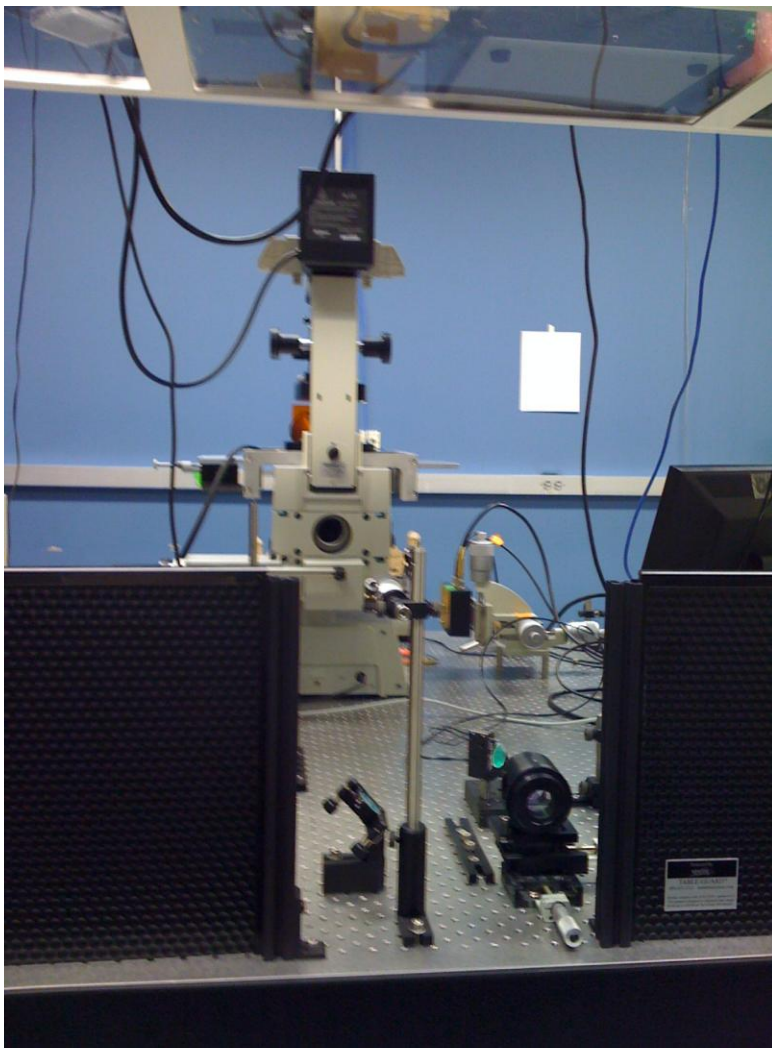
University of California Riverside
Laser Safety Manual



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A. Introduction

The purpose of these requirements is to provide reasonable and adequate guidance to personnel for the safe use of lasers and laser systems. Both Federal Occupational Safety and Health Administration (OSHA) regulations (21 CFR 1010& 1040) and Cal OSHA regulations (CCR Title 8) address issues of laser safety and recognize under its general duty clause, standards developed by the American Standards Institute (ANSI) as the accepted standard for the safe use of lasers. Therefore, the following requirements are based on the current ANSI standard (ANSI Z136.1-2007).

The laser safety policy requires that all Class 3B and 4 lasers and laser systems (whether purchased, borrowed, fabricated, or brought in for use by others) be operated in accordance with the requirements established by the latest American National Standards Institute (ANSI) Z136.1 document, Standards for the Safe Use of Lasers and this Laser Safety Manual. Class 1 lasers are considered safe when operated under the manufacturer's instructions. Most lasers are capable of causing eye injury to anyone who looks directly into the beam. In addition, reflections of high-power laser beams can similarly produce permanent eye damage. Laser beams can also induce injury to skin and pose other potential dangers such as fire, electrical and chemical hazards.
To properly implement this program, laser operations at the University of California Riverside (UCR) are reviewed by the Department of Environmental Health and Safety (EH&S). Also, copies of the ANSI Z136.1 2007 Standard for Safe Use of Lasers and ANSI Z136.5 2009 Standards for the Safe Use of Lasers in Educational Institutions can be reviewed at UCR EH&S.

Setting Up a Laser Laboratory

This manual contains regulatory requirements, university policies and prudent practices that apply to the use of lasers in laboratories and the use of lasers for entertainment purposes on the UCR campus. Using the information contained in the Laser Safety Manual, laser users can be assured of establishing a safe and compliant laser system. Laser users must follow the authorization process for Class 3B and 4 lasers and the Laser Safety Officer (LSP) must subsequently evaluate and approve the application.

Laser Safety Overview

"Laser" is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. Laser radiation or light is coherent electromagnetic radiation characterized by one or more specific wavelength(s), the values of which are determined by the composition of the lasing medium. Laser radiation may be emitted in the ultraviolet (0.18 to 0.40 μm), visible (0.40 to 0.70μm) or infrared (0.70μm to 1mm) regions of the electromagnetic spectrum.
The energy emitted by laser radiation can be transmitted, absorbed or reflected, depending upon the characteristics of the material with which the laser light

comes into contact. Materials that transmit laser beams are said to be transparent. Conversely, opaque materials either absorb or reflect the laser energy.

Transmission and Absorption
Laser transmission and absorption depends not only on the chemical and physical makeup of the target material, but also on the wavelength and energy of the laser being used. At visible wavelengths, laser radiation impinging on the eye is focused on the retina and other pigmented structures and, if sufficient energy is absorbed can cause cell and tissue destruction. At longer and shorter wavelengths, such as the far infrared and ultraviolet regions, radiation striking the eye is absorbed by water, the cornea and the lens rather than the retina. Excessive energy absorption can cause injury to these tissues and cause vision impairment.

Reflection
Reflection is primarily a function of the physical characteristics of the surface of the target material. A smooth, polished surface generally provides a high-quality or specular reflection, whereas rough, uneven surfaces are usually poor reflectors and produce a diffuse reflection. A reflector such as a flat mirror changes the direction of an incident beam with little or no absorption. A curved mirror or surface will change the divergence angle of the impinging laser beam as well as its direction.
For a diffuse reflection, the reflected energy is scattered in multiple directions thereby reducing the energy or power density. Generally, diffusely reflective surfaces are favored when designing a laser experiment, since their use reduces the likelihood of a specular reflection and thus increases the safety of the experiment.

