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Part 20: Ionizing Radiation/Nonionizing Radiation

Document 20.8
Lasers

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Lasers*

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Lasers

1.0 Introduction

A laser is a device that produces an intense, coherent directional beam of light energy. LLNL uses many types of lasers—from small lasers used in a laboratory or in the field, to large lasers, such as the National Ignition Facility. This document describes the different types of lasers used at LLNL, their classifications, and the required controls for each classification. This document also describes the responsibilities of personnel who work with or supervise laser operations and identifies the training required for all LLNL operations involving laser use.

Unless specifically stated otherwise in this document, work standards for the safe operation of lasers and laser systems at LLNL shall follow the recommendations of ANSI Z136.1-2000, "American National Standard for Safe Use of Lasers," (with exemptions), and ANSI Z136.2 -1997 "American National Standard for Safe Use of Fiber Optic Communication Systems Utilizing Laser Diode and LED Sources." The appendices (of the standards) are not part of ANSI Z136.1 or ANSI Z136.2, and are for informational use only.

1.1 Scope

This document applies to the operation of lasers at wavelengths between 180 nm and 1 mm in use by LLNL for any experimental or developmental work, and to the personnel who use them at LLNL, both onsite and offsite. Laser users at the Nevada Test Site (NTS) shall also follow the requirements in Appendix A. For more information, contact your area ES&H Team.

Examples of lasers and laser systems that this document applies to may include:

- Commercially available lasers that are used as a part of an experiment or laser development.
- LLNL-designed or -built lasers or laser systems.
- Applications of any laser or laser system that are determined to be hazardous by the LLNL Laser Safety Officer (LSO), Hazards Control Department, or directorate management following an inspection, evaluation, or review, based on an intended use or application at LLNL.
- Commercially available lasers that have been modified, assembled, or incorporated into a device built by LLNL.

This document does not apply to lasers incorporated into commercially available devices for use by the general public, unless opened, serviced, modified, or incorporated into a device built by or for LLNL, or as specifically addressed in this document. Although misuse of these lasers may pose a hazard, it is generally accepted that the risk of injury from these devices is minimal if used as intended by the manufacturer. Examples of lasers and laser systems not covered by this document include:

- CD players, laser printers, lasers used in surveying and construction, laser gun sights, and handheld diagnostic equipment used by the Fire Department, Plant Engineering Department, electricians, or security personnel.
- Analytical devices that conform to 21 CFR 1040. Servicing of an installed laser that may expose personnel to hazardous light at LLNL is required to conform to this document.

This document also includes six appendices:

- Appendix A describes the requirements for laser use at NTS.
- Appendix B discusses safety issues in a laser beam alignment procedure.
- Appendix C specifies how to order laser eyewear.
- Appendix D describes the requirements for warning signs.
- Appendix E shows an interlock checklist.
- Appendix F lists terms and definitions.

1.2 Laser Safety Officer

The LSO is designated with the authority and responsibility to monitor and enforce the control of laser hazards, and to effect the knowledgeable evaluation and control of laser hazards as described in this document. The responsibilities of the LSO are described in Section 16.8.

1.3 Deputy Laser Safety Officer

The LSO may identify one or more Deputy Laser Safety Officer (DLSO) to fulfill the duties of the LSO. This person shall be an industrial safety engineer assigned to an ES&H Team. Formal Laser Safety Officer training is required; see the LSO for details.

2.0 Hazardous Characteristics of Lasers

Using any laser involves exposure to varying degrees of hazards. Most lasers at LLNL can injure the eyes of anyone who looks directly into the beam or its specular (i.e., mirror-like) reflection. In addition, diffuse reflections created by some high-power laser beams can cause permanent eye damage. High-power laser beams can also burn exposed skin, ignite flammable materials, and heat materials so that they release hazardous fumes, gases, debris, or ionizing and nonionizing radiation.

Note: The most common hazard when working with lasers is eye injury. To prevent such an injury, workers shall avoid looking directly into the laser beam or its specular reflections. This rule shall be followed regardless of the protective eyewear worn or the type of hazard classification of laser unless specifically authorized in an Integration Work Sheet/Safety Plan (IWS/SP).

The classification of lasers and laser systems is based on their capability to cause injury. Class 1 (Section 6.0) and Class 2 (Section 7.0) are considered low-hazard lasers. Class 3a lasers (Section 8.0) are considered medium-hazard lasers. Class 3b and 4 lasers (Section 9.0) are considered high-hazard lasers and require more stringent controls.

Equipment and optical apparatus required for producing and controlling laser energy also introduce other hazards, including high voltage, high pressure, cryogenics, noise, additional radiation, flammable materials, laser dyes and solvents, and toxic fluids.

3.0 Accidents

Individuals who suspect they have had a laser eye exposure or skin burn shall immediately call 911 (447-6880 from a cell phone) notify their supervisor and others in the work area. Because of the nature of physical injury from an eye exposure, individuals should not attempt to drive themselves to the Health Services Department or a doctor. If damage to a blood vessel in the eye is suspected, the individual should remain in a sitting position during transport and examination to prevent further damage to the retina. An ophthalmologist shall examine the individual to determine whether an injury exists. Call the LLNL Fire Department at 911 (447-6880 from a cell phone) to report any unintentional fire caused by a laser.

4.0 Prework Planning for Lasers

Before the initial use of a laser or laser system, the Responsible Individual shall conduct prework planning, including:

- Review of the proposed project.

- Completion of a hazard analysis.
- Selection of the necessary controls to minimize exposure.
- Identification of the work procedures to be followed.
- Identification of the personnel who are to conduct the operation, and the materials and hardware to be used.

The level of detail for each step depends on the proposed activity's complexity and degree of risk. Because many controls for lasers are case-dependent, early involvement of the area ES&H Team is essential. The original project decisions may have to be modified after further analysis. For more information on the prework planning process, including preparation of an Integration Work Sheet (IWS) and other required documentation, see Document 2.2, "Managing ES&H for LLNL Work," in the *ES&H Manual*.

Prework planning, using the IWS, shall encompass the specific hazards of building up a system, including initial laser and optical alignments, connections to power, and pressurized systems. See Appendix B and Document 3.4, "Preparation of Work Procedures," in the *ES&H Manual* for considerations in writing a beam alignment procedure.

