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LASER SAFETY PROGRAM (LSP)

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SAN LUIS OBISPO

LASER SAFETY PROGRAM (LSP)

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1. SCOPE and APPLICATION

1.1 This program identifies the requirements for preventing injuries from the use and handling of lasers. It includes beam and non-beam hazards.

1.2 The LSP applies to all employees – faculty, staff, student assistants, and identified volunteers that work with lasers and may be exposed to their hazards.

1.3 All lasers and laser controlled areas must be evaluated for the following elements:

1.4 This includes lasers used in labs, classrooms, field locations, and optical fiber communication systems.

1.4.1 Laser class.

1.4.2 Proper labeling is present on all lasers.

1.4.3 Use, handling, and maintenance according to manufacturer's instructions

1.4.4 Identify all Class 3b and Class 4 laser users.

1.4.5 Document training for all users of Class 3b and Class 4 lasers.

1.4.6 Registration of all Class 3b and Class 4 lasers.

1.4.7 Evaluation of each Class 3b laser, Class 4 laser, and laser control area for proper control measures, including:

1.4.7.1 required postings

1.4.7.2 engineering controls

1.4.7.3 administrative controls

1.4.7.4 standard operating procedure

1.4.7.5 medical surveillance (if needed)

1.4.7.6 personal protective equipment (PPE)

2. ROLES AND RESPONSIBILITIES

2.1. EHS Program Administrator is responsible to:

2.1.1. Establish, communicate, and maintain this program in accordance with applicable regulations, and executive orders.

2.1.2. Review training content to maintain compliance with this program.

2.1.3. Conduct program reviews and communicate results to the organization.

2.1.4. Track and trend results of program review by college or unit.

2.1.5. Communicate hazard and control measure information to the organization.

2.1.6. Assist the campus with identification of laser hazards and appropriate control measures related to laser safety.

2.1.7. Communicate any changes related to the written program, training content or program review to stakeholders.

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2.2. Associate Vice President (AVP)/Deans, or designee are responsible to:

2.2.1. Communicate program to directors and department heads/chairs

2.2.2. Provide resources to directors and department heads/chairs to communicate, implement and maintain program

2.2.3. Request feedback from directors and department heads/chairs on the communication and implementation of this program.

2.2.4. Set priorities for the college or unit on implementation and maintenance with assistance from EHS.

2.3. Directors/Department Heads and Chairs are responsible to:

2.3.1. Communicate program to managers, supervisors, leads, and principal investigators

2.3.2. Provide resources to managers, supervisors, leads, and principal investigators to communicate, implement and maintain program

2.3.3. Request feedback from managers, supervisors, leads, and principal investigators on the communication and implementation of this program.

2.3.4. Set priorities for managers, supervisors, leads, and principal investigators on implementation and maintenance with assistance from EHS.

2.4. Managers/Supervisors/Leads/Principal Investigators are responsible to:

2.4.1. Communicate program to staff, student workers, and identified volunteers.

2.4.2. Complying, and ensuring their staff comply, with the program.

2.4.3. Conducting/arranging laser hazard assessments of all work areas under their control.

2.4.4. Ensuring their staff obtains and uses the proper protective equipment identified in the hazard assessment.

2.4.5. Ensures their staff are trained to recognize laser hazards and use administrative controls, engineering controls, and protective equipment as appropriate.

2.4.6. Documents their training on the laser hazards they may encounter and the proper use of protective equipment.

2.4.7. Ensure that Standard Operating Procedures (SOP's) are written for all Class 3b and Class 4 lasers and their use areas.

2.4.8. Consulting the Laser Safety Officer when needed.

2.5. Staff are responsible for:

2.5.1. Obtaining the relevant online and in-person training.

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2.5.2. For knowing the hazards associated with lasers and protective equipment requirements for areas in which they work or enter, and for properly wearing protective equipment as established in this program and in the hazard assessment.

2.5.3. All workers are responsible for completing training, for knowing how to use the protective equipment, for knowing how to properly put on and take off required protective equipment, and for knowing how to care for, maintain, and inspect their protective equipment.

2.5.4. They are responsible reporting unsafe conditions to their supervisor, or EHS.

2.5.5. Workers are NOT responsible for purchasing their own protective equipment.

2.6. Program Specific Employee Designations and Responsibilities

2.6.1. Laser Safety Officer (LSO)

2.6.1.1. Appointed by the Director of Environmental Health and Safety (EH&S). The LSO has the following responsibilities:

2.6.1.2. Establishes the Laser Safety Program.

2.6.1.3. Classifies or verifies the classification of all lasers under the LSO's jurisdiction.

2.6.1.4. Conducts hazard evaluations.

2.6.1.5. Assures all control measures are implemented and followed.

2.6.1.6. Approves operating procedures related to the use of lasers.

2.6.1.7. Recommends and/or approves laser PPE.

2.6.1.8. Ensures all employees who use or are exposed to laser hazards are provided with information and training on the safe use of the equipment.

2.6.1.9. Recommends medical evaluations when necessary

2.6.1.10. Establishes procedures to investigate all incidents with potential or actual employee exposure to laser radiation.

2.6.2. Authorized Laser Users

2.6.2.1. Attend Laser Safety Training

2.6.2.2. Read, follow, and comply with written procedures, standard operating procedures, hazard assessments, and equipment manufacturers instructions.

2.6.2.3. Ensure applicable engineering controls are in place and ensure surrounding personnel are not at increased risk of laser exposure due to uncontrolled or inadequately controlled beams.

3. REQUIREMENTS – Applicable Regulations

3.1. Safety Overview

3.1.1. Generally - Do not directly view any laser beam no matter what the power.

3.1.2. Control the beam. Do not allow the beam to go in an unknown direction.

3.1.3. Do not direct any laser beam at people, aircraft, or other vehicles.

3.1.4. Generally - Do not directly view any laser beam no matter what the power.

3.1.5. Maximum eye exposure is 1 microwatt/cm^2 for direct staring into beam.

3.1.6. Maximum eye exposure of 1 milliwatt/cm^2 for incidental viewing.

3.1.7. Maximum exposure to diffuse reflected light is 2.5 watts/cm^2

3.2. General Overview

- **Identify all lasers**
- **Determine laser class**
- **Identify laser users for Class 1M, 2, 2M, 3R (formerly 3a), 3b, and 4 Lasers**
- **Complete onsite and online training for Class 3b and 4 Lasers users**
- **Complete "Laser Use Authorization (LUA)" for each Class 3b and 4 Laser. Notify LSO of any acquisition of a laser, any significant modification to laser or Laser Controlled Area; transfer of laser to another department, location, or entity; disposal of laser.**
- **Complete Laser/Laser Controlled Area Hazard Assessment, including beam and non-beam hazards, for each Class 3b and Class 4 laser/LCA.**
- **Implement appropriate controls based on laser class, configuration, and use**
- **Set up Laser Controlled Area (LCA) for each Class 3b and 4 laser with an open or partially open beam path. Contact Laser Safety Officer (LSO) for review of each LCA.**
- **Write Standard Operating Procedure for each Class 3b and 4 laser setup**
- **Periodic program review**

3.3. Identify all lasers under departmental, college, or other entity purview.

3.4. Determine laser class for all lasers.

3.4.1. Laser class is generally indicated by the manufacturer by label on the laser device.

3.4.2. If the laser class is unknown and cannot be obtained from the manufacturer's information then contact the Laser Safety Officer.

3.5. Identify laser users for Class 1M, 2, 2M, 3R (Formerly 3a), 3b, and 4 lasers.

3.6. Training

3.6.1. General

3.6.1.1. Training must be provided prior to use of laser.

3.6.1.2. Training records should be kept at the laser use site.

3.6.1.3. Training Topics:

3.6.1.4. Fundamentals of laser operation

3.6.1.5. Bioeffects of laser radiation on the eye and skin

3.6.1.6. Significance of specular and diffuse reflections

3.6.1.7. Non-beam hazards of lasers

3.6.1.8. Laser and laser system classifications

3.6.1.9. Control measures

3.6.1.10. Management and employee responsibilities in the laser safety program

3.6.1.11. Medical examination practices for laser injuries

3.6.2. Users of Class 3b and 4 Lasers - Required

3.6.2.1. Online SumTotal course: Fundamentals of Laser Safety, _scorm12_spcentralsta_stc_lasersafetyfund

3.6.2.2. In person training by Supervisor or Principal investigator regarding site specific conditions, hazards, and procedures.

3.6.2.3. Review of Laser Safety Program

3.6.3. Users of Class 1M, 2, 2M, and 3R Lasers – Recommended

3.6.3.1. Online SumTotal course: Fundamentals of Laser Safety, _scorm12_spcentralsta_stc_lasersafetyfund

3.6.3.2. In person training by Supervisor or Principal investigator regarding site specific conditions, hazards, and procedures.

3.6.3.3. Review of Laser Safety Program

3.7. Laser Use Authorization Form

3.7.1. Required for all Class 3b and Class 4 lasers.

3.7.2. Required for Class 1 enclosures with embedded/enclosed Class3b/4 lasers where user may be exposed in excess of the maximum permissible exposure (MPE). For Example: Service or adjustment work with the protective housing removed and the laser ON.

