

# LASER SAFETY MANUAL

APR 2020



**USC** University of  
Southern California

Office of  
Environmental  
Health and Safety



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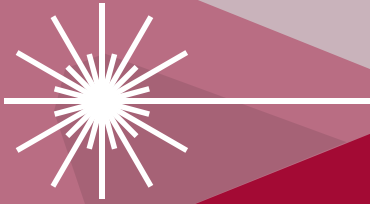
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# 1.0 Introduction

## Purpose and Scope

University of Southern California (USC)'s Laser Safety Program works to ensure that all faculty, staff, students, and volunteers work with and handle all lasers safely, and that adequate protection is provided when working with lasers.

This manual was prepared by the Office of Environmental Health & Safety (EH&S) to help you manage the use of lasers as safely as possible. Although not all lasers are required to be registered with EH&S, safe handling and use of all lasers are within the scope of this program. This manual provides the requirements of USC's Laser Safety Program with special emphasis to the following:

All non-clinical<sup>1</sup> uses of Class 3B or Class 4 lasers

Anyone handling (or in the vicinity of) Class 3B and 4 lasers

The safety areas of concern addressed in this manual include protection from exposure to the laser beam itself as well as protection from non-beam hazards such as:

Electrical

Chemical

Collateral radiation not associated with the primary beam

Fire

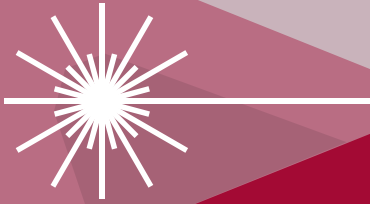
Explosion

Air contaminants

The Laser Safety Program is managed by EH&S via the USC Laser Safety Officer (LSO), a member of EH&S, with oversight by the Laser Safety Subcommittee (LSS). While this manual provides appropriate guidance for all classes of lasers, the main emphasis of the program is directed primarily at the registration of Class 3B and 4 lasers with EH&S and subsequent review and approval of laser operations by the LSO and/or LSS.

<sup>1</sup> This manual does not provide guidance for the use of lasers in a clinical setting. Consult ANSI Z136.3, "Standard for Use of Lasers in Health Care" prior to conducting any research or clinical work involving use of lasers in medical applications.

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## 2.0 Regulatory Requirements

The USC Laser Safety Program requires that all lasers and laser systems are operated in accordance with the following state and federal regulations.



### Standards

American National Standards Institute (ANSI) [Z136.1 - 2014, "Safe Use of Lasers"](#)

American National Standards Institute (ANSI) [Z136.5](#)  
["Safe Use of Lasers in Educational Institutions"](#)



### Federal

Code of Federal Regulation (CFR) and U.S. Food and Drug Administration (FDA): Title 21 Food and Drugs, Chapter 1 Food and Drug Administration, Department of Health and Human Services, Subchapter J Radiological Health

- [Part 1040 Performance standards for light-emitting products](#)
- [Sec. 1040.10 Laser products](#)

Occupational Health and Safety Administration (OSHA)

- OSHA Technical Manual, [Section III: Chapter 6 Laser Hazards](#)

CAL/OSHA Title 8, Subchapter 4 Construction Safety Orders

- [Article 34. Section 1801 Non-ionizing Radiation](#)

### References

University of Hawaii [Laser Safety Manual](#)

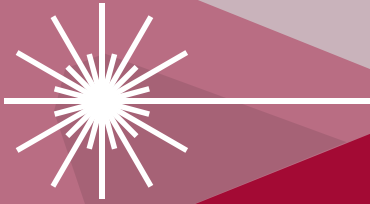
Stanford University [Laser Safety Manual](#)

Journal of the American Medical Association (JAMA) Article: ["Assessment of Alleged Retinal Laser Injuries"](#) Mainster et al. 2004

British Journal of Ophthalmology Article: ["The safety of laser pointers: myths and realities"](#) Marshall 1998

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## 3.0 Roles and Responsibilities

USC has an official Injury and Illness Prevention Policy which explicitly lays out the health and safety roles and responsibilities of the various members of the USC community (<https://policy.usc.edu/injury-prevention/>).

**It is recommended that all USC persons (especially PIs and other supervisory personnel) read and understand this policy.**

### Research Safety Oversight Committee (RSOC)

The RSOC:

- Has the following members:
  - Vice-President for Research - Chair
  - EH&S Executive Director
  - Director of Research Compliance
  - Chairpersons of other USC-wide safety committees
  - USC senior managers
- Provides high-level oversight of all aspects of health and safety at USC.
- Facilitates communication between the specialized safety committees:
  - Institutional Biosafety Committee (IBC)
  - Radiation Safety Committee (RSC)
  - Campus-Wide Chemical Safety Committee (CCSC)
- Reports administratively to the USC Provost and President.

### Laser Safety Subcommittee (LSS)

The LSS is organized as a subcommittee of the USC Radiation Safety Committee (RSC). The LSS is responsible for oversight of laser operations and guidelines related to the use of lasers. The LSS works closely with the Office of Environmental Health and Safety (EH&S) to eliminate or reduce risks to individuals or the environment. This includes a risk assessment to determine how USC personnel handle lasers. The LSO conducts this risk assessment by inspecting each location with registered class 3B and 4 lasers. Based on the results of the risk assessment, the LSO will provide any necessary guidance on how to handle the lasers safely. The LSO provides the results of these assessments to the LSS and seeks guidance and consultation when required. The Office of Environmental Health and Safety provides staff to support the LSS.

The LSS responsibilities include:

- Develops and reviews general policies and practices governing the use of lasers Class 3B and Class 4.
- Ensures that all safety standards developed by USC's Laser Safety Program are in accordance with the American National Standards Institute (ANSI) Z136.1 standard.
- Evaluates the effectiveness of USC's Laser Safety Program with regard to laser use, inspections, training activities, incidents, and best safety practices.
- Reviews all laser-related incidents.
- Reviews, approves, and suggests improvements to EH&S policies, programs, guidelines, and activities related to general and chemical laboratory safety.
- Reviews laboratory incidents or accidents that occur at USC (except incidents falling under the purview of other safety committees such as the IBC or RSC).
- Reviews the adequacy of response of EH&S, PIs, Departments, or Schools to laboratory incidents or accidents.
- Reviews safety controls and management of high-hazard facilities, or proposed potentially very highly hazardous research.

- Provides high-level enforcement of laboratory safety standards in the event of egregious non-compliance or refusal to cooperate with EH&S.
- Refers important items to the RSOC via the RSC chair who is also an ex-officio RSOC member.

The LSS consists of voting members appointed by the Associate Senior Vice President for USC Administrative Operations. Faculty committee members either work directly with lasers or are individuals with expertise in the use of laser instruments. The membership includes at a minimum:

- Four faculty members with expertise in laser use and handling
- Two ex-officio members that include the EH&S Laser Safety Officer and the EH&S Radiation Safety Officer

As a minimum, the LSS uses guidance outlined in the most current version of the "American National Standard for the Safe Use of Lasers," published by the American National Standards Institute. The LSS will also develop additional standards and guidelines, as necessary.

## Office of Environmental Health & Safety

The Office of Environmental Health and Safety is responsible for managing and implementing the USC Laser Safety Program. Authority for oversight of the program is given to the Laser Safety Officer (LSO), who is provided assistance from other radiation safety staff members. The LSO conducts a yearly review of the Laser Safety Program and provides an annual report to the LSS.

### Laser Safety Officer

The Laser Safety Officer (LSO) is a member of EH&S and is responsible for developing and maintaining an inventory of all Class 3B and 4 lasers and laser operators at USC, assisting in the development of general policies for control of laser systems, and collecting and disseminating information relative to laser protection.

Other responsibilities include:

- Evaluate equipment and physical facilities, and operational techniques and procedures.
  - Conduct annual inspections to ensure that laser facilities and procedures are in accordance with USC policies and all applicable regulations; also review documentation, administrative controls, PPE, and engineering controls.
  - Respond to emergencies and investigate accidental exposures.
  - Verify laser classification and coordinate an occupational health program for all Authorized Laser Operators.
  - Supervise the disposal of operational laser components and dyes.
  - Advise on laser adjustments, safe use of lasers and protective measures, fire prevention, and electrical and chemical safety.
  - Provide identification tags, signs, and labels for lasers.
- Assist in evaluating and controlling hazards that may include:
    - Posting of appropriate warning signs
    - Identification of appropriate control areas
    - Calculations of Maximum Permissible Exposure (MPE) and Nominal Hazard Zone (NHZ)
    - Guidance on proper protective eye wear
    - Laser classification of custom built or modified laser systems
  - Provide laser safety training to anyone handling lasers.
  - Update program if any changes in regulations occur.
  - Conduct annual review of program.

## Principal Authorized Laser Operator

The Principal Authorized Laser Operator (PALO) is the individual directly responsible for the acquisition, use, and maintenance of a particular laser or laser system. PALOs are required to:

- Comply with ANSI Z136.1 and 21 CFR Part 1040.10 regulations on safe laser usage.
- Comply with USC Laser Safety Manual and the Laser Safety Committee requirements.
- Assure that only Authorized Laser Operators will use the laser.
- Complete a Lab Hazard Assessment Tool (LHAT) to determine appropriate engineering / administrative controls and PPE for each hazard.
  - Submit the completed LHAT to EH&S at [radsafety@usc.edu](mailto:radsafety@usc.edu).
  - Update the LHAT annually or whenever hazards change.
- Ensure that all laser operators complete laser safety training and other applicable occupational health requirements before they operate any laser.

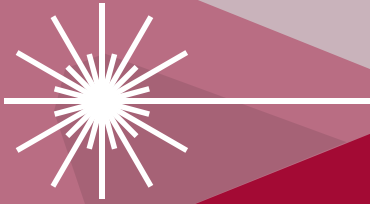
- Write and implement Laser Standard Operating Procedures (LSOPs) for Class 3B and all Class 4 lasers.
- Ensure that all laser operators complete laser safety training before they operate any laser.
- Provide instruction and train on safe and proper laser practices to all persons working within the facilities of the PALO. These rules must be prominently posted in the laboratory area(s) or readily accessible to all persons in the facility.
- Provide emergency procedures for all laboratory personnel. Emergency procedures must include the names and telephone numbers of key lab personnel as well as the Laser Safety Officer (LSO). These procedures shall be prominently posted in work areas where laser systems and devices are used.
- Maintain adequate control of the laser system to ensure that areas beyond the PALO's control are not adversely affected by its use.
- Provide necessary equipment for safe work with lasers and dyes.
- Label all lasers by Class and Type.
- Notify the LSO of any accident or abnormal incident involving or suspected of involving lasers or laser components.
- Inform the LSO of any changes in personnel and any significant changes in lab design or procedures.
- Store each laser securely and safely when not in use so that it is not useable by unauthorized personnel or under unauthorized conditions.
- Notify the LSO prior to the acquisition or fabrication of a new laser to allow for a preliminary safety review and laser inventory update.
- Establish and maintain a current list of personnel approved to operate specific types of Class 3B or 4 lasers under their supervision and provide a copy of the list to the LSO.
- Immediately notify EH&S in the event of a suspected overexposure to the output beam from a Class 3B or 4 lasers.

### **Authorized Laser Operator**

The Authorized Laser Operator (ALO) is an individual other than the PALO who is trained on the use of lasers (e.g., graduate students, postdoctoral fellows, and laboratory technicians) and handles lasers in research. The ALO reports to and is under the supervision of the PALO. NOTE: All personnel operating Class 3b or Class 4 lasers must be authorized to do so by EH&S.

The ALO must:

- Attend EH&S' laser safety class.
- Receive operating and safety training for each specific laser system from the PALO prior to handling laser.
- Follow the USC Laser Safety Manual, Laser SOPs, and any manufacturer's laser-specific safety guidelines for the laser he/she is operating.
- Know and follow emergency procedures.
- Report any unsafe practices to the PALO and the LSO.
- Notify the LSO and EH&S of any accident or incident involving or suspected of involving a laser or non-ionizing radiation-producing device.



## 4.0 Laser Classification

### Laser Classes

Lasers are classified depending upon the power or energy of the beam and the wavelength of the emitted radiation. Laser classification is based on the laser's potential for causing immediate injury to the eye or skin and/or potential for causing fires from direct exposure to the beam or from reflections from diffuse reflective surfaces. The manufacturer provides the classification for most lasers. For custom-built and modified lasers, the Laser Safety Officer will assist with classification.

