CSUDH

CALIFORNIA STATE UNIVERSITY, DOMINGUEZ HILLS

Laser Safety Program

Revised: July 5, 2023

Table of Contents

ACRONYMS

AEL – accessible emission limit
ANSI – American National Standards Institute
ASC – accredited standards committee
CDRH – Center for Devices and Radiological Health (USA)
CFR – Code of Federal Regulations
CPR – cardiopulmonary resuscitation
CW – continuous wave
FDA – Food and Drug Administration
FLPPS – Federal Laser Product Performance Standard Hz-hertz
IEC – International Electrotechnical Commission
IEEE – Institute of Electrical and Electronics Engineers
IR – infrared
J – joules
Laser – Light Amplification by Stimulated Emission of Radiation
LCA – Laser Controlled Area
LEP – laser eye protection
LGAC – laser generated air contaminants
LIDT – Laser-Induced Damage Threshold
LSO – Laser Safety Officer
LTIR – Laser-Target Interaction Radiation
MPE – Maximum Permissible Exposure
MSDS – Material Safety Data Sheet
NBH – non-beam hazard
Nd:YAG – neodymium doped yttrium-aluminum garnet
NEC – National Electrical Code
NFPA – National Fire Protection Association
NHZ – Nominal hazard zone
NLR – Non-laser radiation
NOHD – nominal ocular hazard distance
OD – optical density
OSHA – Occupational Safety and Health Administration
PPE – personal protective equipment
PRF – pulse repetition frequency
SDS – Safety Data Sheet
SOP – standard operating procedure
SSC – standards subcommittee
TL – threshold limit
TSC – technical subcommittee
UV – ultraviolet
VLT – visible luminous transmission

1.0 PURPOSE

The purpose of the CSUDH Laser Safety Program (LSP) is to ensure that lasers are used in a manner that will protect the health and safety of CSUDH students, faculty, and staff; eliminate danger to life and property; and comply with relevant State and Federal regulations. The LSP is based upon guidelines in ANSI Z136.1-2014, the American National Standard for Safe Use of Lasers. This standard covers the safe use of lasers operating between wavelengths of 180 nm and 1000 µm.

This LSP is based on the following components:

- Designation of a Laser Safety Officer (LSO) to manage the LSP
- Training of authorized personnel (LSO, operators, service personnel, and others)
- Application of adequate control measures for the mitigation of laser hazards
- Incident investigations of actual and near-misses
- Medical examinations when required
- Laser Safety Committee

2.0 SCOPE

The Laser Safety Program (LSP) applies to all CSUDH faculty, staff, and students who utilize lasers in the course of their job function, project research, or student studies. The LSP will be overseen by a designated Laser Safety Officer (LSO). A Laser Safety Committee (LSC) will be established to ensure that the required safety measures are implemented and maintained.

3.0 RESPONSIBILITIES

The following responsibilities exist under this LSP.

3.1 NBS Administration

- College of Natural & Behavioral Science Chairs are responsible for ensuring that Principal Investigators follow the elements outlined in this LSP and that safety standards and information are available to control the potential impacts of higher energy lasers (Class 3b and Class 4).

3.2 Laboratory Principal Investigators (PI) or Laboratory Supervisors who use Lasers

- Ensure that a Laser Use Application (LUA) is approved by the EHS prior to submission of purchase requisition for laser.
- Define the Laser Controlled Areas in conjunction with EHS.
- Work with LSO to develop a Laser Standard Operating Procedure that is laser and

area specific.

- Prior to using a laser, ensure all laser users receive adequate and appropriate laser safety and operational training. This must include section **6.1 LASER SAFETY TRAINING.**
- Ensure that non-participating lab personnel working in the laser laboratory receive awareness training and can recognize the nominal hazard zone, and warnings.
- Ensure all appropriate safety procedures are followed, that any laser safety devices(interlocks etc.) are functioning properly, and that the correctly rated goggles are available and used as appropriate.
- Ensure that properly rated goggles are worn whenever the beam is on and there is the potential for beam exposure.
- Supervise or provide adequate supervision of users, visitors, and service personnel.
- Provide adequate security to prevent unauthorized use.
- Correct and control all laser equipment and laser hazards.
- Ensure the LUA is posted on the inside of the main entrance door to the lab.

3.3 Student and Staff Using Lasers

- Be authorized and appropriately trained by PI prior to operating a potentially hazardous laser or entering the LCA.
- Follow all appropriate rules and procedures defined in the SOP and training documents,
- Immediately report accidents or potentially dangerous situations to the PI, LSO, or EHS.
- Students (graduate and undergraduate) may never work alone in the laboratory outside of normal work hours. Unless the P.I. has filled out the Hazard Evaluation form for working alone or independently. EHS recommends a minimum of two people in a lab when working after hours to ensure help can be called if one person has a medical emergency.
- Students are responsible for medical treatment costs if injured in a class or lab.

3.4 Service Personnel Working in LCA

- Obtain permission from PI, LSO, or EHS prior to starting work. Provide a two-week notice before service. If flashing light on door is on, then knock, and wait for lab personnel to open door.
- For Class 3B and 4 lasers, lock out power to laser system.
- Obtain laser safety training from LSO.
- Follow established laser safety protocols, procedures, and warning signs.

3.5 Laser Safety Officer (LSO)

- Review and approve submitted LUA.
- Develop SOPs in conjunction with PI.
- Conduct laser hazard evaluations and laser classifications.
- Ensure prescribed control measures are in effect.
- Approve wording on area signs and equipment labels.
- Approve all new or modified laser installation facilities and laser equipment prior to use.
- Provide consulting services on all matters pertaining to safe use of lasers.
- Chair Laser Safety Committee (LSC) and schedule, at minimum, an annual meeting.
- Suspend and/or terminate laser system if it is deemed not safe.
- Ensure training records are maintained per state requirements.
- Perform root cause analysis for known or suspected accidents resulting from the use of a laser.
- For Class 3b and Class 4 lasers, the LSO is responsible for identifying both the Maximum Permissible Exposure (MPE) that is possible and the Nominal Hazard Zone (NHZ) based on submitted SOP.
- Ensuring laser barriers are adequate in conjunction with PI.
- Develop and conduct training programs on this LSP and on *General Laser Safety Awareness.*
- Conduct annual audits of operating Class 3b and Class 4 laser safety systems to ensure compliance with this LSP and applicable ANSI guidelines.

4.0 LASER INFORMATION

4.1 Hazards

Laser stands for Light Amplification by Stimulated Emission of Radiation. Radiation emitted by lasers is generally non-ionizing (unlike x-rays or gamma rays). They typically do not have the energy to break atomic bonds, are monochromatic (mainly one wavelength), are coherent (beam doesn't spread out), and intense. Lasers usually operate in one or two modes: either continuous wave (CW) or pulsed. Pulsed lasers are generally more hazardous than continuous wave. Beams emitted by lasers can be visible or invisible. Lasers emitting invisible beams can be particularly hazardous.

Laser radiation can be hazardous to the eyes (thermal and retina burns) and skin (sunburn, accelerated skin aging, increased risk of cancer). Other hazards are chemical (e.g., toxic substances may be used or released) and electrical (e.g., electric shock). Lasers can cause fires, either from the beam or from associated electrical equipment.

The following key safety rules apply to laser beams:

- Wear Proper PPE prior to turning on power.
- Remove any reflective jewelry, any unnecessary sources of specular reflection in beam path.
- A person's eye level should not be at the same level as the beam, when seated or standing, to minimize unintended exposure.
- Keep body parts out of the beam path.

DO NOT permit a person to stare at a laser from within the beam path.

DO NOT point the laser at a person's eye.

4.2 Laser Classification System

Lasers are classified into different classes based on the ability of the beam to cause biological damage to the eye or skin during use. The higher the class, the more potential for biological damage can occur. The following lasers classes exist:

Class 1 Laser System: Considered incapable of producing damaging radiation levels duringoperation and exempt from any control measures.