3.7.3. See Appendix 8.3 Laser Use Authorization

3.8. Laser/Laser Controlled Area Hazard Assessments

3.8.1. Required for Class 3b and Class 4 lasers and Laser Controlled Areas.

3.8.2. May be useful for any laser.

3.8.3. Must be performed by Supervisor, Principal investigator, LSO, or designee with adequate knowledge and training.

3.8.4. See Appendix 8.4 Laser/Laser Controlled Area Hazard Assessment

4. DEFINITIONS

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

4.2. Access Level (FSOCS)[Communications]: The potential hazard at any position associated with an free-space optical communication system (FSOCS) installation based on the level of optical radiation that could become accessible in reasonably foreseeable circumstances during operation, e.g., walking into an open beam path. The access level is closely related to the laser classification.

4.3. Accessible Emission Limit (AEL): The maximum accessible emission level permitted within a particular laser hazard class.

4.4. Accessible Laser Radiation: Laser radiation emitted from a laser that is compared to the AEL to determine its hazard class. Includes accessible radiant energy and power.

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

4.6. ANSI Z136.1 "American National Standard for Safe Use of Lasers-2014": This document is the regulatory laser protection standard in the US. The Cal Poly Laser Safety Program is based on this standard.

4.7. Aperture: An opening, window, or lens through which optical radiation can pass.

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

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

4.10. Average Power: The total power in an exposure or emission divided by the duration of that exposure or emission.

4.11. Aversion Response (Blink Response): Closure of the eyelid, eye movement, pupillary constriction, or movement of the head to avoid an exposure to a noxious or bright light stimulant. The aversion response to an exposure from a bright, visible, laser source is assumed to limit exposure of a specific retinal area to 0.25s or less.

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4.12. Cladding: The dielectric material surrounding the core of an optical fiber. By design, the cladding has a lower refractive index than the core.

4.13. Class of Laser: (see Laser Classification)

4.14. Coherence: A term describing light as waves which are in phase in both time and space. Monochromacity and low divergence are two properties of coherent light.

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

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

4.16.1. Collecting optics can cause a Class 1M or 2M laser to be an eye hazard.

4.17. Collimated Beam: Effectively, a parallel beam of light with a very low divergence or convergence.

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

4.19. Continuous Wave (CW): A laser operating with a continuous output for a period > 0.25 s is regarded as a CW laser.

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

4.21. Convergence: The convergence is the reduction in the diameter of the laser beam.

4.22. Core: The central region of an optical waveguide through which optical energy is transmitted. By design, the core has a higher refractive index than the cladding.

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

4.24. Critical Frequency: The pulse repetition frequency above which the laser output is considered continuous wave (CW). For example, for a short unintentional exposure (0.25 s to 10 s) to nanosecond (or longer) pulses, the critical frequency is 55 kHz for wavelengths between 0.40 and 1.05 μm, and 20 kHz for wavelengths between 1.05 and 1.40 μm.

4.25. 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. A diffuse reflector will cause the reflected laser radiation to be spread over a wider area, and have a significantly reduced hazard level compared to the direct laser beam (see “Specular Reflection”)

4.26. Divergence: The divergence is the increase in the diameter of the laser beam.

4.27. Effective Energy: Energy, in joules, through the applicable measurement aperture.

4.28. Effective Power: Power, in watts, through the applicable aperture.

4.29. Embedded Laser: An enclosed laser that has a higher classification than the laser system in which it is incorporated, where the system's lower classification is appropriate due to the engineering features limiting accessible emission. Many laser cutters are Class 4 lasers in a Class 1 laser enclosure, and require no special laser safety precautions as long as the factory installed safety features remain intact.

4.30. 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 removing of the protective housing provides additional access to laser radiation above the applicable MPE than possible with the protective housing in place (an embedded laser is an example of one type of enclosed laser).

4.31. End-to-End System: An optical communication system that is composed of at least one transmitter, one receiver and any peripheral hardware necessary for the effective transfer of data along the transmission path from one location to another. The entire end-to-end system may contain optical fiber and/or free-space links.

4.32. Engineering Control Measures: Key controls, interlocks, beam housings, shutters, etc. designed to prevent exposure to hazardous levels of laser radiation. Engineering controls are considered the most effective laser safety control measures.

4.33. Erythema: Redness of the skin due to exposure from laser radiation.

4.34. Eye-Safe Laser: A Class 1 laser product. Because of the frequent misuse of the term “eye-safe wavelength” to mean “retina-safe,” (e.g., at 1.5-1.6 μm) and eye-safe laser to refer to a 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.

4.35. 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.

4.36. Fiber Optics: The branch of optical technology concerned with the transmission of radiant energy through fibers made of transparent materials such as glass, fused silica, or plastic.

4.37. Free-Space Optical Communication System (FSOCS): An installed or temporarily mounted, through the air system typically used for , or intended or promoted for voice, data, or multimedia communications and/or control purposes via the modulated optical radiation produced by a laser or LED. “Free-space” means indoor or outdoor optical wireless applications with both non-directed and directed transmission. Emitting and detecting assemblies may or may not be separated.

4.38. Half-Power Point: the time on either the leading or trailing edge of a laser pulse at which the power is on-half of its maximum value.

4.39. Hazard Level, Optical Fiber Communication System (OFCS): The level of a potential hazard that could become accessible during, installation and service or in the event of a fault such as a fiber break. Hazard level is used for the OFCS hazard assessment and control measures and is closely related to the laser classification.

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

4.41. Infrared (IR): The region of the electromagnetic spectrum between the long-wave extreme of the visible spectrum (700 nm) and the shortest microwave (1000 μm).

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

4.43. Iris: The circular pigmented structure which lies behind the cornea of the human eye. The iris is perforated by the pupil.

4.44. Irradiance: Radiant power incident per unit area upon a surface, expressed in watts-per-centimeter-squared.

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

4.46. 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.

4.47. Laser Classification: An indication of the beam hazard level of a laser or laser system during normal operation. The hazard level of a laser or laser system is represented by a number or a numbered capital letter. The laser classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B and Class 4. In general, the potential beam hazard level increases in the same order. (see Appendix 8.2)

4.48. Laser Controlled Area (LCA): An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser radiation hazards. The Nominal Hazard Zone (NHZ) is within the LCA.

4.49. Laser-Generated Air Contaminants (LGAC): Air contaminants 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.

4.50. Laser Medium: The material that is exited and optically pumped within the laser cavity to produce laser emissions. Some laser media types: Solid State, Gas, Excimer, Dye, and Semiconductor.

4.51. Laser Personnel: Persons who routinely work around hazardous laser beams. Such persons must be protected by engineering controls, administrative procedures, or both.

4.52. Laser Pointer: A laser product that is usually hand held that emits a low-divergence visible beam and is intended for designating specific objects or images during discussions, lectures or presentations as well as for the aiming of firearms or other visual targeting practice. These products are normally Class 1, Class 2 or Class 3R.

4.53. Laser Safety Officer (LSO): One who has authority and responsibility to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

4.54. Laser System: An assembly of electrical, mechanical, and optical components which includes a laser.

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4.55. 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.

4.56. Limiting Aperture: The diameter of a circle over which irradiance or radiant exposure is averaged for purposes of hazard evaluation and classification.

4.57. 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 visual acuity).

4.58. Magnified Viewing: Viewing a small 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 an optical fiber with a laser beam emitted). (see Collecting Optics)

4.59. 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 carried out by the user to ensure the intended performance of the product. Maintenance does not include *operation* or *service*.

4.60. 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. The MPE is useful in laser safety calculations, such as determining the nominal hazard zone (NHZ).

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

4.62. Multi-wavelength Lasers: Lasers capable of emitting multiple discreet frequencies either simultaneously or separately. Classification shall be performed for all emission conditions and the system classification shall be based on the most hazardous operating condition.

4.63. Nominal Hazard Zone (NHZ): Exposure within the boundary of the NHZ to direct, reflected, or scattered laser radiation has the potential to exceed the MPE and thus cause injury. Exposures beyond the boundary of the NHZ are below the MPE, and unprotected exposure will not cause damage to the eye or skin.

4.64. 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 is not expected to exceed the applicable MPE.

4.65. Non-Beam Hazard (NBH): A class of hazards that result from factors other than direct human exposure to a laser beam. Examples include electrical hazards, compressed gases, chemical hazards from dyes or solvents, sharp objects and fire hazards.

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

4.67. Ocular Fundus: The interior posterior surface of the eye (the retina), as seen upon ophthalmoscopic examination.

4.68. 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.*

4.69. Optical Amplifier: A device that may be optically pumped with lasers, or lasers, of the appropriate wavelength to produce stimulated emission at a specific wavelength and, hence, amplification at that wavelength.

4.70. Optical Cavity (Resonator): Space between the laser mirrors where lasing occurs.

4.71. Optical Communication System (OCS): An installed system used for the transmission of voice, data or multimedia communications and/or control purposes via the use of modulated optical radiation produced by a laser or LED. OCS includes end-to-end optical fiber based links (OFCS), fixed or temporarily-mounted terrestrial point-to-point free-space links (FSOCS) or a combination of both.

4.72. 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 Collecting Optics).

4.73. Optical Density (OD): The OD is the measure of the laser radiation permitted to pass through a filter. Laser protective eyewear will always specify an OD for specific wavelengths of laser light. OD is a logarithmic scale: OD = log10 (1/τλ) where τ λ is the transmittance at the wavelength of interest (τ λ=flux received by filter/flux transmitted by filter).

4.74. Optical Detector: A transducer that generates an output signal when irradiated with optical energy.

4.75. Personal Protective Equipment (PPE): Personal safety protective devices used to mitigate hazards associated with laser use [e.g. laser eye protection, protective clothing, and gloves].

4.76. Photochemical Effect: A biological effect produced by a chemical change in molecules resulting from absorption of photons (laser light). The changed molecules fail to function as before.

