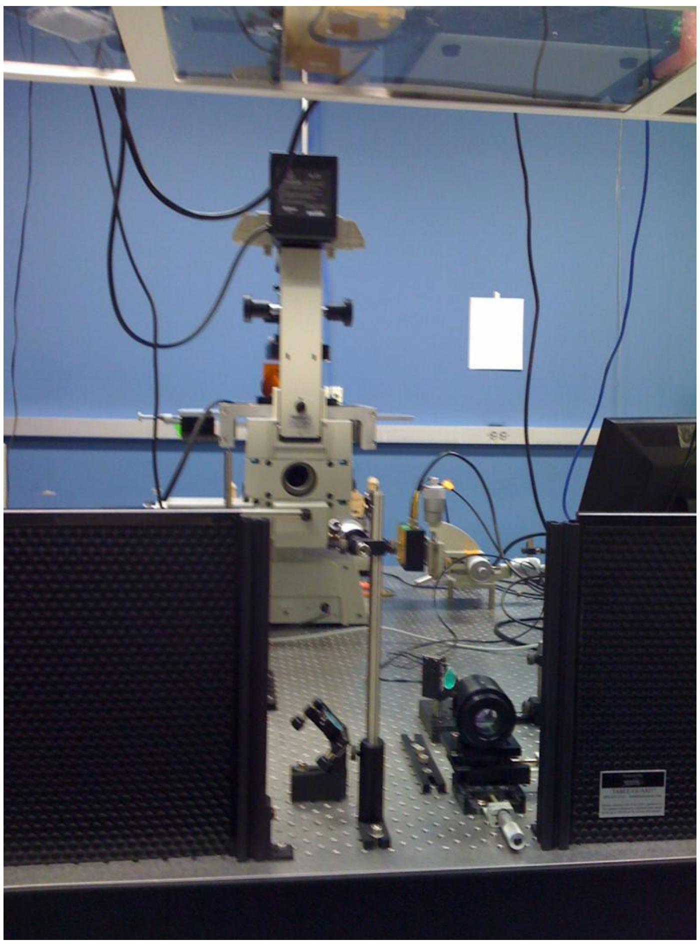
University of California Riverside
Laser Safety Manual



Laser setup courtesy of Dr. Bahman Anvari, Department of Bioengineering at the University of California, Riverside

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Contents

INTRODUCTION

This manual provides 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 Z136.1-2014).

"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, scattered, or reflected, depending upon the characteristics of the material with which the laser light comes into contact.

All lasers and laser systems (whether purchased, borrowed, fabricated, or brought in for use by others) must 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.

This manual contains regulatory requirements and prudent practices that apply to the use of lasers in laboratories. Using the information contained in the Laser Safety Manual, laser users can be assured of establishing a safe and compliant laser safety program. Laser users must follow the authorization process for Class 3B and 4 lasers and the Radiation Safety Committee must subsequently evaluate and approve the application. UCR does not audit or track Class 1, 1M, 2, 2M, or 3R lasers.

Laser Classes

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 supplied by the manufacturer. Custom-built and modified lasers shall be classified by the builder and verified by EH&S Radiation Safety. 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 EH&S Radiation Safety.

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 damage through 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 re-assess 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 EH&S Radiation Safety 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

General Requirements and Safety Practices

General Requirements

Class 3B and Class 4 lasers shall be registered with the EH&S Radiation Safety. A Standard Operating Procedure (SOP) is **required** for each Class 3B and 4 laser.

Each laser and laser application shall meet the safety standards of ANSI Z136.1.

The Radiation Safety Committee must approve all Laser Use Applications.

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.

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. EH&S Radiation Safety shall be notified whenever a laser is reassigned to a new PI or removed from service

Personnel operating Class 3B and Class 4 lasers must complete on-line laser safety training and site-specific training. All training must be documented

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

LASER SAFETY PROGRAM

Laser User Responsibilities

- Complete on-line laser safety training
- Review, understand and comply with the laser safety procedures prior to using the laser
- Wear the required personal protective equipment
- Maintain Engineering Controls on the laser system, and assure that safety

features that are not functioning properly are reported to the Principal Investigator (PI)

- Report any accident involving the laser to the PI.