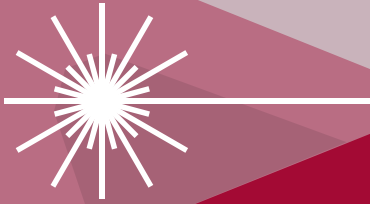
The laser classes are defined per the following:

<b>Class 1</b>	Considered to be incapable of producing damaging radiation levels during operation; (e.g., CD/DVD players, laptop, or personal computer). Exempt from most control measures or other forms of surveillance.
<b>Class 1M</b>	Similar to Class 1 laser systems except potentially hazardous if viewed with optical aids like magnifying glasses, binoculars, etc.
<b>Class 2</b>	Emits in the visible portion of the spectrum (400 to 700 nm). Eye protection is normally afforded by the normal human aversion response (blink reflex) to bright radiant sources. These lasers can be hazardous if viewed directly for extended periods of time. Radiant power < 1mW (e.g., laser pointer and barcode reader).
<b>Class 2M</b>	Similar to Class 2 laser systems except potentially hazardous if viewed with an optical aid like magnifying glasses, binoculars, etc.
<b>Class 3R</b>	Formerly known as Class 3A. Potentially hazardous under some direct and specular reflection viewing conditions if the eye is appropriately focused and stable, but the probability of an actual injury is small. Visible radiant power < 5 mW (e.g., measuring/targeting devices and higher power pointers).
<b>Class 3B</b>	May be hazardous under direct and specular viewing conditions, but is usually not a diffuse reflection or fire hazard. Visible radiant power < 500 mW; uses in spectrometry, stereolithography, and research.
<b>Class 4</b>	Is a hazard to the eye or skin from the direct beam or specular reflection. May pose a hazard from diffuse reflection and may also pose a fire hazard. Other possible hazards include laser generated air contaminants (LGAC) and hazardous plasma radiation; uses in research, surgery, cutting, and welding.

## Types of Lasers

Lasers are also characterized by the type and duration of laser emission (e.g. continuous wave or pulsed laser). The following are examples of various types of lasers.

<b>Continuous Wave (CW)</b>	Operates with a stable average beam power. In most higher-power systems, the power level is adjustable. In low power gas lasers, such as HeNe, the power level is fixed by design and performance usually degrades with long term use.
<b>Single Pulsed (normal mode)</b>	Pulse durations are generally in the range of a few hundred microseconds to a few milliseconds. This mode of operation is sometimes referred to as long pulse or normal mode.
<b>Single Pulsed Q-Switched</b>	Q-switched lasers contain a shutter-like device that does not allow emission of laser light until opened. Energy is built-up in a Q-switched laser and released by opening the device to produce a single, intense laser pulse. Under optimum gain conditions, emission occurs in single pulses; typically, of $10^{-8}$ second time domain. These pulses will have high peak power often in the range from $10^6$ to $10^9$ Watts.
<b>Repetitively Pulsed (scanning lasers)</b>	Generally involves the operation of pulsed laser performance operating at a fixed (or variable) pulse rate which may range from a few pulses per second to as high as 20,000 pulses per second. The direction of a CW laser can be scanned rapidly using optical scanning systems to produce the equivalent of a repetitively pulsed output at a given location.
<b>Mode Locked</b>	Operates as a result of the resonant modes of the optical cavity which can affect the characteristics of the output beam. When the phases of different frequency modes are synchronized, i.e., "locked together," the different modes will interfere with one another to generate a beat effect. The result is a laser output with regularly spaced pulsations, each usually having a duration of $10^{-15}$ (femto) to $10^{-12}$ (pico) seconds. A mode-locked laser can deliver extremely high peak powers; more than the same laser operating in the Q-switched mode. These pulses will have enormous peak power often in the range of $10^{12}$ Watts.



## 5.0 Acquisition, Inventory, and Disposal

All PALOs who handle and use Class 3B and Class 4 lasers must register them with EH&S before initial use. The best time to start that process is when the laser is ordered. If you are already in possession of a Class 3B and/or Class 4 laser(s), please notify EH&S by following steps 2 and 3 in the “Receipt and Registration” section below. Please follow these steps when ordering or taking receipt of new lasers.

### Ordering

Before placing an order, the PALO notifies the LSO by sending copies of requisitions for laser systems, lenses, and other components to [radsafety@usc.edu](mailto:radsafety@usc.edu).

The requisition must include a description of the laser, laser system, and/or part which provides:

- Class and mode of operation
- Type and wavelength
- Maximum power and beam divergence
- Safety features and protective equipment

### Receipt and Registration

When the laser or laser component is delivered to the lab, the PALO must complete the following actions to confirm receipt and register it with EH&S:

1. Check the laser for damage
2. Complete the following forms for each laser/laser system. Submit completed forms to the LSO at [radsafety@usc.edu](mailto:radsafety@usc.edu).
  - a. [Laser System and Personnel Registration](#) (include serial number, class, type and power of laser)
  - b. [Laser Standard Operating Procedure](#)
  - c. [Laser Alignment Procedure](#)
  - d. [Laser Safety for Confocal Microscope](#)
3. Check all safety devices and controls and record the results in the [Laser Safety Inspection Checklist](#). Send a copy of the Laser Safety Inspection Checklist to the LSO at [radsafety@usc.edu](mailto:radsafety@usc.edu).

NOTE: The LSO will conduct annual inventories of all lasers as a part of the inspection process. A discrepancy (or discrepancies) between lasers ordered and lasers received per the PALO's inventory will be noted in the audit summary. The PALO will be given the opportunity to respond and to remedy the finding.

## **Laser Hazard Evaluation**

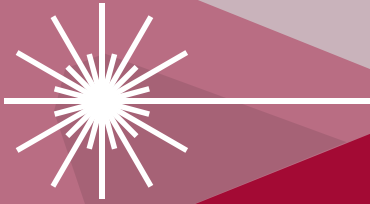
Prepare a Laser Hazard Evaluation Form when receiving or manufacturing a new laser or laser component and save it with all information related to that system. The form must be kept readily available for City/State inspectors or personnel from EH&S.

The LSO will help the PALO perform a hazard evaluation for all Class 3B and Class 4 lasers, and determine the Nominal Hazard Zone (NHZ).

## **Transfer or Disposal of Lasers**

Before transferring or disposing of any lasers, please notify the LSO at [radsafety@usc.edu](mailto:radsafety@usc.edu). The LSO will provide you with appropriate transfer or disposal instructions.





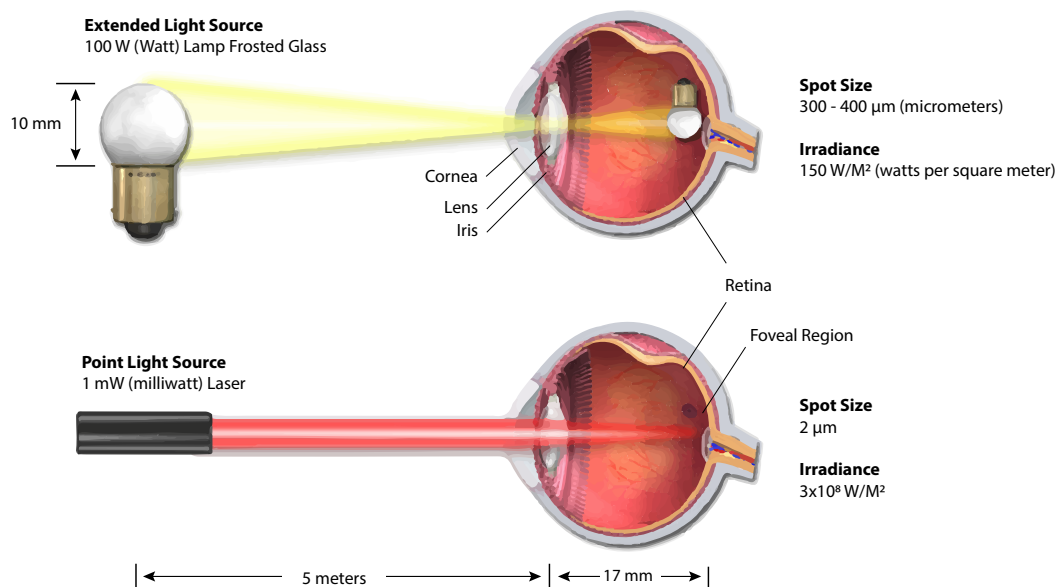
## 6.0 Laser Hazards

### Beam Hazards

#### Eye Injury

Because of the high degree of beam collimation, a laser serves as an almost ideal point source of intense light. A laser beam of sufficient power can theoretically produce retinal intensities at magnitudes that are greater than conventional light sources and even larger than those produced when directly viewing the sun. Exposure can result in permanent blindness. See Figure 6.1 to see how an eye perceives extended and point light sources and source's corresponding power density.

**Figure 6.1. Extended and Point Source Power Density at the retina**



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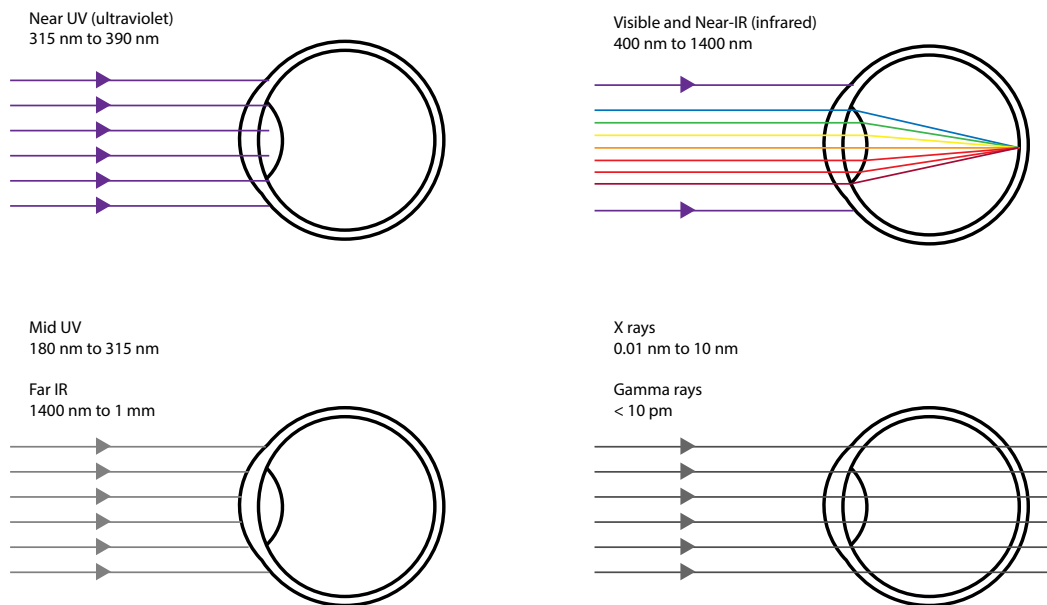
#### Laser Wavelength and the Eye's Response

The eye responds differently to lasers depending on the wavelength of the incident beam (See figure 6.2).

#### Ultraviolet (Invisible to the Human Eye)

Lasers operating in the ultraviolet spectrum (315 – 390 nm) are absorbed by the lens of the eye. An excimer laser is a typical example of a laser that operates in this range which is why they are often used in eye surgery.

**Figure 6.2. Eye's response to different wavelengths**



### Visible

Laser radiation in the visible region of the spectrum (400 – 700 nm) is absorbed primarily within the retina. An ideal eye can concentrate a visible laser beam by as much as 100,000 times. Argon and KTP lasers are typical examples of visible lasers.

### Near-Infrared (Invisible to the Human Eye)

Laser radiation in the near-infrared region of the spectrum (700 – 1400 nm) is also absorbed by the retina and, like the visible region, the lens of the eye can concentrate a laser beam on the retina as much as 100,000 times.

For example, 1 mW/cm<sup>2</sup> irradiance (power density) at the cornea will be 100 W/cm<sup>2</sup> at the retina. Since the eye does not have an aversion response in the near- or far-infrared portion of the spectrum, you will not know that you were overexposed until the injury occurs. This is why this portion of the spectrum is very dangerous.