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

4.78. Plasma Radiation: Laser target interaction radiation (LTIR) produced by plasma. Typically very high temperature at the point of generation.

4.79. Protective Housing: An enclosure that surrounds the laser or laser system and prevents access to 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 and terminals, and may enclose associated optics and a workstation.

4.80. 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.

4.80.1. microsecond (μs) = 10^{-6} seconds

4.80.2. nanosecond (ns) = 10^{-9} seconds

4.80.3. picosecond (ps) = 10^{-12} seconds

4.80.4. femtosecond (fs) = 10^{-15} seconds

4.81. Pulse-repetition Frequency (PRF): The number of pulses occurring per second, expressed in hertz.

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4.82. Pulsed Laser: A laser which delivers its energy in the form of a single pulse or a train of pulses. In this standard, the duration of a pulse is less than 0.25 s. (see Continuous Wave)

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

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

4.85. Radiometry: The measurement of infrared, visible, and ultraviolet radiation.

4.86. Reflection: Deviation of radiation following incidence on a surface.

4.87. Refraction: The bending of light in transmission through an interface between two dissimilar media or in a medium whose refractive index is a continuous function of position.

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

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

4.90. Retinal Hazard Region: Optical radiation with wavelengths between 0.4 and 1.4 μm, where the principal hazard is usually to the retina.

4.91. Safety Latch: A mechanical device designed to require a conscious decision to override the latch to gain entry into a controlled area.

4.92. Saturable Absorption: The property of laser eye protection and other optical materials where the 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.

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

4.94. 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 that need a tool to remove.

4.95. Service: The performance of procedures, typically defined as repair, to bring the laser or laser system or laser product back to full normal operational status. Service does not include *operation* or *maintenance*.

4.96. Shall: The word shall is to be understood as mandatory.

4.97. Should: The word should is to be understood as advisory.

4.98. 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.

4.99. Specular Reflection: A mirror-like reflection. The specular reflection of the laser can be as hazardous as the primary laser beam (see “Diffuse Reflection”)

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

4.101. 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 (binoculars, telescopes), generally collects light through a large aperture , thus magnifying hazards from large-beam, collimated lasers.

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4.102. Thermal Effect: An effect brought about by the temperature elevation of a substance due to absorption of laser energy.

4.103. Threshold Limit (TL): The TL is an expression of the “resistance factor” for beam penetration of a laser protective device (such as eyewear filters, protective windows, and barriers). The Threshold Limit (TL) of the protective device is generally 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 below the TL will limit beam penetration to levels at or below the applicable MPE.

4.104. Tunable Laser: A laser system that can be “tuned” to emit laser radiation over a continuous range of wavelengths or frequencies.

4.105. Ultraviolet Radiation: Electromagnetic radiation with wavelengths between 0.18 and 0.40 µm (shorter than those of visible radiation).

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

4.107. 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.

4.108. Visible Light Transmission (VLT): The percent of visible light transmitted through filter, weighted for the response of the human eye. The VLT of laser protective eyewear should be as high as possible to aid in viewing the work environment.

4.109. Visible Radiation (light): The term is used to describe electromagnetic radiation which can be detected by the human eye. This term is used to describe wavelengths which lie in the range 0.4 to 0.7 µm. Derivative standards may legitimately use 0.38 – 0.78 µm for the visible radiation range.

4.110. Visual Interference Effects: Those effects associated with viewing bright visible lights. These may include glare, flash-blindness, and after-images.

5. GOVERNING DOCUMENT

5.1. CSU Chancellor’s Office Safety and Health Executive Order 1039

6. COMPLIANCE REQUIREMENTS, REGULATORY

6.1. California Code of Regulations, Construct Safety Orders, Section 1801 – Non-Ionizing Radiation

6.2. California Code of Regulations, General Industry Safety Orders, Section 3382 – Eye and Face Protection

6.3. 29 Code of Federal Regulations, Construction Safety Orders, Section 1926.54 – Nonionizing Radiation

6.4. 29 Code of Federal Regulations, Construction Safety Orders, Section 1926.102 – Eye and Face Protection

6.5. Federal OSHA Technical Manual, Section III, Chapter 6 – Laser Hazards

6.6. ANSI Z87.1 “American National Standard, Practice for Occupational and Educational Eye and Face Protection, (Incorporated by reference)

6.7. ANSI Z136.1-2014 “American National Standard for Safe Use of Lasers”, (Incorporated by Reference)

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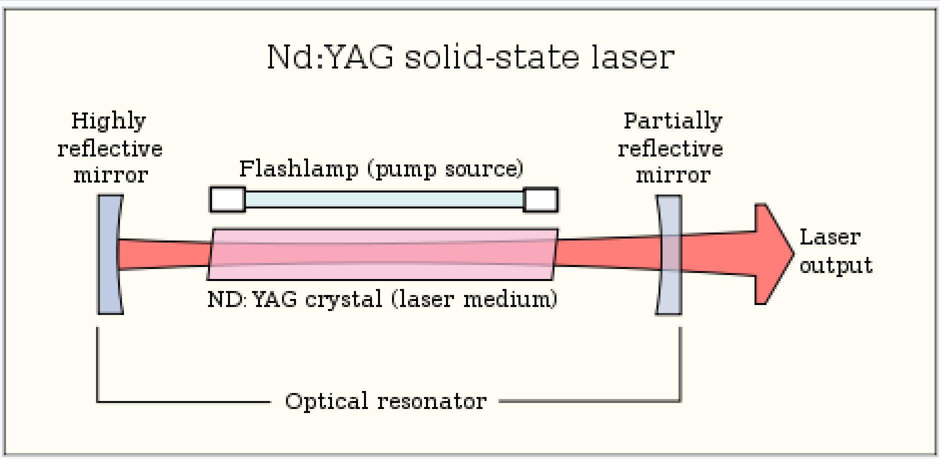
7. REFERENCE DOCUMENTS

7.1. ANSI Z136.2-2012 "American National Standard for Safe Use of Optical Fiber Communication Systems Utilizing Laser Diode and LED Sources"

7.2. ANSI Z136.8-2012 "American National Standard for Safe Use of Lasers in Research, Development, or Testing"

8. APPENDICES

8.1. Laser Operation, Appendix 8.1



Schematic diagram of a typical laser, showing the three major parts

8.1.1. Pump source

The pump source is the part that provides energy to the laser system. Examples of pump sources include electrical discharges, flashlamps, arc lamps, light from another laser, chemical reactions and even explosive devices. The type of pump source used principally depends on the gain medium, and this also determines how the energy is transmitted to the medium. A helium–neon (HeNe) laser uses an electrical discharge in the helium-neon gas mixture, a Nd:YAG laser uses either light focused from a xenon flash lamp or diode lasers, and excimer lasers use a chemical reaction.

8.1.2. Gain medium / Laser medium

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The gain medium is the major determining factor of the wavelength of operation, and other properties, of the laser. Gain media in different materials have linear spectra or wide spectra. Gain media with wide spectra allow tuning of the laser frequency. There are hundreds if not thousands of different gain media in which laser operation has been achieved (see list of laser types for a list of the most important ones). The gain medium is excited by the pump source to produce a population inversion, and it is in the gain medium where spontaneous and stimulated emission of photons takes place, leading to the phenomenon of optical gain, or amplification.

8.1.3. Examples of different gain media include:

Liquids, such as dye lasers. These are usually organic chemical solvents, such as methanol, ethanol or ethylene glycol, to which are added chemical dyes such as coumarin, rhodamine, and fluorescein. The exact chemical configuration of the dye molecules determines the operation wavelength of the dye laser.

Gases, such as carbon dioxide, argon, krypton and mixtures such as helium–neon. These lasers are often pumped by electrical discharge.

Solids, such as crystals and glasses. The solid host materials are usually doped with an impurity such as chromium, neodymium, erbium or titanium ions. Typical hosts include YAG (yttrium aluminium garnet), YLF (yttrium lithium fluoride), sapphire (aluminium oxide) and various glasses. Examples of solid-state laser media include Nd:YAG, Ti:sapphire, Cr:sapphire (usually known as ruby), Cr:LiSAF (chromium-doped lithium strontium aluminium fluoride), Er:YLF, Nd:glass, and Er:glass. Solid-state lasers are usually pumped by flashlamps or light from another laser.

Semiconductors, a type of solid, crystal with uniform dopant distribution or material with differing dopant levels in which the movement of electrons can cause laser action. Semiconductor lasers are typically very small, and can be pumped with a simple electric current, enabling them to be used in consumer devices such as compact disc players.

8.1.4. Optical resonator

The optical resonator, or optical cavity, in its simplest form is two parallel mirrors placed around the gain medium, which provide feedback of the light. The mirrors are given optical coatings which determine their reflective properties. Typically, one will be a high reflector, and the other will be a partial reflector. The latter is called the output coupler, because it allows some of the light to leave the cavity to produce the laser's output beam.

Light from the medium, produced by spontaneous emission, is reflected by the mirrors back into the medium, where it may be amplified by stimulated emission. The light may reflect from the mirrors and thus pass through the gain medium many hundreds of times before exiting the cavity. In more complex lasers, configurations with four or more mirrors forming the cavity are used. The design and alignment of the mirrors with respect to the medium is crucial for determining the exact operating wavelength and other attributes of the laser system.

Other optical devices, such as spinning mirrors, modulators, filters, and absorbers, may be placed within the optical resonator to produce a variety of effects on the laser output, such as altering the wavelength of operation or the production of pulses of laser light.