Principal Investigator (PI) Responsibilities

Assuring a safety review or analysis is conducted by EH&S Radiation Safety prior to use or whenever there are changes in location or conditions (such as modifications) that may affect the safe use of lasers

Notifying EH&S Radiation Safety of the intent to purchase 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 those individuals that completed required training to operate the laser

Providing written operating procedures for approval and ensuring that lasers are used in accordance with those procedures

Ensuring that EH&S Radiation Safety has been notified prior to disposal of a laser

Notifying EH&S Radiation Safety in the event that a laser is reassigned to a new PI

Environmental Health and Safety (EH&S)

Responsible for the surveillance of Class 3B and 4 laser operations as well as the review of protocols for the use of new or additional Class 3B and 4 lasers

Radiation Safety Committee

The Radiation Safety Committee is a body of faculty and other experts appointed by the Vice Chancellor of Research and Economic Development under authority granted by the Chancellor to establish policies and procedures governing the use of ionizing and non-ionizing radiation at UCR. The committee reviews and approves applications for Radiation Use and Laser Use Authorizations as well as EH&S Radiation/Laser Safety operations.

Procurement Services

UCR Procurement Services will notify EH&S Radiation Safety of the purchase of all class 3B and 4 lasers. If a laser system not purchased (e.g., donated, provided by third party for use over a specified time, etc.), the PI must notify EH&S Radiation Safety.

Laser Audits/Compliance

Laser Audits

All Class 3b and 4 lasers are audited annually by EH&S Radiation Safety using *UC Inspect*. A record of non-compliance issues is found in the *Analytics* section of the UC Risk and Safety Solutions Suite.

The Laser safety notebook

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

- A Standard Operating Procedure for every Class 3B and 4 laser
- Laser Registration Forms

Compliance Monitoring of the Laser Safety Program

The responsibility for safe use of lasers is placed on the Principal Investigator (PI). A system of consequences for deficiencies concerning safe use of lasers will be used for educating and alerting the PIs, motivating individual users, and determining future user authorization.

If problems are identified during the annual inspection, EH&S Radiation Safety will prepare a report indicating the items that are not in compliance and send the report to the PI and his/her lab contact with a correction date and request a confirmation of compliance. Serious or chronic non-compliance issues could result in a review by the Radiation Safety Committee.

The following step(s) may be taken by EH&S and by the Radiation Safety Committee to resolve non- compliance issues:

- EH&S Radiation safety performs a follow-up inspection with PI or lab contact
- Radiation Safety Committee Chair contacts the PI with a formal request to the PI and with copies to the Chair of the Department
- Radiation Safety Committee Chair formally informs the Vice Chancellor for Research and Economic Development (VCRED)

Medical Surveillance and Exposure Assessment

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 Radiation safety at 951-827-5528 if you have any questions.

Laser Injuries/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 a Safety Data Sheet. When an employee requires emergency treatment, the incident must be reported to EH&S (827-5528) as soon as possible.

Reporting Injuries
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 employee first report (EFR) must be completed and can be found by accessing the UCR website.
https://auth.ucr.edu/cas/login?service=https://portal.ucr.edu/uPortal/Login

Purchase, 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, and unwanted lasers. Generators of this unwanted material must follow UCR disposal requirements. Contact the EH&S hazardous waste team regarding disposal options.

Ordering Lasers and Laser Systems
EH&S Radiation Safety should be contacted prior to ordering class 3B and 4 lasers or laser systems.

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On Campus Transfer of Lasers and Laser Systems
Whenever lasers are being transferred from one laboratory to another, EH&S Radiation Safety must be notified and provided with the following information

- When the laser will be transferred
- The name of the PI receiving the laser
- The sending and receiving locations
- Serial Number of the laser being transferred

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

LASER CONTROLS

Administrative Controls

Laser Use Authorization

Application for Initial Use of Class 3B and 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 EH&S Radiation Safety, where it will receive an initial review. If the application appears to be adequate, a site visit will be scheduled with the PI to review the laser setup. Once all issues have been addressed, the application will be submitted to the UCR Radiation Safety Committee for review. The committee is comprised of two PIs that are laser users who will review the application and make recommendations to the remaining committee members.

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 EH&S Radiation Safety. More extensive changes will be subject to the same review and approval process as the original application.