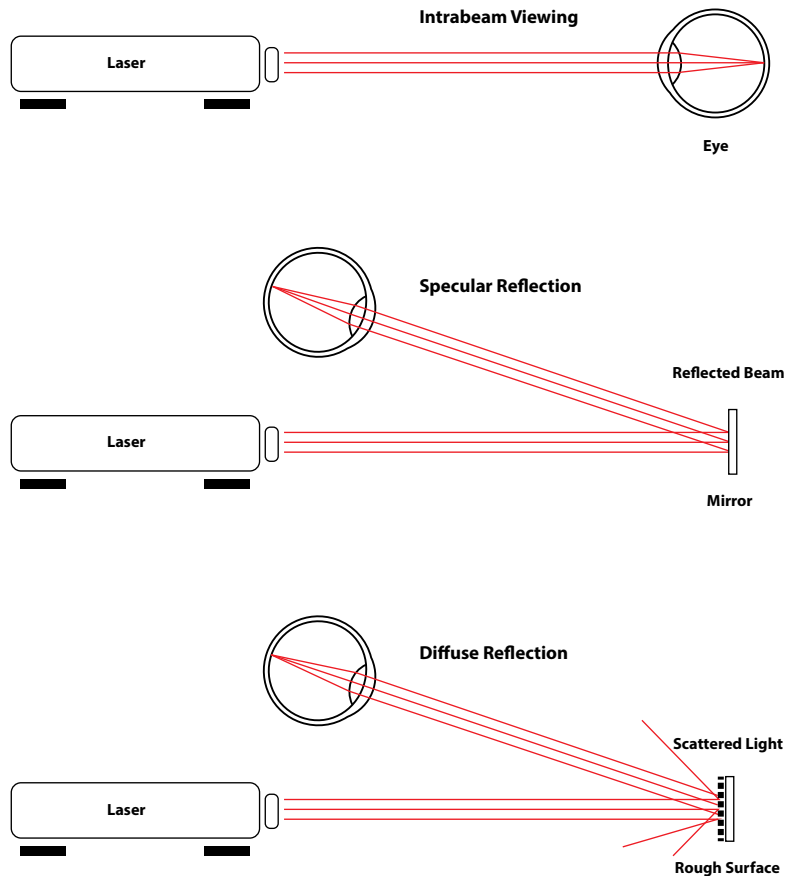
### Far-Infrared

Laser radiation in the far-infrared region of the spectrum (1400 nm – 1 mm) and the mid-ultraviolet (180 – 315 nm) primarily affects the cornea. CO<sub>2</sub> lasers are a typical example of lasers in the far-infrared range.

## Types of Laser Eye Exposure

Injury to the eye is not limited to direct beam exposure (Intrabeam Viewing). Exposure to specular or diffuse beam reflections, particularly from high powered lasers, may be just as damaging as exposure to the primary beam (See Figure 6.3).

*Figure 6.3. Types of laser eye exposure*



### Intrabeam Viewing

Intrabeam exposure occurs when the eye or skin is exposed directly to all or part of the laser beam. The eye or skin is exposed to the full irradiance of the laser and can cause the greatest injury.

### Specular Reflections

Specular reflections from mirror surfaces can be nearly as harmful as exposure to the direct beam, particularly if the surface is flat. Curved mirror-like surfaces will widen the beam such that while the exposed eye or skin does not absorb the full impact of the beam, there is a larger area for possible exposure.

## Diffuse Reflections

A diffuse surface is a surface that will reflect the laser beam in many directions. Mirror-like surfaces that are not completely flat, such as jewelry or metal tools, may cause diffuse reflections of the beam. These reflections do not carry the full power or energy of the primary beam, but may still be harmful (particularly from high powered lasers). Diffuse reflections from Class 4 lasers are capable of initiating fires.

Whether a surface is a diffuse reflector or a specular reflector will depend upon the wavelength of the beam. A surface that would be a diffuse reflector for a visible laser may be a specular reflector for an infrared laser beam.

## Skin (Thermal) Injury

The most common cause of laser-induced tissue damage is thermal in nature, where the tissue proteins are denatured due to the temperature rise following absorption of laser energy.

The thermal damage process (burns) is generally associated with lasers operating at exposure times greater than 10 microseconds and in the wavelength region from the near ultraviolet to the far infrared (0.315  $\mu\text{m}$  – 103  $\mu\text{m}$ ). Tissue damage may also be caused by thermally-induced acoustic waves following exposures to sub-microsecond laser exposures. See Table 6.1 for the effects of light on tissue.

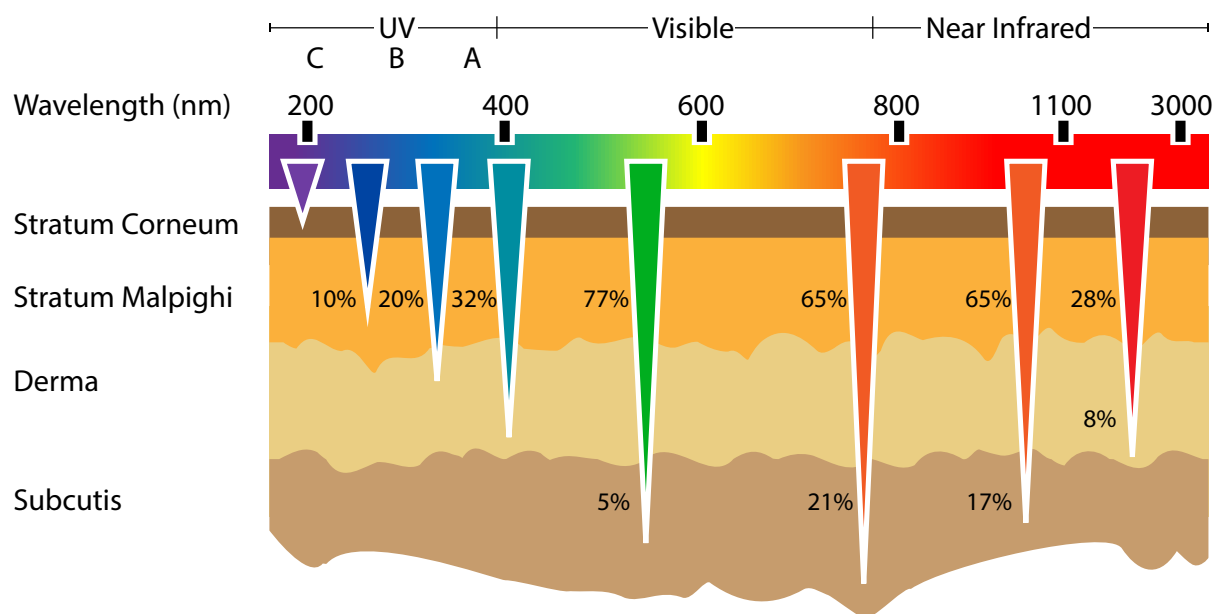
**Table 6.1. Summary of basic biological effects of light** (OSHA Technical Manual Section III, Chapter 6)

Photobiological Spectral Domain	Eye Effects	Skin Effects
Ultraviolet C (0.200 – 0.280 $\mu\text{m}$ )	Photokeratitis	Erythema (sunburn), skin cancer
Ultraviolet B (0.280 – 315 $\mu\text{m}$ )	Photokeratitis	Accelerated skin aging, increased pigmentation
Ultraviolet A (0.315 – 0.400 $\mu\text{m}$ )	Photochemical UV cataract	Pigment darkening, skin burn
Visible (0.400 – 0.780 $\mu\text{m}$ )	Photochemical and thermal retinal injury	Photosensitive reactions, skin burn
Infrared A (0.780 – 1.400 $\mu\text{m}$ )	Cataract, retinal burns	Skin burn
Infrared B (1.400 – 3.00 $\mu\text{m}$ )	Corneal burn, aqueous flare, IR cataract	Skin burn
Infrared C (3.00 – 1000 $\mu\text{m}$ )	Corneal burn only	Skin burn

Biological damage induced by repetitively pulsed or scanning lasers is primarily a thermal process where the effects of the pulses are additive. The principal thermal effects of laser exposure depend upon the following factors:

- Irradiance or radiant exposure of the laser beam along with the absorption and scattering coefficients of the tissues at the laser wavelength. See Figure 6.4 for skin penetration of lasers at various wavelengths
- Duration of the exposure and pulse repetition characteristics, where applicable
- Extent of the local vascular flow
- Size of the area irradiated

**Figure 6.4. Laser wavelength and skin penetration**



The hazards associated with skin exposure are of less importance than eye hazards; however, with the expanding use of higher-power laser systems, particularly ultraviolet lasers, the unprotected skin of personnel may be exposed to extremely hazardous levels of the beam power if used in an unenclosed system design. See Table 6.2 for laser classifications and summary of hazards.

**Table 6.2. Laser classifications and summary of hazards** (OSHA Technical Manual Section III, Chapter 6)

Wavelength Range					Hazards		
Class	UV	Vis	NIR	IR	Direct Ocular	Diffuse Ocular	Fire
1	X	X	X	X	No	No	No
1A	--	X <sup>†</sup>	--	--	Only after 1000 sec	No	No
2	--	X	--	--	Only after 0.25 sec	No	No
3R/3A	X	X <sup>††</sup>	X	X	Yes	No	No
3B	X	X	X	X	Yes	Only when laser output is near Class IIIB limit (0.5 Watt)	No
4	X	X	X	X	Yes	Yes	Yes

<sup>†</sup> Class 1A applicable to lasers "not intended for viewing" ONLY.

<sup>††</sup> CDRH Standard assigns Class 3R to visible wavelengths ONLY. ANSI Z 136.1 assigns Class 3R to all wavelength ranges.

X Indicates class applies in wavelength range.

## Non-Beam Hazards

While exposure to laser beams is the most prominent laser hazard, other hazards pose an equal or possibly greater risk of injury or death. Some of those other non-beam hazards include:

<b>Chemical Hazards</b>	Many dyes used as lasing media are toxic, carcinogenic, corrosive, or pose a fire hazard. Review the Safety Data Sheet (SDS) before handling any chemical in the laser laboratory. The SDS, as well as the Chemical Hygiene Plan ( <a href="#">CHP</a> ), will supply appropriate information pertaining to the toxicity, personal protective equipment, and storage of chemicals. Dyes used in laser labs need to be disposed of properly, visit <a href="https://ehs.usc.edu/hazmat/waste/">https://ehs.usc.edu/hazmat/waste/</a> for more details.
<b>Collateral Radiation Hazards</b>	Radiation other than that associated with the primary laser beam is called collateral radiation. Examples are X-rays, UV, plasma, radio frequency emissions, and ionizing radiation. X-rays can be produced by high-voltage vacuum tubes of laser power supplies, such as rectifiers and thyratrons. A power supply, which requires more than 15 kilovolts (kV), may produce enough x-rays to be a health hazard. Unshielded and loose-fitting components may generate RF fields and any plasma generated may contain hazardous “blue light” UV emissions.
<b>Compressed &amp; Toxic Gas Hazards</b>	Hazardous gases (fluorine, hydrogen chloride) may be used in such laser applications as excimer lasers. If hazardous gases are used, the SOP should contain references for the safe handling of compressed gases, such as seismic restraints, use of gas cabinets, proper tubing and fittings, etc.
<b>Cryogenic Fluid Hazards</b>	Cryogenic fluids are used in the cooling systems of certain lasers. As these materials evaporate, they replace oxygen in the air. Adequate ventilation must be ensured. Cryogenic fluids are potentially explosive when ice collects in valves or connectors that are not specifically designed for use with cryogenic fluids. Condensation of oxygen in liquid nitrogen presents a serious explosion hazard if the liquid oxygen comes in contact with any organic material. While the quantities of liquid nitrogen that may be used are usually small, protective clothing and face shields must be used to prevent freeze burns to the skin and eyes.
<b>Electrical Hazards</b>	Accidental electrocution while working with high voltage sections of laser systems can be lethal. Electrical hazards are not normally present during laser operation, but great care must always be exercised during installation, maintenance, or servicing. Laser users must ensure that high voltage electrodes are not exposed and that capacitors are correctly discharged. Some laser systems incorporate the use of a water cooling system. The combination of water and electrical hazards increases the risk of serious injury. For more information on how to mitigate electrical hazards please visit <a href="https://ehs.usc.edu/occhealth/shop-safety/">https://ehs.usc.edu/occhealth/shop-safety/</a> .
<b>Ergonomic Hazards</b>	Ergonomic problems can arise from a laser operation that causes awkward arm and wrist positions. If these positions occur for prolonged periods of time, medical problems such as repetitive strain injuries may arise. For more information on ergonomics, visit <a href="https://ehs.usc.edu/occhealth/ergonomics/">https://ehs.usc.edu/occhealth/ergonomics/</a> .

<b>Explosion Hazards</b>	High-pressure arc lamps, filament lamps, and capacitors may explode violently if they fail during operation. These components are to be enclosed in a housing which will withstand the maximum explosive force that may be produced. Laser targets and some optical components also may shatter if heat cannot be dissipated quickly enough. Consequently, care must be used to provide adequate mechanical shielding when exposing brittle materials to high intensity lasers.
<b>Fire Hazards</b>	Class 4 lasers represent a fire hazard. Depending on the construction material, beam enclosures, barriers, stops, and wiring, all are potentially flammable if exposed to high beam irradiance for more than a few seconds.
<b>Laser-Generated Air Contaminants (LGAC)</b>	Air contaminants can be generated when Class 3B and Class 4 laser beams interact with matter. The composition of LGAC depends greatly on target material, cover gas, and the beam irradiance. Often aerosols and vapors of the base material are contained in the target plume. Some of these vapors can be carcinogenic or toxic. LGAC from biological materials can contain viable aerosolized pathogens and cells present in the target. Control measures such as exhaust ventilation, and glove boxes can be used to ensure exposure to LGAC is below threshold limit values provided by the American Conference of Governmental Industrial Hygienists (ACGIH). LGACs are generally only formed when target irradiance reaches $10E7 \text{ W/cm}^2$ .
<b>UV and Visible Radiation Hazards</b>	Laser discharge tubes and pump lamps may generate ultraviolet and visible radiation. Plasma radiation can contain UV and high luminance blue light. The levels produced can exceed safe limits and thus, cause skin and eye damage.