Some lasers do not use an optical cavity, but instead rely on very high optical gain to produce significant amplified spontaneous emission (ASE) without needing feedback of the light back into the gain medium. Such lasers are said to be superluminescent, and emit light with low coherence but high bandwidth. Since they do not use optical feedback, these devices are often not categorized as lasers.

8.2. Laser Classifications, Appendix 8.2

8.2.1. Lasers classes are based on the capability of injuring personnel. The manufacturer is responsible for properly classifying lasers using US FDA regulations.

8.2.2. Human Aversion Response: Laser light is very bright compared to ordinary light, bright enough to cause an automatic aversion response against the intense light (blinking to close the eyelid, turning the head to avoid the light, automatic constriction of the pupil). The human aversion response of 0.25 seconds can be used to evaluate the potential for injury from visible laser light, such as Class 1, 2 and 3A lasers. Prevent injury to the eye by avoiding intentionally overcoming this aversion response. Note that Class 3B and Class 4 lasers are capable of causing injury before the aversion response has time to protect the eye; Class 3A and 3R have the potential in certain cases to cause injury before the aversion response can protect the eye.

8.2.3. Class 1: These are low-power lasers and laser systems that cannot emit radiation levels greater than the maximum permissible exposure (MPE). Class 1 lasers and laser systems are incapable of causing eye injury under normal operating conditions. This class may include lasers of a higher class whose beam are confined within a suitable enclosure so that access to laser radiation is physically prevented.

8.2.4. Class 1M: Class 1M lasers produce large-diameter beams, or beams that are divergent. The MPE for a Class 1M laser cannot normally be exceeded unless focusing or imaging optics are used to narrow down the beam. If the beam is refocused, the hazard of Class 1M laser may be increased and the product class may be changed.

8.2.5. Class 2: A Class 2 laser emits in the visible region. It is presumed that the human blink reflex (<0.25 seconds) will be sufficient to prevent damaging exposure, although prolonged viewing may be dangerous. Class 2 lasers are limited to 1 mW when operating in the continuous wave mode, or more if the emission time is less than 0.25 seconds.

8.2.6. Class 2M: A Class 2M laser emits in the visible portion of the spectrum in the form of a large diameter or divergent beam. It is presumed that the human blink reflex will be sufficient to prevent damaging exposure, but if the beam is focused down, damaging levels of radiation may be reached and may lead to a reclassification of the laser.

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8.2.7. Class 3R (Formerly Class 3a): A Class 3R laser is potentially hazardous under some direct and specular reflection viewing condition 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 diffused-reflection hazard. Class 3R visible lasers (0.4 to 0.7 um) are limited to 5 mW when operating in continuous wave mode. For other wavelengths and pulse lasers, other limits apply.

8.2.8. Class 3B: Class 3B lasers are capable of causing eye damage from short-duration (< 0.25s) viewing of the direct or specularly-reflected beam. Diffuse reflections from these lasers are generally not hazardous, except for intentional staring at distances close to the diffuser.

8.2.9. Class 4: Lasers in this class are high powered and capable of causing severe eye damage with short- duration exposure to the direct, specularly-reflected, or diffusely-reflected beam. They are also capable of producing severe skin damage. Flammable or combustible materials may ignite if exposed to the direct beam. Accidental exposure to high powered Class 4 lasers may result in serious injury or death.

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9. Laser Use Authorization, Appendix 8.3

Laser Use Authorization/Registration (Class 3B & Class 4 Lasers)

LUA#:______________________(EH&S Use Only)

Contact Person:
Person in charge/Contact, Title, Office Location, Extension:_______________________
____

Training and experience in laser use:_____________________________________
____

Laser Information:
Laser Class: ☐ 3b ☐ 4 ☐ Class 1 Enclosure w/ Embedded Class 3b or 4
Other

Laser Type (Argon, CO2, HeNe, Diode, Dye, Fiberoptic):_______________________
____

Emission Wavelengths(nm):____
Is laser system capable of emitting multiple wavelenths simultaneously:________
Emission Type: ☐ Continuous Wave ☐ Pulsed ☐ Both

If used in pulse mode: Total/Peak Energy per Pulse_____________
Pulse Duration:_______________ Rep. Rate:__________________ ☐ Q-Switched

Maximum Beam Power (Watts):_____________
Input Power (Volts/Amps/Phase):____

Beam Path (Fully Enclosed, Partially Enclosed, Open):___________________________

Are there any activities that will require the laser to be operated with the interlocks defeated (service/repair) or an open beam path: No Yes ,

If Yes - Explain____
____

Beam Excitation Type (Flash Lamp, RF, High Voltage DC, etc.):___________________
____
Cooling Type (Air, Recirculating Water, Temperature Controlled Water, etc):__________
____

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Site Information:

Laser Location (Building and Room):____

Typical Laser Use (Project Description):______________________________________
____

Are any of the following materials used/present at the use site:
Flammable Gases Flammable Liquids/Solids Reflective Surfaces Windows

Other Information:____
____

Personnel Information:
Who has access to the laser (Faculty, Staff, Students, and Public):________________
____

How are the laser users trained?____

How is the laser use controlled?____

General Information: ☐ Laser Controlled Area
What protective equipment is used?_______________________________________
____

Are Standard Operating Procedures available? What Form?______________________

How is the laser maintained? (In house, sent off-site, etc.):_____________________
____

This form completed by:______________________________ Date:____________

Please return this form to Tim Hastings, Environmental Safety, Bldg. 080, Ext. 6-6651, thasting@calpoly.edu

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9.1. Laser/Laser Controlled Area Hazard Assessment, Appendix 8.4

Name of Principal Investigator/Supervisor:______________________________________

Date of Inspection:____

Location:____

Laser (LUA): **Class:**

Inspection Conducted By:____

#	Findings	Y	N	NA	Comments
	Engineering Safety Controls:				
L01	Laser generating machine secured				
L02	Laser optics secured to prevent stray beams				
L03	Laser beam path not at eye level				
L04	Open beam (# of laser in comments)				
L05	Enclosed beam (# of laser in comments)				
L06	Beam stops/barriers/attenuators in place				
L07	Protective housing with interlocks present				
L08	Emergency stop/key or master switch present				
L09	Activation warning system present (light/sound)				
L10	Beam viewing optics hazard present				
L11	Windows in room covered				
L12	Reflective materials kept out of beam path				
L13	Fiber optics present				
	Administrative Safety Controls:				
L14	All users have appropriate laser training				
L15	SOP up-to-date and signed by users				
L16	SOP posted and available in same room				
L17	Laser Controlled Area (LCA) posted				
L18	Warning labels on the machine present				
L19	Door signs posted				
L20	Beam alignment procedure available				
L21	Bean not directed towards windows or entry points				
L22	Laser Safety guidelines posted				

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#	Findings	Y	N	NA	Comments
L23	Laser Safety Manual available				
L24	Emergency contact list posted				
L25	Fiber optics connector tag present				
	Personal Protective Equipment (PPE):				
L26	Proper laser eye protection available				
L27	Laser Safety eyewear available in good condition				
L28	Eyewear is the correct OD and correct wavelength				
L29	UV protection available				
L30	Proper skin protection available				
L31	Laser protective barriers or curtains present				
	Non-Beam Hazards:				
L32	Electrical Hazard				
L33	Collateral Radiation Hazard				
L34	Fire and/or explosion				
L35	Compressed gases in use				
L36	Chemical hazard – Toxic laser media, dye and solvents				
L37	LGAC production				
L38	Cryogenic use				
L39	Biological Hazard				
	Documentation:				
	All Class 3B and Class 4 lasers registered with EHS				
	All SOP's and alignment procedures submitted to EHS				
	Lab specific training documented				
	All documents required for audit present				
	Other (Specify):				

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9.2. Laser Controls, Appendix 8.5

9.2.1. Control Measures for Specific Laser Applications

9.2.1.1. Control Measures for Laser Pointers

Laser Pointers shall not exceed Class 3R, and are exempted from area posting requirements. Users must be aware of the potential hazards and follow safety procedures provided by the manufacturer.

When used responsibly for the intended purpose such as an aid in visual presentations, laser pointers are valuable tools that present little potential hazard. However, laser pointers have received a lot of attention in the media and have raised public concern. The safety concerns regarding the use of lasers are the potential optical hazards. These optical hazards may be exposures from momentary direct viewing with the potential side effects being glare, flash-blindness, after images and possible startle effects. Typically these side effects last on the order of several minutes up to a few hours.

Under no circumstances will visible laser beams be directed toward automobiles, aircraft, or other manned structures or vehicles, or otherwise disrupt critical tasks.

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9.2.2. Control Measures for Laser Levels

Laser levels and other laser devices used in construction are typically Class 3A or 3R. These can produce spot blindness and other eye injuries, but are safe to use if you follow the laser safety precautions from the manufacturer, and observe basic laser safety practices:

Never stare into a laser beam.

Don’t try to repair or disassemble a laser level.

Read the instruction manual before you use a laser level.

Never point a laser level at vehicles, drivers, people, or pets.

Don’t let children play with laser levels.

Always turn the laser level off when you’re not using it. Leaving it on increases the risk of someone unintentionally staring into the laser beam.

Don’t remove or deface any laser level labels.

The laser light is very bright compared to ordinary light, enough to cause an automatic aversion response against the intense light (blinking to close the eyelid, turning the head to avoid the light, automatic constriction of the pupil). Prevent injury to the eye by avoiding intentionally overcoming this aversion response.

Don’t operate a laser level near flammable liquids, gasses, or dust.

Don’t aim the laser beam at shiny or reflective surfaces; they’re not suitable for laser use.