Standard Operating Procedures (SOPs)

This first step requires each investigator or laboratory work group to assess all hazards associated with laser operations and describe safety precautions necessary to avoid employee exposures and injuries. SOPs must be specific to each laboratory operation, and must be reviewed and approved by the PI. After approval, SOPs are then incorporated into or attached to written materials and methods, must be readily available in the laboratory where the experiment or operation will be performed.

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: https://ehs.ucr.edu/laser/

Postings and Signage

The ANSI Z136.1 standard requires that lasers and laser systems have appropriate warning labels posted on the entryways to the laser use area. Signs for laser laboratory doors can be found on the EH&S website: https://ehs.ucr.edu/laser/signs.html

Laser Control Areas

Class 3B and Class 4 lasers shall only be operated in areas approved by EH&S Radiation Safety. 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 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 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.

- 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

- Infrared and Ultraviolet 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

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 EH&S Radiation Safety at 951-827-5528.

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. PPE should be addressed in SOP for the laser.

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 maximum permissible exposure (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 EH&S Radiation Safety 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. EH&S Radiation Safety can assist in identifying protective equipment that is appropriate for the intended use. This equipment must be addressed in the written standard operating procedure (SOP).

Training

Principal investigators 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 Class 3B and Class 4 laser users are required to complete Online Laser Safety Initial Training, should participate in a medical surveillance program and complete *site-specific training prior to performing this activity. A link to the courses that are offered is located on our EH&S Website: https://ehs.ucr.edu/training/online/index.html

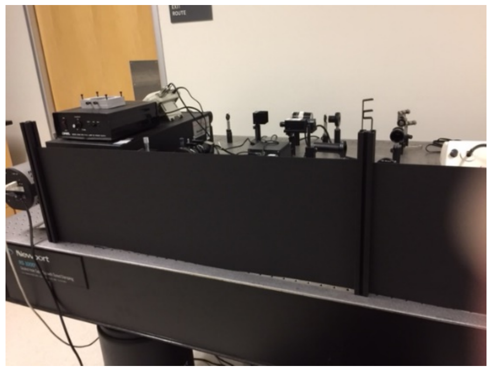
*Site-Specific Training

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 should include:

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

Site-specific training documents will be kept on file in the laboratory for review by EH&S Radiation Safety.

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.

Optical instruments for viewing laser systems must be equipped with filters, attenuators and interlocks to keep exposures below the maximum permissible exposure limit (MPE) 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 EH&S Radiation Safety

• 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 beam

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 specular 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 EH&S Radiation Safety 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 EH&S.

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 a safety data sheet (SDS). The SDS 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, face shields, and gloves 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 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 EH&S 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
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 Laser Generated Air Contaminants (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 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

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 **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.

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 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:
$D\lambda = -\log10\ \tau\lambda$, 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).

Ultrafast 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).

APPENDICIES

Appendix A 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.

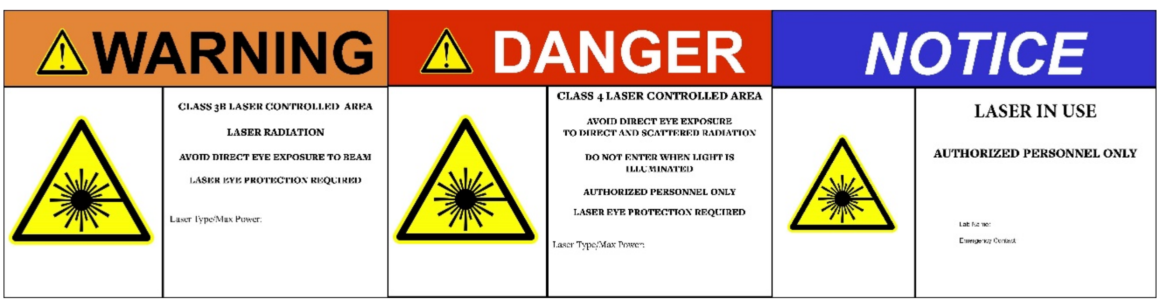
The most likely effects from exposure are afterimage, flash-blindness, and glare.