Class 1M Laser Systems: Considered incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with collecting optics (e.g., telescope) and is exempt from any control measures other than to prevent potentially hazardous optically aided viewing.

Class 2 Laser Systems: Emits in the visible portion of the spectrum (400 nm to 700 nm) and eyeprotection is normally afforded by the aversion response (duration of a blink) for unaided viewing. These are usually Helium-Neon devices with a power output of 1 milliWatt (mW) or less.

Class 2M Laser Systems: Same as Class 2, but potentially hazardous when viewed with optical aids. Class 2M lasers should bear a CAUTION label stating, "**Do Not Stare Into Beam**."

Class 3R Laser Systems (previously classified as 3A): Has reduced control requirements and 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 a diffuse reflection hazard. Many laser pointers fall into this category. The power output of Class 3R lasers is < 5 mW.

Class 3B Laser Systems: May be hazardous under direct and specular reflection viewing conditions, but is normally not a fire hazard, diffuse reflection hazard, nor a laser generated aircontaminant (LGAC) production hazard. Some high-power green laser pointers fall into this category. Class 3B power output ranges from 5 mW to 500 mW.

Class 4 Laser Systems: Is a hazard to the eye or skin from the direct beam, may pose a fire hazard or diffuse reflection hazard, and may produce "laser generated air contaminants" (LGAC) and hazardous plasma radiation. Lasers with power ratings greater than 0.5 Watt (W)are Class 4. Table 1: Laser Classifications Summary and Associated Requirements

Class	Control Measures	Training	LSO	Engineering Controls
1	Not Required	Not Required	Not Required	Not Required
1M	Required	Application Dependent	Application Dependent	Application Dependent
2	Not Required	Not Required	Not Required	Not Required
2M	Required	Application Dependent	Application Dependent	Application Dependent
3R	Not Required	Not Required	Not Required	Not Required
3B	Required	Required	Required	Required
4	Required	Required	Required	Required

5.0 LASER SAFETY

5.1 Administrative Controls for Laser Safety

5.1.1 Laser Safety Committee (LSC)

CSUDH will have a Laser Safety Committee (LSC), which reviews applications for proposed use of any regulated laser device (Class 3B or Class 4). The LSC works with each applicant to set control measures that ensure compliance with the safety requirements. The LSC then issues a formal Laser Use Authorization (LUA). The College Laser Safety Officer (LSO) chairs the LSC and runs the laser safety program on a day-to-day basis. LSC shall be comprised of another EHS personal and a LUA holder, laser safety experts, and administrative personnel. The LSC meets at least annually.

5.1.2 Laser Safety Officer (LSO)

The LSO will manage the LSP and must meet the following requirements:

- Obtain a certification for an LSO Program from a competent laser-training organization(Laser Institute of America).
- Monitor LUA holders for compliance, perform routine inspections and report to the LSC.The LSO has the authority to shut down any laser operation that is judged to be an immediate danger. LSO actions are subject to review by the LSC.
- Complete hazard analysis, for Class 3B or Class 4 lasers or lower hazard class lasers with embedded Class 3B or Class 4, to determine nominal hazard zone (NHZ) and the appropriate **L**aser-**C**ontrolled **A**rea (LCA).
- Ensure administrative and engineering controls are in place before LUA are

approved.

- Ensure laser output data is valid so classification can be correctly based on maximum output power or radiant energy available for intended use. Typically, this information can be provided by the manufacturer.

5.1.3 Laser Use Authorization (LUA)

Operation of a Class 3b or 4 laser requires an approved LUA, which is readily accessible in the lab where the laser is operated. The LUA specifies locations, laser supervisor, trained users, laser power output, wavelength, and pertinent information related to safe operation. The LUAtemplate is shown in the Appendix and must be filled out and submitted to the LSO.

5.1.4 Standard Operating Procedure (SOP)

An SOP is required for all Class 3B and Class 4 lasers. The document is an integral part of each laser user's safety program. The SOP describes training, responsibilities of personnel, PPE, engineering and administrative controls and alignment procedures. Equipment-specific operating guidelines are also part of the SOP. See the Appendix section for the SOP template. The SOP should contain:

- Description of operation (s) proposed (SOP)
- Alignment procedures
- Output emission limitations if excessive power or radiant energy is accessible duringoperation
- Required education and training
- Identification of authorized personnel to operate, maintain, service laser
- Diagram of LCA and engineering controls (barriers, interlocks)
- Required postings and PPE
- Identification of supervisor in charge
- Beam termination
- Beam path secured to avoid path above or below eye level of a person in any standingor seated position
- Secured power shutoff
- Appropriate control measures identified in ANSI Z136.1
- Ensure Viewing Limited < MPE.

The process of aligning the laser for all Class 3B and Class 4 lasers must be documented in an SOP. The reason for this requirement is that **60 percent of all laser accidents occur during beam alignment and/or manipulation**.

Alignments should only be performed by those who have completed CSULearn laser safety training. Additionally, the following actions should be taken during alignment:

- Exclude unnecessary personnel from the LCA.
- Use low-power visible lasers for path simulation of higher power visible or invisible lasers when possible.
- Wear laser eye protection and protective clothing.
- When aligning invisible laser beams, use beam display devices such as image converter viewers or phosphor cards to locate beams.
- Perform alignment tasks at the lowest possible power level.
- Use a shutter or beam-block to block high-power beams at their source except when actually needed during the alignment process.

5.1.5 Indoor Laser Control Area Requirements (Class 3B or Class 4)

The Class 3B and Class 4 laser control area shall:

- Be controlled to permit lasers and laser systems to be operated only by personnel who have been trained in laser safety and in the operation of the laser or laser system
- Have posting at entrance with the appropriate area warning sign approved by the LSO; postings inside the control area may be necessary as determined by the LSO
- Have flashing red light posted at lab entrance to indicate laser is on
- Be operated in a manner such that the beam path is well defined
- Require the appropriate eye protection for personnel within the laser-control area
- Be under the direct supervision of an individual knowledgeable in laser safety
- Be located so that access to the area by spectators is limited and requires approval ofthe laser control area supervisor
- Have any potentially hazardous beam terminated in a beam stop of an appropriate material
- Have only diffusely reflecting materials in or near the beam path, where feasible
- Have the laser secured such that the exposed beam path is above or below eye level of a person in any standing or seated position, if possible, except as required for medical use
- Have all windows, doorways, open portals, etc., from an indoor facility either covered or restricted in such a manner as to reduce the transmitted laser radiation to levels at or below the applicable ocular MPE
- Require storage or disabling (e.g., removal of the key or lock-out/tag-out) of the laser or laser system when not in use to prevent unauthorized use
- All Class 4 areas or entry way safety controls **SHALL** be designed to allow both rapid egress by laser personnel **AT ALL TIMES**; admittance to the laser-controlled area under emergency conditions.

5.1.6 Spectators around Class 3B or Class 4 Lasers

Spectators shall be permitted within the LCA if they have completed appropriate training and are wearing required PPE, or equipment is powered down and locked out of service. In eithercase, spectators are not allowed to use the equipment in the LCA.

5.1.7 Service Personnel (All Classes)

Personnel who require access to Class 3B or Class 4 lasers or laser systems enclosed within a protective housing or protected area enclosure shall comply with the appropriate control measures of the enclosed or embedded laser or laser system. The LSO shall confirm that service personnel have the education and safety training commensurate with the class of the laser or laser system contained within the protective housing.

5.2 Engineering Controls

Engineering controls are preferred over administrative controls. All laser products that are sold, imported, or otherwise distributed to users must comply with the Federal Laser Product Performance Standard (FLPPS – http://www.fda.gov/Radiation-EmittingProducts/).
Laser products sold as a component, component subsystems, or repair parts by or for manufacturers of certified laser products are not required to comply with the FLPPS. The manufacturers of such component laser products are required to register these products with the CDRH (https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfPCD/classification.cfm). A laser or laser system may be developed or modified by a user for internal use only. User-developed or user-modified laser products **SHALL** have their engineering controls reviewed and approved by the LSO.

