University of Colorado - Boulder

Laser Safety Manual

October, 2016

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Section 1

Introduction

The purpose of this manual is to ensure the safe use of lasers in research and instructional laboratories at the University of Colorado at Boulder. To achieve this goal, the University has adopted the American National Standard for Safe Use of Lasers, ANSI Z136.1-2007. ANSI Z136.1-2007 is recognized as a minimum standard for laser safety.

Most lasers are capable of causing eye injury from the direct beam and specular reflections. Class 4 lasers are also capable of causing eye injury from diffuse reflections, burning exposed skin, igniting flammable materials and generating hazardous air contaminants. Equipment used to produce the lasing action and control/direct the laser beam can introduce additional hazards associated with high voltage, high pressure, cryogenics, noise, non-ionizing radiation and toxic gases.

Scope

This program applies to all Class 3b and Class 4 lasers used in research and instructional laboratories at the University of Colorado at Boulder.

Responsibilities

Principal Investigators (PIs) are responsible for:
- Supervising laser use in the laboratory.
- Implementing and enforcing the safety recommendations and requirements outlined in this manual.
- Developing Standard Operating Procedures (SOPs) for the laboratory.
- Providing laser operators with hands-on training in operating, administrative and alignment procedures.
- Ensuring that all lasers in the laboratory are properly classified and labeled.
- Ensuring that the proper signs are posted at the entrance(s) to the laboratory.
- Registering all lasers with the CU Radiation Safety Office.
- Completing approved laser safety training.
- Notifying CU Radiation Safety immediately in the event of an exposure to a Class 3b or Class 4 laser beam or reflection.
- Providing adequate medical surveillance for laser users under their purview.

Laser Operators are responsible for:
- Following laboratory Standard Operating Procedures (SOPs).
- Informing the Principal Investigator of any departure from the SOPs.
- Notifying the Principal Investigator in the event of an exposure incident.
- Attending laser safety training.

The **Laser Safety Officer** (LSO) is responsible for:
- Conducting periodic safety audits of laser laboratories.
- Providing assistance in evaluating and controlling hazards.
- Updating the Laser Safety Manual.
- Maintaining records of registered lasers and laser safety training by campus personnel.
- Conducting laser safety training for all personnel working with lasers.
- Participating in accident investigations involving lasers.

Section II

Personnel Training and Qualifications

Only qualified personnel are permitted to operate a laser. The Principal Investigator will identify qualified personnel based on departmental training, technical training and other appropriate learning experience.

All staff and students operating Class 3b and Class 4 lasers should complete laser safety training prior to working with lasers.

Before operating a Class 3b or 4 laser, staff and students should:

- Review the Laser Safety Manual.
- Receive training from the Principal Investigator or laboratory supervisor covering safe operation of the laser to be used, administrative procedures, alignment procedures and other applicable Standard Operating Procedures.
- Review the operating and safety instructions furnished by the manufacturer.

Section III

Laser Classification

Lasers and laser systems are classified based on their capability of injuring personnel.

- Lasers manufactured after August 1, 1976 are classified and labeled by the manufacturer. The Principal Investigator shall classify lasers and laser systems that are constructed or modified in the laboratory.
- There are five laser hazard classes:
  - **Class 1** lasers and laser systems cannot emit accessible levels of radiation that are capable of causing eye injury under any normal operating condition. (A more hazardous laser may be embedded in a Class 1 product that is not accessible during normal operating conditions, but may be during service and maintenance.)
  - **Class 2** lasers and laser systems are visible lasers with an accessible output $\leq$ 1 mW. Class 2 lasers and laser systems are incapable of causing eye injury unless intentionally viewed directly for an extended period. The normal aversion response to bright light (blinking) protects the eye from a momentary exposure.
  - **Class 3a** lasers and laser systems have an accessible output between 1-5 mW and do not pose a serious eye hazard unless viewed through optical instruments.
  - **Class 3b** lasers and laser systems have an accessible output between 5-500 mW for continuous wave lasers and $<$ 0.125 J within 0.25 second for a pulsed laser. Class 3b lasers and laser systems pose a serious eye hazard from viewing the direct beam or specular reflections.
  - **Class 4** lasers and laser systems have an accessible output $>$ 500 mW for a continuous wave laser and $>$ 0.125 J within 0.25 second for a pulsed laser. Class 4 lasers and laser systems pose a serious eye hazard from viewing the direct beam, specular reflections and diffuse reflections. Class 4 lasers and laser systems also pose skin and fire hazards.