One critical decision is selecting the class of laser to use for the proposed experiment or operation because the controls differ for each class of laser. Class 4 lasers require the most rigid controls, including preparation of an IWS and safety plan, because there is a greater risk of injury from direct beams, specular reflections, and diffuse reflections.

Class 1 lasers require the fewest controls. More hazardous Class 3b or Class 4 laser systems may be embedded with engineered controls to allow them to be designated as Class 1 laser systems. This can significantly reduce the number of controls involved. (See Section 10.0 for more details.)

4.1 Hazard Analysis

Table 1 lists the individuals involved in a hazard analysis and the tasks they shall perform during evaluation of the work and preparation of the IWS. For the use of Class 1, 2, and 3a lasers, the hazard analysis information will probably fit on the IWS form. For Class 3b and 4 lasers, hazard analysis documents (e.g., laser hazard calculations) may be attached to the IWS.

Table 1. Performing a hazard analysis.

Persons Performing the Task	Task to Be Performed
Project manager, lead experimenter, facility manager, or other person designated as the Responsible Individual (with the assistance of the ES&H Team)	Determine the hazards involved and the appropriate safety measures and controls required. Identify and evaluate the applicable laser hazards, including: • Laser's capability of injuring personnel • Environment in which the laser is used • Locating potentially hazardous direct and reflected beams (beam mapping) and providing shielding to eliminate or reduce such beams to the appropriate Maximum Permissible Exposure (MPE) level • Personnel who may use or be exposed to laser radiation Evaluate: • Laser classification • Conditions of use and beam alignment • Repair methods • Personnel training • Maximum exposure duration.
ES&H Team, an LSO, or designated ES&H Team member (see Sections 16.8 and 16.9)	Assist in evaluating each operation's degree of hazard and in determining applicable regulations and requirements. This evaluation determines the extent of the hazard analysis, control selection, and documentation requirements for the project. The LSO or DLSO determines a hazard classification and calculates a MPE for all laser sources based on: • Laser classification • Exposure duration • Radiated wavelength • Output power or energy • Pulse duration and pulse repetition rate if appropriate • Beam size
LLNL LSO, DLSO, or Program LSO[a] (see sections 16.8 and 16.9)	Evaluate a laser or laser system if: • It involves outdoor laser operations or laser operations for public viewing (which are considered unusual conditions) unless an existing FSP or OSP specifically covers the operation. Section 12.0 contains additional information on laser use in public areas. • A commercially built laser has been modified, embedded, or incorporated into another system (LLNL-built or otherwise). • A change in the laser's output could decrease the safety of the system. Determine the hazard classification of an LLNL-built laser or laser system by measuring or calculating power or energy during operation. Recommend appropriate posting and labeling to the controlled area and laser or laser system.

[a] **LSO assessments may cover classification or reclassification of the laser or laser system, or labeling and posting of the laser based on measurements made during operation, calculations, or information provided by the Responsible Individual. The latter may include reasonable assessments of the maximum potential level of hazards attainable by a laser or laser system without actually requiring a laser to achieve that level.**

4.2 Controls for Non-Beam Hazards in Laser Areas

Many hazards other than laser radiation can be found in the laser area. The Responsible Individual shall adequately control the hazards to prevent injury while working with lasers. These non-beam hazards are discussed in this section.

4.2.1 Dyes and Solutions

Dye lasers normally use a lasing medium that comprises a complex, fluorescent, organic dye dissolved in an organic solvent. Animal experimentation has shown these dyes to vary greatly in toxicity and carcinogenicity, and several have been found to be mutagens. Treat all dyes as hazardous chemicals (unless it is known that they are not).

In many instances, the solvent in which the dye is dissolved plays a major role in the solution's hazards. Most suitable dye solvents are flammable and toxic if inhaled, ingested, or absorbed through the skin. In the case of dye solutions that are premixed by the manufacturer, make an effort to determine their composition. Dioxane, a potential carcinogen, can form explosive peroxides and therefore should be avoided or handled as a carcinogen. See Document 14.12, "Safe Handling of Carcinogenic Materials," in the *ES&H Manual*. Avoid the use of dimethyl sulfoxide (DMSO) and ethylene dichloride.

For additional information concerning the handling of laser dyes and solutions, refer to Document 14.11, "Laser Dyes," in the *ES&H Manual* and the material safety data sheets (MSDSs), or contact the area ES&H Team industrial hygienist. Document 14.11 describes the hazard class assigned to laser dyes. A list of laser dyes and their hazard classes are available from your area ES&H Team industrial hygienist. A laser dye safety course (HS4242, "Special Training for Toxic Laser Dye Solution") is available through your ES&H Team or the Safety, Education, and Training Division of the Hazards Control Department.

4.2.2 Electrical Equipment and Systems

The Responsible Individual shall ensure that the installation, operation, and maintenance of electrical equipment and systems conform to the standards in Document 16.1, "Electrical Safety," in the *ES&H Manual*. Metal laser tables with electrical equipment in use shall be appropriately bonded to the electrical system ground. The bonding cable and conductive path to ground shall be of sufficient size to safely conduct any fault current likely to be imposed.

4.2.3 Gases Used in Lasers

When toxic gases are used as a lasing medium, exhaust ventilation shall be used to remove gases that could escape into occupied areas. Conditions warranting ventilation at system connections might be filling, purging, or recharging. Review Document 14.3, "Toxic, Corrosive, or Reactive Gases," and Document 12.2, "Ventilation," in the *ES&H Manual* for applicable requirements, or contact your ES&H Team.

4.2.4 Hazardous Materials

Use adequate controls to prevent laser beams and strong reflections from impinging on combustible materials, explosives, highly flammable liquids or gases, or substances that decompose into highly toxic products under elevated temperatures.

Prior to use, conduct or sponsor tests that establish the effects of beam interactions with hazardous materials. Use test results to determine safe parameters for laser operations. Refer to Document 14.1, "Chemicals," in the *ES&H Manual* for other specific controls.

Provide exhaust ventilation when organic or toxic materials are to be vaporized by laser beams. Contact your ES&H Team for guidance or see Document 12.2.