5.2.1 Protective Housing

A protective housing shall be provided for all classes of lasers or laser systems. The protective housing may require interlocks and labels. If a user-created enclosure does not meet the requirements of a protective housing (e.g., a non-interlocked cover), it shall be considered as abarrier or curtain. An advisory protective housing label that indicates the relative hazard of laser radiation contained within the housing shall be placed on all removable protective housings that have no safety interlock and which can be removed or displaced during operation, maintenance, or service, and thereby allow access to laser radiation in excess of the applicable MPE.

The LSO shall require posting advisory protective housing labeling on long distance {>3 m) beam conduits that contain beams operating above Class 1 levels. Such labeling shall be placed on the outside of the conduit at appropriate intervals (- 3 m), to provide warning of the relative hazards of laser radiation contained within the conduit. A laser sunburst logo-type symbol is not required on such advisory protective housing labels.

5.2.2 Operating a Laser without a Protective Housing (Class 3B or Class 4)

If a laser is operated without a protective housing, the LSO shall require a hazard analysis and ensure that adequate engineering control measures are implemented appropriate to the classof maximum accessible emission level. The addition of engineering controls may include, but are not limited to barriers, shrouds, beam conduits, and beam stops.

5.2.3 Interlocks on Removable Protective Housings (All Classes with Embedded Class3B or 4)

Protective housings that enclose Class 3B or Class 4 lasers or laser systems shall be provided with an interlock system that is activated when the protective housing is opened or removed during operation and maintenance. The interlock or interlock system shall be designed to prevent access to laser radiation above the applicable MPE. The interlock may, for example, be electrically or mechanically interfaced to a shutter that interrupts the beam when the protective housing is opened or removed.

5.2.4 Access Panels (All Classes)

Portions of the protective housing that are only intended to be removed from any laser or laser system by service personnel, which then permit direct access to laser radiation associated with a Class 3B or Class 4 laser or laser system, shall either:

- Be interlocked (fail-safe interlock not required); or
- Require a tool for removal and shall have an appropriate warning label on the panel.

If the interlock can be bypassed or defeated, a warning label with the appropriate indications shall be located on the protective housing near the interlock (see 4.6.6). The label shall include language appropriate to the laser hazard (see 4.6.1.3). The interlock design shall not permit theservice access panel to be replaced with the interlock remaining bypassed or defeated.

5.2.5 Equipment Labeling

All laser equipment shall have appropriate warning labels. The label shall be affixed to a conspicuous place on the laser housing or control panel. Such labels should be placed on boththe housing and the control panel if these are separated by more than 2 meters.

5.2.6 Key Control (Class 3B or Class 4)

Class 3B or Class 4 lasers or laser systems ***should be provided with a master switch***. This master switch shall affect beam termination and/or system shutoff and shall be operated by a key or by a coded access (such as a computer code). As an alternative, the master switch can be designedto allow system activation using a momentary switch action (or alternative) that initiates system operation with the option that the key (or alternative) can be removed after

operation commences. In this mode, if the system ceases to operate, the key switch (or alternative) must again be used to restart the laser or laser system.

A single master switch on a main control unit shall be acceptable for multiple laser installationswhere the operational controls have been integrated.

All energy sources associated with Class 3B or Class 4 lasers or laser systems shall be designedto permit lockout/tag-out procedures required by the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor (see Section 10).

5.2.7 Viewing Windows and Diffuse Display Screens (All Classes)

All viewing windows and diffuse (reflective or transmitted) display screens included as an integral part of a laser or laser system shall incorporate a suitable means (such as interlocks, filters, attenuators) to maintain the laser radiation at the viewing position at or below the applicable MPE as determined by the LSO.

Note: Flammability and decomposition products are important factors to consider in the selection of window and display screen materials. It is essential that the material used for viewing windows and diffuse display screens does not support combustion or release LGAC above the current occupational limits following exposure to laser radiation unless the proper safeguards are in place to ensure personnel safety.

5.2.8 Collecting Optics

All laser protective viewports and films sold other than as an integral part of a product should be labeled with the optical density and the spectral region for which protection is afforded. This information shall be obtained from the original equipment manufacturer.

5.2.9 Facility Window Protection (Class 3B or Class 4)

Facility windows (exterior or interior) that are located within the NHZ of a Class 3B or Class 4 laser or laser system shall be provided with an appropriate absorbing filter, scattering filter, blocking barrier, or screen that reduces any transmitted laser radiation to levels below the applicable MPE. Such laser windows shall be specifically selected to withstand direct and diffusely scattered beams. In this case, the window barrier shall exhibit a damage threshold for beam penetration for a specified exposure time commensurate with the total hazard evaluationfor the facility and specific application.

Note: Flammability and decomposition products are important factors to consider in the selection of the window material. It is essential that the window does not support combustionor release toxic airborne contaminants following a laser exposure.

All laser protective windows, sold other than as an integral part of a product, shall be labeled with the optical density and wavelength(s) for which protection is afforded. Such

windows should also be labeled with the exposure time for which the limit applies and the conditions under which protection is afforded.

5.2.10 Laser Protective Barriers and Curtains (Class 3B or Class 4)

A blocking barrier, screen, or curtain that can block or filter the laser beam at the entryway should be used inside the LCA to prevent the laser radiation from exiting the area at levels above the applicable MPE. In some cases, where the barrier does not extend completely to the ceiling or to the floor, the LSO shall conduct an NHZ analysis to ensure safety is afforded to all workers outside the barrier-protected area.

Laser barriers shall be specifically selected to withstand direct and diffusely scattered beams. The barrier shall exhibit a damage threshold for beam penetration for a specified exposure time commensurate with the total hazard evaluation for the facility and specific application.

Note: Flammability and decomposition products are important factors to consider in theselection of the barrier material.

All laser protective barriers sold other than as an integral part of a product shall be labeled withthe barrier exposure time for which the limit applies and the beam exposure conditions under which protection is afforded.

5.2.11 Collecting Optics (All Classes)

All collecting optics (e.g., lenses, telescopes, microscopes, endoscopes, and eye-loupes) that integrate the use of a laser or laser system shall incorporate suitable means, such as interlocks,filters, and attenuators, to maintain the laser radiation transmitted through the collecting optics to levels at or below the applicable MPE, as determined by the LSO.

Note: Normal or prescription eyewear is not considered collecting optics.

All permanently mounted collecting optics housings containing laser protective filters sold other than as an integral part of a product shall be labeled with the optical density and wavelength(s) for which protection is afforded. All collecting optics filter housings should also be labeled with the threshold limit (TL) and exposure time for which the limit applies and the conditions under which protection is afforded.

5.2.12 Beam Paths (Class 3B or Class 4)

Control of the laser beam path shall be accomplished as described in the following:

5.2.12.1 Fully Open Beam Path (Class 3B or Class 4)

In applications of Class 3B or Class 4 lasers or laser systems where a beam path is enclosed a laser hazard evaluation shall be conducted by the LSO. In some cases, the total hazard assessment may be dependent upon the nature of the environment, the geometry of the

application, or the spatial limitations of other hazards associated with the laser use. This may include, for example, localized fume or radiant exposure hazards produced during laser material processing or surgery, robotic working envelopes, location of walls, barriers, or other equipment in the laser environment.

5.2.12.2 Limited Open Beam Path (Class 3B or Class 4)

In applications of Class 3B or Class 4 lasers or laser systems where the beam path is confined bydesign to significantly limit the degree of accessibility of the open beam, a hazard analysis shall be conducted by the LSO. The analysis will define the area where laser radiation is accessible at levels above the appropriate MPE and will define the appropriate control measures in that area. The LSO shall establish controls appropriate to the magnitude and extent of the accessible radiation.

5.2.12.3 Enclosed Beam Path (All Classes)

In applications of lasers or laser systems where the entire beam path is enclosed and the enclosure fulfills all requirements of a protective housing [i.e., limits exposure to laser radiation to levels at or below the applicable MPE, the requirements of Class 1 are fulfilled, and no further controls are required. When the protective housing requirements are temporarily relaxed, such as during service, the LSO shall affect the appropriate controls.

