should be developed to increase the likelihood of predictable assessment of- and behavior during- an emergency. This plan should become part of the training procedure.

Research groups should consider other emergencies unique to their process and document them in this section. The SOP isn’t pertinent unless it contains information that is useful to the group.

When working with class 3B and 4 lasers, the most common emergencies are eye or skin injuries due to beam exposure, fires caused by ignition of flammable materials by the laser beam, or electrocution while servicing laser power supplies.

## Necessary emergency equipment

Emergency equipment must be present before work is begun. Operators should be familiar with locations of all emergency equipment.

* Fire alarm - identify the locations of pull stations.
* Fire extinguisher of the correct type. Your department or Facility Manager for your location can help assure that the lab is equipped with the correct fire extinguisher.
* Emergency off (EMO) button (if so equipped).

## What to do if there is a material release or a fault in the process.

### Fire

In almost all imaginable cases, a fire warrants immediate evacuation of the laboratory and activation of the building fire alarm!

* If possible, turn off the power to the laser when leaving the laboratory. Do not put yourself in danger to accomplish this.
* Activate the building fire alarm and alert nearby personnel to evacuate.
* Call 911 from a safe location to alert emergency responders. Meet responders to inform them of the situation.

If the fire is contained and it is safe to do so, you may use the fire extinguisher to extinguish it. Do not put yourself in danger to accomplish this.

## What to do if there is an exposure or injury

**Beam exposure:** If your eye is exposed to laser light, the services of an ophthalmologist should be obtained immediately. If possible, turn off the power to the laser when leaving the laboratory. If your skin is exposed, treat for minor burns and seek medical assistance. If needed, get help from a lab mate or another person.

\*See the Division of Research Safety guidance document [**Medical Treatment Options**](http://www.drs.illinois.edu/AccidentResponse/MedicalTreatmentOptions) for more information.

PIs and Lab managers: enter first aid information for specific materials used in your lab. Document is not valid until filled in.

# Storage

## Introduction to proper storage of hazardous materials

The storage of chemicals goes beyond simply placing bottles on shelves for easy retrieval. Proper storage involves careful separation of incompatible chemicals, examination of containers for integrity, use of appropriately-sized secondary containment and management of time-sensitive or temperature-sensitive chemicals. Improper storage has led to unsafe conditions and incidents, and must be avoided.

For the SOP author: Identify and recognize incompatibilities and describe ways to safely store chemicals involved in this SOP.

## Special storage requirements

Prior to storage, lasers operated with hazardous materials such as dyes and toxic gases should be cleaned or sealed to avoid leakage of the hazardous materials.

### Laser parts and consumables

Store these items where they won’t be damaged or contaminated. Optical surfaces should be cleaned before installation to avoid damage and malfunction. Flash lamps can explode if not installed and stored in an appropriate manner or if they are not clean.

### Chemicals

All chemicals should be stored according to hazard class and compatibility considerations.

* Chemicals should be stored according to manufacturer’s SDS.
* They should be stored away from chemically incompatible materials.
* They should be stored away from electric circuits or electrically energized systems.
* Their quantities should be kept to a minimum.
* Gas cylinders should be stored/operated in an upright fashion, secured at midpoint or above with the appropriate bracket mounted to a secure structure.

## Quantity limits and other storage considerations

Specify applicable regulatory or self-imposed storage quantity limits.

# Reference

## Definition of terms

**Accessible Emission Level**: The magnitude of laser radiation to which human access is possible. It is 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. The limits were defined on the powers and energies emitted by the laser and accessible to the user – this explains the acronym A.E.L. Each laser class is labeled by a maximum accessible emission that must not be exceeded. AEL limits are based on laser emission, in contrast to MPE, which are limits based on the radiation received by the eye or the skin – directly from the beam or after reflection.

**ANSI Z136**: The American National Standards Institute’s standard for safe use of lasers.

**Aperture:** An opening through which laser radiation can pass. This term usually refers to the opening on the laser (or a protective housing) from 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 typically assumed to occur within 0.25 second.

**Beam path**: The path which the laser beam follows.

**Cataract:** a condition in which a part of the eye (called the lens) becomes cloudy and impairs vision.

**Continuous Wave (CW) Laser**: A laser that 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 matte surface.

**Divergence (φ):** Divergence is the plane angle projection of the cone that includes 1-1/e (i.e., 63.2%) of the total radiant energy or power. The value of divergence is expressed in radians or milliradians.

**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 that does not permit hazardous optical radiation emission from the enclosure.

**Erythema:** Redness of the skin due to congestion of the capillaries. This can occur as a result of laser exposure.

**Fiber Optics:** A system of flexible quartz or glass fibers with internal reflective surfaces that guide light through many 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 that lie within the range of 0.70 to 1000 micrometers.

**Irradiance or Intensity:** The optical power per unit area reaching a surface (W/cm2).

**Laser:** A device that 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 that includes a laser.

**Maximum Permissible Exposure (MPE):** The level of laser radiation to which a person may be exposed without hazardous effect of adverse biological changes in the eye or skin. The criteria for MPE for the eye and skin can be found in ANSI Z136.1 – 2014 edition.