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9.2.3. Control Measures for Confocal Microscopes

Laser scanning confocal microscopes are Class 1 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 shall be established and control measures appropriate to the class of the embedded laser shall be implemented.

9.2.4. Control Measures by Laser Classification

Potential hazards exist to all individuals working near a laser system. Such individuals should be warned of the existence and location of lasers, and of the meaning of the warning labels for all classes of lasers.

Particular attention should be given to the environment where the laser is used. This factor should be considered together with the class and application of the laser for determining the control measures to be applied. Basic elements to be considered are:

- number and class of lasers
- laser location
- presence (access) of uninformed, unprotected personnel
- permanence of beam paths
- presence of objects that may have specular surfaces or reflecting objects near the beam path
- use of optical devices such as lenses, microscopes, etc.

Control measures may be broken down to two types: administrative controls, such as signage, procedures, etc., and engineering controls, such as beam housings, shutters, etc. The following are general considerations for work with lasers, per laser hazard class.

9.2.5. Class 1

Many Class 1 lasers have higher class lasers enclosed within a protective housing. If the Class 1 laser has an enclosed Class 3b or 4 laser, interlocks should be provided on any removable parts of the housing, or the laser should have a service access panel that is either interlocked or requires a tool for removal. If the protective housing is removed, control measures appropriate for the enclosed laser class should be followed.

All Class 1 lasers must be labeled.

9.2.6. Class 2

Class 2 lasers must be labeled.

The laser beam should not be purposefully directed toward the eye of any person. Alignment of the laser optical systems (mirrors, lenses, beam deflectors, etc.) should be performed in such a manner that the primary beam, or specular reflection of the primary beam, does not expose the eye to a level above the MPE for direct irradiation of the eye.

The work area should be posted with a warning label or sign cautioning users to avoid staring into the beam or directing the beam toward the eye of individuals.

If the MPE is exceeded, design viewing portals and/or display screens to reduce exposure to acceptable levels.

If the Class 2 laser has an enclosed Class 3b or 4 laser, interlocks should be provided on any removable parts of the housing, or the laser should have a service access panel that is either interlocked or requires a tool for removal. If the protective housing is removed, control measures appropriate for the enclosed laser class should be followed.

9.2.7. Class 3R

Class 3M/R lasers must be labeled accordingly. The work area should be posted with a warning label or sign cautioning users to avoid staring into the beam or directing the beam toward the eye of individuals.

Removable parts of the housing and service access panels should have interlocks to prevent accidental exposure. A permanent beam stop or attenuator may also be used.

If the MPE is exceeded, design viewing portals and/or display screens to reduce exposure to acceptable levels. Alignment procedures should be designed to ensure the MPE is not exceeded.

9.2.8. Class 3b

Class 3B lasers and laser systems must be labeled accordingly. These lasers are used in areas where entry by unauthorized individuals can be controlled. If an individual who has not been trained in laser safety must enter the area, the laser operator or supervisor should first instruct the individual as to safety requirements and must provide protective eyewear, if required.

If the entire beam is not enclosed or if a limited open beam exists, the laser operator, supervisor or laser safety officer should determine a Nominal Hazard Zone (NHZ). An alarm, warning light or verbal countdown should be used during use or start up of the laser.

The controlled area should:

- have limited access to spectators,
- have beam stops to terminate potentially dangerous laser beams,
- be designed to reduce diffuse and specular reflections,
- have eye protection for all personnel,
- not have a laser beam at eye level,
- have restrictions on windows and doorways to reduce exposure to levels below the MPE, and
- require storage or disabling of the laser when it is not being used.
- If the MPE is exceeded, design viewing portals and/or display screens to reduce exposure to acceptable levels. Alignment procedures and collecting optics should be designed to ensure the MPE is not exceeded.
- Only authorized, trained individuals should service the laser. Approved, written standard operating, maintenance and service procedures should be developed and followed.

9.2.9. Class 4

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In addition to the control measures described for Class 3b, Class 4 lasers should be operated by trained individuals in areas dedicated to their use. Failsafe interlocks should be used to prevent unexpected entry into the controlled area, and access should be limited by the laser operator to persons who have been instructed as to the safety procedures and who are wearing proper laser protection eyewear when the laser is capable of emission.

- Laser operators are responsible for providing information and safety protection to untrained personnel who may enter the laser controlled areas as visitors.
- The laser area should be:
- restricted to authorized personnel only
- designed to allow for rapid emergency egress
- equipped with a device that allows for deactivation of the laser or reduction of the output to below the MPE
- designed to fulfill Class 3b controlled area requirements
- designed with entry safe controls
- designed such that the laser may be monitored and fired from a remote location
- (for pulsed systems) have interlocks designed to prevent firing of the laser by dumping the stored energy into a dummy load
- (for continuous wave systems) have interlocks designed to turn off the power supply or interrupt the beam by means of shutters.
- The beam path must be free of specularly reflective surfaces and combustible objects and the beam terminated in a non-combustible, non-reflective barrier or beam stop.

9.3. Additional Laser Controls and Laser Controlled Area, Appendix 8.6

9.3.1. When the entire beam path from a Class 3b or Class 4 laser is not sufficiently enclosed and/or baffled to ensure that radiation exposures will not exceed the MPE, a "laser-controlled area" is required. During periods of service, a controlled area may be established on a temporary basis. The controlled area will encompass the NHZ. Those controls required for both Class 3b and Class IV installations are as follows:

9.3.2. Posting with Appropriate Laser Warning Signs
Class 3R (beam irradiance 2.5 mW/cm2), Class 3b and Class 4 lasers: Require the ANSI DANGER sign format: white back-ground, red laser symbol with black outline and black lettering. Note that under ANSI Z 136.1 criteria, area posting is required only for Class 3b and Class 4 lasers.

Class 2 or Class 3R areas (if area warning is deemed unnecessary by the LSO): All signs (and labels) associated with these lasers (when beam irradiance for Class IIIA does not exceed 2.5 mW/cm2) use the ANSI CAUTION format: yellow background, black symbol and letters.

During times of service and other times when a temporary laser-controlled area is established, an ANSI NOTICE sign format is required: white background, red laser symbol with blue field and black lettering. This sign is posted only during the time when service is in progress.

9.3.3. Operated by Qualified and Authorized Personnel. Training of the individuals in aspects of laser safety is required for Class 3b and Class 4 laser installations.

9.3.4. Transmission from Indoor Controlled Area. The beams shall not, under any circumstances, be transmitted from an indoor laser-controlled area unless for specific purposes (such as testing). In such cases, the operator and the LSO must assure that the beam path is limited to controlled air space.

9.3.5. Class 4 Laser Controls--General Requirements

Those items recommended for Class 3b but required for Class 4 lasers are as follows:

9.3.5.1. Supervision directly by an individual knowledgeable in laser safety.

9.3.5.2. Entry of any noninvolved personnel requires approval.

9.3.5.3. A beam stop of an appropriate material must be used to terminate all potentially hazardous beams.

9.3.5.4. Use diffusely reflecting materials near the beam, where appropriate.

9.3.5.5. Appropriate laser protective eye wear must be provided all personnel within the laser controlled area.

9.3.5.6. The beam path of the laser must be located and secured above or below eye level for any standing or seated position in the facility.

9.3.5.7. All windows, doorways, open portals, etc., of an enclosed facility should be covered or restricted to reduce any escaping laser beams below appropriate ocular MPE level.

9.3.5.8. Require storage or disabling of lasers when not in use.

9.3.6. Entryway Control Measures (Class IV)

In addition, there are specific controls required at the entryway to a Class 4 laser controlled area. These can be summarized as follows:

9.3.6.1. All personnel entering a Class IV area shall be adequately trained and provided proper laser protective eye wear.

9.3.6.2. All personnel shall follow all applicable administrative and procedural controls.

9.3.6.3. All Class IV area and entryway controls shall allow rapid entrance and exit under all conditions.

9.3.6.4. The controlled area shall have a clearly marked "Panic Button" (nonlockable disconnect switch) that allows rapid deactivation of the laser.

9.3.6.5. Class IV areas also require some form of area and entryway controls. In the past, doorway interlocking was customary for Class IV installations. The ANSI Z 136 Standard now provides four options that allow the LSO to provide an entryway control suited for the installation. The options include:

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9.3.6.6. Nondefeatable Entryway Controls: A nondefeatable control, such as a magnetic switch built into the entryway door which cuts the beam off when the door is opened, is one option. In this case, training is required only for those persons who regularly work in the laser area.

9.3.6.7. Defeatable Entryway Controls: may be used at an entryway, for example, during long-term testing in a laser area. In this case the controls may be temporarily made inactive if it is clearly evident that there is no hazard at the point of entry. Training is required for all personnel who may frequently require entry into the area.

9.3.6.7.1. Such defeatable controls shall be designed to allow both rapid egress by the laser personnel at all times and admittance to the laser controlled area in an emergency condition. A readily accessible "panic button" or control/disconnect switch shall be available for deactivating the laser under such emergency conditions.

9.3.6.7.2. Under conditions where the entire beam path is not completely enclosed, access to the laser-controlled area shall be limited only to persons wearing proper laser protective eye wear when the laser is capable of emitting a beam. In this case, all other optical paths (for example, windows) from the facility shall be covered or restricted in such a way as to reduce the transmitted intensity of the laser radiation to levels at or below the MPE for direct irradiation of the eye.