4.2.5 Ionizing Radiation

Contact your area ES&H Team for a safety evaluation before starting a laser operation if it may involve ionizing radiation that originates from the presence of radioactive materials, the interaction of the laser beam with matter, or the use of electrical voltage that exceeds 10 kV. See Document 20.1, "Occupational Radiation Protection," in the *ES&H Manual*.

4.2.6 Nonionizing Radiation

Laser systems or support equipment may generate electromagnetic fields and radiation. Objects, when struck and vaporized by laser beams, can emit non-coherent optical radiation. For specific guidance, contact the area ES&H Team industrial hygienist.

4.2.7 Lighting

Provide adequate lighting in controlled areas. If the lights are to be extinguished or dimmed during a laser operation, one should:

- Install lighting control switches or radio-controlled switches in convenient locations.
- Use luminescent strips to identify equipment, corners of tables, and locations of switches and aisles.

Install emergency lighting wherever the natural lighting is insufficient to allow safe exiting of a laser area during an electrical power failure. More intense room or area lighting may be required for lasers operating at multiple wavelengths to compensate for the low visible-light transmission of some laser protective eyewear.

4.2.8 Pressure Vessels and Systems

All pressure vessels and systems used with lasers, including all toxic gas systems, shall meet the requirements of Document 14.3 and Document 18.1, "Pressure," in the *ES&H Manual*. Vacuum vessels shall be designed to prevent overpressurization during purging or venting operations.

4.2.9 Seismic Safety

Laser and optical tables shall be evaluated for seismic safety. If necessary, bracing shall be installed. New tables ordered after the approval date of this document shall be ordered with seismic bracing. For assistance, contact the DLSO assigned to the area ES&H Team. Plant Engineering or Mechanical Engineering personnel can also design and install custom seismic bracing for laser and optical tables.

5.0 General Controls for All Lasers

Once the hazards have been evaluated, the Responsible Individual selects appropriate controls tailored to the hazard level. Engineered controls should be used to keep laser light exposures below the MPE whenever practical. If engineered controls are impractical, the Responsible Individual may be authorized to use administrative controls. Personal protective equipment (PPE) is used when engineered and administrative controls provide insufficient protection.

5.1 Integrated Safety Management

For work involving lasers that is not commonly performed by the public, use of the IWS may indicate the need for a written safety plan. Document 3.3, "Facility Safety Plans and Integration Work Sheets with Safety Plans," in the *ES&H Manual* provides guidance on how to prepare an IWS/SP. If necessary, contact the area ES&H Team for assistance. The requirement for an IWS/SP may not apply to a temporary operation, such as an initial installation or setup or the turning on of a laser or laser system to measure power or determine operability. However, even in such cases, the LSO/DLSO shall conduct a safety evaluation or hazard assessment, and the appropriate management authorizations shall be obtained for the work. The recommendations contained in the evaluation should be implemented through an IWS.

An IWS/SP is required for any laser operation that meets one or more of the following conditions:

- The laser is classified as Class 4 and is normally operated with exposed beams, except during temporary operations as stated above.
- The project uses two (or more) Class 3b lasers and any of the following situations exist [continuous-wave (CW) lasers having multiple helium-neon diodes and operating at or below 15 mW in the visible wavelengths are exempt from this requirement]
  - — Different operators controlling the lasers at the same time in the same area without barriers.
  - — More than one wavelength is present.
  - — Accessible levels greater than 15 mW, continuous wave in the visible wavelengths are used.
- Non-LLNL personnel (e.g., contract labor or visiting scientists) will use or operate a Class 3b or 4 laser. Document 2.1, "Laboratory and ES&H Policies, General Worker Responsibility, and Integrated Safety Management," in the *ES&H Manual* contains additional information on supervision and training of non-Laboratory personnel.
- Unattended Class 3b or 4 laser operations that do not conform to the conditions described in Section 9.0 are to be performed.
- A worker will intentionally directly view a Class 2, 3a, 3b, or 4 laser beam or will be required to use optical viewing aids located close to the beam.
- A Class 3b or 4 laser or laser system will be used outdoors or offsite when operated or managed by LLNL personnel.
- Lasers or laser systems will be operated jointly with another organization, either on site or offsite.
- The laser operation does not include all the mandatory safety controls listed in this document, but the LLNL LSO determines that the operation may proceed.

  Note: This particular authority shall not be delegated to DLSOs or Directorate/Program LSOs.
- ES&H Team or program management determines that an IWS/SP is required.
- The safety interlock system (Section 9.3.5) either
  - — Is complex (i.e., there are multiple zones whose access status depends on operating configuration).
  - — Does not meet the conditions described in Section 9.3.5.

- Modification that decreases the safety of a system certified by the Food and Drug Administration's (FDA's) Center for Devices and Radiological Health (CDRH). See Section 13.2 for further information.
- Warning devices that are not listed in Table 2 (or equivalent) are used. Access panels with liquid crystal displays or light-emitting diodes with equivalent messages may be used.

IWS/SPs should include or reference plan-view drawings that show the locations of the safety interlock systems. The drawings should show the location of interlock sensors, such as door switches or floor mat sensors, laser shutters, or power supplies controlled by the interlock system, status displays, panic buttons, and interlock system controllers.

Table 2. Safety access warning panel.

Light color	Audible signal	Laser area status	Meaning
Green	Silent	Class 1, 2, 3a, or 3b (if visible and ≤15mw CW) laser may be in operation.	Area is open.
Yellow (steady)	Silent	Class 3b (except visible CW ≤15mW) or Class 4 laser is ready to operate (i.e., power on, but no exposed beam).	Controlled laser area—Entry allowed, but PPE shall be carried. See Sections 5.3 and 9.3.
Yellow (flashing)	Silent	Class 3b (except visible CW ≤15mW) or Class 4 laser in operation. No laser beam hazard present at the entrance.	Controlled laser area—Request entry permission. Door interlock system engaged. System will shut down if interlock chain is broken.
Red (flashing)	Activated	Hazardous remote operation in progress. Used only for unmanned operations.	No entry to anyone. Door interlock system engaged. System will shut down if interlock chain is broken.