## Laser Hazard Evaluation

The LSO will perform a hazard analysis whenever exposure to a Class 3B and/or a Class 4 laser beam is possible. The first part of the hazard analysis consists of a series of calculations that yield a numerical description of the magnitude of the hazard, or the ability of the laser to cause an injury. It includes calculations of the following values:

- Maximum Permissible Exposure (MPE)
- Optical Density of Eyewear (OD)
- Nominal Hazard Zone (NHZ)
- Nominal Ocular Hazard Zone (NOHD)

The second part is an assessment of the environment in which the laser is used. The hazards present and the controls required in an industrial setting might be quite different from those found in a research laboratory. The third part considers the nature of the personnel who operate the laser. Well-trained laser personnel are best fit to control laser hazards in the workplace.



The MPE, OD, NHZ and NOHD can be determined using free web-based software like the [Kentek Hazard Analysis Software](#) or by consulting the Laser Safety Officer.

### Maximum Permissible Exposure (MPE)

The maximum permissible exposure is the level of laser light to which a worker may be exposed with no risk of injury. It is the highest level of energy per unit of surface area which is safe. The MPE depends on the exact exposure conditions, and changing the exposure conditions will change the MPE. Worst case exposure conditions are used to derive MPEs as well as the control measures needed to protect laser operators.

The primary factors that affect the MPE are:

- The exposure type (Intra-beam eye exposure is the worst case.)
- The laser wavelength
- The pulse characteristics of the laser output
- Exposure duration

Exposure duration of 0.25 seconds is usually used for an accidental exposure to a visible laser. Exposure duration of 10 seconds is usually used for an invisible laser.

### Optical Density of Eyewear (OD)

Optical Density is a mathematical method of describing the ability of a filter to reduce the intensity of light transmitted. Optical density numbers represent “orders of magnitude” or “powers of 10.” This means that increasing the OD number by 1 increases the attenuation of the filter by a factor of 10 (see Table 6.3).

**Table 6.3. Optical density and percent transmission**

OD	Attenuation Factor ( $H_0$ /MPE)	% Transmission
1	10	10%
2	100	1%
3	1000 ( $1 \times 10^3$ )	0.1%
4	10000 ( $1 \times 10^4$ )	0.01%
5	100000 ( $1 \times 10^5$ )	0.001%
6	1000000 ( $1 \times 10^6$ )	0.0001%

$$OD = \log_{10} \left[ \frac{H_0}{MPE} \right]$$

The formula for calculating OD is:

Where  $H_0$  is the anticipated worst case exposure conditions (in joules/cm<sup>2</sup> or watts/cm<sup>2</sup>) and the MPE is expressed in the same units as  $H_0$ . The area used to determine the irradiance of the beam is the limiting aperture which can be determined from Table 8a of ANSI A136.1. This provides a worst-case OD based on the assumption that the entire beam enters the eye. If the beam diameter is smaller than the pupil of the eye, the hazard does not increase. The worst situation is when the largest beam possible enters the eye. This produces the smallest spot on the retina.

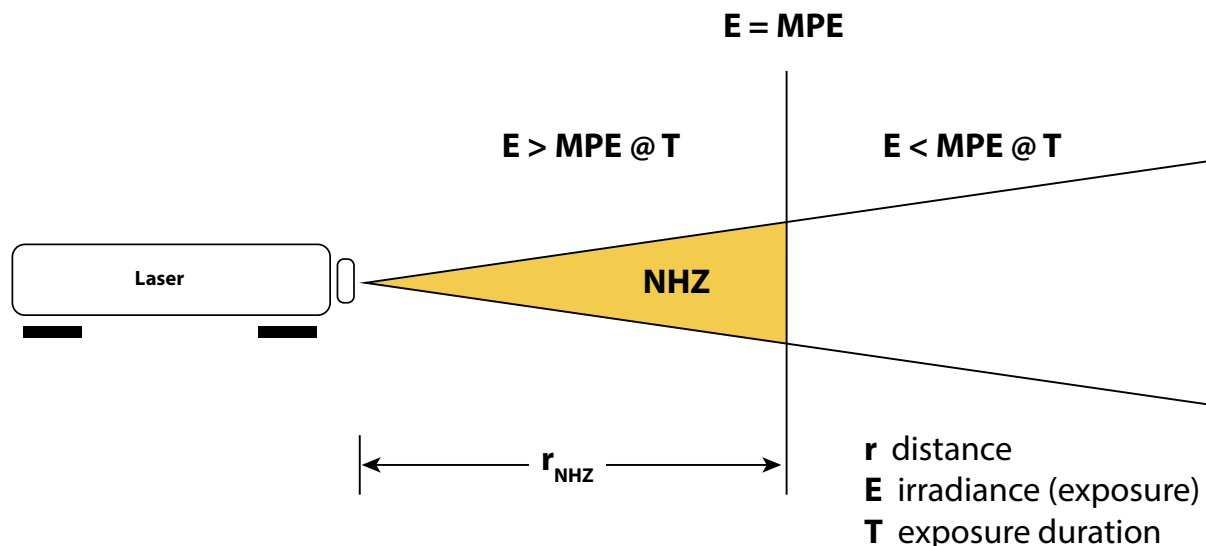
If the laser beam is significantly larger than the pupil, the actual area of the beam may be used. This will result in an OD that will protect the eye from the larger beam but will not provide adequate protection if a smaller beam of the same power enters the eye.

Correct OD can also be found by using an online calculator offered by Laser Institute of America (LIA): <http://www.lia.org/evaluator/od.php>.

### Nominal Hazard Zone (NHZ)

Nominal Hazard Zone (See Figure 6.5) is the space within which potential exposure exceeds the MPE and is determined for Class IIIB and Class IV lasers.

*Figure 6.5. Nominal hazard zone (NHZ)*



The formula to calculate NHZ is:

$$NHZ = \frac{1}{\phi} \left[ \left( \frac{4\Phi}{\pi * MPE} \right)^{1/2} - \alpha \right]$$

Where,

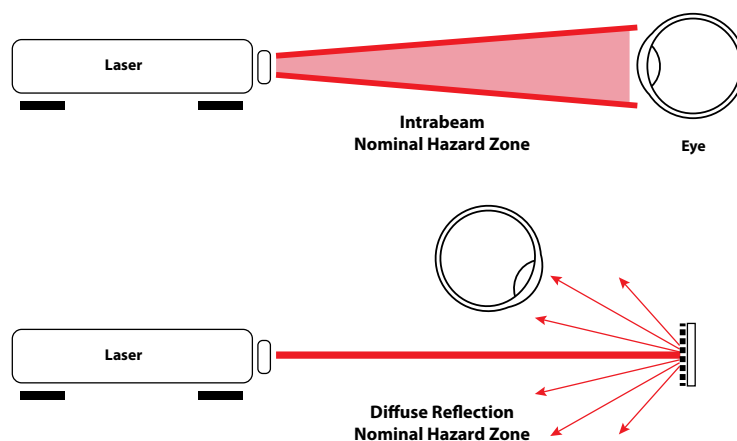
- $\emptyset$  is the emergent beam divergence measured in radians;
- $\Phi$  is the radiant power (total radiant power for continuous wave lasers or average radiant power of a pulsed laser) measured in watts; and
- $\alpha$  is the diameter of the emergent laser beam, in centimeters.

The NHZ describes the space within which the level of direct, reflected, or scattered radiation during normal operation exceeds the appropriate MPEs and is determined from the following characteristics of the laser:

1. Power or energy output
2. Beam diameter
3. Beam divergence
4. Pulse repetition frequency (prf)
5. Wavelength
6. Beam path including reflections
7. Beam profile
8. Maximum anticipated exposure duration

The intrabeam NHZ is the distance the beam must travel before it has diverged enough that the irradiance in the center of the beam drops below the MPE (see Figure 6.6). This is often a large distance and safety requires that the beam be terminated on a diffuse reflecting beam block. NOTE: Serious injuries have resulted when laser workers failed to block high power beams. The diffuse reflection NHZ is the distance from a beam block for which the irradiance of the scattered light exceeds the MPE (See Figure 6.6). This is always much smaller than the intra-beam NHZ, but this hazard extends in all directions.

**Figure 6.6. Intrabeam and diffuse reflection NHZ**



### **Nominal Ocular Hazard Distance (NOHD)**

The NOHD is the distance from the source at which the intensity or the energy per surface unit becomes lower than the Maximum Permissible Exposure (MPE) on the cornea and on the skin (See Figure 6.7). The laser beam can be considered dangerous if the operator is closer to the source than the NOHD. This distance depends on several parameters:

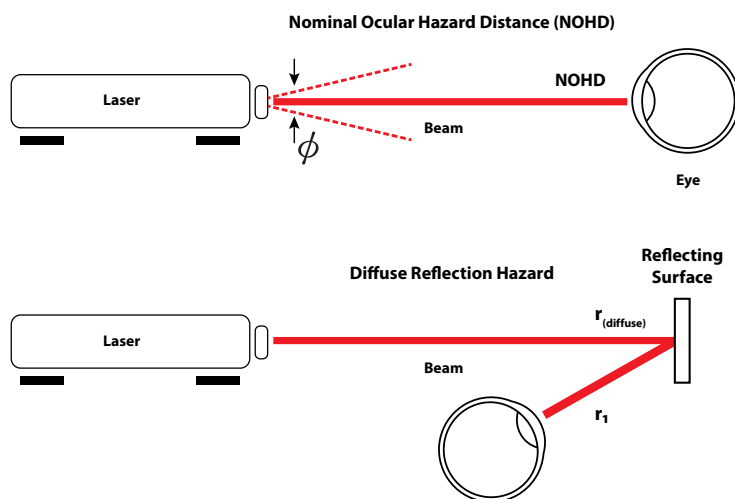
- Beam characteristics: output power, diameter and divergence

- MPE value on the cornea
- Optical system inserted in the beam trajectory

Determination of the NOHD is critical in a laser safety analysis for outdoor laser operations involving Class 3 or Class 4 lasers. The calculation of the NOHD is necessary for the determination of the Nominal Hazard Zone (NHZ).

Personnel who are inside the NHZ are at risk of injurious ocular exposure and are required to wear eye protection per ANSI Z136.6. Personnel outside the NHZ are not at risk and therefore, do not require the use of eye protection.

**Figure 6.7. Nominal ocular hazard distance (NOHD)**

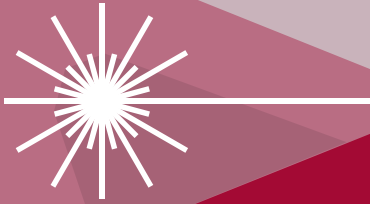


Cal/OSHA publishes maximum light intensity limits for certain exposure conditions. These are depicted in Table 6.4.

**Table 6.4. Maximum Light Intensity - Cal/OSHA Limits.**

Exposure Condition	Maximum Light Intensity
Direct Staring	1 $\mu\text{W}/\text{cm}^2$
Incidental Observing	1 $\text{mW}/\text{cm}^2$
Diffuse Reflected Light	2.5 $\text{W}/\text{cm}^2$

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## 7.0 Laser Safety Controls

ANSI Z136.1 standard has established control measures to reduce or eliminate the possibility of eye and skin exposure to laser radiation during normal operation and maintenance. These control measures can be categorized into engineering controls, administrative controls, and personnel protective equipment (PPE). Table 7.1 below summarizes the three groups.