Classes of Lasers
To provide a basis for laser safety requirements, all lasers and laser systems in the United States are classified according to the ANSI Z136.1 Standard and the Federal Laser Products Performance Standard. The laser classification is most often supplied by the manufacturer. Custom-built and modified lasers shall be classified by the builder and verified by the LSP. The standards are enforced by the Occupational Safety and Health Administration (OSHA). The Laser Products Performance Standard is enforced by the Centers for Devices and Radiological Health, a division of the Food and Drug Administration. The following section describes the classification for continuous-wave lasers. The same hazard levels also apply to pulsed lasers with pulse duration of less than 0.25 seconds(s), but classification is more complex for these devices. The ANSI Z136.1 Standard is available by contacting
either EH&S for details of both continuous- and pulsed laser classification.

Class 1 and 1M Lasers
Class 1 lasers are considered to be incapable of producing damaging radiation levels during operation and are exempt from any control measures or other forms of surveillance. A completely enclosed laser that does not emit hazardous radiation under normal operating conditions would be considered a Class 1 laser. Equipment such as laser printers, laser disc players, and confocal microscopes are examples of this class.

Class 2 and 2M Lasers
Class 2 lasers emit accessible, visible (0.4 to 0.7μm) laser light with power levels less than 1 milliwatt (mW) radiant power and are capable of causing eye and skin damagethrough chronic exposure. The human eye blink reflex, which occurs within 0.25s, provides adequate protection. However, it is possible to overcome the blink response and stare into the Class 2 laser long enough to damage the eye. Consequently, Class 2 equipment housing lasers/laser systems shall bear a label warning against staring into the beam. Equipment such as some visible continuous wave Helium-Neon lasers and some laser pointers are examples of Class 2 lasers.
Class 2M lasers emit laser light in the visible portion of the spectrum and eye protection is normally afforded by the aversion response for unaided viewing. However, Class 2M is potentially hazardous if viewed with certain optical aids.

Class 3R Lasers
Class 3R laser systems are 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. This laser will not pose either a fire hazard or diffuse-reflection hazard. Class 3R lasers have power levels of 1 to 5 mW and normally do not produce a hazard if viewed only momentarily by the unprotected eye. However, they pose severe eye hazards when viewed through optical instruments (e.g., microscopes, binoculars or other collecting optics). Therefore, Class 3R lasers shall bear a label warning against direct eye exposure or viewing directly with optical instruments. Equipment such as some visible continuous wave Helium-Neon lasers and some solid-state laser pointers are examples of Class 3R laser systems. This type of equipment is 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. This laser will not pose either a fire hazard or diffuse-reflection hazard. Class 3R lasers have power levels of 1 to 5 mW and normally do not produce a hazard if viewed only momentarily by the unprotected eye. However, they pose severe eye hazards when viewed through optical instruments (e.g., microscopes, binoculars, or other collecting optics). Therefore, Class 3R lasers shall bear a label warning against direct eye exposure or viewing directly with optical instruments. Equipment such as some visible continuous wave Helium-Neon lasers and some solid-state laser pointers are examples of

Class 3R lasers. Lasers used as pointers in classrooms must not be rated higher than Class 3R.

Class 3B Lasers
Class 3B laser systems may be hazardous under direct and specular reflection viewing conditions, but is normally not a diffuse reflection or fire hazard. Class3B continuous wave lasers are ultraviolet, infrared, or visible laser systems with power levels of 5 mW to 500 mW, but cannot emit an average radiant power greater than 500 mW for more than 0.25 s or cannot produce a radiant energy greater than 0.125 J (joules) for an exposure lasting less than 0.25 s. Class 3B pulsed lasers are visible or near infrared systems with power levels of 5 mW to 500mW, but cannot emit an average radiant power greater than 500 mW for longer than 0.25 s or cannot produce a radiant energy greater than 0.03 J per pulse. These lasers bear a sign warning against direct exposure to the beam. Specific control measures covered in Class 3B lasers shall be used in areas where entry by unauthorized personnel can be controlled. Entry into the area by personnel untrained in laser safety may be permitted if accompanied by the laser operator, instructed in applicable safety requirements prior to entry and provided with appropriate protective eye wear.

Class 4 Lasers
Class 4 lasers are systems with power levels greater than 500 mW. These laser systems are a hazard to the eye or skin from the direct beam, and may pose a diffuse reflection or fire hazard. They may also produce laser generated air contaminants (LGACs) and hazardous plasma radiation. Consequently, these lasers/laser systems shall bear signs warning against eye and skin exposure from direct or scattered radiation.

Lasers Classified Under Previous Standards
There is no requirement to reassess lasers that were previously classified. Products that were previously in Class 1 remain in Class 1. Laser products previously classified as Class 3A are now Class 3R unless the emergent beam diameter exceeds 7 mm, in which case they could be Class1M or 2M. The reclassification of a laser by the LSO may provide regulatory relief in labeling and signage.

Embedded Lasers
Embedded lasers are found in laser products with lower class ratings. However, laser printers, CD players, laser welders, and con-focal microscopes may have Class 3B or Class 4 lasers in their protective and interlocked housings. When such a laser system is used as intended, the lower laser class applies. When an embedded laser system is opened and the higher classified laser is accessible (e.g., for service or alignment), the requirements for the higher class laser shall be followed.

Specific Administrative Responsibilities
Laser Operator
The laser operator is responsible for:

- Meeting all applicable requirements including training, outlined in Section F before operating lasers
- Operating lasers safely and in a manner consistent with this manual, applicable Standard Operating Procedures (SOPs) and guidance from the LSP
- Meeting all safety requirements as outlined in the Laboratory Safety Manual

Principal Investigator
The PI or Laser Supervisor is responsible for:

- Assuring a safety review or analysis is conducted by the LSP prior to use or whenever there are changes in location or conditions (such as modifications) that may affect the safe use of lasers
- Ensuring that each assigned laser is operated safely and in accordance with applicable requirements
- Notifying his or her respective safety office of the intent to procure or build a laser and providing required information for authorization and hazard assessments
- Ensuring that lasers are stored securely and safely when not in use so that they are not accessible by unauthorized personnel or used under unauthorized conditions
- Permitting only authorized laser operators to use lasers
- Providing the LSP written SOPs for approval and ensuring that lasers are used in accordance with the SOPs
- Providing and documenting laser-specific training for operators, in consultation with the respective safety office
- Designating laser operators
- Maintaining records of Class 3B and Class 4 laser training