5.2 Medical Monitoring

All individuals who work with Class 3b or 4 lasers shall have a baseline eye examination:

- Before beginning work with Class 3b or 4 lasers or laser systems.
- Following any accidental exposure if an eye injury is suspected.

Medical monitoring requirements do not apply to service or repair vendor personnel working on any class of laser. Medical monitoring of service personnel is a responsibility of the service company.

Contact the Health Services Department to schedule laser eye exams. Laser eye exams shall comply with the requirements found in ANSI Z136.1-2000 for medical surveillance.

The Responsible Individual shall notify the payroll supervisor of the need to have a baseline eye examination before beginning work with these lasers. The payroll supervisor or worker shall contact the Health Services Department to schedule this examination.

At the recommendation of the Health Services Department, the LSO or DLSO evaluates the workplaces of personnel with preexisting eye or medical conditions. The LSO or DLSO determines whether additional controls are needed.

At the time of employment termination, an eye examination by an ophthalmologist is available at the employee's request through the Health Services Department. This examination is not required.

5.3 Personal Protective Equipment

Engineered and administrative controls shall minimize the time that personnel spend in proximity to laser beams and their reflections. They shall also minimize the need to work in close proximity to open beams or hazardous reflections. When engineered and administrative controls cannot prevent exposure above the MPE level, PPE (e.g., protective eyewear and clothing) shall be utilized. PPE shall be specified in the safety plan or IWS.

5.3.1 Laser Eyewear

The Responsible Individual, in consultation with the LSO or DLSO, shall determine the appropriate laser eyewear. Maximum permissible exposure calculations are based on worst-case situations (i.e., intrabeam exposures). Calculated optical densities (ODs) may not be available (i.e., ODs >7), or it may not be practical to provide protection to MPE values. In that case, the LSO may specify comparable controls to minimize the risk of exposures that exceed the MPE.

The LSO or DLSO shall approve all laser eyewear purchases. Industrial Optometry shall approve all prescription spectacles regardless of how the spectacles are ordered. (More information regarding ordering laser eyewear can be found in Appendix C.)

Even when the accessible radiation levels are considered safe, it is good practice for laser personnel to wear eye protection when lasers are in use. Eyewear users shall check the condition of their eyewear before each use and store the eyewear to prevent damage from scratching or contact with water or chemicals. Examples of adequate storage

containers can be the pouches or cases supplied with the eyewear, compartmentalized plastic shoe bags from a discount store, felt-lined wooden boxes, or other types of storage containers that protect the eyewear from damage.

Laser eyewear may be used for wavelengths other than those specified by the manufacturer. The required wavelength and OD information for the particular application shall be etched into or attached to the eyewear, and a graph or data table of wavelength vs. OD for the eyewear shall be readily available at the location of use. Production lot numbers indicated on the graph or in the data table shall match those indicated on the eyewear itself. Lot numbers are usually etched into the lens of plastic eyewear. The date of manufacture shall also be indicated for glass eyewear.

Before the use of new eyewear, wavelength and OD shall be verified to ensure that the eyewear ordered is what was received. Eyewear users should read the manufacturer's instructions regarding the proper care and use of the eyewear.

Laser eyewear should not be subjected to high-intensity beams. High-average-intensity and high-peak-intensity beams can physically damage the lenses, resulting in loss of eye protection. Glass lenses exposed in tests have been shown to crack and shatter up to 15 minutes after high-power laser exposure. Plastic lenses can burn and melt.

High-peak-intensity beams can bleach eyewear momentarily, allowing hazardous transmission to the eye without causing permanent or obvious damage to the eyewear itself. Because of this effect, special engineering and administrative controls shall be established for lasers with sub-nanosecond pulse widths. Eyewear research data for sub-nanosecond pulse widths is currently limited, but has shown that the effective OD rating may be as much as 50% lower than the stated value of the eyewear. This can create a false sense of security that the eyewear will protect the worker from an exposure.

5.3.2 Protective Clothing

In addition to eyewear, some laser operations require protective clothing. This may be based on explicit skin protection calculations made by the LSO or DLSO.

Protective clothing is necessary for those operations in which direct-beam ultraviolet (UV) exposures exceed 10 s. Face shields and garments that cover all bare skin shall be worn.

Clothing made from fabrics that are not easily ignited—such as close-knit wool or silk, or commercially available flame-retardant fabrics—should be worn during operations involving exposures to visible and infrared (IR) lasers where accessible beam irradiance exceeds 2 W/cm^2. When accessible irradiance exceeds 10 W/cm^2, these fabrics shall be worn.

Clothing made of flame-retardant cotton should be replaced after repeated launderings as recommended by the manufacturer. The flame-retardant chemical washes out over time, and laundering opens the weave of the fabric.

Clothing made of cellulose fibers (such as untreated cotton and rayon) should never be used for skin protection.

Contact the area ES&H Team for advice on selecting protective clothing.

5.4 Training

5.4.1 Class 1, 2, and 3a Lasers or Laser Systems

Course HS 5200, "Laser Safety," is not required for those using Class 1, 2, or 3a lasers. Users shall read the safety documentation and operator's manuals for the particular device they will operate. The manufacturer's information, as well as familiarity with the equipment, provides sufficient awareness training about the hazards and controls of these low power devices. If not, contact the LLNL LSO for an awareness briefing. Examples of such laser devices are: laser pointers, barcode scanners, laser surveying, leveling and construction equipment, hand held diagnostic equipment used by electricians, firemen and others, gun sights, or other low hazard laser equipment that is easily available to the general public.

5.4.2 Class 3b and 4 Lasers or Laser Systems

These training requirements also pertain to Class 1 enclosed or embedded systems which may expose LLNL or contract personnel to Class 3b or 4 levels of laser radiation during periodic access, such as: 1) adjustment or alignments during operation, 2) during maintenance activities, or 3) during service.

- Read the safety instructions provided by the equipment manufacturer.
- Receive a thorough review of the laser equipment to be used from the Responsible Individual. The payroll or program management organizations may require further training.
- Successfully complete Course HS5200-CBT or HS5200-RW. An exam is available in lieu of periodic retraining. Contact the Safety, Education, and Training section of the Hazards Control Department to schedule the examination.
- Read this document and any relevant OSPs and work procedures.