Section IV

Laser Bio-Effects

The site of damage and threshold at which damage occurs depends on the wavelength, whether it is a small or extended source, the exposure duration, whether it is continuous wave or pulsed, and, if pulsed, the pulse length and pulse repetition frequency.

Operating lasers under reduced external light conditions increases the optical hazards because of pupil dilation.

The Maximum Permissible Exposure (MPE) is the level of laser radiation that a person may be exposed to without experiencing adverse health effects. Contact the Laser Safety Officer for assistance in calculating the MPE.

Eye

Bio-effects of the eye are summarized in the following table:

SPECTRUM	LOCATION	EFFECT
UV-C (200-280 nm)	Cornea	Photokeratitis
UV-B (280-315 nm)	Cornea	Photokeratitis
UV-A (315-400 nm)	Lens	Cataract
Visible (400-780 nm)	Retina	Retinal injury*
IR-A (780-1400 nm)	Retina, Lens	Retinal burn, cataract
IR-B (1400-3000 nm)	Cornea, Lens	Corneal burn, cataract
IR-C (3000-1000000 nm)	Cornea	Corneal burn

*Retinal injury can be thermal, acoustic or photochemical.

Skin

Bio-effects of the skin are summarized in the following table:

SPECTRUM	LOCATION
UV-C (200-280 nm)	Erythema, cancer, accelerated aging
UV-B (280-315 nm)	Erythema, increased pigmentation, cancer, accelerated aging
UV-A (315-400 nm)	Erythema, increased pigmentation, skin burn
Visible (400-780 nm)	Photosensitive reactions, skin burn
IR-A (780-1400 nm)	Skin burn
IR-B (1400-3000 nm)	Skin burn
IR-C (3000-1000000 nm)	Skin burn

Section V

Registering Lasers

The Principal Investigator is asked to register all Class 3b and Class 4 lasers and laser systems in use. The Laser Safety Officer can help update the registry when lasers are taken out of service or new lasers are purchased/developed. The Laser Registration Form is available online:
http://ehsonline.colorado.edu/lasers

Section VI

Medical Surveillance

Medical surveillance of personnel working with certain lasers is recommended in the ANSI standard, and is the responsibility of the Principal Investigator.

Individuals operating Class 1, Class 2 and Class 3a lasers are exempt from medical surveillance.

Class 3b and Class 4 laser operators should have a *baseline eye examination* prior to using a laser. The exam should include:

- Ocular history
- Visual acuity
- Amsler grid test
- Color vision

It is recommended that incident personnel (individuals working in areas where there is potential for exposure to laser radiation from a Class 3b or Class 4 laser, but do not operate the laser) have a baseline eye examination for visual acuity.

An eye examination is also recommended when an individual terminates his or her work in a laser laboratory.

Section VII

Exposure Incidents

Medical attention should be sought in the event of an exposure or suspected exposure to laser radiation capable of causing an eye or skin injury.

Notify the Principal Investigator and Laser Safety Officer if an exposure incident occurs.

Section VIII

Laser Hazard Evaluation

Different high-power lasers have different individual hazards, including optical hazards, UV radiation, high voltages, ozone generation, toxic chemicals and gases, etc.

Prior to beginning work with a new laser, it is a good idea to perform a laser hazard evaluation to identify the hazards associated with a laser or laser system and to determine the necessary control measures. The Laser Safety Officer can provide assistance with the hazard evaluation if needed.

The hazard evaluation should take into account the following:

- The laser or laser system's capability of injuring personnel.
- The environment in which the laser is used.
- The personnel who may use or be exposed to laser radiation.

Section IX

Operation, Maintenance and Service

It is important to distinguish between operation, maintenance and service when considering control measures. Lasers and laser systems are classified based on the level of accessible laser radiation during normal operation. Maintenance tasks are performed to support routine performance of the laser or laser system, such as cleaning and replenishing expendables. Maintenance tasks may or may not involve access to the beam. Service occurs less frequently than maintenance and often requires access to the beam. Service tasks include replacing laser resonator mirrors and replacing or repairing faulty components.