- Maintaining inspection records for each laser or laser system
- Ensuring that all applicable requirements of the Laboratory Safety Manual are implemented for the laboratory
- Ensuring the LSP has been notified prior to disposal of a laser and/or laser system so that the final disposition of possible hazardous components contained within the laser and /or laser system can be properly disposed
- Ensuring that unused or deactivated laser and/or laser systems are secured from unauthorized access
- Ensuring the LSP has been notified prior to the acquisition or fabrication of a new laser
- So that a preliminary safety review can be completed
- Ensuring the LSP has been notified prior to the operation of a new laser so that a final safety review or analysis can be completed
- Notifying the LSP in the event that a laser is reassigned to a new PI

EH&S
EH&S is responsible for:

- Maintaining inventories of all Class 3B and Class 4 lasers and verifying classification if necessary
- Approving SOPs, alignment procedures and other control measures before initial use
- Ensuring that Class 3B and Class 4 lasers are inspected at least annually for compliance with safety requirements
- Providing assistance in evaluating and controlling hazards
- Maintaining records of Class 3B and Class 4 laser inspections
- Participating in accident investigations involving lasers
- Providing laser safety training
- Maintaining the Laser Safety Manual

- Reviewing and authorizing the use of Class 3B and 4 lasers in research applications |notifying approved users of the necessity of a medical evaluation prior to laser use

B. Process Planning

Laser safety in the laboratory does not happen by accident. Properly planning laser processes will help you identify hazards, establish hazard control measures and, ultimately, keep you and other lab personnel safe.

General Requirements for Laser Operations

The following safety measures are required prior to laser use. Additional requirements may apply to specific lasers at UCR. Contact the LSP for specific requirements.

- Class 2, Class 2M, Class 3R, Class 3B, and Class 4 lasers shall bear a warning label containing the laser classification, type and other warnings
- Class 2,2M, and 3R lasers shall be registered with the LSP.
  No standard operating procedure is required for these laser classes
- Class 3B and Class 4 lasers shall be registered with the LSP. An SOP is **recommended** for Class 3B lasers and is **required** for Class 4 lasers
- Each laser and laser application shall meet the safety standards of ANSI Z136.1
- The LSP may approve lasers or laser systems that meet standards equivalent to ANSI Z136.1

• Each Class 3B and Class 4 laser shall be assigned to a PI who is responsible for the safe use and storage of that laser. The LSP shall be notified whenever a laser is reassigned to a new PI or removed from service

• Laser operators operating Class 3B and Class 4 lasers must complete all training and retraining requirements per **Section F**

• Lasers shall be operated in accordance with applicable ANSI Z136.1 safety standards and in a manner consistent with safe laser practices. Written Standard Operating Procedures (SOPs) are **recommended** for all Class 3B and **required** for all Class 4 laser systems. Alignment procedures are required for Class 3B and Class 4 laser systems

• SOPs shall be specific to each laser or laser system. The SOPs shall include discussion of alignment procedures, interlock testing and Personal Protective Equipment (PPE) requirements

• Every Class 3B and Class 4 laser shall be used in a controlled area that restricts access to unauthorized personnel. These controlled laser areas shall be posted with appropriate warning signs

• Class 3B and Class 4 lasers shall undergo a preliminary safety review by the LSO prior to acquisition or fabrication. These lasers shall also receive a final safety review via completion of a Laser Hazard Assessment by the laser system supervisor and the LSP prior to initial use. The final review will cover user qualifications, safe operation practices, electrical safety, area controls, and written SOPs

• Class 3B or Class 4 laser operators shall wear appropriately rated protective equipment (e.g. eyewear) as required

• The LSP shall be notified when Class 3B and Class 4 lasers or laser systems are purchased or constructed

Standard Operating Procedures (SOPs)
Process planning must begin with development of SOPs. This first step requires each investigator or laboratory work group to assess (i.e., identify and evaluate) all chemical, biological, radiological, and physical hazards associated with laser operations and describe safety precautions necessary to avoid employee exposures and injuries. SOPs must be specific to each laboratory operation. SOPs must be reviewed and approved by the PI or the lab supervisor. After approval, SOPs are then incorporated into or attached to written materials and methods. Laboratory personnel must be trained on the elements of the SOP before performing an experiment or operation, and must sign off indicating that the SOP will be followed. The template for writing a laser SOP can be found on the EH&S website.

SOPs must be readily available in the laboratory where the experiment or operation will be performed. SOPs should be reviewed and updated annually. SOP's are **recommended** for Class 3B lasers and **required** for and 4 lasers/laser systems.

Special Procedures
Special procedures must be developed for work involving materials or equipment that present a significant risk of exposure or damage to the human body. Examples include: carcinogens, reproductive toxins, teratogens, highly toxic substances, explosives, controlled substances, select biological agents, radioactive materials, radiation producing devices, and lasers. The following special procedures must be developed and specified on the SOP.

• Identify authorized personnel that may work with these materials or equipment. Authorized persons must receive training on the unique hazards of these materials or equipment before use

• Establish a designated use area (fume hood, glove box, lab bench, lasers, etc.) and identify the area with signs or postings. Restrict access to this area to authorized personnel. If an entire lab is designated, then access must be restricted to authorized personnel

• Specify special safety precautions for experiments or laboratory operations where these materials of equipment are used. Be sure to identify specialized equipment, shielding or security requirements to be used

Laser Control Areas
Class 3B and Class 4 lasers shall only be operated in laser control areas approved by the LSP. Laser control areas confine laser hazards to well-defined spaces that are entirely under the control of laser users. The control areas shall be equipped with the prescribed safety features. Operations must meet the following safe operating standards

• The Class 3B laser control area must be posted with appropriate warning signs that indicate the nature of the hazard(s)

• Only authorized personnel listed on a laser use authorization or variance) are allowed to operate Class 3B and Class 4 laser systems

• Spectator access is controlled by the laser operator. Access should only be permitted to the area after appropriate instruction has been provided to the spectators by the laser operator and protective measures are taken. Written instructions and a list of spectators must be maintained by the laser operator

• The laser beam must be terminated within the control area by appropriate beam stop devices

• Light levels in excess of the maximum permissible exposure (MPE) limit must not pass the boundary of control areas

• All openings through which laser light might escape control areas (entryways, doorways, windows, and other open portals) must be shielded in a manner to preclude the transmission of laser light through the openings to below the MPE limit

• Personnel must be provided with and wear appropriate eye protection within the controlled area

• Class 3B IR and UV lasers require additional controls since beams are not readily detectable

- Highly absorbent, non-specular stops must terminate beams
- Signs and light should warn those in the area when lasers are being operated
- Special attention must be given to the production of ozone, skin sensitizing agents and other hazardous products when ultraviolet lasers are used

• Class 4 lasers require additional controls. Contact the LSP for details about these controls and how to ensure compliance

Temporary Laser Control Areas

For servicing of embedded lasers, and in special cases where permanent laser control areas cannot be provided (lecture demonstrations, displays, etc.), temporary laser control areas can be created. Contact the LSPfor details.