5.5 Authorized Operator

The Responsible Individual shall specifically authorize individuals to operate each Class 3b or Class 4 laser or laser system, ensuring that they are medically qualified and properly trained. In addition, the Responsible Individual shall require non-LLNL employers to certify that their personnel meet LLNL's training and operational qualifications and medical monitoring requirements before working with lasers at LLNL.

5.6 Safety Walkthrough

All safety interlock systems shall be operational before a laser system is used. Before work begins, a safety walkthrough shall occur to verify that work procedures are implemented as specified in the IWS/SP.

5.7 Evaluation of Modified Laser Systems

The ES&H Team and the LSO shall evaluate all modifications to commercial laser systems. Any modifications that decrease the safety controls will require an IWS/SP. Modifications to commercial lasers may require FDA certification or a DOE exemption from FDA certification if the laser or laser system is to be moved offsite. See Section 13.0 for further information about laser modifications and moving lasers offsite. Contact your area ES&H Team for an evaluation as soon you expect the system to be moved offsite.

5.8 Protective Enclosures

Plastic enclosures made by LLNL may be used to reduce the OD requirements of protective eyewear. The Responsible Individual shall have available the OD properties of the plastic for the wavelengths of the laser in use. This information can be obtained from the plastic manufacturer's literature, transmission measurements, or other suitable published source on the optical characteristics of the plastic.

6.0 Class 1 Lasers

The number of Class 1 lasers at LLNL is increasing because IR lasers and laser diodes (i.e., lasers emitting wavelengths above 1400 nm) are becoming more common. General-purpose Class 1 lasers are not hazardous. They are incapable of producing harmful accessible radiation or causing a fire. Therefore, Class 1 lasers are generally exempt from most control measures or other forms of surveillance. An exception may be when more-hazardous lasers (Class 2 or higher) are enclosed in a protective housing (thus becoming embedded Class 1 lasers). Such a housing shall be labeled to indicate the hazard level of the enclosed lasers and shall either be interlocked or require a tool for removal. See Section 10.0.

Some special-purpose lasers may receive a Class 1 rating because their intended use limits exposure to a nonhazardous level. When such lasers are used for other than their original intent, a hazard evaluation shall be conducted, and an IWS shall be developed. Lasers that are not used for their intended purpose may require reclassification.

6.1 Engineered Controls for Class 1 Lasers

Class 1 lasers shall be placed in protective housings whenever practical.

6.2 Administrative Controls for Class 1 Lasers

The following administrative controls apply to all Class 1 lasers:

- Signs or labels are not required for Class 1 lasers.
- Beam controls are not required.
- A Class 1 laser beam may be viewed directly if the LSO determines that
  - The laser's output still complies with the classification given on the laser hazard label or in the manufacturer's operating manual, and
  - The laser is being used as the manufacturer intended.

7.0 Class 2 Lasers

A Class 2 laser emits visible but low-power radiation in either CW or pulsed visible wavelengths of 400 to 700 nm. CW Class 2 lasers are limited to powers of less than 1 mW.

Natural human aversion time of 0.25 s to bright light provides the necessary eye protection for Class 2 laser users; however, directly viewing the beam of a Class 2 laser for periods exceeding the 0.25-s aversion time may be hazardous. Class 2 lasers do not present a fire hazard.

Typically, Class 2 lasers are used in barcode scanners; laser pointers; some surveying, leveling, and construction equipment; handheld diagnostic equipment used by electricians, firefighters, and others; and laser gun sights. Although the beams from these lasers are not intended for viewing, they are not hazardous even if an individual views the beam for up to 1000 s. Training to operate the above devices consists of reading the manufacturer’s instruction manual.

7.1 Engineered Controls for Class 2 Lasers

The following engineered controls apply to all Class 2 lasers:

Protective Housings: Class 2 lasers shall be placed in protective housings whenever practical.

Interlocks on Protective Housings: Class 3b and 4 lasers that are enclosed to prevent accessible radiation from exceeding Class 2 levels shall have an interlocked housing to prevent inadvertent exposure to hazardous levels of laser radiation, or the housing shall be fastened closed requiring special tools for housing removal.

Service Access Panels: Portions of the protective housing that are intended to be removed from any laser or laser system only by service personnel, and that permit direct access to Class 3b or 4 laser radiation, shall be interlocked or designed so as to require a tool for removal.

Collecting Optics: Optical systems used to view the laser beam or its interaction on a material shall be evaluated by the LSO or DLSO and have permanently attached attenuators or shutters to prevent hazardous levels of radiation from entering the eye when the beam equals or exceeds the MPE.

Housing and Cover Labeling: An advisory label that indicates the relative hazard of laser radiation contained in the housing shall be placed on all removable protective housings that have no safety interlock and that can be removed or displaced during maintenance or service, thereby allowing access to laser radiation in excess of the applicable MPE.

7.2 Administrative Controls for Class 2 Lasers

In addition to the administrative controls for Class 1 lasers, the following administrative controls apply to all Class 2 lasers, except for laser pointers, handheld diagnostic equipment, surveying and construction lasers, laser gun sights, and barcode scanners.

7.2.1 Beam Control

To minimize the potential for direct eye exposure, observe the following precautions in beam control:

- Enclose laser beams as much as possible.
- Position lasers in such a manner that no beam or hazard exists at the room's entrance.
- Confine all laser beams to a well-defined area of use.

- Mark or block access to areas where beams cross pedestrian or vehicular thoroughfares.
- Terminate the beam at the end of its useful path.
- Position the beam path at a height other than eye level whenever practical.
- Block unnecessary beam reflections and remove shiny objects (e.g., jewelry and tools) that may cause unexpected reflections.

7.2.2 Signs and Labels

Evaluate the area and usage to determine whether posting is necessary. If so, post a hazard warning sign indicating that the work area includes Class 2 lasers (except the lasers listed at the end of Section 7.0). See Appendix D for requirements for laser hazard warning signs. Warning signs are available from your area ES&H Team.

7.2.3 Beam Alignment and Direct Viewing

Personnel shall never intentionally look directly into the beam of a Class 2 or higher laser without proper authorization. In cases where direct viewing cannot be avoided, the LSO shall conduct a comprehensive safety review (an IWS/SP may be required) and specifically approve the planned work or alignment procedure.