Section X

Control Measures for all Laser Classes

The purpose of control measures is to prevent exposure to laser radiation above the MPE. Use engineering controls whenever possible. When engineering controls are not able to reduce exposure below the MPE, administrative controls and personal protective equipment should be used.

Protective Housing
Place lasers in protective housings whenever practical. When protective housings are not practical, the Laser Safety Officer may perform a hazard analysis to ensure that control measures are implemented to ensure safe operation.

Protective housings or service panels enclosing embedded Class 3b and 4 lasers should be interlocked or fastened closed in a way which requires special tools for removal.

When it is necessary to remove protective housings or service panels, a temporary laser controlled area should be established. A temporary laser controlled area will not have the built-in protective features that are part of a laser-controlled area, but provide all safety requirements to protect personnel within and outside the area. The temporary laser controlled area should include:

- Restricted access to the area.
- Control of the beam to prevent the beam and reflections from extending beyond the area.
- Removal of reflective materials in and near the beam path.
- Appropriate laser eye protection if there is a possibility of exposure to laser radiation above the MPE.
- A warning sign posted outside the area. (See Section XIX for the warning sign requirements.)

Collecting Optics
Collecting optics used to view the laser beam or its interaction with a material need to have permanently attached attenuators, filters or shutters to prevent hazardous levels of radiation from entering the eye.

Beam Control

- Ensure the beam height is not at the normal eye position of a person in a standing or seated position.
- Position the laser so that the beam is not directed toward doorways or aisles.

- Securely mount the laser system to maintain the beam in a fixed position during operation and limit beam movements during adjustments.
- Ensure beam path is well defined and controlled.
- Terminate the beam at the end of its useful path.
- Confine beams and reflections to the optical table. The addition of beam-stopping panels to the sides of the optical table is recommended.
- If the beam path extends beyond the optical table, a physical barrier needs to be used to prevent accidental exposure.
- Where feasible, have only diffusely reflecting materials in or near the beam path.
- Absorb unwanted reflections. Scatter should not be permitted.

Section XI

Additional Control Measures for Class 3b and Class 4 Lasers and Laser Systems

All of the control measures outlined in Section X should be met for lasers in use on campus. The following are additional requirements for Class 3b and Class 4 lasers and laser systems.

Nominal Hazard Zone (NHZ)
A NHZ shall be established for Class 3b and Class 4 laser applications which require an open beam. The NHZ is the area in which the level of direct, reflected or scattered laser radiation exceeds the MPE. The Laser Safety Officer can assist in defining the NHZ.

Laser-Controlled Area
A laser-controlled area should be established for Class 3b and Class 4 lasers. The laser-controlled area will contain the NHZ, if needed. The walls, ceiling and floor of the room often define the laser-controlled area.

Class 3b Laser Controlled Area

- Only personnel trained in the operation of the laser and laser safety should be permitted to operate the laser or laser system.
- An individual knowledgeable in laser safety needs to directly supervise the laser-controlled area.
- The area should be posted with appropriate warning signs. (See Section XIX.)
- Access should be restricted to the laser controlled area.
- The beam should be controlled to prevent any misdirected beams or reflections. (See Section X.C.)
- Eye protection should be provided for all personnel working in the laser-controlled area. (See Section XVII.)
- Cover all windows and other openings to prevent laser radiation from extending beyond the laser-controlled area

Class 4 Laser-Controlled Area
All of the requirements for a Class 3b laser-controlled area should be met. In addition, at least one of the following *entryway controls* must be incorporated into a Class 4 laser controlled area.

- *Non-Defeatable Entryway Safety Controls:*
  Non-defeatable safety latches or interlocks that deactivate the laser or reduce the output to levels below the MPE in the event of unexpected entry are the preferred method of entryway control.

- *Defeatable Entryway Safety Controls:*
  If non-defeatable controls limit the intended use of the laser, defeatable entryway safety controls may be used. Defeatable entryway controls allow authorized personnel to override the controls and should be used only if there is no laser radiation hazard at the point of entry. Personnel must be properly trained and provided with adequate personal protective equipment in this circumstance.