C. Laser Registration

The UCR laser registration form must be filled out regardless of the laser class. If you have a Class 4 laser the UCR Laser SOP form must be submitted in addition to the registration form. If you have a Class 3B laser, submission of the UCR SOP form is recommended but not required. Each new project involving the use of class 3B or 4 lasers must be specifically approved by the LSP.

Application for Initial Use of Class 4 Lasers

The individual who is to be in charge of the project, referred to as the PI, begins the process by completing the Laser Registration form and Laser SOP form. The complete application must be submitted to the LSP, where it will receive an initial review. At this time the LSP may require additional information from the applicant. If the application appears to be adequate, the LSP or the designee will meet the PI and perform a Laser Hazard Assessment. Once all issues have been addressed and the application has been approved, the LSO will sign the form and forward it to the PI. EH&S will also review procedures for additional hazards involving chemical and biological materials and physical hazards. Approval for procedures involving additional hazards may be delayed until safety and regulatory measures are addressed.

Application to Amend Use

Approval for any modification to an original authorization may be requested from EH&S either in written or electronic form. Minor changes, such as additional personnel or changes in location are reviewed and, if appropriate, approved by the LSP. More extensive changes will be subject to the same review and approval process as the original application.

Ordering Lasers and Laser Systems

The LSP should be contacted prior to ordering class 3B and 4 laser or laser systems. Including the LSP as part of your ordering process will decrease procurement delays and reduce potential regulatory deficiencies. The LSO can recommend protective measures to consider for the specific system.

D. Emergency Planning

Planning for emergencies enables communication of hazards through signage/postings and allows laboratory personnel to develop and follow emergency action plans.

Postings and Signage

For information regarding general lab safety postings and signage and emergency action plans contact EH&S.

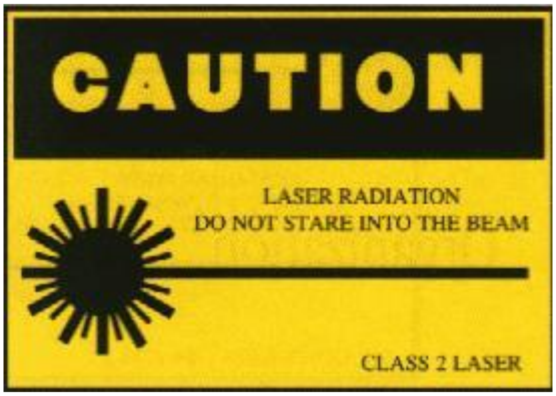
ANSI Z136.1 requires that lasers and laser systems have appropriate warning labels and that the rooms in which they operate bear appropriate warning signs. Sign for laser laboratory doors are provided by the LSP; however, laboratory supervisors and laser users/operators must be familiar with the signage requirements.

- The signal word "Danger" must be used with all signs and labels associated with all lasers and laser systems that exceeded the MPE for irradiance, including all Class 3R, Class 3B and Class 4 lasers/laser systems. The Optical Density (OD) of the protective eyewear and wavelength shall be shown on the sign for a location requiring the use of eyewear.

Class 3B sign

Class 4 sign

- The signal word "Caution" must be used with all sign and labels associated with all Class 2 and Class 2M lasers and laser systems, which do not exceed the appropriate MPE for irradiance.



Class 2 sign

- The signal word "Notice" must be used on signs posted outside temporary laser-controlled area such as during periods of service. Please contact EH&S at 827-5748 if you plan on servicing an embedded laser so the appropriate signage can be posted.

Notice Sign

E. Equipment

Use of Engineering Controls

Engineering controls must be implemented where possible to reduce hazards associated with the use of lasers and laser systems. Engineering controls should be considered in the following order:

1. Substitution of less hazardous equipment or processes
2. Physical isolation of the operator or process
3. Local and general exhaust ventilation and/or filtration

Specific Engineering Controls

- All lasers require a protective housing.
- Beams must be enclosed as much as is operationally practical. Items to consider for enclosing the beam may include curtains, side shields, partitions, or entryway mazes.
- All Class 3B and Class 4 lasers must be equipped with protective housing interlock systems to prevent emission of laser radiation when the protective housing is open.
- Viewing portals in the protective housing must be equipped with filters and attenuators that keep escaping light below the MPE limit.
- Optical instruments for viewing laser systems must be equipped with filters, attenuators and interlocks to keep exposures below the MPE limit for all conditions of operation and maintenance.
- All Class 3B and Class 4 lasers must adhere to the following engineering controls guidelines:
    - ❖ Lasers must be equipped with removable master key switches and must not be operable when the keys are removed
    - ❖ Lasers must be equipped with electrical connections allowing the lasers to be controlled by area interlock systems and remote shut-off devices

- When terminals are open-circuited, lasers must not emit any radiation in excess of the MPE

- Class 4 laser systems must have integral and permanently attached beam stop or attenuator capable of preventing the emission of laser light in excess of the MPE limit when the laser system output is not required such as during warm-up procedure

- All listed engineering controls shall be designed and incorporated into locally built lasers and must function with the laser system

- Exceptions shall be approved by the LSP

Personal Protective Equipment

Despite the application of all practicable engineering and administrative controls, there are occasions when it is necessary to work near an open Class 3B or Class 4 laser beam. On these occasions, personal protective equipment (PPE) shall be used to protect the eyes and skin. For more information about general lab PPE call EH&S.