As an alternative, special provisions (e.g., filters, beam expansion, or controls on the exposure time) may be developed to ensure that the beam's intensity is below the MPE for the viewing conditions.

7.2.4 Operator Training

At a minimum, users shall read the manufacturer’s operating instructions that came with the laser or equipment.

8.0 Class 3a Lasers

Class 3 lasers are divided into two subclasses (3a and 3b). Class 3a lasers can emit visible or invisible radiation. Normally, their beams are not hazardous when viewed momentarily with the naked eye; but when viewed with optical instruments (such as microscopes or binoculars), the beams can be hazardous to the eyes. Diffuse reflections of Class 3a lasers are usually not hazardous. A Class 3a laser is not a fire hazard.

Visible Class 3a lasers have accessible output powers up to five times the emission limits of Class 2 lasers. Invisible Class 3a lasers have accessible output powers up to five times the emission limits of Class 1 lasers. Actual values depend on the laser's

wavelength, pulse duration, exposure duration, and number of pulses during the exposure duration. Engineered and administrative controls are not applicable to public-use lasers (e.g., those in laser pointers and bar code scanners).

Class 3a laser pointers are covered separately in Section 12.2. Class 3b lasers are covered in Section 9.0.

8.1 Engineered Controls for Class 3a Lasers

In addition to the engineered controls for Class 2 lasers, the following engineered controls apply to all Class 3a lasers. Laser pointers, surveying and positioning equipment, and other systems as determined by the LSO are excluded from these requirements but not from the manufacturer's labeling required by 21 CFR 1040.

8.1.1 Nominal Hazard Zone

When a Class 3a or higher laser is to be operated outdoors or in open areas within buildings, the LSO/DLSO shall establish a nominal hazard zone (NHZ) in the space around a laser in which exposure to laser light possibly exceeds the MPE. The boundary of the NHZ shall be clearly identified by signs, barricades, walls, tape, or ropes, and no laser radiation exceeding the MPE may exist outside the NHZ.

8.2 Administrative Controls for Class 3a Lasers

In addition to the administrative controls for Class 2 lasers, the controls below apply to all Class 3a lasers.

8.2.1 Signs and Labels

Lasers generating beams with irradiances or radiant exposures below the MPE (e.g., 2.55 mW/cm^2 for visible CW lasers for less than 0.25 s)—including laser pointers—shall be labeled with CAUTION labels. Lasers generating beams with equal or higher power shall have DANGER labels. Labels shall be firmly affixed to the laser or the carrying case in which the laser is stored.

Evaluate the area and usage to determine whether posting signs is necessary. If so, post a hazard warning sign indicating that the work area includes Class 3a lasers (except the lasers listed at the end of Section 7.0). Areas where Class 3a lasers operate at invisible wavelengths shall be posted.

See Appendix D for requirements for hazard warning signs. Warning signs and labels are available from your area ES&H Team.

9.0 Class 3b and Class 4 Lasers

Class 3b and Class 4 lasers are considered *hazardous*. These lasers can cause eye injury so quickly that the natural aversion response will not prevent eye injury. They can also injure the skin.

9.1 Class 3b Lasers

Class 3b lasers have average powers up to 500 mW for CW or repetitive-pulsed lasers. Single-pulse emission levels range from 30 mJ to 150 mJ, depending on the wavelength. Class 3b lasers are hazardous to unprotected eyes and may be hazardous to the skin. Diffuse reflections from Class 3b lasers may also be hazardous, such as when an individual stares at the diffusing surface from within the NHZ.

9.2 Class 4 Lasers

The average power of a CW or repetitively pulsed Class 4 laser can exceed 500 mW. Single-pulse emission levels are 30 mJ to 150 mJ, depending on the wavelength. Beams can be either visible or invisible. Class 4 lasers are powerful enough to produce diffuse reflections that could rapidly injure the eyes or skin. Consequently, Class 4 lasers are hazardous to the eyes and skin, whether exposure is to the direct beam of the laser, its specular reflection, or diffuse reflections.

Some Class 4 lasers are capable of igniting combustible materials. As a rule of thumb, lasers emitting more than 2 W/cm^2 are considered ignition hazards.

9.3 Engineered Controls for Class 3b and Class 4 Lasers

Engineered controls specified for Class 2 and 3a lasers also apply to Class 3b and 4 lasers unless the following requirements specifically supersede the requirements for lower-class lasers.

9.3.1 Controlled Laser Area

Class 3b and Class 4 lasers shall only be operated in areas designated for laser operations unless specifically authorized in an IWS/SP. In general, the area should be an enclosed room or laboratory with walls or barriers that block laser radiation. Controlled laser areas can be divided into sections so that eyewear is required in one section but not in the other. This can occur if the following conditions are met:

- Walls, partitions, or curtains separate the controlled laser area so that beams, specular reflections, and hazardous diffuse reflections cannot travel from one section to another.

- The protective eyewear used in all sections has the same wavelength and minimum OD.
- People passing between sections are required to don laser protective eyewear before entering any other section. Eyewear can then be removed only after verifying that it is safe to do so.
- These controls are included in an IWS/SP.

9.3.2 Temporary Installations

Under some circumstances, it may be necessary to establish a temporary controlled laser area so that laser radiation greater than the MPE does not escape. Mark the entrances to these areas with flashing yellow lights and standard laser warning signs showing the hazard level (i.e., Class 3b or 4) and the characteristics of the exposed laser beams.

Activities requiring temporary control of a laser area may include:

- Operating a demonstration laser.
- Performing a short-term experiment in an uncontrolled location.
- Conducting service adjustments, maintenance, and special training exercises requiring the removal of protective enclosures, equipment interlocks, or other safety devices. Such steps may be necessary to allow entry to a more hazardous class of laser light than the area controls are designed to contain. Temporary laser controlled areas may be needed if service adjustments affect the operation of area controls.
- Initial installation, setup, or turning on of a laser or laser system to measure power or determine operability.