These may include establishing a temporary laser-controlled area and instituting appropriate administrative controls.

Protective housings that are of sufficient size to allow personnel within the enclosure require special interlocking (see 4.4.2.1.2).

5.2.13 Area Warning Device (Class 3B or Class 4)

A Class 3B laser-controlled area should and a Class 4 laser-controlled area shall have an area-warning device that is visible prior to entering the area. The purpose of the area warning deviceis to ensure that persons who are about to enter the laser-controlled area are aware that a laser is emitting or is about to begin emitting accessible laser radiation within the area.

5.2.13.1 Visible Warning Device

A visible warning device is any device, mechanical or electrical, that indicates when the laser is operating. Examples include a single lamp, a laser warning sign that is lighted, or flashes when the laser is operating. The warning device shall be visible through laser eye protection. This light or lighted sign can be electrically interfaced and controlled by the laser power supply so that the light is on (or flashing) only when the laser is operating. If used, the emission indicator should be clearly noticeable under all anticipated lighting conditions, be conspicuously different from general lighting, and have a specific meaning within the operational area where it is used.

Note: Typically, green designates "safe," yellow designates "energized," and red designates "emitting."

5.2.13.2 Audible Warning Device

This device may be used to warn individuals in a greater space than the immediate laser area about startup or activation of the laser(s).

5.2.13.3 Laser Radiation Emission Warning (Class 3B or Class 4)

Within the laser-controlled area, an audible or visible laser radiation emission warning device (or emission indicator) should be used with Class 3B and **shall** be used with Class 4 lasers or laser systems during activation or startup. The purpose of this radiation emission warning is to ensure that persons already within the laser-controlled area are aware that a laser is emitting or is about to begin emitting accessible laser radiation within the area. The most common laser radiation emission warning device is a single (red) light located on the laser or its control panel.This form of emission warning device is a requirement for any Class 3B or Class 4 laser or laser system certified for compliance with the CDRH or with IEC standards.

5.2.13.4 Visible Laser Radiation Emission Warning Devices

All lasers and laser systems complying with the CDRH or with IEC standards will have a visible laser radiation indicator. However, the LSO may determine that this visible laser radiation emission indicator is not easily visible everywhere within the laser-controlled area. In such cases, the LSO should consider adding another indicator such as a laser warning light or lighted sign that is viewable within the laser-controlled area and indicates when the laser is operating. This light or lighted sign **should** be electrically interfaced and controlled by the laser power supply so that the light is on or perhaps flashing only when the laser is operating. This indicator should be visible through laser protective eyewear.

Another possible configuration can be a warning light assembly that may be interfaced to the laser controller to indicate conditions of enabled laser (high voltage on), laser on (beam on), and area clear (no high voltage or beam on). A green light should be used to indicate a safe condition. In this case, the green light will indicate when the laser is not operational (high voltage off) *and* by an additional (yellow) light when the laser is powered up (high voltage applied, but no laser emission) *and* by an additional (flashing optional) red light that activates when the laser is operating.

5.2.13.5 Audible Laser Radiation Emission Warning Devices

For single-pulse lasers or laser systems, an audible warning system may commence operation when the laser power supply is charged for operation, for example, during the charging of capacitor banks.

Note: Any distinctive and clearly identifiable sounds that arise from auxiliary equipment (such as a vacuum pump or fan) and that are uniquely associated with the emissionof laser energy are also acceptable as audible warnings.

5.2.13.6 Other Considerations

The LSO **SHALL** also consider alternative control measures for the hearing and visually impaired.

5.2.14 Laser Controlled Area (Class 4)

In the Laser Controlled Areas, the following must be designed into the location.

5.2.14.1 Rapid Egress

All Class 4 area or entryway safety controls shall be designed to allow both rapid egress by laser personnel **AT ALL TIMES** and admittance to the laser-controlled area under emergency conditions.

5.2.14.2 Emergency Conditions

For emergency conditions, there shall be a clearly marked "Emergency Stop" or other appropriately marked device suitable for the intended purpose (remote controlled connector or equivalent device) of deactivating the laser or reducing the output to levels at or below the applicable MPE.

5.2.14.3 Entryway Controls

All Class 4 laser-controlled areas shall incorporate one of the following alternatives:

- Non-Defeatable (non-override) Area or Entryway Safety Controls

Non-Defeatable entryway interlocks (e.g., electrical switches, pressure-sensitive floor mats, infrared, or sonic detectors) **shall** be used to deactivate the laser or reduce power output below the applicable MPE in the event of unexpected entry into the laser-controlled area (see Figure 1).

- Defeatable Area or Entryway Safety Controls.

Defeatable entryway interlocks **shall** be used if Non-Defeatable controls limit the intended use of the laser. Applications requiring operation without interruption (e.g., long term testing) would be justified if it is clearly evident that there is no laser radiation hazard at thepoint of entry. Override of the safety controls shall be permitted to allow access to authorized personnel provided that they have been adequately trained and provided with adequate PPE (see Figure 2).

Figures 1 and 2 may be found on page 34

- Procedural Area or Entryway Safety Controls.

Where interlocks are not feasible or are inappropriate (e.g., medical procedures, service procedures, shared spaces) the following shall apply (see Figure 2):

1) All authorized personnel shall be adequately trained and be provided with adequate personal protective equipment shall be provided upon entry.

2) A door, blocking barrier, screen, curtains, etc., shall be used to block, screen, or attenuate the laser radiation at the entryway. The level of laser radiation at the exteriorof these devices shall not exceed the applicable MPE, nor shall personnel experience any exposure above the MPE immediately upon entry.

3) At the entryway, there shall be an area-warning device indicating that the laser isenergized and operating at Class 4 levels.

5.2.14.4 Scanning Devices

Scanning devices, including rotating mirrored balls, shall incorporate a means to prevent laser emission if scan failure or other failure resulting in a change in either scan velocity or amplitude would result in exposures above the MPE.

5.3 Personal Protective Equipment (PPE)

PPE shall be determined by the LSO and the PI. For a detailed discussion on PPE, see ANSI Z136.1.

5.3.1 Laser Eye Protection (LEP)

Eye protection devices that are specifically designed for protection against radiation from Class 3B and Class 4 lasers or laser systems shall be required within the NHZ and their useenforced according to the SOP for the lab.

LEP may include goggles, face shields, spectacles, or prescription eyewear using special absorptive filter materials or reflective coatings (or a combination of both) to reduce the potential ocular exposure to or below the applicable MPE.

The following factors shall be considered when selecting appropriate LEP to use:

- Laser power and/or pulse energy
- Wavelength(s) of laser output
- Potential for multi-wavelength operation

- Radiant exposure or irradiance levels for which protection (worst case) is required
- Exposure time criteria
- MPE
- Optical density requirement of eyewear filters at laser output wavelength(s)
- Angular dependence of protection afforded
- Visible luminous (light) transmission (VLT) requirement and assessment of the effect of the eyewear on the ability to perform tasks while wearing the eyewear (if VLT < 20%, there may be insufficient light to perform the intended task)
- Need for side-shield protection and maximum peripheral vision requirement
- Radiant exposure or irradiance and the corresponding time factors at which laser safety filter characteristics degradation occurs, including saturable absorption especially for ultrashort (ultrafast) pulse lengths
- Need for prescription glasses
- Comfort and fit
- Strength of materials and capability of the front surface to produce a hazardous specular reflection
- Requirement for anti-fogging design or coatings
- LEP is to be cleaned and inspected annually to ensure a satisfactory condition

Users of LEP shall be trained to understand potential early signs of damage. These may include, but are not limited to, smoke, flame, incandescence, and luminescence.

5.3.2 Skin Protection

Skin protection around Class 4 lasers can best be achieved through engineering controls. In some cases, a laboratory jacket or coat may be used if fibers are tightly woven, and the fabric is flame-retardant. LSO and PI approval is required for PPE.