Eye Protection

Eye protection suitable to the laser class and wavelength must be provided and worn within the laser control area during operation and alignment if there is a potential for exceeding the MPE limit. Protective eyewear may include goggles, face shields, spectacles, or prescription eyewear using special filter materials or reflective coatings. Exceptions may be approved in the written SOPs or by the LSP if the eyewear produces a greater hazard than when eye protection is not worn, such as in low-light situations. No single type of eyewear will provide protection against all wavelengths of laser radiation, therefore, eye protection should

- Provide enough visibility to move about safely

- Be able to withstand the maximum power of laser radiation likely to be encountered

- Be able to absorb the specific wavelength of radiation that is being used

- Be clearly labeled with its designed wavelength, the optical density at that wavelength and the maximum power rating

- Be inspected by the laser operator to ensure that pitting, cracking and other damage will not endanger the wearer

Lasers that can be tuned through a range of wavelengths present special problems. Broadband laser goggles may provide the level of protection required but they must be chosen with great care. If there is any doubt regarding the suitability of a particular type of eye protection, contact the LSP for guidance.

Because various wavelengths of laser radiation require different eyewear, more than one type of laser should not be run simultaneously in the same laboratory unless they are under the control of the same person. The laboratory must be equipped with eye protection that is suitable for the laser(s) in use.

Eyewear must meet the following minimum criteria

- Eyewear must be labeled with the optical density (OD) and wavelengths for which the eyewear is designed. Labeling can be self adhered and must be legible.

- The OD on eyewear must meet the levels required for the laser application.

- The protective eyewear must be appropriate for the wavelength(s) used in the laser application.

- The eyewear must be inspected for pitting, crazing, cracking, etc., of the filter material.

- The goggle frame must also be inspected for mechanical integrity and light leaks.

- The quantity of eyewear on hand must be sufficient for the expected number of daily users and visitors for each laser.

- Appropriate eyewear must be used for alignment procedures.

- Prescription eyewear is required to be up–to-date.

- Eyewear must be stored in the lab and in a manner that preserves its condition. Holders supplied by the eyewear vendor are recommended.

Skin Protection
Clothing such as gloves and covers for the forearms may be required to protect the skin if laser intensity and wavelength warrant such protection. This is most important for lasers that are running in the ultraviolet region, because very large peak powers with pulsed ultraviolet lasers may be particularly dangerous. The LSO can assist in identifying protective equipment that is appropriate for the intended use. This equipment must be addressed in the written SOP.

F. Training

Principal investigators and/or laboratory supervisors are responsible for ensuring that all personnel are properly trained before they begin work in a laboratory and that they receive additional training when new hazards or procedures are introduced. For details about what general lab trainings are required contact EH&S Radiation Safety.

Only qualified and authorized personnel are permitted to operate laser systems. Therefore, all Class3B and Class 4 laser users are required to complete Laser Safety Training, should participate in a medical surveillance program and complete all required departmental job activity training prior to performing this activity. Laser users must complete retraining every three years.

Laser Safety Training (Initial)

All UCR laser users must complete laser safety training prior to performing laser work. All laser users need to access the EH&S website and complete the web based training. Documentation of training must be sent to the LSP. Additionally, laser users are provided with an informational packet and will be required to sign a Laser User Authorization Form, which acknowledges their responsibility for completing job activity training prior to operating lasers. Medical surveillance including pre- and post-employment laser eye exams is strongly recommended, but not required.

Retraining
UCR employees who use class 3B and class 4 lasers are required to complete retraining every three years.

Laser Laboratory Specific Training

In addition to the lab specific training mentioned in the Laboratory Safety Manual, each laser user must be trained on the operation of each laser or laser system by the laser supervisor (principal investigator). This training must cover

- SOPs
- Alignment procedures
- Secondary hazards
- Protective equipment
- Other pertinent safety information

G. Laser Safety Practices

The following measures are recommended as a guide to safe laser use. Some additional measures may be required for specific laser classes and lasers that emit UV or infrared radiation. Contact the LSOF for specific requirements. For general lab safety practices contact EH&S.

Work Area Safety Practices

- The laser beam must be enclosed to the extent practical.

- The laser must be isolated from areas where untrained or unauthorized persons may be attracted by its operation.

- Doors must be closed and secured when unattended to keep out unauthorized personnel

- Appropriate warning labels and signage must be posted

- The illumination in the room must be as bright as possible in order to constrict users' eye pupils

- The laser must be set up so that the beam path is either above or below normal eye level (below 4.5 ft or above 6.5 ft)

- The potential for specular reflections must be minimized with shielding and by removal of all unnecessary reflective surfaces

- Windows to hallways or other outside areas must have adequate shades or covers

- The main beams and reflected beams must be terminated or dumped. This is required for any accessible laser for which the MPE limit could be exceeded.

• Electrical installation must meet electrical safety standards

• The active laser must never be left unattended, unless it is a part of a controlled environment

• Hazard warning signs must be installed for lasers with invisible beams

Laser Use Safety Practices

Use proper eye protection when working with Class 3B or Class 4 lasers. Remember that safety glasses provide no protection unless they are worn. Safety glass lenses may shatter or melt when the lens specifications are exceeded. In addition, scratched or pitted lenses may afford no protection. Eye protection is specific to a certain type of laser and may not protect at different wavelengths or powers.

• Avoid looking into the primary beam at all times

• Do not aim the laser with the eye; direct reflections could cause retinal damage

• Avoid looking 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 wavelengths not visible to the human eye
.
• Do not wear bright, reflective jewelry or other reflective objects

H. Safety Practices for Specific Hazards

The following are additional laser safety practices that apply to UCR laser laboratories. Contact EH&S regarding other safety practices that may apply to non-laser hazards associated with laser use.

Beam Hazards

The nature of laser beam damage and the threshold levels at which each type of injury may occur depend on the laser beam parameters. These include wavelength of light, energy of the beam, divergence, and exposure duration. Pulse length, pulse repetition frequency and pulse train characteristics are additional parameters for pulsed lasers. The ANSI Z136.1 Standard establishes Maximum Permissible Exposure (MPE) limits for laser radiation. Damage can occur to the skin, retina, lens, cornea, and conjunctival tissue surrounding the eye. For lasers over 0.5 watts (W), the beam can ignite flammable or combustible materials.