The LSO shall perform a documented initial safety evaluation unless the temporary laser installation is already described in an IWS/SP. Because this laser area will not have all the standard safety features, the evaluation shall either indicate the temporary controls necessary to mitigate the hazards or require a new IWS/SP that specifies the duration of the temporary condition. Documentation of this evaluation and any additional controls necessary may be accomplished with an IWS.

9.3.3 Multiple Occupancy

To the extent practical, a controlled laser area should have only one laser or laser system. In addition:

- When more than one laser or laser system operation is necessary, the appropriate shielding shall be installed, and the conditions of coexistence and methods for maintaining a safe work environment shall be defined.
- If two or more Class 3b and Class 4 lasers are operated in the same area by different operators without intervening barriers, an IWS/SP shall be written and approved.

9.3.4 Access and Spectator Control

Laser laboratories and controlled laser areas shall be designed so that personnel can easily enter and leave these areas during an emergency. Unless approved in an IWS/SP, the doors to controlled laser areas shall not be locked in a manner that makes escape difficult for people inside those areas.

Directorate management, in consultation with the Responsible Individual, should consider maintaining spare keys and a list of active cipher codes required to enter laboratories in their areas. This list and the keys should be controlled and inaccessible to visitors, tours, or unauthorized individuals or groups without proper program management authorization and a valid purpose to enter the laboratory. Examples of authorized individuals who need periodic access to laboratories include the LSO, Assurance Manager, or Program Safety Officer.

Access to the area during laser operations requires permission from the laser operator. Spectators or visitors shall not enter these areas during laser operations without prior permission from the laser operator and the implementation of appropriate safety measures. The Responsible Individual or lead experimenter (or designee) shall brief these individuals on the hazards and controls used in the controlled laser area.

9.3.5 Safety Interlocks

Controlled laser areas may require a safety interlock system on access panels and doors. Class 3b lasers (except Class 3b CW lasers with an output of ≤15 mW in the visible wavelengths) should include one of the area controls listed below when practical. Class 4 lasers also shall include one of these controls.

- **Nondefeatable Area or Entryway Safety Control** (safety latches and entryway or area interlocks such as electrical switches, pressure-sensitive floor mats, or motion detectors) shall be used to deactivate the laser or reduce

the output levels to the MPE or below should unauthorized entry into the laser area occur.

- **Defeatable Area or Entryway Safety Control** (safety latches and entryway or area interlocks) shall be used if the controls in the previous paragraph adversely affect the intended use of the laser or laser system. If no laser light hazard exists at the entry point, the interlock may be bypassed to allow access to authorized personnel provided that they have been adequately trained and provided with adequate PPE.
- **Procedural Area or Entryway Safety Controls.** Where the above entryway safety controls are impractical or inappropriate, the following 3 conditions shall apply
  - — Authorized personnel shall be trained and the proper eyewear and skin protection shall be provided at the entryway.
  - — Laser radiation shall be blocked from reaching the entryway by using screens, partitions, curtains, or walls, as appropriate for the laser characteristics. No laser radiation above the MPE shall be allowed to escape the area or expose personnel immediately upon entry.
  - — The entryway shall have a visible or audible signal indicating that a Class 4 laser is operating inside. Existing installed laser warning signs or flashing lights on stanchions may satisfy this requirement.

Note: An interlock switch is energized from a different source than the equipment it controls and therefore shall be energized even if the laser equipment is not. Older, 110-V interlock systems can remain in use or be moved to a new location; new interlock systems shall operate at or less than 24 VDC.

Laser users shall test all safety interlocks at least annually to ensure they are operational and shall maintain a written record of each test conducted. An IWS, IWS/SP, FSP, or work procedure may mandate more frequent checks of safety interlocks. Complicated systems should have an interlock check procedure.

Safety interlock circuits shall deactivate the laser or use shutters to interrupt the beam. Interlocks shall be designed so that after being triggered, beam emission cannot occur unless the system is reset manually or in the manner authorized by an approved IWS/SP.

9.3.6 Warning Systems

The activation of a laser shall be preceded by one or more of the following: a verbal warning or countdown, bells, chimes, or lighted status panels. In lieu of any mechanical emission delay, the laser operator shall always make an announcement

before laser emission commences to allow workers the opportunity to take appropriate protective action.

Portable rotating or flashing yellow lights mounted on stanchions are commonly used to indicate that a laser operation is in progress with a nonfunctioning interlock system (such as during maintenance by factory service representatives). A blue NOTICE sign indicating that interlocks are not functioning shall be posted in addition to the DANGER sign.

9.3.7 Safety Access Warning Panel

When an interlock system controls access into a laser area, a safety access warning panel shall be used. The warning panel shall include lights that indicate the laser area's safety status. The lights on the warning panel shall always be lit whether or not the area is in use. However, when a laboratory is in a safe mode for a prolonged period (such as overnight or longer) the panel may turn off as long as either of the following measures is taken:

- Instructions are posted that allow immediate verification that the panel is functioning and that the facility is safe.
- A notice is attached indicating that no laser activity is being conducted within the laboratory and the interlock system does not require maintenance or testing.

Table 2 lists the purpose for each of the various lights and audible signals. Red flashing lights shall be used to indicate the occurrence of remote laser operations. Remote operations occur when a laser beam is present in an area that is not under the laser operator's direct observation and control. See Document 12.1, "Access Control, Safety Signs, Safety Interlocks, and Alarm Systems," in the *ES&H Manual* for more information on remote operations.

Newer safety access warning panels include a light-emitting diode or liquid-crystal display indicating the laser area's safety status. Individuals who are inside or outside a controlled laser area where an interlocked warning light or a CAUTION or DANGER sign is displayed may override the safety interlock system to allow access to the laser area under certain circumstances. Interlock system bypass can occur only if the following conditions are met:

- The laser operator authorizes entry into the area.
- No laser beam hazard is present at the entrance. Installation of a partition or other sight barrier just inside the doorway often removes this hazard.

- Individuals who enter the area don the required PPE prior to proceeding past the door, partition, or other sight barrier.
- Individuals who enter the area are aware of and follow all applicable administrative and procedural controls.
- A maximum 15-s clock is designed into the interlock control circuit to automatically reactivate the safety interlock system after system bypass.
- The external interlock bypass switch is key or cipher-lock operated. The switch may be manually operated to extend the bypass period for special entry conditions (e.g., to allow the passage of equipment or multiple people).