**Table 7.1. Laser control measures by classification**

Control Measures	Wavelength Range						
	1	1M	2	2M	3R	3B	4
<b>Engineering Controls</b>							
Protective Housing	✓	✓	✓	✓	✓	✓	✓
Without Protective Housing	LSO will establish alternative controls						
Interlocks on Protective Housing	*	*	*	*	*	✓	✓
Service Access Panel	*	*	*	*	*	✓	✓
Key Control	--	--	--	--	--	R	R
Protective Viewing Portals						MPE	MPE
Collecting Optics	✓	✓	✓	✓	✓	✓	✓
Totally Open Beam Path	--	--	--	--	--	✓, NHZ	✓, NHZ
Limited Open Beam Path	--	--	--	--	--	✓, NHZ	✓, NHZ
Remote Interlock Connector						R	✓
Emergency Stop	--	--	--	--	--	R	✓
Permanent Beam Stop / Attenuator						R	✓
Audible Warning Device	--	--	--	--	--	R	✓
Visible Warning Device	--	--	--	--	--	R	✓
Emission Delay							✓
Protective Windows	--	--	--	--	--	MPE	MPE
<b>Administrative Controls</b>	<b>1</b>	<b>1M</b>	<b>2</b>	<b>2M</b>	<b>3R</b>	<b>3B</b>	<b>4</b>
Laser Control area	--	--	--	--	--	✓	✓
Laser Area Warning Signs	--	--	--	--	--	✓	✓
Written and Approved SOPs	--	--	--	--	--	R	✓
Written/Approved Maintenance and Service Procedures						R	✓
Written and Approved Alignment SOPs	*	✓	✓	✓	✓	✓	✓
Authorized Personnel	--	--	--	--	--	✓	✓
Education and Training	--	R	R	R	R	✓	✓

Control Measures	Wavelength Range						
Personal Protective Equipment (PPE)	1	1M	2	2M	3R	3B	4
Laser Eye Protection	--	--	--	--	--	R, MPE	✓
Skin Protection	--	--	--	--	--	R, MPE	R, MPE
Protective Clothing	--	--	--	--	--	MPE	MPE

R Recommended; ✓ Required; -- Not required; \* Required if enclosed in Class 3B and Class 4  
MPE Required if the Maximum Exposure is exceeded; NHZ Nominal Hazard Zone analysis required

## Engineering Controls

Engineering controls are methods that are built into the design of the laser system. Examples include protective housing, interlocks, access panels, key controls, emergency stops, viewing portals, filters, electronic or mechanical means to guide internal laser alignment, and beam stops (e.g., beam cap, shutter).

### Protective Housing

Protective housing is required on all classes of lasers (see Figure 7.1). In certain instances, operation of a laser or laser system without protective housing may be necessary. In these instances, the Laser Safety Officer will conduct a hazard analysis and ensure that alternative controls are used. Alternate controls may include, but are not limited to:

- Access restrictions
- Eye protection
- Area controls
- Barriers, shrouds, beam stops, or other suitable measures
- Additional training and administrative controls

**Figure 7.1. Example of protective housing**



Source: Phys.org

**Figure 7.2. Laser interlock system**



### Interlocks on Protective Housing

Class 3B and Class 4 lasers require an interlocked protective housing which is activated when the protective housing is opened during operation and maintenance (see Figure 7.2). The interlock is designed to prevent access to the beam above the applicable MPE and can be mechanically or electrically interfaced with a shutter.

### Service Access Panel

Panels of protective housing for a Class 3B or Class 4 beam must either be interlocked or require a special tool for removal. NOTE: Only service personnel may access these panels. Affix a label to the panel which reads: "Caution-Laser Radiation Inside. Avoid Exposure."

### Key Control/Emergency Stop

A master switch is operated by a key (see Figure 7.3) or by coded access (e.g., computer code). The appropriate supervisor is vested with the authority to enable the master switch. The master switch is disabled when the laser is not in use.

### Viewing Portals

Viewing portals (see Figure 7.4) and display screens are suitable methods to assure personnel are not exposed to laser radiation greater than the applicable MPE during conditions of operation and maintenance.

### Collecting Optics

When using collecting optics (see Figure 7.5) such as lenses, telescopes, microscopes, or endoscopes, use interlocks, filters, or attenuators to ensure personnel are not exposed to laser radiation levels greater than the applicable MPE.

### Wide Open and Limited Open Beam Path

In instances where the laser beam from a Class 3B or Class 4 laser is either completely unenclosed or partially open (see Figure 7.6), the Laser Safety Officer will perform a hazard analysis and determine the area (or Nominal Hazard Zone) surrounding the laser beam wherein the MPE is exceeded. Controls will then be required to assure personnel are not exposed to levels greater than the MPE.

High-power lasers require more rigid control measures because of the greater risk of injury from the direct beam or specular reflections and from hazardous diffuse reflections. The entire beam path capable of producing hazardous diffuse reflections must be control.

### Remote Interlock Connectors

A remote interlock connector allows connection to an emergency master disconnect interlock, or to a room, entryway, floor, or area interlock. Safety latches or interlocks are used to deactivate the laser in the event of an unexpected entry into laser control areas. The design of interlocks must allow both rapid egress and admittance by laser personnel in emergency situations.

**Figure 7.3. Key control and emergency stop**



**Figure 7.4. Laser safety window**



Source: lasersafety.com

**Figure 7.5. Collecting optics**



**Figure 7.6. Open beam path**





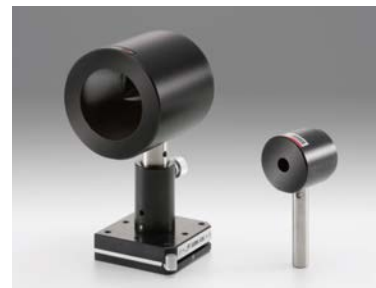
The person in charge of the laser control area is permitted to momentarily override the room access interlocks when continuous laser operation is necessary, but specification for the momentary override must have the approval of the LSO.

Interlocks will not allow automatic re-energizing of the power supply, but must be designed so that the power supply or shutter must be reset manually. A control-disconnect switch ("panic button") shall be available for deactivating the laser.

### **Beam Stop or Attenuator**

A beam stop or attenuator (see Figures 7.7 and 7.8) provides a means of preventing access to laser radiation in excess of the MPE. In some cases (e.g., during beam alignment), a beam attenuator can reduce the output of a laser beam to a level at or less than the MPE, thereby allowing one to operate the laser without the need for protective eyewear. Consideration must be given to the material composition of the beam stop to reduce the risk of fire or burn-through.

**Figure 7.7. Beam Stop**



Source: OptoSigma

### **Activation Warning System**

Activation warning systems consist of audible sounds (e.g., chimes, bells), warning lights, or a verbal "countdown" which notifies personnel that the laser is being activated.

**Figure 7.8. Attenuator**



Source: Newport Corporation

### **Emission Delay**

An emission delay warning system consists of audible alarms, warning lights, or a verbal "countdown" to notify personnel the laser will be activated before the laser emission occurs. This gives personnel adequate time to leave the laser beam area before use of the laser begins.

## **Administrative Controls**






Administrative and procedural controls are methods or instructions that specify rules and/or work practices which implement or supplement engineering controls. An instruction example would be, "Turn off laser when transmission is not required." Never use administrative controls in lieu of engineering controls.

## Signs and Labels

- Post warning signs in all areas where Class 3B and 4 lasers are used. Include specific information on the sign regarding the laser hazards. Signs are available at the [Laser Fact Sheets and Lab Postings](#) section of the Laser Safety web page.
- Consult with the LSO on selection of proper laser warning signs.
- Display warning signs conspicuously in locations chosen to most effectively warn personnel of potential safety hazards.
- Do not remove laser safety signs unless authorized by the LSO or the PALO for the corresponding laser, and then only after the laser is effectively taken out of operation or enclosed so it may be classified as a Class 1 laser system.







## Warning Signs

<b>Laser control areas</b>	Post appropriate warning signs at the entryway(s) and within the laser control area.	
<b>Warning</b>	Use appropriate signage and labels at all Class 3B, Class 3R, and Class 4 lasers and laser systems that exceed the appropriate MPE.	
<b>Danger</b>	Post appropriate signage and labels at Class 4 lasers/laser systems with high power (multi-kW) or pulse energy.	
<b>Caution</b>	Use signs and labels (see example at right) at Class 2 and 2M lasers/laser systems and Class 3R lasers/laser systems that do not exceed the appropriate MPE.	
<b>Notice</b>	Post outside temporary laser control areas. Post alongside appropriate Warning or Danger signs at temporary control areas for Class 3B or Class 4 lasers/laser systems.	

### Equipment/Instrument Labels

All laser systems except Class 1 are required to have appropriate warning labels placed on both the housing and control panel.

<b>Class 2</b>	Laser Radiation: Do Not Stare into Beam	
<b>Class 3R/3A</b>	Laser Radiation: Avoid Direct Eye Exposure	
<b>Class 3B</b>	Laser Radiation: Avoid Direct Eye Exposure	
<b>Class 4</b>	Laser Radiation: Avoid Eye or Skin Exposure to Direct or Scattered Radiation	

### Laser Standard Operating Procedures

A written Standard Operating Procedure (SOP) is required for Class 4 laser systems and is recommended for Class 3B laser systems. All Authorized Laser Operators must be familiar with the laser SOP of their system prior to using lasers. A copy of the SOP will be either posted near the laser or readily available for review. The SOP may include a checklist that includes both beam and non-beam hazards and emergency response.

In the case of enclosed systems (e.g. laser scanning confocal microscopy), the requirement for an SOP may be reduced or waived entirely after a review by the LSO, who will then determine if any SOP sections are required.

### Laser Safety Training

All individuals who work with lasers must have documented training and qualification to be able to use the lasers in the lab, per CAL/OSHA regulations. EH&S will provide initial training that covers the basics of lasers, safety involved in working with lasers, labeling requirements, hazard communication, SOPs, and emergency response.

The PALO is responsible for ensuring that staff and students working in the lab attend the basic laser safety training and for conducting specific training in their labs.

Before using a Class 3B and Class 4 laser, all users are required to:

1. Contact the LSO to receive initial laser safety training.
2. Read the Laser Safety Manual.
3. Receive lab-specific training that covers topics such as beam alignment, engineering controls and SOPs of all protocols from the PALO or lab manager.
4. Read and sign each applicable SOP.

NOTE: All individuals (including Faculty, Technical Staff, and students) must complete the General Laboratory Safety course and the initial Laser Safety Training course before they may work with lasers in the laboratory. Individuals must also be trained on the specific lasers in the lab and any associated SOPs by having their signature on the SOP and hard copies of training records must be available for inspection per CAL/OSHA regulations. Re-training is required whenever a new laser is introduced into the work area or if there are any changes to procedures. Additionally, it is lab-specific, conducted by the PALO, and documented.

### **Laser Safety Practices**

The following measures are recommended as a guide to work with and handle lasers safely. Some additional practices may be required for specific classes of lasers and lasers that emit invisible radiation. See ANSI Z136.1 for more details, or contact the LSO for additional information.

### **Work Area Safety Practices**

- Set up and isolate lasers away from public areas. Keep lab doors closed and locked to keep out unauthorized personnel. Post proper warning signs.
- Set up the laser so that the beam path is above or below normal eye level (below 4.5 ft. or above 6.5 ft.).
- Illuminate the laser area as bright as practical to constrict the eye pupils of users.
- Enclose the laser system or beam wherever possible to prevent accidental exposure to the beam.
- Minimize specular reflections with shields and by removal of all unnecessary shiny surfaces.
- Windows to hallways or other outside areas must be provided with adequate shades or covers when necessary to keep the Nominal Hazard Zone (NHZ) within the room.
- Terminate/dump main and reflected beams. This is required for any accessible laser that can exceed the MPE limit.
- Electrical installation must meet electrical safety standards.

- Never leave the active laser unattended unless it is a part of a control environment.
- Warning devices must be installed for lasers with invisible beams to warn of operation.
- Keep the laser work area free of clutter to eliminate accidents or ignition of combustible material.
- Ensure that lasers are well-secured to the work surface to prevent stray beams.

### **Laser Alignment Safety Practices**

- No unauthorized personnel will be in the room or area.
- Laser protective eyewear will be worn (see [PPE and Other Protective Equipment](#)).
- All laser users must attend USC Laser Safety Training.
- Anyone who moves or places an optical component on an optical table is responsible for identifying and terminating each stray beam emitted from that component.
- To reduce accidental reflections, remove watches and reflective jewelry before any alignment activity begins.
- Secure all beam blocks.
- A solid stray beam shield must be securely mounted above the area to prevent accidental exposure to the laser beam.
- All laser users must receive an orientation to the control area by an authorized laser user of that area.
- The lowest possible/practical power must be used during alignments.
- Conduct a coarse alignment with a HeNe alignment laser whenever possible.
- Have beam paths at a safe height, below eye level when standing or sitting - not at a level that tempts one to bend down and look at the beam. If necessary, place a step platform around the optical table.

### **Laser Use Safety Practices**

- DO NOT look into the primary beam.
- DO NOT aim the laser with the eye; direct reflections could cause retinal damage.
- DO NOT look at the pump source.
- Clear all personnel from the anticipated path of the beam.
- Before operating the laser, warn all personnel and visitors of the potential hazard, and ensure all safety measures are satisfied.
- Be very cautious around lasers that operate at frequencies not visible to the human eye.
- Remove all jewelry and unnecessary reflective surfaces from the area of the beam path.