Thermal burn and photochemical damage to the retina may occur from laser light in the near ultraviolet (UV), visible and near infrared (IR) regions (below 400 nm - 1400 nm). Damage occurs as the laser light enters the eye and is focused on the retina (see Fig. 1). Normal focusing of the eye amplifies the irradiance by approximately 100,000 times; thus, a beam of 1 mW/cm^2 results in an exposure of 100 W/cm^2 to the retina. Energy from the laser beam is absorbed by tissue in the form of heat, which can cause localized intense heating of sensitive tissues. The most likely effect of excess exposure to the retina is thermal burn, which destroys retinal tissue. Since retinal tissue does not regenerate, the damage is permanent and may result in the loss of sight in the damaged area. Intrabeam viewing of the direct beam and the specularly reflected beam are most hazardous when the secondary reflector is a flat, polished surface. Secondary diffuse reflections from rough, uneven surfaces are usually less hazardous. Extended source viewing of normally diffuse reflections are usually not hazardous except for very high-powered lasers (Class 4). Extra care shall be taken with infrared (IR) lasers since diffuse reflectors in the visible spectrum may reflect IR radiation differently and produce greater exposures than anticipated.

Non-Beam Hazards

Beam hazards of a laser are only one concern in using lasers. The other associated hazards described below must be understood to ensure the safe use of a laser or laser system. Contact the LSP for specific training requirements associated with working around these hazards.

Electrical Hazards

The most lethal hazards associated with lasers are the high-voltage electrical systems required to power lasers. Electrical equipment in general presents three potential hazards – shock-resistive heating and ignition of flammable materials. Several deaths have occurred when commonly accepted electrical safety practices were not followed by those working with high voltage components of laser systems. The following is a list of recommended electrical safety practices:

- Prior to working on electrical equipment, de-energize the power source. Lock out and tag out the disconnect switch
- Do not wear rings, watches, or other metallic apparel when working with electrical equipment
- When working with high voltage, regard all floors as conductive and grounded

- Do not handle electrical equipment when hands or feet are wet or when standing on a wet floor
- Be familiar with electrocution rescue procedures and emergency first aid
- Check that each capacitor is discharged and grounded prior to working in the area
- Use shock prevention shields, power supply enclosures and shielded leads in all experimental or temporary high-voltage circuits

Laser Generated Air Contaminates (LGAC)
Air contaminates may be generated when certain Class 3B and Class 4 laser beams interact with matter. The quantity, composition and chemical complexity of the LGAC depend greatly upon target material, cover gas and the beam irradiance. Some compounds may be gaseous or particulate and can, under certain conditions, pose occupational concern. For further information, contact your respective safety office.

Chemical Hazards
Many dyes used as lasing media are toxic, carcinogenic, corrosive, or pose a fire hazard. All chemicals used in the laser system must be accompanied by an MSDS. The MSDS will supply appropriate information pertaining to toxicity, personal protective equipment (PPE) and storage of chemicals. Various gases may be exhausted by lasers or produced by targets. Proper ventilation is required to reduce exposure levels to the gas products below acceptable limits. For further information, contact EH&S.

Cryogenic Liquids
Cryogenic liquids are used in the cooling systems of certain lasers. As these materials evaporate, they displace oxygen in the air; thus, adequate ventilation must be maintained where cryogenic liquids are used. Cryogenic liquids are potentially explosive from expansion forces when ice collects in valves or connectors that are not specifically designed for use with cryogenic liquids. Although the quantities of liquid nitrogen used are small, protective clothing, eye protection and face shields must be used to prevent freeze burns to the skin and eyes.

Compressed Gases
Compressed gases used in or with lasers also present potential health and safety hazards. Problems may arise when working with unsecured cylinders, cylinders of hazardous materials not maintained in ventilated enclosures, and when certain

gases (toxins, corrosives, flammables and oxidizers) are stored together. For additional gas cylinder safety guidelines, contact EH&S.

Collateral Radiation

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 could be produced from two main sources in the laser laboratories: electric-discharge lasers and high-voltage vacuum tubes of laser power supplies such as rectifiers, thyratrons and crowbars. Any power supply that requires more than 15 kilovolts (kV) may produce enough X-rays to cause a health hazard. Interaction between X-rays and human tissue may cause cancer (such as leukemia) or permanent genetic effects. Contact the LSP for a collateral radiation consultation if you have questions regarding your system.

UV and Visible Radiation

Laser discharge tubes and pump lamps may generate UV and visible radiation. The levels produced may exceed the MPE limit and cause skin and eye damage.

Photosensitizing agents

From industrial chemicals or medications can make an individual more susceptible to these effects.

Plasma Emissions

Interactions between very high-power laser beams and target materials may produce plasmas that may contain hazardous UV emissions. Plasma emissions created during laser-material interactions may contain sufficient UV and blue light (0.18 to 0.55 um) to raise concern about long-term ocular viewing without protection.

Electric, Magnetic and Electromagnetic Fields

Power supplies and other electrical equipment associated with some lasers are capable of generating intense power frequency electric and magnetic fields that exceed published federal guidelines. Q-switches and plasma tubes are RF excited components.

Unshielded components may generate RF fields that exceed federal guidelines. Appropriate warning signs and labels should be used.

Fire Hazards

Class 4 lasers represent potential fire hazards. Depending on the construction material, beam enclosures, barriers, stops, and wiring are potentially flammable if exposed to high beam irradiance for more than a few seconds. Under some situations where flammable compounds or substances exist, it is possible that fires can be initiated by Class 3 lasers.

Biological Agents

These include LGAC and infectious materials. LGAC may be generated when high power laser beams interact with tissue. Infectious materials, such as bacterial and bacterial organisms, may survive beam irradiation and become airborne. Contact the Biosafety Officer for a biological agent consultation if you have questions regarding your system.

Explosion Hazards

High-pressure arc lamps, filament lamps and capacitors may explode violently if they fail during operation. These components shall be enclosed in a housing that is able to 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, adequate mechanical shielding shall be used when exposing brittle materials to high intensity lasers.

I. Laser Audits/Compliance

Laser Audits

Lasers will be audited by UCR EH&S on a yearly basis. This allows EH&S to update any changes in inventory and personnel .

Compliance Monitoring of the Laser Safety Program

The responsibility for safe use of lasers is placed on the primary investigators (PI), EH&S Radiation Safety, and Radiation Safety Committee (RSC). A system of consequences for deficiencies concerning safe use of lasers will be used for educating and alerting the authorized users, motivating individual users, and determining future user authorization.