5.4 Warning Signs

Warning signs shall be used with Class 3b and Class 4 laser systems to conform with ANSI Z535.2 requirements. A standard sign used at CSUDH, meeting the ANSI standard, is shown in Figure 3. Four different signal words can be used with the following definitions:

DANGER – Indicates an immediately hazardous situation that, if not avoided, could result indeath or serious injury. Limit use of this word to the most extreme conditions.

WARNING – Indicates an imminently hazardous situation that, if not avoided, could resultin death or serious injury.

CAUTION – Indicates a hazardous situation that, if not avoided, could result in minor or moderate injury.

NOTICE – Is the preferred signal word to address practices not related to personal

injury.The safety symbol shall not be used with this word. This signal word shall not be used in place of DANGER, WARNING, or CAUTION.

Figure 3. The signage shall be easily visible to laboratory occupants and visible from each access point into an area. See ANSI Z535.2 for more information.

5.5 Non-Beam Hazards

Non-beam hazards (NBH) are all hazards arising from the presence of a laser system, excluding direct exposure of the eyes or skin to a laser beam. NBH may occur when a material is exposed to a laser beam (e.g., fire or airborne contaminants), when materials usedto generate the beam (e.g., flow- through gases, dyes and solvents) are released into the atmosphere, or when individuals contact system components (e.g., electrocution). Some NBH can be life threatening (e.g., electrocution, fire), and may require use of more stringent control measures than those discussed in Section 5.1. NBH include but are not limited to the following areas:

5.5.1 Physical hazards:

- Electrical hazards
- Non-laser radiation
- Fire hazards
- Explosion hazards
- Noise (e.g., pulsed excimer lasers)

- Nanoparticles from interaction of high energy lasers with solids
- Fiber optic fragment hazards

5.5.2 Chemical hazards:

- Laser-generated air contaminants
- Compressed gases
- Laser dyes and solvents
- Chemical agent control measures

All written SOPs shall address non-beam hazards in addition to beam hazards. Due to the diversity of NBH, assistance may be needed from safety, health physics, or industrial hygieneprofessionals.

6.0 TRAINING

6.1 Laser Safety Training

This Laser Safety Program is a specific subset of the General Lab Safety Training Program. All involved in the use of college-regulated lasers shall be currently trained and in good standing with respect to the overall General Laboratory Safety Training Program.

6.1.1 General Training

Laser safety training must effectively communicate, to the users, the control measures and potential hazards of the laser equipment involved. Training is required for Class 1M, 2M, 3B,and 4 lasers.

Any staff and faculty responsible for the operation of a laser must ensure that all appropriate personnel and students receive training prior to operation of the laser. Training will be conducted by the LSO and documented.

General training will consist of the following:

- Read the CSUDH Laser Safety Program document
- Read latest copy of the LIA Laser Safety Guide
- The General Laser Safety Training

The Laser Safety Guide can be purchased online from www.lia.org for $25 or a copy can bechecked out from the EHS Safety Office.

The LSO will document the training. Device-specific training will be provided by the laser supervisor or principal investigator.

6.1.2 Refresher Training

Refresher training will be required for those who have stopped working with lasers for more than six months. They will need to repeat the training listed in section 7.1.1.

6.1.3 Trainer Expertise and Content

Education and training programs shall be conducted by individuals with training skills adequate and appropriate to the subject matter being taught. Each person shall have access to the LSP and specific SOPs that apply to their systems.

6.1.4 Laser Training Materials References

The following sources can be used to obtain information on laser safety. Copies are available in the EHS Safety Office.

- ANSI Z136.1 -2014 American National Standard for Safe Use of Lasers
- ANSI Z136.4 -2010 Laser Safety Measurements for Hazard Evaluation
- Laser Safety Guide by Laser Institute of America
- FLPPS http://www.fda.gov/Radiation-EmittingProducts/

6.2 LSO Training

The LSO will be trained on potential hazards, control measures, and applicable standards pertaining to laser safety. The training should apply to the highest class of laser under the jurisdiction of the LSO. Training can be satisfied by completion of LIA LSO training course which meets LSO training requirements outlined by ANSI and OSHA.

7.0 LASER INCIDENTS

7.1 Laser Incidents or Near Miss Incidents

If an incident or near-miss occurs from the use of a Laser, the user must notify the PI and LSO. The LSO will conduct a root cause analysis of the incident and review with the LSC to determine corrective actions.

7.2 Examination Following a Suspected or Actual Laser Induced Injury

If it is determined that a medical examination is required due to personnel contact with laser beam, radiation, laser produced air toxins, etc., then they shall be performed as soon as practical, usually within 48 hours.

During an emergency, **DIAL 911 FROM ANY OFFICE PHONE** or use one of the special CSUDH emergency phone boxes strategically located throughout campus and inside

buildings. These are direct lines to CSUDH Public Safety. Give them as much information as possible.

For non-emergency type injuries, the following applies to students:

1. Go to the Student Health Services for initial treatment when possible. If the student needs to be transported to the SHC or elsewhere, campus Public Safety will make arrangements.
2. Student must notify their supervisor.
3. Supervisor in charge of the area must file an Incident Report. These forms are available from the LSO or EHS website. **DO NOT** have the injured student fill out the Incident Report; the lab supervisor is required to complete the report. Turn in the completed form to the LSO or EHS.
4. Injured students are responsible for all medical costs incurred through treatment at any location other than SHS. This includes treatment sought for severe injuries (necessitating off-campus treatment) or injuries that occur when the SHC is closed. **EVEN IF THE STUDENTWAS INJURED IN CLASS**.

For non-emergency type injuries, the following applies to Faculty/Staff:

1. If the injury does not require emergency assistance but does require medical attention contact Shaun Milton from Workers Comp. The employee will need to:
    a. Complete an Employee's Claim for Workers Compensation Benefits Form
    b. Complete an Authorization for Medical Treatment Form for the appropriate facility
    c. Arrange transportation to medical facility.
    d. Supervisor must complete Supervisor Review Form and submit to WorkersCompensation Coordinator within one working day.
    e. Forms are located: https://www.csudh.edu/hr/workers-compensation/
2. If the employee feels the injury is not serious enough to warrant medical attention, then the supervisor needs to prepare an Accident Investigation Report Form. Send the completed form to EHS.
    a. Form is located: https://www.csudh.edu/Assets/csudh-sites/rm-ehos/docs/environmental/Forms/Incident_Form_Rv_6_Non_MVA.pdf

8.0 LSP CHANGE LOG

The Laser Safety Program will be reviewed annually with updates recorded on the CSUDH EHS website.

https://www.csudh.edu/ehs/health-safety-programs-policies/

9.0 APPENDIX

9.1 Standard Operating Procedure Template

INSTRUCTIONS: Please save the CSUDH SOP LASER template as a separate document and then updatethe text to customize an SOP for your laser application. When complete, email the completed SOP to the CSUDH LSO or CHO.

SOP LASER template is located: [EHS website insert here]

Fill in information regarding the following:

Prerequisites

Training:

All persons who intend to operate a laser, or who could be exposed to a hazardous laser beam, or its reflection must receive documented CSUDH Laser Safety Training from the Principal Investigator or the CSUDH Laser Safety Officer or Chemical Hygiene Officer.

Persons intending to operate a laser must receive training from the Principal Investigator or their designee, with respect to the safe operation of a specific laser. This training must be documented.

Medical Surveillance:

Not required at this time.

Responsibilities (see LSP):

Principal Investigator:

- Details regarding how laser users receive adequate and appropriate laser safety training prior to operating the laser(s). This training must include the review of the ***CSUDH Laser Safety Program***. This training must be documented. The PI is also responsible for training laser users in the specific operation of individual lasers; this training should be documented. Each student must have ready access to a copy of the written operations guide.
- Ensure that all appropriate safety procedures are followed, that any laser safety devices(interlocks etc.) are functioning properly.
- Ensure that properly rated goggles are worn if a user could potentially be exposed to ahazardous beam or its reflection.
- Determine the nominal hazard zone (NHZ) of the laser. Safety devices such as beam stops, wall blocks, interlocks etc. must be used whenever possible to reduce the size ofthe NHZ.