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

Appendix B Examples of Laser Signage



Appendix C Laser Applications Outside the Laboratory

Any Class 3B or 4 laser that is used outdoors for research projects must submit a Laser Use Authorization (LUA) and the following requirements must be addressed in the Standard Operating Procedure:

- Establish a Nominal Hazard Zone (NHZ) which is defined as any area where maximum permissible exposure (MPE) is exceeded. The NHZ must be posted, and the PI must ensure that only personnel that have completed initial on-line laser safety training are allowed to enter the NHZ and operate the laser. Proper PPE must be provided
- That laser beams shall not be directed toward structures, automobiles, aircraft, or other vehicles within the NHZ unless training and PPE is provided within these structures/vehicles.
- Provide Federal Aviation Administration (FAA) notification, which is required if the laser is being used in navigable airspace. Contact EH&S Radiation Safety for more information.

Lasers Used for Public Displays/Entertainment (Non-Research)

Any Class 3B or 4 laser used for entertainment displays, demonstrations, or any related use intended for public viewing (indoors or outdoors) shall be operated in accordance with federal, state, local, and campus regulations/requirements.

The operators of laser systems used for entertainment are required by law to file a "Report on Laser Light Show Display" (or variance document) with the Food and Drug Administration's Center for Devices and Radiological Health (FDA/CDRH). If the venue is outdoors and the beam(s) may terminate in navigable airspace, the operators are also required to file a report with the FAA.

Campus department, campus-affiliated groups (student or otherwise) shall notify EHS Radiation Safety of any laser light show (indoor or outdoor). EH&S Radiation Safety will request a copy of the CDRH required "Report on Laser Light show Display (or variance document) prior to the show. Upon receipt EH&S Radiation Safety shall review the description of the show and the operator's safety procedures, and may require additional safety measures to assure safety of operators, performers, or audience.

Laser Safety Requirements-Laser Light Shows (Note: A Laser Use Authorization is not normally required for laser light shows)

- The CDRH requirements must be met
- Any audience exposure to laser radiation must not exceed the ANSI class 1 limit
- Operators, performers, and employees must be able to perform their duties without having to directly view laser radiation exceeding the ANSI Class 1 limit, and without being exposed to laser radiation exceeding the ANSI Class 2 limit
- All laser scanners(including mirror balls) must incorporate proper scanning safeguards
- If the laser is not under continuous operator control, any Class 3R,3B, or 4 level of laser radiation cannot be closer than 6 m vertically or 2.5m horizontally from any standing surface or standing position where the audience may be located
- An operator with an accessible control to terminate the beam must be available if conditions become unsafe
- FAA notification is required(for Class 3r, 3b and 4 lasers) if the display is being used in navigable airspace
- Additional safety requirements may be required as specified by EH&S radiation safety
- The CDRH "Report on Laser Light Show Display" Form is available from EH&S Radiation Safety

Emergencies

In the event that an individual suspects an eye injury, the operators of the lasers system shall be notified immediately so the laser beam(s) can be terminated. The event staff shall also be notified and medical attention shall be provided to the injured individuals if needed. EH&S should be informed if a laser injury is suspected by calling 951-827-5528 between 8am-5pm or 951-827-5522(after 5 or on weekends and holidays).

Regulatory References

Food and Drug Administration's Center for devices and radiological Health (FDA/CDRH)

https://www.fda.gov/downloads/AboutFDA/ReportsManualsForms/Forms/UCM081634.pdf

Federal Aviation Administration (FAA)

https://www.faa.gov/documentLibrary/media/Order/7400.2G.pdf

American National Standards Institute (ANSI Z136.1 2014) Safe Use of Lasers

ANSI Z136.6 (2005) for safe use of lasers outdoors

Appendix D Additional References

ANSI Standards

Z136.1 Safe Use of Lasers

Z136.2 Safe Use of Optical Fiber Communication Systems Utilizing Laser Diodes LED Sources

Z136.4 Recommended Practice for Laser Safety Measurements

Z136.5 Safe Use of Lasers in Educational Institutions

Z136.6 Safe Use of Lasers Outdoors

Z136.8 Safe Use of Lasers in Research, Development, or Testing

Z136.9 Safe Use of Lasers in Manufacturing Environments

UCR Laser Safety Website: https://ehs.ucr.edu/laser/

This website has information on laser Training, forms, labels, and labels along with a list of vendors for laser supplies. ANSI Standards Z136.1, Z136.4, and Z136.5 are available at EH&S or can be purchased from Laser Institute of America at: https://www.lia.org/

UCR Laser Safety Contacts:

Karen Janiga, Radiation Safety Officer 951-827-5748

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