A deficiency will generally be identified by a member of the EH&S staff during a routine audit . If the same deficiency is found during a subsequent audit, the point value for that deficiency is doubled. Also, if the deficiency is not corrected within 30 days of the written notice to the PI, the points that are accumulated are doubled. We provide each PI with a copy of the audit results following each audit inspection, even if deficiencies are not identified.

We have developed a point system based on the deficiency as well as three action levels based on the number of points that are accumulated during a calendar year. The point values for the individual deficiencies as well as the action levels and associated corrective actions are listed below for the radiation safety program.

Deficiencies assigned a point value of 1:

- Contact information on signs not current
- Laser dyes not properly contained
- Fume hood for dye mixing not functional
- Compressed gas cylinders not secured
-

Deficiencies assigned a point value of 2:

- Optical tables not secured
- Worker list not current
- Laser inventory not current

Deficiencies assigned a point value of 3:

- Laser signs not posted
- Laser classification labels not present
- Improper storage of eyewear
- No PPE for skin protection
- Eyewear requirements not posted

Deficiencies assigned a point value of 4:

- Protective housing not in place
- SOP not available(Class 4)
- Alignment procedures not available(Class 3B and 4)
- Worker training not completed
- Lasers and optics not secured
- Window/door openings not covered
- Barriers not demarcated
- Beams not blocked from open by-passed doors

Deficiencies assigned a point value of 5:

- Access door interlocks not functional
- Interlock and interlock bypasses not functional
- Proper eyewear not available
- Beam not properly contained
- Beam not enclosed where available
- Inadequate enclosure when beam leaves table

Action Level I (Less than or equal to 30 points)

- A written notice sent to the PI
- Receipt of a written notice to the RSOF from the PI within 30 days indicating that the deficiencies have been corrected.

Action Level II (Greater than 30 points but less than 60 points)

- Written notice to PI, Department Chair, and Chair of RSC that laser use will be suspended until the deficiencies are corrected. The Laser Safety Officer will perform a follow-up inspection prior to ensure that these deficiencies are corrected prior to PI being re-instated as a laser user.

Action Level III (Greater than or equal to 60 points)

- Written notice to PI, Department Chair, and Chair of RSC that laser use will be suspended until the deficiencies are corrected. The Laser Safety Officer will perform a follow-up inspection prior to ensure that these deficiencies are corrected and report results to the RSC.
- PI must submit a written request to the RSC to be re-instated as a laser user.

Deficiency tracking

A tracking system in HP Assist and Excel will be used as a metric in order to determine the effectiveness of the laser safety program at UCR.

The Laser safety notebook

Every laboratory that uses lasers should have the following documents in a binder:

- SOPs for every Class 4 laser including alignment procedures
- Laser Registration Forms
- Audit Results
- A copy of the UCR Laser Safety Manual

J. Disposal and Transfer of Lasers

Laser laboratories need to ensure the proper disposal of contaminated laser-related material, such as organic dyes and solvent solutions. Generators of this unwanted material must follow UCR disposal requirements. Contact the hazardous waste manager regarding disposal options.

Unwanted Lasers and Laser Systems
The following minimum guidelines are required when dealing with unwanted lasers or laser systems.

• Ensure all hazardous substances have been removed and the equipment decontaminated.
• Verify that EH&S has inspected/tested the equipment and authorized transfer and/or disposal.
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On Campus Transfer of Lasers and Laser Systems
Whenever lasers are being transferred from one laboratory to another, the LSP must be notified and provided with the following information

• When the laser will be transferred
• The names of the person(s) transferring and receiving the laser
• The sending and receiving locations
• Phone numbers of responsible person(s)

EH&S will update the laser inventory for both laboratories and perform a laser hazard assessment in the new location.

Off Campus Transfer of Lasers and Laser Systems
When planning to transport of ship a laser or laser system off campus EH&S must be informed in advance to determine correct shipping conditions. The laboratory is responsible for all costs associated with laser shipments. The LSP must be provided with the following information
• When the laser will be transferred
• The names of the person(s) transferring and receiving the laser
• The sending and receiving locations
• Phone numbers of responsible person(s)

Laser Laboratory Waste
Laboratories generate a wide variety of unwanted chemical, biological and/or radiological materials. Contact the UCR hazardous waste manager for information regarding disposal options.

K. Medical Surveillance and

Exposure Assessment

Medical Surveillance

A baseline eye exam is recommended for employees who are routinely engaged in work where they may be exposed to laser radiation from Class 3B and Class 4 lasers. Contact EH&S at 951-827-5528 if you have any questions.

Laser Related Injury Treatment and Exposure Assessment

University employees and students exposed or injured while at work or in the course of employment should seek medical attention at Loma Linda Medical Center**.** Any relevant safety information such as an MSDS should accompany the employee to the appointment.

Medical Emergencies

If injury, illness, or exposure necessitates immediate treatment, transport the employee to the Emergency Room at Riverside Community Hospital. If emergency transport is needed, dial 911. Take along any relevant safety information, such as an MSDS. When an employee requires emergency treatment, the incident must be reported to EH&S (827-5528) as soon as possible.

Reporting

All work related injuries, illnesses, or exposures must be reported to the employee's supervisor, even when medical attention is not required or is refused by the employee**.** An injury report must be completed within 24 hours of the accident. And can be found by accessing the Human Resources website at:
http://humanresources.ucr.edu/Forms/IncidentReportForm.doc

L. Laser Pointers

Reference: Barat, Laser Safety Management, 2006

Laser pointers are widely used in classrooms and meetings. Due to the low cost of laser pointers, they are being purchased by the general public and used in ways that are not recommended by the manufacturer.

While the majority of the laser pointers are low to moderately powered diode lasers, more powerful lasers can be purchased from other countries. These lasers have the potential for eye injury and are not properly labeled according to FDA regulations.

There are currently no restrictions for purchasing laser pointers in the United States. The FDA issued a warning in December of 1997 for laser pointers. The full text of this warning can be found on the CDRH web page at: http://www.fda.gov/bbs/topics/NEWS/NEW00609.html

Types of Laser Pointers

The majority of the laser pointed used in the US have either a Class 2 laser with a maximum power output of less than 1mW or a class 3a diode lasers in the 630-680nm wavelength with a maximum power output between 1 and 5 mW.

There have been reports of more powerful laser pointer imported from overseas that lack the appropriate warning labels. Some of these lasers emit green beams which could pose a significant threat if they are directed at aircraft.