- *Procedural Entryway Controls:*
  If safety latches or interlocks are not feasible, procedural entryway controls may be used. When procedural entryway controls are used, the following conditions should be met:
  - All authorized personnel need to be adequately trained.
  - Personal protective equipment should be provided.
  - A door, barrier, screen or curtains should be used to block or attenuate the laser radiation below the MPE at the entryway.
  - The entryway should be equipped with a lighted laser warning sign that indicates the laser is operating

Permanently Attached Beam Stop or Attenuator
Some lasers or laser systems have long warm-up times, and it may not be practical to turn the power off to the laser when the laser is not in use. In these cases, Class 3b and 4 lasers should be equipped with a permanently attached beam stop or attenuator. The beam stop or attenuator must limit accessible laser radiation to below the MPE and be employed when the laser is not in use. For lasers that do not require warm-up time, it is a better practice to turn the power off when not in use.

Standard Operating Procedures
Written Standard Operating Procedures (SOPs) need to be developed for each laser system, covering operating, alignment, maintenance, and service activities. The Principal Investigator is responsible for writing the SOPs and providing them to the Laser Safety Officer for review. SOPs should then be reviewed with all laser personnel and posted in the area of the laser or laser system.

The manufacturer's operating manual is not a substitute for an SOP, though it may make up part of it. The SOP should express clear instructions for the individual laboratory.

SOPs should include:

- Data and information about the specific laser in use
- Contact information for Principal Investigator, Laser Safety Officer, and others
- Control measures for the unit
- Personal protective equipment required or recommended
- Start up and shut down procedures
- Experimental procedures
- Emergency procedures
- Non-beam hazards present in the laboratory

Output Emission Limitations
It is recommended that the laser or laser system be operated at the lowest level of power or radiant energy required for the application.

Section XII

Additional Control Measure for Class 3b and Class4 Single Pulse or Intermittant Operations

An alarm, a warning light or a verbal "countdown" command should be used during activation or startup of single pulse or intermittent operations.

Section XIII

Additional Control Measures for Class 3b and Class 4 Ultraviolet and Infrared Lasers

All of the control measures in Sections X-XII should be met. The following are additional control measures for Class 3b and Class 4 *ultraviolet and infrared* lasers:

- Visible or audible warning devices should be installed in areas where accessible laser radiation may exceed the MPE. These warning devices should be clearly identified and visible from all areas of potential exposure.
- Wear gloves, long sleeves and a face shield when manipulating UV beams
- Install shielding that will attenuate UV radiation levels to below the MPE.
- Infrared beam enclosures or backstops should be constructed of infrared absorbent materials. Enclosures, backstops or other materials that may contact a Class 4 infrared laser also need to be fire resistant.

Section XIV

Alignment

More laser accidents occur during beam alignment than any other laser manipulation. Use the following techniques to prevent accidents.

- Exclude unnecessary personnel from the laser controlled area during alignment.
- Perform alignment at the lowest possible power level.
- Use low-power visible lasers for path simulation of high-power visible or invisible lasers, when possible.
- Use a temporary beam attenuator over the beam aperture to reduce the level of laser radiation below the MPE, when possible.
- Wear laser safety eyewear during alignment. Alignment eyewear may be used when aligning a low power visible laser. (See section XVIII.)
- Use beam display devices (image converter viewers or phosphor cards) to locate beams when aligning invisible lasers.
- Use shutters or beam blocks to block high-power beams at their source except when needed during the alignment procedure.
- Use beam blocks to block high-power beams downstream of the optics being aligned
- Use beam blocks or protective barriers when alignment beams could stray into areas with uninvolved personnel.
- Place beam blocks behind optics such as turning mirrors to terminate beams that may miss the mirrors during alignment.
- Locate and block all stray reflections before proceeding to the next optical component or section.
- Ensure that all beams and reflections are terminated before resuming high-power operation.

Section XV

Enclosing Beam Path to Convert Laser or Laser System to Class I

A laser or laser system in which the entire beam path is enclosed and the enclosure fulfills all requirements of a protective housing is considered to be Class 1 and no further controls are needed. However, if the protective housing is removed, a temporary laser controlled area should be established and control measures applicable to the class of the embedded laser implemented. (See Section X.A.)

Modifications to commercial laser systems should be evaluated by the Laser Safety Officer.