- Supervise or otherwise ensure the adequate supervision of users, visitors and service personnel as appropriate, and provide adequate security to prevent unauthorized use.
- Correct and control all laser equipment and laser hazards, as appropriate.

Laser Users

- Must be authorized and appropriately trained to **either operate** or **be in the presence** ofa potentially hazardous laser.
- Must wear properly rated goggles if the individual could be exposed to a hazardous beam or its reflection.
- Adhere to all appropriate rules and procedures.
- Immediately report any accidents or potentially dangerous situations to the LSO, Supervisor and/or safety personnel. Common sense and prudent practice must be considered at all times when operating a laser.

The Laser Safety Officer (LSO) is responsible for implementing the CSUDH laser safety policies. Specifically, the LSO will be responsible for periodic safety review of laser facilities, performing basic laser safety training, evaluating protective equipment, and initiating corrective measures as necessary.

Protective Equipment

Protective eyewear must be worn that is appropriate for the power and wavelength(s) of the lasers in use must in accordance with Section 6.0 of this procedure.

A lab coat or other protective apparel should be worn by personnel if laser operations involvethe emission of UV radiation.

A lab coat and fully enclosed chemical splash goggles will be worn at all times while working with chemicals that could injure the eyes or skin. Appropriate laser goggles shall be worn in lieuof chemical goggles when the potential exists for the eyes to be exposed to a hazardous beam or its reflection.

Alignment

For the Laser Alignment Process, describe your alignment procedure **step-by-step**.

- Include all safety features described below which apply to your setup.
- Describe how your setup will prevent someone accidentally getting expose to the beam.
- Detail appropriate security measures to restrict access to the laboratory during theAlignment Process to protect personnel not wearing protective equipment from exposure.
- Assemble all needed items or tools to perform the alignment. Remember to

keep objects off the laser table which may cause specular reflections.

- The laser should be set to the lowest practical power while performing alignments.
- **Avoid working with the room lights off**. Reducing the illumination in the room causes the pupils to dilate and increases the possibility of eye injury. The potential for electricalshock or other hazard also increases when vision is hampered.
- Appropriate eye protection must be worn by persons performing alignments and persons present in an area where a direct or reflected source of laser light could come into contact with their eye.
- Beam stops should be in place at locations where the beam may leave the table or strayoff its intended path. If beam stops, enclosures or other safety devices were moved to perform an alignment, they must be replaced prior to operation.
- Never look directly into the beam. If intra-beam viewing is required to align the beam, use a remote viewing camera.
- In the case of invisible laser emissions, a visible low power laser should be used for thepurposes of alignment wherever possible.

Remember that 60% of laser accidents occur during alignment and beam manipulation.
Use beam splitters with extreme caution and never fully rely on attenuating filters as they may fail

Engineering & Administrative Controls

Engineering controls are interlocks or other physical restraints which limit the operation of thelaser or impede access to the beam.

List applicable engineering controls e.g., locks on lasers, beam is enclosed by a plastic/metal/cardboard tube, laser is fastened to stationary base, laser is in locked areaetc.

Administrative controls are policies and procedures which laser users are obligated to comply with. Users must comply with policies and procedures described in this SOP.

List applicable administrative controls in addition to those described in this SOP e.g., only faculty have keys, faculty send all students to Laser Safety Officer or Chemical Hygiene Officer for training prior to laser use, etc.

Operational Steps

- Set-up all necessary equipment for the experiment, with power off.
- For Start-up: Describe start-up procedure in detail. If keys are used, include who haskeys and where they are kept.

Procedural steps

- Briefly (three to four paragraphs is typical), describe what you do during a typical experiment.
- Please give the actual “hands on” procedure, not the theory behind your experimentation.

Shut down

- **Describe in much detail as possible**

10.0 Definitions

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

Accessible emission limit (AEL): The maximum accessible emission level permitted within alaser hazard class.

Accessible laser radiation: Laser radiation emitted from a laser that is compared with the AEL to determine its hazard class. Includes accessible radiant energy and power. *See also:* **effective energy; effective power.**

Administrative control measure: Control measures incorporating administrative means [e.g., training, safety approvals, LSO designation, and standard operating procedures (SOP)] to mitigate the potential hazards associated with laser use.

Alpha max: The angular subtense of an extended source beyond which additional subtensedoes not contribute to the hazard and need not be considered. Symbol: <Xmax·

Alpha min: The angular subtense of a source below which the source can be effectivelyconsidered as a point source. Alpha min has a value of 1.5 mrad. Symbol: llmin·

Aperture: An opening, window, or lens through which optical radiation can pass. The aperturelimits the energy or power for measurement or exposure.

Apparent visual angle: The angular subtense of the source as calculated from source size and distance from the eye. It is not the beam divergence of the source. Symbol: a.

Attenuation: The decrease in the radiant flux as it passes through an absorbing and/orscattering medium.

Authorized personnel: Individuals approved by management to operate, maintain, service, or install laser equipment.

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

that exposure or emission. Symbol: (/J.

Aversion response: Closure of the eyelid, eye movement, pupillary constriction, or movementof the head to avoid an exposure to a noxious or bright light stimulant. In this standard, the aversion response to an exposure from a bright, visible, laser source is assumed to limit the exposure of a specific retinal area to 0.25 s or less.

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

Beam diameter: The distance between diametrically opposed points in that cross-section of a beam where the power or energy is 1/e (0.368) times that of the peak power or energy.

Beam divergence: For purposes of this standard, divergence is the increase in the diameter of the laser beam with distance from the beam waist, based on the full angle at the point where the irradiance (or radiant exposure for pulsed lasers) is 1/e times the maximum value. Symbol:¢.

Carcinogen: An agent potentially capable of causing cancer.

Coagulation: The process of congealing by an increase in viscosity characterized by a condensation of material from a liquid to a gelatinous or solid state.

Collateral radiation: Any electromagnetic radiation, except laser radiation, emitted by a lasersystem. This does not include laser target interaction radiation (reradiation). Note that reradiation from a target is addressed in this standard as a non-beam hazard.

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

Collimated beam: Effectively, a "parallel" beam of light with very low divergence orconvergence.

Conduit: A pipe or hollow cable through which laser energy passes.

Continuous wave (CW): In this standard, a laser operating with or modeled as having a continuous output for a period 2: 0.25 s is regarded as a CW laser.

Control measure: A means to mitigate potential hazards associated with the use of lasers. Control measures can be divided into three groups: engineering, procedural (administrative),and personal protective equipment (PPB).

Controlled area: An area where the occupancy and activity of those within is subject to controland supervision. See also: laser-controlled area.

Cornea: Transparent outer layer of the human eye that covers the iris and the crystalline lens.The cornea is the main refracting element of the eye.

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 that has a higher classification than the laser system inwhich it is incorporated, where the system's lower classification is appropriate due to the engineering features limiting accessible emission.

Enclosed laser: A laser that is contained within a protective housing of itself or of the laser or laser system in which it is incorporated. Opening or removal of the protective housing providesadditional access to laser radiation above the applicable MPE than possible with the protectivehousing in place.

Energy: The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers, generally expressed in joules (J). Symbol: Q

Engineering control measure: Control measures designed or incorporated into the laser or laser system (e.g., interlocks, shutters, watch-dog timer) or its application.

Epithelium (of the cornea): The layer of cells forming the outer surface of the cornea.

Erythema: For the purposes of this standard, redness of the skin due to exposure from laser radiation.

Extended source: A source of optical radiation with an angular subtense at the cornea larger than in eye-safe laser. Class 1 laser product. Because of the frequent misuse of the term eye-safe wavelength to mean retina-:-safe, (e.g., 1500 nm to 1800 nm) and eye-safe laser to refer toa laser emitting at wavelengths outside the retinal-hazard region, the term eye-safe can be a misnomer. Hence, the use of eye-safe laser is discouraged.