- Use proper eye protection when working with a Class 3B or Class 4 laser. Remember that: (a) eye protection is specific for the type of laser and may not protect at different frequencies or powers; (b) safety glass lenses may shatter or melt when the lens specifications are exceeded; (c) scratched or pitted lenses may afford no protection; and (c) frequent inspection of protective eyewear is recommended. See PPE and Other Protective Equipment section below for more details.

### **Special Requirements for Invisible Laser Beams**

Infrared (IR) and ultraviolet (UV) wavelengths are normally invisible to human eyes, and they possess a higher hazard potential than visible light lasers. Therefore, use of laser eyewear that will protect against exposure is required at all times during laser operations.

#### **Infrared Lasers**

- The collimated beam from a Class 3B laser is required to be terminated by a highly absorbent backstop wherever practical. Many surfaces which appear dull visually can act as reflectors of IR.
- A Class 4 laser beam is required to be terminated by a fire resistant material whenever practical. Periodic inspection of the absorbent material is required since many materials degrade with use.

#### **Ultraviolet Lasers**

- Minimize exposure to UV by using shield material that attenuates the radiation to levels below the appropriate MPE for the specific wavelength.
- UV radiation causes photochemical reactions in the eyes and the skin, as well as in materials that are found in laboratories. The latter may cause hazardous by-products such as ozone and skin sensitizing agents. The use of long-sleeved lab coats, gloves, and face protectors is recommended.

## **PPE and Other Protective Equipment**

Personal Protective Equipment (PPE) for skin and/or eyes is often necessary in addition to engineering and administrative controls, when working with Class 3B or Class 4 lasers.

### **Eye Protection**

Eye protection suitable to the laser must be provided and worn within the laser control area if there is a potential for exceeding the MPE limit.

Protective eyewear may include specialized goggles, face shields, spectacles, or prescription eyewear using special filter materials or reflective coatings. Exceptions may be approved in the written SOPs if the eyewear produces a greater hazard when worn.

Note that no single type of eyewear will provide protection against all wavelengths of laser radiation. Consult the [Laser Safety Eyewear Fact Sheet](#) (see Figure 7.9) for more information.

Consider the following steps for eye protection:

- Use engineering controls (i.e., enclose the entire beam path) whenever possible to eliminate the need for laser protective eyewear.
- Wear laser protective eyewear when working in the control area of a Class 3B or Class 4 laser or laser system in an open beam configuration during laser operation.
- Many factors are considered in determining proper laser protective eyewear including: laser/pulse energy, laser wavelength(s), and potential exposure time. Consult with the LSO on selection of appropriate laser protective eyewear for each laser.
- Keep laser protective eyewear in good condition and replace any damaged or defective eyewear.
- Label laser protective eyewear with the laser type and/or wavelength of light it is designed to protect against.
- Direct and scattered UV radiation pose a hazard to the eyes and skin. Wear protective clothing in UV laser control areas in addition to protective eyewear.

Figure 7.9. Laser Safety Eyewear Fact Sheet



## Skin Protection

Skin injuries from lasers primarily fall into two categories: thermal injury (burns) from acute exposure to high power laser beams and photochemically induced injury from chronic exposure to scattered ultraviolet laser radiation. Thermal injuries can result from direct contact with the beam or specular reflections. These injuries, although painful, are usually not serious and are normally easy to prevent through proper beam management and hazard awareness.

Photochemical injury may occur over time from ultraviolet exposure to the direct beam, specular reflections, or even diffuse reflections. The effect can be minor or severe sunburn, and prolonged exposure may promote the formation of skin cancer. Proper protective eyewear and clothing may be necessary to control UV skin and eye exposure. At minimum use following precautions:

- Use engineering controls against potential skin exposures.
- Use protective clothing such as lab coats, tightly woven fabric, opaque clothes, and equipment such as beam shields to reduce exposure to UV radiation.
- For high-energy Class 4 lasers, wear a flame resistant lab coat to protect against skin exposure.

### Laser Curtains and Barriers and Window Protection

- Laser curtains, blocks, and screen are commercially available that can filter and/or block Class 3B and Class 4 lasers (see Figure 7.10).
- Select the materials based on the flammability factor of the material per laser type and its ability to withstand direct and scattered beam.
- Place barriers and curtains inside the laser control area to prevent laser beams from exiting the area above the applicable MPE levels.
- Interior/exterior windows that are located inside the Nominal Hazard Zone (NHZ) can be protected with suitable blocking/absorbing materials or scattering filters to reduce laser radiation levels below applicable MPE.

**Figure 7.10. Laser curtain**



Source: Kentek Laser

## Confocal Microscopes

Laser scanning confocal microscopes (see Figures 7.11 and 7.12) are Class 1 laser systems that contain embedded Class 3 or Class 4 lasers. When the confocal microscope is used as intended, no additional engineering control measures are necessary.

All laser scanning confocal microscopes must be registered with Radiation Safety and all authorized users must attend Laser Safety Training to cover best practices.

If the exterior of a confocal microscope is labeled as Class 3B or Class 4, then the applicable requirements for the class of the embedded laser must be followed.

If the protective housing is removed for alignment, maintenance or service activities, a temporary laser control area shall be established and control measures appropriate to the class of the embedded laser shall be implemented.

Use of any Class 3R laser with telescopes, microscopes, or alignment devices must be reviewed by the LSO prior to operation.

**Figure 7.11. Laser confocal microscope during operation**

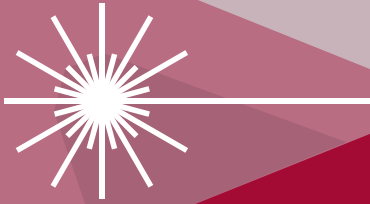


**Figure 7.12. Laser confocal microscope**





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## 8.0 Inspection Program

The Laser Safety Program ensures effective implementation and compliance with: USC Laser Safety Manual; USC safety policies; and all regulatory requirements through:

- Inspection of all laboratories where lasers are used
- Follow-up on items of non-compliance
- Tracking of training data to ensure all individuals working with lasers are trained.
- Updates of policies on a regular basis to reflect changes in regulatory requirements.

### Inspections

Inspections of laser use permits include the following to ensure compliance with CAL/OSHA regulations:

- Functionality of engineering controls:
  - Lasers are secured so they can't be moved easily
  - Laser optics are secured to prevent stray beams
  - Lasers not at eye level
  - Open beam vs. enclosed beam
  - Beam stops/barriers/attenuators in place
  - Protective housing with interlocks
  - Emergency stop by key or master switch
  - Warning systems
  - Laser beams directed away from windows or entry points; covered windows
  - Reflective materials kept out of the beam path
- Administrative safety controls, such as:
  - Proper signage,
  - Laser safety guidelines
  - Emergency contact lists
  - Beam alignment procedures
  - Laser controlled areas (LCAs)
  - Clearly posted, door signs
  - SOPs that are up-to-date, available, and signed by all users
  - Fiber optics connection tags when relevant

- Personal protective equipment (PPE) in good condition:
  - Eyewear for the appropriate wavelength with required OD
  - UV laser protection if present in the lab
  - Lab coat, protective gloves, and closed-toe shoes to protect exposed skin
  - Protective barriers
- Availability of the Laser Safety Manual
- Authorized rooms used for work involving lasers and authorized lasers being present
- Proper documentation of laser safety training including EH&S Laser Safety Training as well as lab-specific training
- Availability of the manufacturer's operating manual
- Mitigation of non-beam-hazards such as electrical hazards, collateral radiation hazards, physical hazards (e.g., fire/explosion, compressed gases, and cryogenics), chemical hazards, biological hazards and precautions for any LGACs produced
- Compliance with CAL/OSHA regulations regarding exposure to light intensities found in CAL/OSHA Title 8, Subchapter 4, Article 34, Section 1801

## **Non-compliance**

When items of non-compliance are discovered, the Laser Safety Program will first determine the criticality of the finding (Levels 1 through 3; 3 equals Severe). For all criticality levels, the PALO will be provided written notification of all findings within 24 hours of the inspection. In addition, the following actions will occur for levels 1 through 3:

### **Level 1 Findings (Non-Critical)**

For Level 1 findings that were not corrected at the time of inspection, the permit will be re-inspected after 20 business days, with escalated actions and notifications for continued non-compliance (see Figure 8.1).

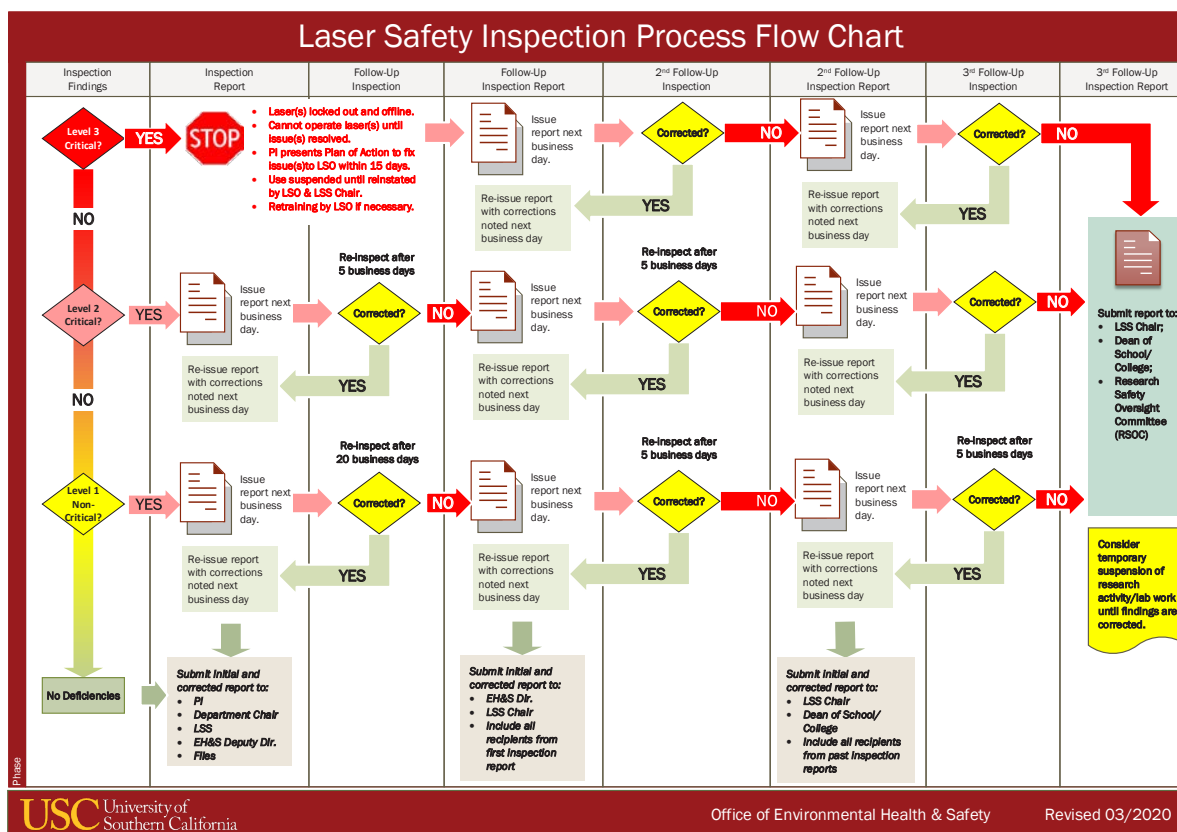
### **Level 2 Findings (Critical)**

For Level 2 findings that were not corrected at the time of inspection, the permit will be re-inspected after 5 business days, with escalated actions and notifications for continued non-compliance (see Figure 8.1).

### **Level 3 Findings (Immediate Suspension)**

For Level 3 findings, laser use by the PALO and any ALO under the PALO, is immediately suspended until reinstated by the Laser Safety Subcommittee. Lasers will be locked out. In order to reinstate the permit, the Permit Holder must submit a Plan of Action to prevent recurrence, within 15 days of the inspection, and then present the plan to the LSO and LSS Chair. Additionally, the PI and staff will be re-trained in proper procedures by the LSO (see Figure 6.1 for more details).

Figure 8.1. Laser Safety Inspection Flowchart



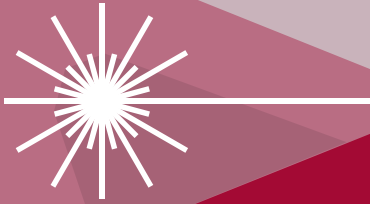
When a Plan of Action is required for submittal to the LSO and LSS Chair, the PALO will provide: 1. What caused the item(s) of non-compliance, 2. Actions taken to date by the PALO to correct the item(s), and 3. Corrective actions the PALO took or will take to prevent recurrence.

Regardless of the level of any inspection finding, chronic non-compliance could result in an administrative review by the LSS and may lead to cancellation of the permit. Where evaluation by the LSO indicates recurring or chronic problems, continued authorization of the laser use by the PALO may be contingent upon a more frequent/extensive monitoring program and additional personnel training.