Requirements for Protective Housings:
- Protective housings shall limit the accessible laser radiation below the MPE
- Protective housings shall prevent access to the laser during normal operations
- Protective housings shall be equipped with safety interlocks wherever the protective housing can be opened, removed or displaced.
- The safety interlocks shall be designed to prevent access to laser radiation above the MPE. (For example, the interlock may be electrically or mechanically interfaced to a shutter that interrupts the beam when the protective housing is opened or removed.)
- The safety interlock shall be fail-safe. The use of redundant electrical series connected interlocks would fulfill this requirement.
- Adjustments or procedures during service shall not cause the interlocks to be inoperative when the laser is placed back in operation.
- The protective housing shall be labeled in accordance with ANSI Z136.1-2000. (See Section XIX.C.)
- The embedded laser shall be labeled in accordance with ANSI Z136.1-2000. (See Section XIX.C.)

Section XVI

Confocal Microscopes

Laser scanning confocal microscopes are Class I laser systems that contain embedded Class 3 or Class 4 lasers. When the confocal microscope is used as intended, no control measures are necessary.

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

Section XVII

Controls for Non-Beam Hazards

Electrical Hazards
Use of lasers or laser systems presents an electric shock hazard. Most lasers contain high-voltage power supplies and capacitors or capacitor banks that store lethal amounts of electrical energy. Exposures may occur from contact with energized components operating at potentials of 50 volts and

above. These exposures most often occur during set up or installation, maintenance, modification and service when protective covers are removed.

To reduce electrical hazards:

- Lasers and associated electrical equipment must be designed, constructed, installed and maintained in accordance with the latest revision of the National Electric Code (NEC.)
- When protective housings or covers will be removed, potentially exposing energized components, the following measures must be followed:
    - Enclose high voltage sources and terminals whenever possible.
    - Turn off power and ground all high voltage points before working on power supplies.
    - Check that each capacitor is discharged and grounded prior to working near the capacitor. (Capacitors must be equipped with bleeder resistors, discharge devices or automatic shorting devices.)
    - Do not wear rings, watches or other jewelry when working with or near electrical equipment.

Laser-Generated Air Contaminants (LGAC)
Air contaminants may be generated when Class 4 and some Class 3b laser beams interact with matter. The quantity, composition and chemical complexity of the LGAC depend on the target material, cover gas and beam irradiance. Materials such as plastics, composites, metals and tissues may release carcinogenic, toxic and noxious air contaminants. Ozone is produced around flash lamps and can build up with high repetition rate lasers. Special optical materials used for far infrared windows and lenses may also release hazardous air contaminants.

Concentrations of LGAC must be maintained below the exposure limits specified by OSHA, NIOSH or ACGIH. There are three major control measures to reduce the concentration of LGAC to acceptable levels:

- Use local exhaust ventilation to remove the LGAC at the point of generation. Local exhaust ventilation should be vented to the outside.
- Isolate the process whenever possible.
- Respiratory protection shall be used only when engineering controls are not feasible. The Department of Environmental Health & Safety must be contacted prior to wearing a respirator.

Collateral and Plasma Radiation
Collateral radiation (radiation not associated with the primary laser beam) may be produced by system components such as power supplies, discharge lamps and plasma tubes. Radiation may be in the form of X-rays, UV, visible, IR, microwave and radiofrequency (RF.)

When high power pulsed laser beams (peak irradiance of 10^{12} W/cm^2 or greater) are focused on a target, plasma is generated that may also emit collateral radiation.

Contact the Laser Safety Officer for evaluation of these hazards. The LSO or other member of the Radiation Safety Office will evaluate hazards associated with ionizing radiation.

Fire Hazards
Class 4 laser beams can ignite flammable solvents, gasses and combustible materials. To reduce fire hazards:

- Terminate laser beams with non-combustible materials
- Bring only necessary materials into the laser area.
- Store flammable and combustible solvents and materials properly and away from the laser beam.

Explosion Hazards

High-pressure arc lamps, filament lamps and capacitor banks may explode if they fail during operation. The laser target and elements of the optical train may shatter during operation.

To reduce explosion hazards:

- Enclose high-pressure arc lamps and filament lamps in housings that can withstand an explosion if the lamp disintegrates.
- Enclose the laser target and optical train in protective housing during laser operation.
- Ensure that capacitors are equipped with current-limiting devices and are shielded.

Compressed Gases

Hazardous gasses are used in some laser applications including chlorine, fluorine, hydrogen chloride and hydrogen fluoride. Contact EH&S for questions regarding compressed gas safety.

Laser Dyes and Solvents

Laser dyes are complex fluorescent organic compounds that are dissolved in a solvent to form a lasing medium. Some dyes are highly toxic or carcinogenic. Most solvents suitable for dye solutions are flammable and toxic by inhalation and/or skin absorption.