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.

Field of view: The full solid angle from which a detector's active area receives radiation.

Focal length: The distance from the secondary nodal point of a lens to the secondary focal point. For a thin lens imaging a distant source, the focal length is the distance between the lensand the focal point.

Focal point: The point toward which radiation converges or from which radiation diverges orappears to diverge.

Hertz (Hz): The unit that expresses the frequency of a periodic oscillation in cycles per second.The term also describes the number of repetitive pulses occurring per second.

Hot spot: Term applied to a laser beam to denote areas within the beam, not necessarilycentered in the beam, that are above the average irradiance.

Illuminance: The luminous flux per unit area incident upon a surface. The basic units of illuminance is lumens·m-2 (lux). Some instruments that measure illuminance are calibrated infoot-candles (lumens·ff2).

Infrared (IR): For purposes of this standard, the region of the electromagnetic spectrum between the long-wavelength extreme of the visible spectrum (700 nm) and the shortestmicrowaves (1000 µm).

Installation: Placement and connection of laser equipment to enable intended operation.

Integrated radiance: The integral of the radiance over the exposure duration, expressed injoules-per-centimeter-squared per-steradian (J.cm--2 sf 1).

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

Iris: The annular pigmented structure that lies behind the cornea of the human eye. The centralopening is the pupil.

Irradiance: Radiant power incident per unit area upon a surface, expressed in watts-per-centimeter-squared (W-cm-2). Symbol: E.

Joule (J): A unit of energy. 1 joule= 1 watt·second (W· s).

Laser: A device that produces radiant energy predominantly by stimulated emission. Laserradiation may be highly coherent temporally, or spatially, or both. An acronym for Light Amplification by Stimulated Emission of Radiation.

Laser barrier: A device used to block or attenuate incident direct or diffuse laser radiation. Laser barriers are frequently used during times of service to the laser system when it is desirable to establish a boundary for a controlled laser area.

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 lM, Class 2, Class 2M, Class 3R, Class 3B and Class 4.

Laser-controlled area (LCA): A laser use area where the occupancy and activity of those withinis controlled and supervised. This area may be defined by walls, barriers, or other means.
Within this area, potentially hazardous beam exposure is possible.

Laser diode: A laser employing a forward-biased semiconductor junction as the active medium.

Laser personnel: Persons who routinely work around hazardous laser beams.

Laser pointer: A laser or laser system designed or used to specify a discrete point or location,

such as those lasers used in classroom lectures or for the aiming of firearms. These products areusually Class 1, Class 2, or Class 3R.

Laser product: Any manufactured product or assemblage of components that constitutes, incorporates, or is intended to incorporate a laser or laser system. A laser or laser system intended for use as a component of an electronic product is itself considered a laser product.

Laser safety officer (LSO): One who has authority and responsibility to monitor and enforce thecontrol of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

Laser system: An assembly of electrical, mechanical, and optical components that includes a laser.

Laser target interaction radiation (LTIR): Non-laser radiation, including ionizing radiation,emitted by a material as a result of that material's exposure to laser radiation.

Lesion: A change in the structure of an organ or part due to injury or disease. **Macula:** The small uniquely pigmented specialized area of the retina of the eye, which in normal individuals, is predominantly employed for acute central vision (i.e., area of best visualacuity).

Magnified viewing: Viewing an object through an optical system that increases the apparent object size. This type of optical system can make a diverging laser beam more hazardous, (e.g.,using a magnifying optic to view the end of an energized optical fiber). See also: collecting optics.

Maintenance: Performance of those adjustments or procedures (specified in the user information provided by the manufacturer, and considered preventative, to maintain optimal performance of the laser system), which are to be carried out by the user to ensure the intended performance of the product. Maintenance does not include operation or service as defined in this section.

Maximum permissible exposure (MPE): The level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin.

Measurement aperture: The aperture used for classification of a laser to determine the effective power or energy that is compared with the AEL for each laser hazard class.

Nominal hazard zone (NHZ): The space within which the level of the direct, reflected, or scattered radiation may exceed the applicable MPE. Exposure levels beyond the boundary ofthe NHZ are below the applicable MPE.

Nominal ocular hazard distance (NOHD): The distance along the axis of the unobstructed beam from a laser, fiber end, or connector to the human eye beyond which the irradiance or radiant exposure does not exceed the applicable MPE.

Non-beam hazards (NBH): All hazards arising from the presence of a laser system, excludingdirect human exposure to direct or scattered laser radiation.

Non-laser radiation (NLR): All radiation arising from the operation of a laser system, excludinglaser radiation. This includes collateral radiation and laser target interaction radiation.

Ocular fundus: The interior posterior surface of the eye (the retina) as seen during ophthalmoscopic examination.

Operation: The performance of the laser or laser system over the full range of its intended functions (normal operation). Operation does not include maintenance or service as defined inthis section.

Ophthalmoscope: An instrument for examining the interior of the eye.

Optically aided viewing: Viewing with a telescopic (binocular) or magnifying optic. Under certain circumstances, viewing with an optical aid can increase the hazard from a laser beam.See also: telescopic viewing; magnified viewing.

Optical density (OD): The logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength.

Personal protective equipment (PPE): Personal safety protective devices used to mitigatehazards associated with laser use [e.g., laser eye protection (LEP), protective clothing, andgloves].

Photochemical effect: A biological effect produced by a chemical change in molecules resultingfrom the absorption of photons. The changed molecules fail to function as before.

Photosensitizers: Substances that increase the biological response of a person to exposure by optical radiation.

Plasma radiation: Laser target interaction radiation (LTIR) generated by a plasma.

Point source: For purposes of this standard, a source with an angular subtense at the corneaequal to or less than alpha-min (llmin), i.e., 1.5 mrad.

Power (): The rate at which energy is emitted, transferred, or received. Unit: watt (W) (1 W =1 J*s-1 .

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Procedural control measure: See: administrative control measure.

Protective housing: An enclosure that surrounds the laser or laser system and prevents accessto laser radiation above the applicable MPE. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing limits access to other associated radiant energy emissions and to electrical hazards associated with

components andterminals. May enclose associated optics and a workstation.

Pulse duration: The duration of a laser pulse, usually measured as the time interval between the half-power points on the leading and trailing edges of the pulse. Symbol: t

Pulse-repetition frequency (PRF): The number of pulses occurring per second, expressed in hertz. Symbol: F

Pulsed laser: A laser that delivers its energy in the form of a single pulse or a train of pulses. For purposes of this standard, the duration of a pulse is less than 0.25 s.

Pupil: The variable aperture in the iris through which light travels to the interior of the eye.

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

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

Radian (rad): A unit of angular measure equal to the angle subtended at the center of a circle by an arc whose length is equal to the radius of the circle. 1 radian - 57.3 degrees; 2n radians =360 degrees.

Radiance: Radiant flux or power output per unit solid angle per unit area expressed in watts-per- centimeter squared per-steradian (W-cm-.2 sf1). Symbol: L.

Radiant energy: Energy emitted, transferred, or received in the form of radiation. Unit: joules (J). Symbol: Q.

Radiant exposure: Surface density of the radiant energy received, expressed in units of J-cm^2.Symbol: H.

Radiant flux: Power emitted, transferred, or received in the form of radiation. Unit: watts(W). Syn: radiant power. Symbol: (/),

Radiant power: Power emitted, transferred, or received in the form of radiation, expressed in watts (W). Syn: radiant flux.

Radiometry: For the purposes of this standard, the measurement of infrared, visible, andultraviolet radiation.

Reflectance: The ratio of total reflected radiant power to total incident power. Syn:reflectivity. Symbol:p.

Reflection: Deviation of radiation following incidence on a surface.

Refraction: The bending of a beam of light in transmission through an interface between twodissimilar media or in a medium whose refractive index is a continuous function of position (graded index medium).

Refractive index (of a medium): The ratio of the velocity of light in a vacuum to the velocity oflight in the medium. Symbol: n. Syn: index of refraction.