9.3.6.8. Procedural Entryway Controls: A blocking barrier, screen, or curtain that can block or filter the laser beam at the entryway may be used inside the controlled area to prevent the laser light from exiting the area at levels above the applicable MPE level. In this case, a warning light or sound is required outside the entryway that operates when the laser is energized and operating. All personnel who work in the facility shall be appropriately trained.

9.3.6.9. Entryway Warning Systems: In order to safely operate a Class 4 laser or laser system, a laser warning system shall be installed as described:

9.3.6.9.1. A laser activation warning light assembly shall be installed outside the entrance to each laser room facility containing a Class IV laser or laser system.

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9.3.6.9.2. In lieu of a blinking entryway warning, the entryway light assembly may alternatively be interfaced to the laser in such a manner that a light will indicate when the laser is not operational (high voltage off) and by an additional light when the laser is powered up (high voltage applied) but not operating and by an additional (flashing) light when the laser is operating.

9.3.6.9.3. A laser warning sign shall be posted both inside and outside the laser-controlled area.

9.3.7. Temporary Laser-Controlled Area

9.3.7.1. Should overriding interlocks become necessary during periods of special training, service, or maintenance, and access to Class 3b or Class 4 lasers is required, a temporary laser-controlled area shall be devised following specific procedures approved by the LSO. These procedures shall outline all safety requirements necessary during such operation.

9.3.7.2. Such temporary laser-controlled areas, which by nature will not have the built-in protective features as defined for a laser-controlled area, shall nevertheless provide all of the safety requirements for all personnel, both within and without the temporary laser-controlled area during periods of operation when the interlocks are defeated.

9.3.8. Administrative and Procedural Controls

9.3.8.1. Standard Operating Procedures. One of the more important of the administrative and procedural controls is the written Standard Operating Procedure (SOP). The ANSI Z 136.1 standard requires an SOP for a Class 4 laser and recommends SOP's for Class 3b lasers.

9.3.8.2. The key to developing an effective SOP is the involvement of those individuals who operate, maintain and service the equipment under guidance of the LSO. Most laser equipment comes with instructions for safe operation by the manufacturers; however, sometimes the instructions are not well suited to a specific application due to special use conditions.

9.3.8.3. Alignment Procedures. Many laser eye accidents occur during alignment. The procedures require extreme caution. A written SOP is recommended for all recurring alignment tasks.

9.3.8.4. Limitations on Spectators. Persons unnecessary to the laser operation should be kept away. For those who do enter a laser area with unenclosed Class IIIB or Class IV beam paths, appropriate eye protection and instruction is required.

9.3.8.5. Protective Equipment. Protective equipment for laser safety generally means eye protection in the form of goggles or spectacles, clothing, and barriers and other devices designed for laser protection.

9.3.9. Laser Protective Eyewear and Clothing

9.3.9.1. Eye-protection devices designed to protect against radiation from a specific laser system shall be used when engineering controls are inadequate to eliminate the possibility of potentially hazardous eye exposure (i.e., whenever levels of accessible emission exceed the appropriate MPE levels.) This generally applies only to Class IIIB and Class IV lasers. All laser eye wear shall be clearly labeled with OD values and wavelengths for which protection is afforded.

9.3.9.2. Skin protection can best be achieved through engineering controls. If the potential exists for damaging skin exposure, particularly for ultraviolet lasers (0.200-0.400 m), then skin covers and or sun-screen creams are recommended. For the hands, gloves will provide some protection against laser radiation. Tightly woven fabrics and opaque gloves provide the best protection. A laboratory jacket or coat can provide protection for the arms. For Class IV lasers, flame-resistant materials may be best.

9.3.9.3. In general, other controls should serve as primary protection rather than depending on employees to use protective eye wear. Many accidents have occurred when eye wear was available but not worn. This may be because laser protective eye wear is often dark, uncomfortable to wear, and limits vision.

9.3.10. Laser Barriers and Protective Curtains

9.3.10.1. Area control can be effected in some cases using special barriers specifically designed to withstand either direct or diffusely scattered beams. The barrier will be described with a barrier threshold limit (BTL): the beam will penetrate the barrier only after some specified exposure time, typically 60 seconds. The barrier is located at a distance from the laser source so that the BTL is not exceeded in the worst-case exposure scenario.

9.3.10.2. Currently available laser barriers exhibit BTL's ranging from 10 to 350 W/cm2 for different laser wavelengths and power levels. An analysis conducted in a manner similar to the NHZ evaluations described previously can establish the recommended barrier type and installation distances for a given laser. It is essential that the barrier also not support combustion or be itself consumed by flames during or following a laser exposure.

9.3.11. Engineering Controls

9.3.11.1. Engineering controls are normally designed and built into the laser equipment to provide for safety. Specifics on some of the more important engineering controls recommended in the ANSI Z 136.1 standard are detailed as follows:

9.3.11.1.1. Protective Housing. A laser shall have an enclosure around it that limits access to the laser beam or radiation at or below the applicable MPE level. A protective housing is required for all classes of lasers except, of course, at the beam aperture. In some cases, the walls of a properly enclosed room area can be considered as the protective housing for an open beam laser. Such a "walk-in" enclosure can also be a FDA/CDRH Class I provided that controls preclude operation with personnel within the room (viz.: pressure sensitive floor-mat switches, IR sensors, door interlocks, etc.)

9.3.11.1.2. Master Switch Control. All Class 4 lasers and laser systems require a master switch control. The switch can be operated by a key or computer code. When disabled (key or code removed), the laser cannot be operated. Only authorized system operators are to be permitted access to the key or code. Inclusion of the master switch control on Class 3b lasers and laser systems is also recommended but not required.

9.3.11.1.3. Optical Viewing System Safety. Interlocks, filters, or attenuators are to be incorporated in conjunction with beam shutters when optical viewing systems such as telescopes, microscopes, viewing ports, or screens are used to view the beam or beam-reflection area. For example, an electrical interlock could prevent laser system operation when a beam shutter is removed from the optical system viewing path. Such optical filter interlocks are required for all except Class 1 lasers.

9.3.11.1.4. Beam Stop or Attenuator. Class 4 lasers require a permanently attached beam stop or attenuator which can reduce the output emission to a level at or below the appropriate MPE level when the laser system is on "standby." Such a beam stop or attenuator is also recommended for Class 3R and Class 3b lasers.

9.3.11.1.5. Laser Activation Warning System. An audible tone or bell and/or visual warning (such as a flashing light) is recommended as an area control for Class 3b laser operation. Such a warning system is mandatory for Class 4 lasers. Such warning devices are to be activated upon system start-up and are to be uniquely identified with the laser operation. Verbal "countdown" commands are an acceptable audible warning and should be a part of the SOP.

9.3.11.1.6. Service Access Panels. The ANSI Z 136.1 standard requires that any portion of the protective housing that permits direct access to an embedded Class 3b or Class 4 laser (intended for removal only by service personnel) must have either an interlock or require a tool in the removal process. If an interlock is used and is defeatable, a warning label indicating this fact is required on the housing near the interlock. The design shall not allow replacement of a removed panel with the interlock in the defeated condition.

9.3.11.1.7. The FDA/CDRH Federal Laser Product Performance Standard requires warning labels on removable protective housing panels under all conditions.

9.3.11.2. Protective Housing Interlock Requirements

9.3.11.2.1. Interlocks, which cause beam termination or reduction of the beam to MPE levels, must be provided on all panels intended to be opened during operation and maintenance of all Class 3R, Class 3b, and Class 4 lasers. The interlocks are typically electrically connected to a beam shutter. The removal or displacement of the panel closes the shutter and eliminates the possibility of hazardous exposures.

9.3.11.2.2. Under the requirements of the ANSI Z 136 Standard, for embedded Class IIIB and Class IV lasers only, the interlocks are to be "fail-safe." This usually means that dual, redundant, electrical series-connected interlocks are associated with each removable panel.

9.3.11.2.3. Adjustments or procedures during service on the laser shall not cause the safety interlocks to become inoperative or the laser radiation outside a Class I laser protective housing to exceed the MPE limits, unless a temporary laser-controlled area is established.

9.3.11.2.4. Remote Interlock Connector. All Class 4 lasers or laser systems must have a remote interlock connector to allow electrical connections to an emergency master disconnect ("panic button") interlock or to room, door or fixture interlocks. When open circuited, the interlock shall cause the accessible laser radiation to be maintained below the appropriate MPE level. The remote interlock connector is also recommended for Class 3b lasers.

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9.4. Standard Operating Procedure Template, Appendix 8.6

Black Text – is considered mandatory content

Red text – fill in appropriate information for factual accuracy

Blue Text – (sample text) may be retained, edited, or deleted as appropriate for factual accuracy

Approved by Supervisor/Principal Investigator:
_______________________________Date:_________________

Reviewed by Laser Safety Officer:
_______________________________Date:_________________

Standard Operating Procedure

Location____

Type of Laser(s) or experiment____

Date, version#____

9.4.1. Purpose

This Standard Operating Procedure (SOP) outlines requirements to be considered by an authorized user of the Type of Laser(s) or experiment as well as describes the normal operation of the laser and any hazards that may be encountered during normal operation. Finally, the SOP explains how to minimize any hazards and how to respond in an emergency situation. This document is to be reviewed one year from the date of approval or as conditions warrant, whichever is the shorter time period.