The following measures should be followed when working with dyes:

- Whenever possible, do not use dimethylsulfoxide (DMSO) as a solvent for cyanine dyes because it aids in the transport of dyes through the skin and into the blood stream. If DMSO must be used, wear gloves. Disposable nitrile gloves may be worn if prolonged contact with DMSO is not anticipated. Other glove choices include neoprene, natural rubber and butyl gloves. PVA and PVC gloves are not recommended for use with DMSO. Obtain material safety data sheets (MSDSs) for all dyes and solvents prior to working with them.
- Prepare and handle dye solutions in a fume hood.
- Use disposable bench covers.
- Wear a lab coat, safety glasses and gloves.
- Pressure test all dye laser components before using dye solutions. Pay particular attention to tubing connections.
- Install spill pans under pumps and reservoirs.

Noise

Noise levels from some lasers, such as pulsed excimer lasers, may be high enough to require hearing protection. A good rule of thumb is: if it is difficult to conduct a normal conversation at approximately 3 feet away, hearing protection may be required. Contact EH&S for noise monitoring and assistance in selecting hearing protection.

Section XVIII

Laser Safety Eyewear

Enclosure of the laser equipment or the beam path is the preferred method of control. However, when enclosures are not feasible and there is a potential exposure to the beam or reflected beams at levels above the MPE, it may be necessary to wear protective eyewear.

Availability and Use of Laser Safety Eyewear

- Laser safety eyewear shall be available and worn by laser operators, incident personnel and visitors in laboratories where a Class 3b or Class 4 laser is present and there is a potential exposure to the beam or reflected beams at levels above the MPE.
- Laser safety eyewear is not required for Class 2 or Class 3a lasers unless intentional long-term (>.25 seconds) direct viewing is required.
- The Principal Investigator is responsible for ensuring that the appropriate eyewear is available and worn.

Selecting Laser Safety Eyewear

- Laser safety eyewear is wavelength specific.
- The following information is needed to select the appropriate laser safety eyewear:
  - Wavelength(s)
  - Mode of operation (continuous wave or pulsed)
  - Maximum exposure duration (assume worst case scenario)
  - Maximum irradiance (W/cm2) or radiant exposure (J/cm2)
  - Maximum permissible exposure (MPE)
  - Optical density (OD)

Contact the LSO for assistance in calculating the MPE and OD and selecting appropriate eyewear.

Laser safety eyewear should be chosen based on the level of protection needed to protect the eyes from a worst case scenario. If several laser safety eyewear products offer sufficient protection, the following factors should also be considered:

- Visible light transmission
- Effect on color vision
- Field of view provided by the design of the eyewear
- Reversible bleaching of absorbing media
- Need for prescription lenses
- Fit and comfort
- Impact resistance

Types of Laser Safety Eyewear

Glass: Glass laser eyewear is heavier and more costly than plastic, but it provides better visible light transmittance. There are two types of glass lenses, those with absorptive glass filters and those with reflective coatings. Reflective coatings can create specular reflections and the coating can scratch, minimizing the protection level of the eyewear.

Polycarbonate: Polycarbonate laser eyewear is lighter, less expensive and offers higher impact resistance than glass, but allows less visible light transmittance.

Diffuse Viewing Only (DVO): As the name implies, DVO eyewear is to be used when there is a potential for exposure to diffuse reflections only. DVO eyewear may not provide protection from the direct beam or specular reflections.

Alignment Eyewear: Alignment eyewear may be used when aligning low power visible laser beams. Alignment eyewear transmits enough of the specified wavelength to be seen for alignment purposes, but not enough to cause damage to the eyes. Alignment eyewear cannot be used during operation of high power or invisible beams and cannot be used with pulsed lasers.

Laser Safety Eyewear for Multiple Wavelengths
One pair of laser safety eyewear may not be sufficient when working with tunable or multiple wavelength lasers. Always check the OD and wavelength prior to use. Eyewear with multiband filters and flip-up eyewear are available for some applications.

Laser Safety Eyewear for Ultra-Fast (Femtosecond) Lasers
Temporary bleaching may occur from high peak irradiances from ultra-fast laser pulses. Contact the manufacturer of the laser safety eyewear for test data to determine if the eyewear will provide adequate protection before using them.