**Nominal Hazard Zone (NHZ):** The space within which the level of direct, reflected, or scattered radiation during normal operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.

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

**Photokeratitis:** Inflammation of the cornea caused by exposure to ultraviolet radiation.

**Pilot Laser:** A low-power laser commonly used in lieu of a high-power laser during alignment. It is aligned such that its beam follows the same path as the high-power laser.

**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. A specular surface is one in which the surface roughness is smaller than the wavelength 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 that can be detected by the human eye. It is commonly used to describe wavelengths that lie in the range between 400 nm and 700 nm.

**Wavelength:** The length of the light wave that determines its color. Common units of measurement are the micrometer (micron) and the nanometer (nm).

## Tools and resources

### Tools for Performing a Lab Risk Assessment

Hazard recognition and identification is the first step to creating a risk assessment for your laboratory procedure. The following links provide guidance in identifying hazards and assessing the risks from the hazards.

* [Laser Institute of America: Web-based Laser Safety Hazard Analysis System](https://www.lia.org/evaluator/)
* [University of Warwick: Laser Risk Management, Guidance on Hazards and carrying out risk assessments.](https://www2.warwick.ac.uk/services/healthsafetywellbeing/guidance/lasers/laserriskmanagement/guidanceonhazards/)  Includes a recommended [laser risk assessment form](https://www2.warwick.ac.uk/services/healthsafetywellbeing/guidance/lasers/laser_risk_assessment_pro-formas.docx).
* [American Chemical Society: Hazard Assessment in Research Laboratories](https://www.acs.org/content/acs/en/about/governance/committees/chemicalsafety/hazard-assessment.html)
* [Division of Research Safety: Standard Operating Procedures](https://www.drs.illinois.edu/Programs/StandardOperatingProcedures)

### Tools for selection of hazard controls

Once the hazards have been identified, control measures aim to eliminate or mitigate (lessen) the risk from each hazard. Guidance on proper selection of controls may be obtained from the following:

* Barat, Ken. Laser Safety Management, 2006, CRC Press. Chapters [10](http://www.crcnetbase.com/doi/abs/10.1201/9781420015546.ch10) and [14](http://www.crcnetbase.com/doi/abs/10.1201/9781420015546.ch14).
* [American Chemical Society: Control Measures](https://www.acs.org/content/acs/en/about/governance/committees/chemicalsafety/hazard-assessment/fundamentals/control-measures.html)
* For further guidance on PPE, consult: [Division of Research Safety: Personal Protective Equipment](https://www.drs.illinois.edu/SafetyLibrary/PersonalProtectiveEquipment)

Sources of laser safety equipment:

* <http://www.kenteklaserstore.com>
* <http://www.lasersafety.com/>
* <http://www.lasersafetyindustries.com>
* <https://www.lia.org>
* <http://www.newport.com>
* <http://noirlaser.com/>
* <http://www.phillips-safety.com>
* <http://www.thorlabs.com>

### Change management

The SOP should be reviewed on an annual basis and whenever events or conditions arise that trigger a review, such as:

1. An incident or significant near miss or close call.
2. Modifications to equipment other than replacement in kind.
3. Use of a commercial product for a purpose for which it was not designed.
4. Increased risk beyond what is covered in the SOP.
5. New experiment, equipment, or control software.
6. A change/improvement in an SOP or other program document is made.
7. New materials are introduced to an experiment that were not accounted for in the SOP.
8. Changes in essential personnel.

It also helps to maintain a *change management document* that lists sections or items in the SOP that should be checked in every review, such as: web links, names of resource persons, or other information that might become outdated.

### Reference material

[ANSI Z136. American National Standard for Safe Use of Lasers. Published by the Laser Institute of America.](https://www.lia.org/store/ANSI+Z136+Standards)

[Laser Safety Management (e-book, available through UIUC Library). Barat, Ken. 2006. CRC Press.](http://www.crcnetbase.com/isbn/9780824723071)

[Laser safety: Risks, hazards, and control measures. Smalley, Penny.](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3799025/) [Laser Ther. 2011; 20(2): 95-106](http://doi.org/10.5978/islsm.20.95).

[Prudent Practices in the Laboratory. Handling and Management of Chemical Hazards. NRC (National Research Council). National Academy Press: Washington, DC, 2011.](http://www.nap.edu/catalog/12654/prudent-practices-in-the-laboratory-handling-and-management-of-chemical)

[Identifying and Evaluating Hazards in Research Laboratories. ACS (American Chemical Society) 2015.](http://www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/publications/identifying-and-evaluating-hazards-in-research-laboratories.pdf)

# Record of changes made to this SOP

Describe the changes made to this document since its creation. Identify the personnel who made the edits or revisions and when the change was made.

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Standard Operating Procedure for

# Training record

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# Appendix

Examples of signs for use with lasers

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