9.4.2. Personnel

Authorized Personnel: The Type of Laser(s) or experiment may be operated only by authorized personnel who are fully cognizant of all safety issues involved in the operation of such a device. These personnel are to ensure that the laser is only operated in the manner laid out in this document. To become an authorized user, one must:

- Complete the online SkillPort - Fundamentals of Laser Safety Course (_scorm12_spcentralsta_stc_lasersafetyfund).
- Read and fully understand the SOP
- Receive hands-on training on the Type of Laser(s) or experiment by an authorized user.
- **Sign the authorized user sheet to affirm that the above steps have been completed.**

Unauthorized personnel: No unauthorized personnel may enter room location during laser operation unless accompanied by an authorized user. All visitors must be briefed on proper safety protocol and must wear appropriate laser protective eyewear located on the premises.

9.4.3. Hazards

Laser Hazards: The Laser Type is a Class 4 or 3B (list class) laser. Severe eye damage (including blindness) and skin damage can result from direct beam and specular reflections. Eye damage can also result from diffuse reflections (Class 4).

Electrical Hazards: electrical shock or electrocution could result from direct contact with high voltage. List types of electrical hazards associated with laser use, equipment, or experiment.

Chemical: List types of chemical hazards associated with laser use, equipment, or experiment.

Pressure Hazards: List types of pressure hazards associated with laser use, equipment, or experiment.

E. Other: List types of other hazards associated with laser use, equipment, or experiment.

9.4.4. Hazard Controls

- Only authorized personnel will operate lasers.
- The laboratory doors will be closed and locked whenever laser is operating.
- During alignments, the laboratory doors will be closed, locked, and a sign posted stating "**Laser alignment in progress. Do not enter. Laser Eye Protection required.**"
- Unauthorized personnel will be only allowed entry to the laboratory during laser operation with the supervision of an authorized user under the terms specified in section 2.
- Laser eye protection (LEP) for sufficient protection against (*list wavelengths used*) nm is available and is located at (detail the location of where laser eye protection is in lab and also describes the different types of eyewear if multiple pairs are needed). Laser eye protection is required to be worn for all beam alignments/beam manipulations or anytime there is an open beam that exceeds the maximum permissible value.
- Please note : Laser Eye Protection is wavelength specific and proper section is critical.
- Specular and diffuse reflections will be controlled using beam stops, beam barriers, beam housings and enclosures. All of these control methods must be in place during normal operation.
- No jewelry or other reflective materials are to be worn while working with the Laser, especially on the hands and neck.
- Personal in the laser lab should avoid bending over or otherwise putting their eyes at the level of the beam path while the laser is in operation.
- Laser alignment must be performed only by following the steps outlined in the alignment procedure supplement or alignment section.
- Perform physical surveys to determine if there are stray beams (specular or diffuse) emanating from each laser and its optics, and then document the beam surveys noting the location of stray beams and the measures taken to control them. *Please indicate method of documentation of survey (checklist or log, etc.)*

- If the beam path must be changed significantly by relocating the laser or optics, all users must be notified of the change.

- The same precautions that are taken for safe operation of the laser must also be followed when adjusting any of the optics in use with the apparatus.

- When a new principal researcher/experimenter takes over use of the laser system, the new user must conduct a survey for unwanted stray or diffuse beams. Appropriate tools such as IR sensitive cards or IR viewer shall be used for locating the possibility of stray IR light.

- Experimental end stations should be treated the same as the laser system with regards to the proceeding safety procedures.

Electrical (List controls used to mitigate the hazard)

- Enclosures for protection against the high voltages of the laser power supply or laser head may only be removed after the power supply has been unplugged from the outlets and after following the safety procedures outlined in the safety and operations manual provided by the manufacturer.
- Only qualified personnel may perform all internal maintenance to the laser and more than one user must be present when performing said maintenance.
- Every portion of the electrical system, including the printed circuit cards, should be assumed to be at dangerous voltage level.

Chemical List controls used to mitigate the hazard

Pressure List controls used to mitigate the hazard

Other List controls used to mitigate the hazard

9.4.5. Normal Operation

(SAMPLE TEXT – text below may be retained, edited, or deleted as appropriate for factual accuracy)

Inspect all electrical and water connections for damage and connectivity.

Complete the “check-in” portion of the checklist included in this document. The checklist serves to confirm that all basic systems are operating within expected parameters and that basic safety mechanisms are in place. The laser run log is a set of forms adjacent to the experimental set up and is used to ascertain the current state of the laser. Log all use and add individual notes as necessary. Also, replacement of optics and other routine maintenance should be noted in the log. Once the checklist is complete, the laser may be turned on.

Turn laser system on.

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System alignment. See the attached alignment procedure supplement/alignment section for details.

Shutdown laser system.

After a run is finished, complete the log entry and the checkout portion of the checklist.

9.4.6. Emergency Procedures

A. Laser accidents: Follow the steps outlined in the Procedure for Laser Accidents.

B. Power outage: If there is a power outage, turn off the laser to avoid a hazardous situation when power is restored.

Integrated Safety Management

Take ownership of your safety!

Before starting any work, ask yourself:

What will I be doing?

Do I know what the hazards are?

Do I have everything I need to do the job safely?

Am I doing the job safely?

What can we do better?

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9.4.7. Authorized Users:

I have read and understood the Standard Operating Procedures for type of laser or experiment

Name (print)	Signature	Date	PI Initial

9.4.8. Checklist for using Type of laser or experiment

Check in: (SAMPLE TEXT – text below may be retained, edited, or deleted as appropriate for factual accuracy)

-Door is closed and all personnel are wearing the appropriate laser protective eyewear.

-Inspect the apparatus for any blockages or apparent misalignment.

-Confirm that the beam path is set up to hit the sample properly.

-Ensure that all beam enclosures and /or beam stops are placed properly in the work area.

-Record laser energy in the logbook.

-During the run, ensure that the laser is hitting the sample correctly.

-Record any anomalous behavior in the logbook.

Check out:

Shut off the laser.

9.4.9. Procedure for Laser Accidents

In the event of a laser accident, follow the procedure below:

Ensure that the laser is shut off.

Provide for the safety of the personnel (first aid, evacuation, etc.) as needed. Note — if an eye injury is suspected, have the injured person keep his/her head upright and still to reduce bleeding in the eye. A physician should evaluate laser injuries as soon as possible.

Obtain medical assistance for anyone who may be injured.

Emergencies, University Police (UPD)	**911**
Non-Emergency Assistance, (UPD)	**(805) 756-2281**

If there is a fire, pull the alarm, and contact University Police by calling 911. Do not fight the fire unless it is very small and you have been trained in fire fighting techniques.

Inform the Office of Environment Health, & Safety (EH&S) as soon as possible.

During normal working hours, call the following:

EH&S Office	**(805) 756-6665**
Laser Safety Officer	**(805) 756-6651**

After normal working hours, call (805) 756-2281 (UPD).

Inform ***(PI NAME/Supervisor)*** and the current group safety officer as soon as possible. If there is an injury, ***(PI NAME/Supervisor)*** will need to submit a report of injury to the Worker's Compensation Office.

After the incident, do not resume use of the laser system until the Laser Safety Officer has reviewed the incident and approved the resumption of laser use.

9.4.10. Alignment Procedures

9.4.10.1. Pre-Alignment Safety

- Post the “Laser Alignment in Progress” notice sign outside the laser lab before beginning any alignment procedure.
- Check that the laser curtain is securely closed with no gaps.
- Only authorized personal are allowed in the laser lab during alignment.
- All personal in the room must wear the appropriate laser protective eyewear during alignment.
- To reduce accidental reflections, watches, rings, dangling badges, and other reflective jewelry or materials must be taken off before any alignment activity begins.
- Alignment should only be performed when there is at least two authorized users present who have been trained to respond to a laser safety emergency.
- Check for and remove any foreign objects in the beam path other than safety controls such as beam blocks. Remove all unnecessary equipment, tools, and combustible materials from the laser table and immediate area to minimize the possibility of stray reflections and non-beam accidents.

9.4.10.2. General Alignment Safety Concerns

- Use of non-reflective alignment tools should be considered. When reflective tools are required, be mindful to keep tools out of the beam path.
- Never allow the beam to propagate beyond the point to which you have aligned and always be aware of the full beam path.
- Always block the beam upstream when inserting/removing anything into/from the beam path, such as alignment irises.
- Use a pair of index cards when checking the alignment of the beam so that you never have to leave the beam unblocked to move a card past a mirror.
- As alignment proceeds down the table, a beam block should always be placed down stream in a position to catch the beam directly after the pair of mirrors being aligned, preventing the beam from propagating through an unaligned path.

- Be aware that all transmissive optics generate back reflections and some reflective optics have substantial leak through. When working with these components be sure to track, block, and record all stray beams. This is a particular concern with filters (We currently use both ND and Bandpass filters), which generate strong specular reflections that can propagate back up stream a long way before diverging off the beam path due to very slight miss alignments. When such a reflection travels back upstream and encounters a beam splitting optic a new beam path can be formed in an unexpected direction.
- When working with focusing elements, it important to be aware that there may be sufficient intensity at the focus to burn skin and/or ignite combustible materials, such as index cards. At sufficiently high powers the focus may create plasma in the air resulting in a loud “popping” noise at the repetition rate of the laser, a glowing white spot at the focus where nonlinear optical processes are occurring, and the creation of ozone that smells like electric discharge. This can be disconcerting when unexpected. If this occurs simply block the beam upstream from the focusing element and either reduce the power of the beam or change the focusing element to a less tightly focusing optic.