Labeling of Laser Safety Eyewear
Laser safety eyewear shall be labeled with the optical density and the wavelength(s) the eyewear provides protection for. Additional labeling may be added for quick identification of eyewear in multiple laser laboratories.

Inspection and Cleaning of Laser Safety Eyewear
Laser safety eyewear should be inspected periodically for the following:

- Pitting, crazing, cracking and discoloration of the attenuation material.
- Mechanical integrity of the frame.
- Light leaks.
- Coating damage.

Follow manufacturers' instructions when cleaning laser safety eyewear. Use care when cleaning eyewear to avoid damage to absorbing filters or reflecting surface.

Section XIX

Warning Signs and Labels

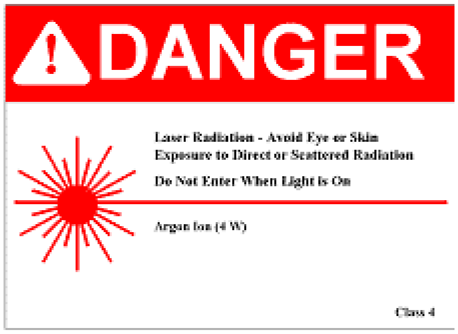
Lighted Warning Signs
Entrances to all laboratories where a Class 3b or Class 4 laser is present should have a *lighted warning sign* that is activated when the laser is energized.

Written Warning Signs
The following warning signs should be posted at the entrances to laboratories where lasers are present:

- Laboratories with a Class 2, Class 3a, Class 3b or Class 4 laser: A sign or label on the door stating "Caution – Laser Radiation"
- Alternately, laboratories with Class 3b and Class 4 lasers: A sign or label on the door stating "Danger – Laser Radiation." This wording may also be used for a Class 3a laser that generates a beam with an irradiance or radiant exposure equal to or greater than the MPE.

The "Danger" sign should indicate precautionary instructions or protective actions required, the type of laser or wavelength, the pulse duration (if applicable), the maximum output, and the class of the laser or laser system.

Example:

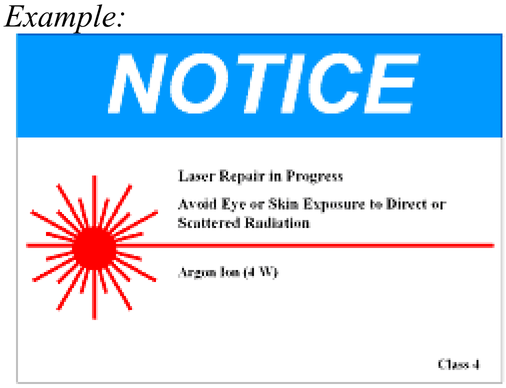


The "Caution" sign should indicate precautionary instructions, the type of laser or wavelength and the class of the laser or laser system.

Example:

The outside boundary of a *temporary laser controlled area* should be posted with a "Notice" sign indicating the reason for the temporary controls, the precautionary instructions or protective actions required, the type of laser or the wavelength, the pulse duration (if applicable), the maximum output, and the class of the laser.

Example:



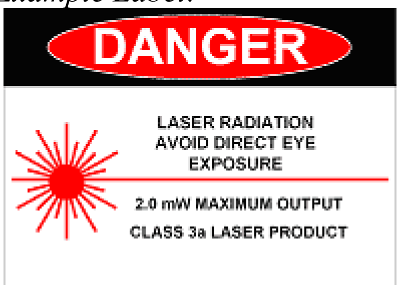
Labels

Lasers should be properly labeled in accordance with the ANSI standard.

- All Class 2, Class 3a, Class 3b and Class 4 lasers and laser systems should have a label conspicuously affixed to the housing. The label indicates the precautionary instructions or protective actions required, the type of laser or the wavelength, the pulse duration (if applicable),

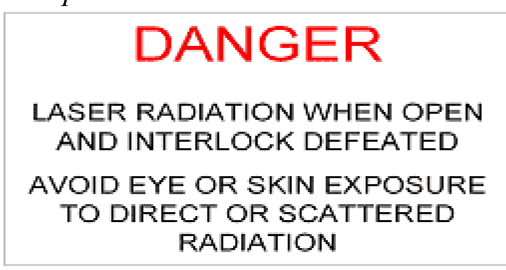
maximum output, and the class of the laser or laser system. The label usually incorporates the sunburst symbol.
- Manufacturers are required to label lasers in accordance with the Federal Laser Product Performance Standard (21CFR1040.10.) and these labels satisfy the ANSI requirement.
- Contact the LSO for label specifications if the laser was not labeled by the manufacturer, or if it was modified or built in the laboratory.