## Documentation

All laser safety-related training or education that employees receive will be documented and maintained on file for review by the Radiation Safety Program.

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## 9.0 Medical Surveillance

### Pre-Placement Exams

USC does not require medical surveillance for employees who handle lasers. However, notify your supervisor and the LSO if you have concerns regarding an existing condition (e.g., cataract, macular degeneration, hyper-sensitivity to light, pterygium, retinitis pigmentosa, or previous laser-related eye injury). An eye examination from an Occupational Medicine physician may be warranted.

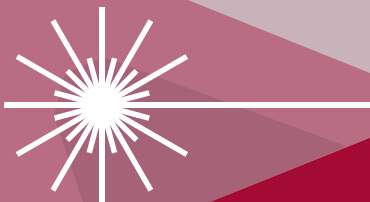
**Table 8.1. Medical exams recommended by user type**

User Type	Medical Exams
Laser Operators	(1) ocular history; (2) visual acuity; (3) macular function (e.g., Amsler grid test); (4) color vision responses
UV Laser Operators	(1) skin examination; (2) potential for photosensitization
Incidental Personnel	(1) visual acuity

### Access to Records

The records of individuals will be furnished upon request to their private physician. All non-personally identifiable records of the medical surveillance examinations will be made available on written request to authorized physicians and medical consultants for epidemiological purposes.

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## 10.0 Emergency Response/ Injury & Incident Reporting

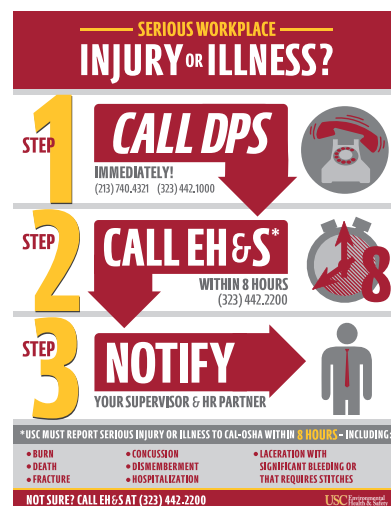
### Incident Reporting

#### Serious Injury or Illness Reporting

Employers in the State of California are required to notify Cal-OSHA within 8 hours of all serious occupational injuries and illnesses, or any workplace injury or medical event which results in an employee staying in hospital overnight or longer. EH&S investigates and records incidents at USC and determines if Cal-OSHA notification is required, or if other actions are needed. Employers who fail to report serious occupational injury or illness within eight hours are subject to a \$5,000 penalty.

**It is essential for PIs, Lab Managers, other laboratory personnel, and HR Partners to notify EH&S as soon as possible in the event of the following:**

- ◆ Exposure to harmful material (chemical, biological, or radiological) or radiation
- ◆ Eye injury or exposure, regardless of how minor it may appear
- ◆ Needlestick injury
- ◆ Chemical or thermal burn
- ◆ Cuts or lacerations, if there is significant bleeding, stitches are required, or there are complications such as hazardous materials contamination or embedded broken glass.
- ◆ Concussion (actual or suspected)
- ◆ Fracture
- ◆ Dismemberment
- ◆ Death
- ◆ Any event requiring transport to hospital, e.g. sudden illness



For a work-related injury or illness that requires emergency response, follow the procedures on the [Emergency Notification Protocol](#) web page. Post the [1-2-3 Serious Injury Reporting](#) flier in a conspicuous area of the laboratory to help the research group become familiar with the process. It is also recommended to also post the 1-2-3 flyer in offices and common areas. Contact [EHS@usc.edu](mailto:EHS@usc.edu) for printed copies of the poster.



## Eye Injury Treatment

For eye injury treatment or surgery during business hours, seek care at the USC Roski Eye Institute 1450 San Pablo St., Los Angeles, CA 90033. Tel: 323-442-6335. Outside of business hours, the nearest Emergency Room or any of the USC-Approved Medical Facilities (see list at [Workers' Compensation](#) web page) is recommended. NOTE: These facilities may not specialize in eye surgery.

It is very important to first contact Broadspire (USC's workers' compensation administrator) at (800) 495-2315 to initiate a workers' compensation claim and obtain a claim number (see [Workers' Compensation](#) web page for details). Issue the claim number to the medical facility providing the treatment or surgery.

## Non-Serious Injury or Illness Reporting

Even if an injury or illness does not meet the requirements for Cal-OSHA reporting, it is important that the affected employee receives proper care (see [Workers' Compensation](#) web page for details).

## Near Misses

A near miss is an unanticipated event that did not result in harm or injury, but had the potential to do so. An example would be a Class 4 laser beam that is unexpectedly reflected across the face of a visitor walking into a laser control area.

The LSO will maintain a database of accidents and near misses for educational purposes to increase user awareness of potentially hazardous situations.

## How to Report

The USC Department of Public Safety (DPS) has continuous access to EH&S via a rotating 24-hour EH&S on-call personnel. DPS is also the contact between USC and emergency services (fire, ambulance, etc.). **DPS is the first contact in an emergency situation, or when a significant incident needs to be reported outside normal working hours.** DPS may be reached as follows:

- ◆ DPS Emergency Numbers: 213.740.4321 (UPC) and 323.442.1000 (HSC)
- ◆ DPS Non-Emergency Numbers: 213-740-6000 (UPC) and 323-442-1200 (HSC)

It is strongly recommended that all PIs and laboratory personnel have DPS emergency and non-emergency numbers pre-programmed into their mobile phones. It is also recommended for the numbers to be displayed adjacent to fixed-line phones in labs and offices.

Within normal working hours, and in the absence of an emergency, EH&S should be contacted directly on (323) 442-2200 to report safety incidents. Further information on emergency notification and incident reporting may be found on the EH&S website (<https://ehs.usc.edu/occhealth/injury-prevention/incident-reporting/>).

## Incident Investigation

Upon being notified of a laser safety incident, the LSO will conduct an accident investigation which includes the following:

- Interviews with injured workers and witnesses
- Examination of the workplace for factors associated with the accident/exposure
- Determination of possible cause(s) of the accident/exposure
- Corrective action(s) to prevent the accident/exposure from recurring
- Documentation of the findings and corrective actions taken

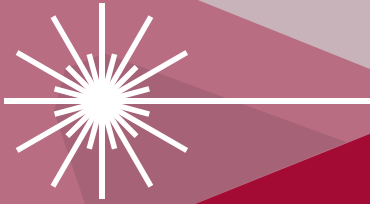
If an incident results in significant injury, is a “near miss” (i.e. could easily have been much more severe), or reveals systemic problems in safety management and culture within a research group, then the report may be circulated more widely, with appropriate recipients potentially including:

- Department/School
  - Safety Officer/Coordinator (when position exists)
  - Senior management (Head of Department, Dean, Vice Deans)
  - Safety committee chairperson
- USC Senior Management (Associate Senior Vice President for Administrative Operations, Senior Vice President for Administration, Vice President of Research)
- USC-wide safety committee chairpersons and members (CCSC, RSOC, others as appropriate)

The purpose of the LSO/EH&S investigations is to clarify what happened and to identify contributing factors, in order to learn lessons and thereby improve future safety. Incident reports will normally contain specific recommendations for addressing any safety deficiencies or contributing factors identified during the investigation. It is important for PIs and laboratory personnel to understand that LSO/EH&S incident investigations are not intended to be punitive or to apportion blame.

Personnel are expected to cooperate fully with LSO/EH&S incident investigations by providing full and accurate information, in accordance with USC policy (<https://policy.usc.edu/cooperation-with-compliance-investigations/>).

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## 11.0 Glossary

Term	Definition
<b>American National Standards Institute (ANSI)</b>	The technical body which releases the Z136.1 Standard for the Safe Use of Lasers. The secretariat for the Z136.X standard series is the Laser Institute of America (LIA).
<b>Aperture</b>	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.
<b>Attenuation</b>	The decrease in the radiant flux of any optical beam as it passes through an absorbing or scattering medium.
<b>Aversion Response (Blink Reflex)</b>	Closure of the eyelid or movement of the head to avoid exposure to a bright light. The average blink reflex to a bright laser source occurs within 0.25 seconds.
<b>Beam</b>	A collection of rays that may be parallel, convergent, or divergent.
<b>Beam Diameter</b>	The distance between diametrically opposed points in the cross section of a circular beam where the intensity is reduced by a factor of $e^{-1}$ (0.368) of the peak level (for safety standards). The value is normally chosen at $e^{-2}$ (0.135) of the peak level for manufacturing specifications.
<b>Beam Divergence</b>	Angle of beam spread measured in radians or milliradians (1 milliradian = 3.4 minutes of arc or approximately 1 mil). For small angles where the cord is approximately equal to the arc, the beam divergence can be closely approximated by the ratio of the cord length (beam diameter) divided by the distance (range) from the laser aperture.
<b>Coherent Radiation</b>	Radiation whose waves are in-phase. Laser radiation is coherent and therefore, very intense.
<b>Continuous Wave (CW)</b>	Constant, steady-state delivery of laser power.

Term	Definition
<b>Control Area</b>	An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser hazards. Examples of control area boundaries include: doors, curtains, and partitions.
<b>Diffuse Reflection</b>	Change of the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.
<b>Divergence</b>	The increase in the diameter of the laser beam with distance from the exit aperture. The value gives the full angle at the point where the laser radiant exposure or irradiance is e-1 or e-2 of the maximum value, depending upon which criteria is used.
<b>Infrared Radiation (IR)</b>	Invisible electromagnetic radiation with wavelengths that lie within the range of 0.7 to 1000 micrometers.
<b>Intrabeam Exposure</b>	Exposure involving direct on-axis viewing of the laser beam. Looking into the laser beam would constitute intrabeam exposure. NOTE: Intrabeam viewing of lasers is not permitted on campus.
<b>Intrabeam Viewing</b>	The viewing condition whereby the eye is exposed to all or part of a laser beam.
<b>Irradiance (E)</b>	Radiant flux (radiant power) per unit area incident upon a given surface. Units: Watts per square centimeter. (Sometimes referred to as power density, although not exactly correct).
<b>Laser</b>	A device that emits a collimated (pencil-like), coherent, and monochromatic beam of either visible or invisible electromagnetic radiation (light) that consists of a cavity with mirrors at the ends filled with a material such as crystal, glass, liquid, gas, or dyes. The acronym LASER stands for Light Amplification by Stimulated Emission of Radiation.
<b>Laser Control Area</b>	An area where the occupancy and activity of those within are subject to control and supervision for the purpose of protection from laser hazards.
<b>Laser Medium</b>	Material used to emit the laser light and for which the laser is named.
<b>Laser System</b>	An assembly of electrical, mechanical, and optical components which includes a laser.

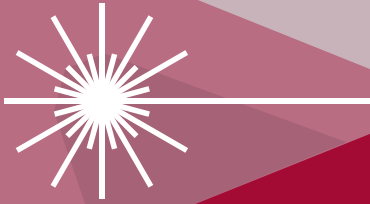
Term	Definition
<b>Limiting Aperture</b>	The maximum circular area over which radiance and radiant exposure can be averaged when determining safety hazards.
<b>Maximum Permissible Exposure (MPE)</b>	The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin.
<b>Nominal Hazard Zone (NHZ)</b>	The space within the level of the direct, reflected, or scattered radiation during normal operation that exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.
<b>Nominal Ocular Hazard Distance (NOHD)</b>	The distance from the source at which the intensity or the energy per surface unit becomes lower than the Maximum Permissible Exposure (M.P.E.) on the cornea and on the skin.
<b>Optical Cavity (Resonator)</b>	Space between the laser mirrors where lasing action occurs.
<b>Optical Density</b>	A logarithmic expression for the attenuation produced by an attenuating medium, such as an eye protection filter.
<b>Output Power</b>	The energy per second measured in watts emitted from the laser in the form of coherent light.
<b>Peak Power</b>	The highest instantaneous power level in a pulse. The peak power is a function of the pulse duration. The shorter the pulse, the greater the peak power.
<b>Photokeratitis</b>	A burn of the cornea (the clear front surface of the eye) caused by ultraviolet B or C (UVB or UVC) rays.
<b>Power</b>	The rate of energy delivery expressed in watts (Joules per sec.). Thus: 1 Watt = 1 Joule/sec
<b>Protective Housing</b>	A protective housing is a device designed to prevent access to radiant power or energy.
<b>Pulse</b>	A discontinuous burst of laser, light or energy, as opposed to a continuous beam. A true pulse achieves higher peak powers than that attainable in a CW output.