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

Retina: The sensory tissue that receives the incident image formed by the cornea and lens ofthe human eye.

Retinal hazard region: Optical radiation with wavelengths between 400 nm and 1400 nm,where the principal hazard is usually to the retina.

Safety latch: A device designed to require a conscious decision to override in order to gainentry into a controlled area.

Saturable absorption: The property of laser eye protection and other optical materials wherethe absorption of light decreases (OD decreases) with increasing irradiance. This has been shown to occur with certain laser eye protection materials with high-energy nanosecond and shorter duration pulses.

Scanning laser: A laser having a time-varying direction, origin, or pattern of propagation with respect to a stationary frame of reference.

Secured enclosure: An enclosure to which casual access is impeded by an appropriate means (e.g., a door secured by a magnetically or electrically operated lock or latch, or by fasteners thatneed a tool to remove).

Service: The performance of procedures, typically defined as repair, to bring the laser or lasersystem or laser product back to full and normal operational status. Service does not include operation or maintenance as defined in this section.

Shall: The word, **SHALL,** is to be understood as mandatory.

Should: The word, **SHOULD**, is to be understood as advisory.

Solid angle: The three-dimensional angular spread at the vertex of a cone measured by the areaintercepted by the cone on a unit sphere whose center is the vertex of the cone. Unit: steradians (sr).

Source: A laser or a laser-illuminated reflecting surface.

Spectator: An individual who wishes to observe or watch a laser or laser system in operation,and who may lack the appropriate laser safety training.

Specular reflection: A mirror-like reflection.

Steradian (sr): The unit of measure for a solid angle. There are 41t steradians about any point in space.

Standard operating procedure (SOP): Formal written description of the safety and administrative procedures to be followed in performing a specific task.

Telescopic viewing: Viewing an object from a long distance with the aid of an optical system that increases the visual size of the image. The system (e.g., binoculars), generally collects lightthrough a large aperture, thus magnifying hazards from large-beam, collimated lasers.

Thermal effect: For purposes of this standard, an effect brought about by the temperatureelevation of a substance due to absorption of laser energy.

Threshold limit (TL): The term is applied to laser protective eyewear filters, protectivewindows, and barriers. The TL is an expression of the "resistance factor" for a beam.

Penetration of a laser protective device: This is generally related by the Threshold Limit (TL) ofthe protective device, expressed in W-cm-2 or J.cm-2• It is the maximum average irradiance or radiant exposure at a given beam diameter for which a laser protective device provides adequate beam resistance. Thus, laser exposures delivered on the protective device at or belowthe TL will limit beam penetration to levels at or below the applicable MPE.

Tmax: The total expected or anticipated exposure duration, which may differ depending upon its use.

Tmin: The shortest exposure duration greater than 1 ns for which the MPE, expressed as radiant exposure (J-cm^2), decreases as the exposure duration decreases, reflecting a thermaldamage mechanism. tmin is an analogue for the "thermal confinement time" for biological effects, a duration for which there is no significant flow of heat from the volume of tissue in which the energy was absorbed, and therefore no cooling of the absorbing tissue during the exposure.

Transmission: Passage of radiation through a medium.

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

Ultraviolet radiation (UV): Electromagnetic radiation with wavelengths between 180 nm and400nm.

Uncontrolled area: An area where the occupancy and activity of those within is not subject tocontrol and supervision for the purpose of protection from radiation hazards.

Viewing window: A visually transparent part of an enclosure that contains a laser process. It may be possible to observe the laser processes through the viewing windows.

Visible radiation (light): The term is used to describe electromagnetic radiation that can be detected by the human eye. For purposes of this standard, this term is used to describe wavelengths that lie in the range 400 nm to 700 nm. Derivative standards may legitimately use380 nm to 780 nm 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).

Figures 1 and 2

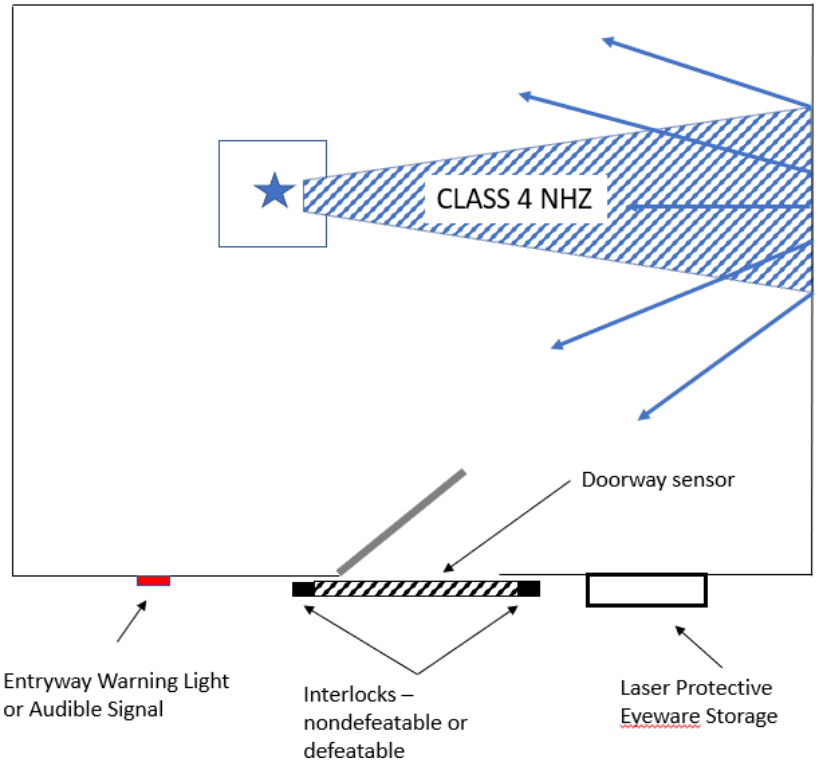

Figure 1. Area/Entryway Safety Controls for Class 3b and 4 LasersUtilizing Entryway Interlocks

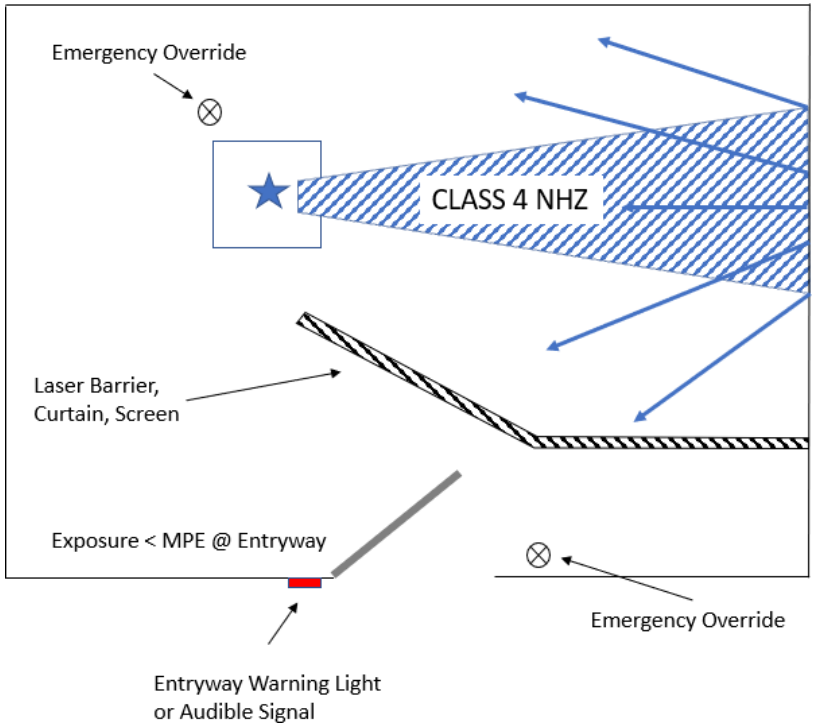

Figure 2. Entryway Safety Controls for Class 3B and 4 Lasers

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