Example Label:



All removable protective housings will have a label affixed in a conspicuous location that conforms to the ANSI standard. The label indicates the hazard of the enclosed laser. This label does not need to contain the sunburst symbol.

Example:



Appendix A

Additional Resources

Information Resources
American National Standards Institute (ANSI) www.ansi.org
Laser Institute of America www.laserinstitute.org
Rockwell Laser Institute www.rli.com

Laser Safety Eyewear Resources
Lase-R Shield www.lase-rshield.com
UVEX www.uvex.com

Appendix B

Glossary

Accessible laser radiation
Laser radiation to which the human eye or skin may be exposed for the condition (operation, maintenance or service) specified.

American National Standard for Safe Use of Lasers (ANSI Z136.1-2007)
Document that provides guidance for the safe use of lasers and laser systems by defining control measures for each of four laser classifications. The University of Colorado has adopted this standard as a minimum standard for laser safety.

Attenuation
The decrease in the radiant flux as it passes through an absorbing or scattering medium.

Authorized personnel
Individuals approved by the Principal Investigator to install, operate or service laser equipment.

Average power
The total energy in an exposure or emission divided by the duration of the exposure or emission.

Aversion response
Closure of the eyelid or movement of the head to avoid an exposure to a noxious stimulant or bright light. Aversion response to an exposure from a bright laser source is assumed to occur within 0.25 seconds, including the blink reflex time.

Collateral radiation
Any electronic radiation, except laser radiation, emitted by a laser or laser system that is physically necessary for its operation.

Collecting optics
Lenses or optical instruments having magnification and thereby producing an increase in energy or power density. Such devices may include telescopes, binoculars or loupes.

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

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

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

Embedded Laser
An enclosed laser with an assigned class number higher than the inherent capability of the laser system in which it is incorporated, where the system's lower classification is the result of engineering features

which limits the accessible emission.

Failsafe 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.

Incident personnel
Individuals working in areas where there is a potential for exposure to laser radiation from a Class 3b or Class 4 laser, but do not operate the laser.

Infrared radiation
Electromagnetic radiation with wavelengths that lie within the range 0.7 µm to 1 mm.

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

Laser operator
See Authorized Personnel.

Laser controlled area
See Controlled Area.

Laser Safety Officer (LSO)
One who has the authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards. The LSO for the University of Colorado is on the staff of the Department of Environmental Health & Safety.

Laser system
An assembly of electrical, mechanical, and optical components that includes one or more lasers.

Maintenance
Performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser or laser system, which are to be performed by the user to ensure the intended performance of the product.

Maximum permissible exposure (MPE)
The level of laser radiation to which a 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 (joules/cm2) or irradiance (watts/cm2). The criteria for MPE are detailed in ANSI Z136.1.

Nominal hazard zone (NHZ)
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.)

Operation
The performance of the laser or laser system over the full range of its intended functions (normal operation.)

Optical density
Logarithm to the base ten of the reciprocal of the transmittance. The higher the optical density, the lower the transmittance.

Pulsed laser
A laser that delivers its energy in the form of a single pulse or a train 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, respectively.

Repetitive pulse laser
A laser with multiple pulses of radiant energy occurring in sequence.

Reversible bleaching
The absorbing filter of laser eyewear may become temporarily saturated from an ultrashort laser pulse, causing the beam to pass through.

Service
The performance of those procedures or adjustments described in the manufacturer's service instructions that may affect any aspect of the performance of the laser or laser system. These are usually performed by qualified technical personnel provided by the manufacturer or other service companies.

Specular reflection
A mirror-like reflection.

Ultraviolet radiation
Electromagnetic radiation with wavelengths smaller than those of visible radiation; for the purpose of this manual, 0.18 to 0.4 μm.

Visible radiation (light)
Electromagnetic radiation that can be detected by the human eye. This term is commonly used to describe wavelengths that lie in the range 0.4 to 0.7 μm.

Wavelength (λ)
The distance between two successive points on a periodic wave which have the same phase.