9.4.10.3. Internal Alignment Mirrors

- (SAMPLE TEXT – text below may be retained, edited, or deleted as appropriate for factual accuracy)
- Ensure that all users are wearing appropriate laser protective eyewear, warning signs are posted, and laboratory doors are closed. Check that the laser path goes to the power meter and is enclosed.
- Turn on the cooling water.
- Turn on the power supply, checking that the water light comes on.
- Turn to current mode/ full power; turn on the laser and press start.
- Adjust vertical and horizontal knobs back to maximum power.
- Turn off the laser and power supply.
- Take off the lid and screw on safety overrides.
- Test the power again (after turning the laser back on). Adjust to full power.

- Use a non-reflective 7/16 wrench. Turn the vertical front knob to ___ power and adjust the back vertical knob in the opposite direction to see if power increases past the original power. If so, repeat. If not, turn the front knob in the other direction and repeat.

- When the power is maximized, turn off the laser.

- Replace the laser covering and let the cooling water run for 30 minutes.

9.4.11. External Optics

- (SAMPLE TEXT – text below may be retained, edited, or deleted as appropriate for factual accuracy)
- Ensure that all users are wearing appropriate laser protective eyewear, warning signs are posted, and laboratory doors are closed. Check that the laser path will be blocked.
- Turn on the cooling water.
- Turn on the power supply, checking that the water light comes on.
- Turn to current mode/ full power; turn on the laser and press start. *(LASER BEAM POWER SETTING-USE LOWEST POSSIBLE POWER FOR ALIGNMENT)*
- Set up the first optic, block the beam path optic, and carefully release the original block to ensure that the beam will hit the center of the mirror.
- Set up two targets in the beam path, unblock the beam, and center the beam using adjustments on the optic. Make sure that that beam does not “clip” (i.e. that part of beam does not go past mirror, or strike the corner of another mirror and set sent off at unexpected angles. Use card held directly in front of mirror to determine that the beam is centered, and directly after the mirror to check beam profile for “clipping”.
- Continue until optics are set up properly. Check that all mounts are tightly in place and will not inadvertently shift, causing changes in alignment.
- Check for stray beams at each step and again after completing all alignment steps, using IR viewer or IR card if necessary. Please indicate method of documentation of survey (checklist or log, etc.)
- Check that ALL laser beam enclosure and /or beam stops are in place.

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9.5. Wavelengths of Common Lasers, Appendix 8.8

Laser type	Wavelength (μmeters)	Laser type	*Wavelength (μmeters)*
Argon fluoride (Excimer-UV)	0.193	Helium neon (yellow)	0.594
Krypton chloride (Excimer-UV)	0.222	Helium neon (orange)	0.610
Krypton fluoride (Excimer-UV)	0.248	Gold vapor (red)	0.627
Xenon chloride (Excimer-UV)	0.308	Helium neon (red)	0.633
Xenon fluoride (Excimer-UV)	0.351	Krypton (red)	0.647
Helium cadmium (UV)	0.325	Rohodamine 6G dye (tunable)	0.570-0.650
Nitrogen (UV)	0.337	Ruby ($CrAlO_3$) (red)	0.694
Helium cadmium (violet)	0.441	Gallium arsenide (diode-NIR)	0.840
Krypton (blue)	0.476	Nd:YAG (NIR)	1.064
Argon (blue)	0.488	Helium neon (NIR)	1.15
Copper vapor (green)	0.510	Erbium (NIR)	1.504
Argon (green)	0.514	Helium neon (NIR)	3.39
Krypton (green)	0.528	Hydrogen fluoride (NIR)	2.70
Frequency doubled Nd YAG (green)	0.532	Carbon dioxide (FIR)	9.6
Helium neon (green)	0.543	Carbon dioxide (FIR)	10.6
Krypton (yellow)	0.568		
Copper vapor (yellow)	0.570		

UV = ultraviolet (0.200-0.400 μm)
VIS = visible (0.400-0.700 μm)
NIR = near infrared (0.700-1.400 μm)
FIR = far Infrared

9.6. Non-Beam Hazards, Appendix 8.9

In some laser operations, particularly in the research laboratory, general safety and health guidelines should be considered.

9.6.1. Industrial Hygiene

Potential hazards associated with compressed gases, cryogenic materials, toxic and carcinogenic materials and noise should be considered. Adequate ventilation shall be installed to reduce noxious or potentially hazardous fumes and vapors, produced by laser welding, cutting and other target interactions, to levels below the appropriate threshold limit values, e.g., American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit values (TLV's) or Occupational Safety and Health Administration's (OSHA) permissible exposure limits (PEL's).

9.6.2. Explosion Hazards

High-pressure arc lamps and filament lamps or laser welding equipment shall be enclosed in housings which can withstand the maximum pressures resulting from lamp explosion or disintegration. The laser target and elements of the optical train which may shatter during laser operation shall also be enclosed.

9.6.3. Nonbeam Optical Radiation Hazards

This relates to optical beam hazards other than laser beam hazards. Ultraviolet radiation emitted from laser discharge tubes, pumping lamps and laser welding plasmas shall be suitably shielded to reduce exposure to levels below the ANSI Z 136.1 (extended source), OSHA PEL's, and/or ACGIH TLV's.

9.6.4. Collateral Radiation

Radiation, other than laser radiation, associated with the operation of a laser or laser system, e.g., radio frequency (RF) energy associated with some plasma tubes, x-ray emission associated with the high voltage power supplies used with excimer lasers, shall be maintained below the applicable protection guides. The appropriate protection guide for RF and microwave energy is that given in the American National Standard "Safety levels with respect to human exposure to radio frequency electromagnetic fields, 300 kHz to 100 GHz," ANSI C95.1; the appropriate protection guides for exposure to X-ray emission is found in the Department of Labor Occupational Safety and Health Standards, 29 CFR Part 1910.1096 and the applicable State Codes. Lasers and laser systems which, by design, would be expected to generate appreciable levels of collateral radiation, should be monitored.

9.6.5. Electrical Hazards

The intended application of the laser equipment determines the method of electrical installation and connection to the power supply circuit (for example, conduit versus flexible cord). All equipment shall be installed in accordance with the National Electrical Code and the Occupational Safety and Health Act. [Additional specific recommendations can be found in Section 7.4 of ANSI Z 136.1 (1993)].

9.6.6. Flammability of Laser Beam Enclosures

Enclosure of Class 4 laser beams and terminations of some focused Class 3b lasers, can result in potential fire hazards if the enclosure materials are exposed to irradiances exceeding 10 W/cm2. Plastic materials are not precluded as an enclosure material, but their use and potential for flammability and toxic fume release following direct exposure should be considered. Flame-resistant materials and commercially available products specifically designed for laser enclosures should also be considered.

9.7. Biological Effects of the Laser, Appendix 8.10

9.7.1. Eye Injury

Because of the high degree of beam collimation, a laser serves as an almost ideal point source of intense light. A laser beam of sufficient power can theoretically produce retinal intensities at magnitudes that are greater than conventional light sources, and even larger than those produced when directly viewing the sun. Permanent blindness can be the result.

9.7.2. Thermal Injury

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

The thermal damage process (burns) is generally associated with lasers operating at exposure times greater than 10 microseconds and in the wavelength region from the near ultraviolet to the far infrared (0.315 μm-103 μm). Tissue damage may also be caused by thermally induced acoustic waves following exposures to sub-microsecond laser exposures.

With regard to repetitively pulsed or scanning lasers, the major mechanism involved in laser-induced biological damage is a thermal process wherein the effects of the pulses are additive. The principal thermal effects of laser exposure depend upon the following factors:

The absorption and scattering coefficients of the tissues at the laser wavelength.

Irradiance or radiant exposure of the laser beam.

Duration of the exposure and pulse repetition characteristics, where applicable.

Extent of the local vascular flow.

Size of the area irradiated.

9.7.3. Other

Other damage mechanisms have also been demonstrated for other specific wavelength ranges and/or exposure times. For example, photochemical reactions are the principal cause of threshold level tissue damage following exposures to either actinic ultraviolet radiation (0.200 μm-0.315 μm) for any exposure time or "blue light" visible radiation (0.400 μm-0.550 μm) when exposures are greater than 10 seconds.

To the skin, UV-A (0.315 μm-0.400 μm) can cause hyperpigmentation and erythema.

Exposure in the UV-B range is most injurious to skin. In addition to thermal injury caused by ultraviolet energy, there is the possibility of radiation carcinogenesis from UV-B (0.280 mm - 0.315 mm) either directly on DNA or from effects on potential carcinogenic intracellular viruses.

Exposure in the shorter UV-C (0.200 µm-0.280 µm) and the longer UV-A ranges seems less harmful to human skin. The shorter wavelengths are absorbed in the outer dead layers of the epidermis (stratum corneum) and the longer wavelengths have an initial pigment-darkening effect followed by erythema if there is exposure to excessive levels

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

9.8. Medical Surveillance, Appendix 8.11

F2.1.2 Periodic Medical Examinations. Periodic examinations are not required by this standard. At present, no chronic health problems have been linked to working with lasers. Also, most uses of lasers do not result in chronic exposure of employees even to low levels of radiation. A large number of these examinations have been performed in the past, and no indication of any detectable biological change was noted. Employers may wish to offer their employees periodic eye examinations or other medical examinations as a health benefit. However, there does not appear to be any valid reason to require such examinations as part of a medical surveillance program.

10. ATTACHMENTS: None

11. DOCUMENT MAINTENANCE

11.1. DOCUMENT RECISION-

Delete or replace documents from the EH&S website due to this document release: NA

11.2. DOCUMENT APPROVER-

David Korpan, EH&S Director, Cal Poly

11.3. DOCUMENT OWNER-

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11.4. DOCUMENT CONTACT-

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11.5. REVISION NOTES-

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Changes from previous: NA