Term	Definition
<b>Pulse Duration</b>	The "on" time of a pulsed laser, it may be measured in terms of milliseconds, microseconds, or nanoseconds as defined by half-peak-power points on the leading and trailing edges of the pulse.
<b>Pulsed Laser</b>	Laser which delivers energy in the form of a single or train of pulses.
<b>Q-Switch</b>	A device that produces very short (10-250 ns) intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium.
<b>Radiant Energy (Q)</b>	Energy in the form of electromagnetic waves usually expressed in units of Joules (watt-seconds).
<b>Radiant Exposure (H)</b>	The total energy per unit area incident upon a given surface. It is used to express exposure to pulsed laser radiation in units of J/cm <sup>2</sup> .
<b>Scanning Laser</b>	A laser having a time-varying direction, origin, or pattern of propagation with respect to a stationary frame of reference.
<b>Specular Reflection</b>	A mirror-like reflection.
<b>Stimulated Emission</b>	When an atom, ion, or molecule capable of lasing is excited to a higher energy level by an electric charge or other means, it will spontaneously emit a photon as it decays to the normal ground state. If that photon passes near another atom of the same frequency which is also at some metastable energy level, the second atom will be stimulated to emit a photon. Both photons will be of the same wavelength, phase, and spatial coherence. Light intensified in this manner is intense, coherent, and monochromatic.
<b>Tunable Laser</b>	A laser system that can be "tuned" to emit laser light over a continuous range of wavelengths or frequencies.
<b>Ultraviolet Radiation (UV)</b>	Electromagnetic radiation which can be detected by the human eye. It is commonly used to describe wavelengths which lie in the range between 400-700 nm.

Term	Definition
<b>Visible Radiation (Light)</b>	Electromagnetic radiation which can be detected by the human eye. It is commonly used to describe wavelengths which lie in the range between 400-700 nm.
<b>Wavelength</b>	The length of the light wave, usually measured from crest to crest, which determines its color. Common units of measurements are the micrometer (micron) and the nanometer (nm).



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## 12.0 Frequently Asked Questions

### What type of training do I need to use a laser?

Laser safety training is divided into on-the-job training in the PALO's lab, as well as formal training through USC EH&S Radiation Safety. One without the other is considered to be insufficient to operate a laser safely. Persons wishing to use a laser should do so under the supervision of a knowledgeable operator. Many accidents have occurred to persons who operate an unfamiliar laser. All laser operators must read the laser standard operating procedure which contains specific safety information for each Class 3B and 4 laser. The SOP shall be readily available to all operators.

For Laser Safety Training, contact EH&S Radiation Safety at [radsafety@usc.edu](mailto:radsafety@usc.edu).

### Do all lasers need to be registered? How do I register a laser?

Only Class 3B and 4 lasers are required to be registered with the LSO.

To register a laser with the LSO, please complete the [laser registration form](#) online at USC EH&S Laser Safety and forward to the LSO at [radsafety@usc.edu](mailto:radsafety@usc.edu) for review.

### How do I dispose of a laser?

Several considerations should be given when disposing of a laser – making the laser inoperative, removing it from the inventory, and proper disposal of any hazardous waste that may be involved. Under no circumstances should a Class 3B or 4 laser be abandoned. It is the responsibility of the laser owner to properly dispose of a laser.

**Disable Laser** – The purpose of disabling a discarded laser is to ensure that it cannot be used by anyone. This removes the potential for misuse and harm. The laser can be disabled by methods such as cutting the power cord and/or dismantling the controls.

**Removal from Inventory** – Notify LSO upon completion of disabling of laser. In addition, remove any laser warning signs that are no longer needed from doors or other locations.

**Disposal of Hazardous Waste** – Certain lasers, such as those using dyes, may contain hazardous materials that need to be properly disposed. Contact EH&S to determine the proper disposal procedures for your laser.

### **What labels and signs do I need for my laser?**

Warning labels must be affixed to all classes of lasers (except Class 1) by the manufacturer. If the manufacturer is unable to provide one, contact the LSO. Warning signs must be posted at the point where a person would have access to a Laser Controlled Area. The sign must be conspicuous to provide adequate notice to a person entering the area. Laser Warning signs are required to be properly worded, according to the ANSI Standards.

### **Do I need an eye exam if I work with lasers?**

Laser eye exams are not required but recommended for Class 3B and 4 laser users.

### **When am I required to wear protective eyewear?**

Protective eyewear is recommended for persons that have access to Class 3B laser radiation and required for Class 4 laser radiation. Eyewear for lower class lasers is not required.

### **Where can I purchase eyewear?**

Contact the LSO for a listing of laser eyewear vendors. Some of the vendors on this list offer prescription laser eyewear.

### **If I have laser eyewear, will it protect me from all types of laser radiation?**

Laser eyewear is not designed for protection against all wavelengths. All laser eyewear is required to be clearly labeled with the wavelength(s) it provides protection against and the optical density for each wavelength listed. Misusing eyewear (i.e., using eyewear which does not provide protection against the laser in use) may result in serious eye injury.

### **Are regular lab safety glasses acceptable for protection against lasers?**

No. Laser safety glasses are designed to provide protection against specific types of lasers. Lab safety glasses must not be used in place of laser safety glasses. A laser user must first determine the wavelength and required optical density of the laser and, then, select laser safety glasses that meet this requirement.

### **How do I perform safety checks of laser safety eyewear?**

A visual check of all laser safety eyewear is required to be performed and documented every six months. In addition, eyewear should be inspected before each use. Eyewear should be checked for cracks, holes, deep scratches, discoloration or other damage (such as stems or straps that may not properly support the glasses in front of the eyes).

### **Are there any specific symptoms of laser eye injuries?**

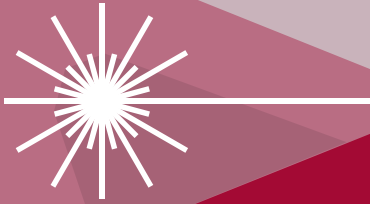
Exposure to the invisible carbon dioxide laser beam (10,600 nm) can be detected by a burning pain at the site of exposure on the cornea or sclera. Exposure to a visible laser beam can be detected by a bright color flash of the emitted wavelength and an after-image of its complementary color (e.g., a green 532 nm laser light would produce a green flash followed by a red after-image).

Exposure to a Q-switched Nd-YAG beam (1064 nm) is especially hazardous and may initially go undetected because the beam is invisible and the retina lacks pain sensory nerves. Photoacoustic retina damage may be associated with an audible “pop” at the time of exposure. Visual disorientation due to retinal damage may not be apparent to the operator until considerable thermal damage has occurred.

### **Is Radiation Safety Training required for users of lasers?**

Radiation Safety Training is not required for people who only use lasers. Laser Safety Training is the required training for those working with Class 3B and Class 4 lasers.

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## Appendix A Forms and Templates

### Laser Registration Forms

Laser System and Personnel Registration	<a href="http://tiny.cc/usc-ehs-lsr-rgstr">http://tiny.cc/usc-ehs-lsr-rgstr</a>
Laser Standard Operating Procedures	<a href="http://tiny.cc/usc-ehs-lsr-SOP">http://tiny.cc/usc-ehs-lsr-SOP</a>
Laser Alignment Procedure	<a href="http://tiny.cc/lsr-align-ff">http://tiny.cc/lsr-align-ff</a>
Laser Safety for Confocal Microscope	<a href="http://tiny.cc/lsr-cnfcfl-ff">http://tiny.cc/lsr-cnfcfl-ff</a>

### Inspections

Laser Safety Inspection Flow Chart	<a href="http://tiny.cc/lsr-inspect-fc">http://tiny.cc/lsr-inspect-fc</a>
Laser Safety Inspection Guidelines	<a href="http://tiny.cc/lsr-inspect-guide">http://tiny.cc/lsr-inspect-guide</a>
Laser Safety Inspection Checklist	<a href="http://tiny.cc/lsr-chkfst-ff">http://tiny.cc/lsr-chkfst-ff</a>
PPE Inspection Checklist	<a href="http://tiny.cc/usc-ppe-inspect-checklist">http://tiny.cc/usc-ppe-inspect-checklist</a>

### Lab Posting

Laser Safety Fact Sheet	<a href="http://tiny.cc/lsr-safT-fs">http://tiny.cc/lsr-safT-fs</a>
Laser Safety Eyewear Fact Sheet	<a href="http://tiny.cc/usc-ehs-lsrEye-fs">http://tiny.cc/usc-ehs-lsrEye-fs</a>
Laser Door Sign - Class 3B	<a href="http://tiny.cc/lsr3B-sign">http://tiny.cc/lsr3B-sign</a>
Laser Door Sign - Class 4	<a href="http://tiny.cc/lsr4-sign">http://tiny.cc/lsr4-sign</a>
Do Not Enter - Laser in Use	<a href="http://tiny.cc/lsr-inUse-sign">http://tiny.cc/lsr-inUse-sign</a>

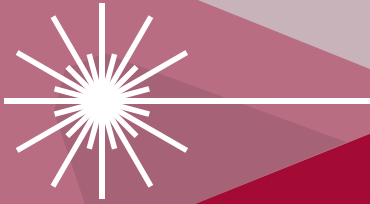
### Reporting

Workers' Compensation Form	<a href="#">WC form</a>
Manager's Incident Report	<a href="#">Report of Incident</a>
Volunteer Injury or Illness Report	<a href="#">Volunteer II Report</a>
Report a Safety Concern Online Form	<a href="#">Report a Safety Concern</a>

### Other

Site-Specific Training Record Form	<a href="#">Site-Specific Training Record</a>
Employee Training Record Form	<a href="#">Employee Training Record</a>

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## Appendix B Laser Pointer Safety

### Applicability

All Class 2 or 3R laser pointers used for class room instruction or presentations shall be operated under the guidelines established in this document. It is not required to file a Laser Registration Form for Class 3R laser pointers. These guidelines are not applicable to any Class 3B and Class 4 laser devices, nor shall such devices be used in instruction or presentations without prior notification of the LSO.

### Rationale

By definition, a Class 3R laser can cause eye injury. However, the intended use of laser pointers carries a very low probability of injury. For this reason, EH&S has approved the use of Class 3R pointers for their intended use as instruction and presentation aids.

### Labeling of Pointers

The manufacturer is required by the FDA Center for Devices and Radiological Health (CDRH) to provide correct labeling for their laser pointers. This includes the laser hazard symbol, laser classification, maximum power output, and laser wavelength. This information should be clearly visible on the laser pointer. Operating and safety instructions should also be provided by the manufacturer.

If the laser is fabricated in-house or does not have the required labeling, contact the LSO before using the pointer. The LSO will classify and provide labels for the pointer.

### Equipment Purchase Considerations

If possible, purchase a Class 2 laser pointer (power does not exceed 1 mW). Class 2 lasers are designed to be safe if the beam accidentally enters the eye for a short period. The aversion response (blinking or turning the head) is fast enough to prevent injury.

The operating switch should be a momentary contact type (designed to shut off the pointer when released). The switch should not have a locking device to keep the beam on when direct pressure is removed from the switch. Pulsed laser pointers shall not exceed the Class 3R hazard class.

Since the human eye perceives light at mid-range wavelengths more brightly, short and long wavelength lasers require more power to maintain the same brightness. For this reason, it is recommended to purchase laser pointers that operate at wavelengths closer to the mid-range.



## **Authorized Users**

University employees handling laser pointers on campus are required to follow these guidelines.

Access to laser pointers should be limited to responsible persons who have been informed of these guidelines by the owner or user. The laser pointer should be kept in a secure place when not in use.

Persons visiting the University who wish to operate laser pointers are expected to abide by these guidelines. Generally, the person acting as host should inform the visitor of these guidelines.

The owner of the laser pointer is responsible for its use at the University.

## **Operating Safety Guidelines**

1. Never intentionally stare into the laser beam.
2. Never intentionally direct the laser beam toward oneself or toward another person. Direct the beam towards the screen and away from the audience.
3. Turn off the beam when not in immediate use.
4. Never point the beam at the eye under any circumstances.
5. Use of Class 3R laser pointers should be limited to the intended purpose. Indiscriminate use may present an eye hazard.
6. Class 3R laser pointer use is prohibited when optically aided viewing of the beam is probable. Optical aids include telescopes, binoculars, viewing optics, and similar devices.

## **Exceptions**

Exceptions to the above guidelines should be coordinated with the LSO.

## **Legal Implications of Laser Pointer Misuse**

The California Penal Code has several sections (417.25 CPC, 247.5 CPC, and 248 CPC) which indicate the willful misuse of a laser pointer can be considered either a misdemeanor or a felony. In particular, directing any laser beam at another person may constitute assault (suggesting the use of a laser gunsight) and directing any laser beam at an aircraft may constitute malicious mischief. Persons convicted of these crimes may be subject to stiff fines and/or jail sentences.



### **Emergencies**

Although the potential for injury from a laser pointer is very slight, notify your immediate supervisor and get medical attention if an eye injury from laser use is suspected. Also, notify the LSO @ 323-442-2214 as soon as possible.