All laser pointer should have a sticker with either a yellow ”Caution” or black and red “Danger” insignia, the laser classification, the maximum output power in mW and the wavelength. Never purchase an unlabeled laser pointer.

Hazards of Laser pointers

The hazards of laser pointers are limited to the eye, with the largest concern being potential damage to the retina. However, most laser pointers are not likely to cause retinal damage.

The most likely effects from exposure are afterimage, flashblindness, and glare.

Safety Considerations

- Never look directly into a laser beam
- Never point a laser beam at a person
- Do not aim the laser at reflective surfaces
- Never view a laser points using a binocular or microscope
- Do not allow children to use laser pointers unless supervised by an adult
- Use only laser pointer that meet the following criteria
    - Labeled with FDA certification stating “DANGER: Laser Radiation” for Class 3a lasers or “CAUTION: Laser Radiation” for Class 2 pointers
    - Classified as 2 or 3a according to the label

- Operates at a wavelength between 630nm and 680nm
- Has a maximum output of less that 5mW, the lower the better

Laser Pointer Incidents

Law enforcement officers have drawn their weapons when light from a laser pointer is mistaken for a gun-sight.

Laser beams projected into airspace and intercept aircraft have caused temporary vision impairment to pilots.

The operator of a roller coaster ride claimed a laser flash temporarily blinded him.

A high school cheerleader reported being exposed at least 3 times. After the last episode, she reported first seeing “green” then experiencing partial vision loss, which lasted several months. An ophthalmic exam showed no retinal damage.

M. Glossary

Absorption
Transformation of radiant energy to a different form of energy by interaction with matter.

Beam
A collection of light/photonic rays characterized by direction, diameter (or dimensions) and divergence (or convergence).

Blink Reflex or Aversion Response
The involuntary closure of the eyelid or movement of the head to avoid exposure to a noxious stimulant or bright light. It often occurs within 0.25 seconds which includes the blink reflex time.

Coherent
A beam of light characterized by a fixed phase relationship (spatial coherence) or single wavelength i.e., monochromatic (temporal coherence)

Continuous Wave (CW)
The output of a laser operated in a continuous rather than a pulsed mode. For purposes of safety evaluation, a laser that is operated with a continuous output for a period of > 0.25 seconds is regarded as a CW laser.

Controlled Area (laser)
An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser radiation hazards.

Diffuse Reflection
Change of spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.

Enclosure
A barrier used to enclose the laser beam.

Energy
The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers and is generally expressed in Joules (J).

Environmental Health and Safety (EH&S)
The department at UCR that has the authority to evaluate, monitor and enforce the control of lasers and laser systems for all laser users.

Fail-Safe Interlock
An interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into or remain in a safe mode.

Housing
The protective enclosure that contains the laser. In the case of Class 3B and Class 4 lasers, this case is required to be interlocked.

Infrared (IR) Radiation
Electromagnetic radiation with wavelengths that lie within a range of 0.7 μm to 1 mm.

Intrabeam Viewing
The viewing condition whereby the eye is exposed to all or part of a laser beam.

Irradiance (E)
Radiant power incident per unit area upon a surface, expressed in W/cm^2.

Laser

A device that produces radiant energy predominantly by stimulated emission. Laser radiation maybe highly coherent temporally or spatially or both. Laser is an acronym for Light Amplification by Stimulated Emission of Radiation.

Laser Classification
An indication of the beam hazard level of a laser or laser system during normal operation or the determination thereof. The hazard level of a laser or laser system is represented by a number or a numbered capital letter. The laser classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B and Class 4. In general, the potential beam hazard level increases in the same order.

Laser Operator
An individual who has met all applicable laser safety training, medical surveillance and approval requirements for operating a laser or laser system.

Laser Safety Officer (LSP)
The individual who has authority to monitor and enforce the safe use of lasers and laser
systems.

Laser Supervisor
The responsible PI for a laser or laser system. See also Principal Investigator.

Maximum Permissible Exposure (MPE)
The level of laser radiation to which an unprotected person may be exposed without hazardous effect or adverse biological changes in the eye or skin. MPE is expressed in terms of either radiant exposure (J/cm^2) or irradiance (W/cm^2). The criteria for MPE are detailed in Section 8 of ANSI Z136.1.

Mode-locked Laser
A laser that emits very short (~1-1000 ps), and high-power pulses.

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

Optical Density (Dλ) Logarithm to the base ten of the reciprocal of the transmittance:
$D\lambda = -\log 10\ \tau\lambda$, where $\tau\lambda$ is the transmittance at the wavelength of interest.

Power
The rate at which energy is emitted, transferred, or received in W or J/s.

Principal Investigator (PI)
The authorized laser user who assumes responsibility for the control and safe use of a laser or laser system. See also Laser Supervisor.

Pulsed Laser
A laser that delivers its energy in the form of a single pulse or a series of pulses. The duration of a pulse is regarded to be < 0.25 s.

Q-switch
A device for producing very short (~10-250 ns), intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium.

Q-Switched Laser
A laser that emits short (~10-250 ns), high-power pulses by means of a Q-switch.

Radiant Exposure (H)
Surface density of the radiant energy received in units of J/cm^2.

Radiant Power (Φ)
Power emitted, transferred, or received in the form of radiation in units of watts (W). Synonym: radiant flux.

Repetitive Pulse Laser
A laser with multiple pulses of radiant energy occurring in a sequence.

Shall
The word shall is to be understood as mandatory.

Should
The word should is to be understood as advisory.

Specular Reflection
A mirror-like reflection.

Standard Operating Procedure (SOP)
Formal written description of the safety and administrative procedures to be followed in performing a specific task. The procedure specifies measures which, if followed, will ensure safe and correct use of the laser or laser system.

Transmittance
The ratio of transmitted power (energy) to incident power (energy).

Ulatrafast Laser
A laser that emits high-power pulses on the order of femto-seconds.

Ultraviolet (UV) Radiation (Light)
For the purpose of this laser safety manual, electromagnetic radiation with wavelengths between 0.18 and 0.40 μm.

Visible Radiation (Light)
Electromagnetic radiation that can be detected by the human eye. This term is commonly used to describe wavelengths of 0.4 to 0.7 μm. Derivative standards may legitimately use 0.38 –0.78 μm for the visible radiation range.

Wavelength
The distance in the line of advance of a sinusoidal wave from any one point to the next point of corresponding phase (e.g., the distance from one peak to the next).