If the laser area is deactivated (i.e., the laser is removed or stored), the safety access warning panel should be removed or covered with a sign indicating that it has been deactivated.

9.3.8 Beam Mapping

Laser operators shall survey controlled laser areas with appropriate measuring devices to locate and identify potentially hazardous direct and reflected beams. Shielding shall be installed to eliminate or reduce such beams to the appropriate MPE level. Particular care shall be taken to locate, identify, and provide shielding of invisible beams from UV or IR lasers.

When measurement is not practical or available, a calculation is another method to determine whether a direct or reflected beam is hazardous.

9.3.9 Beam Controls

Whenever practical, laser beam paths and any potentially hazardous reflections in a controlled area should be enclosed. When it is not practical to fully enclose the laser beam path, the following measures shall be used as appropriate for the specific conditions:

- Terminate any strong reflections and any potentially hazardous transmissions through optics at the end of their useful paths.
- Use nonflammable materials for devices used for backstops, shields, or beam dumps where appropriate with high intensity beams. Mount such devices securely.
- Securely mount the laser system to maintain the beam in a fixed position during operation and limit beam movement during adjustments.
- Enclose or confine primary beams and potentially hazardous reflections to a well-defined area of use.

- Clearly identify or contain open beam paths on the laser table when practical. The beam should not cross potentially occupied areas or traffic paths if possible. If beams need to cross accessible areas beyond a laser table, mark their paths on floors and on tables using red, yellow, or yellow-and-black diagonally striped tape. Beam pipes, chains, ropes, or other barriers may be used to restrict access through an off-the-table beam. However, they should be designed not to impede egress in an emergency.
- Never point beams toward entry doors (unless the door is used only as an emergency exit or is otherwise inactive).
- When the beam path is not fully enclosed in areas accessible to personnel, design the system whenever practical so that it is outside the normal eye-level range (1.2–2 m above the floor). Pay special attention to areas where the use of desks, chairs, or benches lowers an individual's eyes to the height of the laser table. Orient computer monitors positioned at this height so that they cannot be specular reflectors.
- Avoid directing beams upward from standard optical benches (or into other potentially occupied areas) during either alignment or operational use—unless there is *no* practical alternative. Upward-directed beams are a significant cause of laser injuries. When such beams are necessary, they shall be permanently blocked at the end of their useful path. Such beam paths shall be labeled or posted to indicate the hazard.

The addition of beam-stopping panels at the sides of optical tables or entire beam path enclosures of Class 3b and Class 4 lasers is recommended as a general safeguard against improperly aligned laser beams or reflections.

The material used to make beam enclosures for Class 4 lasers shall be fire-resistant.

9.3.10 Reflection Control

Wherever possible, utilize materials that are diffusely reflective or have a low reflection coefficient in place of specularly reflective surfaces. Specularly reflective surfaces that are needed in the vicinity of beams should be enclosed or shielded to minimize personnel exposure. Nonreflective tools should be used, whenever practical.

Badges, jewelry, and other reflective personal items shall be removed or covered during laser alignment or other work near laser beams. Keep laser areas as free as possible of unnecessary clutter. Laser users shall remove unnecessary tools and equipment from laser tables.

9.3.11 Additional Controls for Invisible Beams

UV and IR lasers that emit invisible beams require the following additional controls:

- Visual or audible indicators of beam emission shall be used in areas where laser radiation exceeds the 10-s MPE. Indicators may include the laser firing noise, status panels, or the fluorescence caused by laser light hitting an absorbing surface. The indicators shall be easily detectable under all normal operating conditions, and visible when laser eyewear is worn.
- Areas where personnel may be located during normal activities shall be shielded to limit UV radiation below the skin MPE.
- Beam stops shall be made of material that absorbs or diffusely reflects the laser's invisible radiation.
- Viewing aids, such as IR and UV cards and viewers, shall be used during alignment and to verify there are no stray beams or reflections. Night vision goggles are very useful in spotting stray reflections and observing beam operations. Night vision goggles should be considered for near-IR beams (i.e., up to approximately 950 nm).

  Note: Laminated viewing cards may be specular reflectors, so caution is needed while using them.
- If in doubt, measurements shall be taken or calculations shall be made to confirm that invisible radiation is controlled in the area.
- Methods shall be implemented to remove hazardous byproducts formed by intense radiation reacting with materials in the area.

Near-Infrared Wavelengths (700–1,400 nm). Because all near-IR (NIR) wavelengths are focused by the eye's lens on the central, focused vision area (fovea), special care shall be taken to protect the eyes when working at these wavelengths. In addition, NIR wavelengths of 800–810 nm (e.g., in titanium-sapphire laser emissions) may be only faintly visible and appear on a surface as a faint spot. Many direct eye injuries have occurred when laser operators were lulled into complacency after incorrectly interpreting such faint spots as a weak beam.

Ultraviolet Wavelengths (100–400 nm). UV radiation causes photochemical reactions in the eyes and skin and is particularly dangerous because it is invisible to the eye and because its effects may not appear for some time after exposure. In addition, a direct or reflected beam of UV radiation can also produce hazardous byproducts upon striking the surface of a material. Therefore, both the direct beam and scattered UV radiation should be shielded to the maximum extent practicable to avoid such problems. The use of long-sleeved coats, gloves, and face protectors is recommended. Some medications can increase the sensitivity of the skin or eye surfaces to UV radiation. Medical monitoring of the skin may be required for those working with or around exposed UV laser beams.

9.3.12 Optical Viewing Aids That Concentrate Light

Use of optical systems such as cameras, telescopes, microscopes, and endoscopes to view laser beams may be hazardous to the eye. Therefore, all optical instruments intended for viewing a laser or laser system should be equipped with suitable means (e.g., filters, attenuators, or interlocks) to preclude transmission of laser light exceeding the MPE to the eye. The selected equipment shall prevent transmission under all conditions of operation and maintenance.

Note: Normal prescription eyewear does not fall into this category.

9.4 Administrative Controls for Class 3b and Class 4 Lasers

Administrative controls specified for Class 2 and 3a lasers also apply to Class 3b and 4 lasers unless the following requirements specifically supersede the requirements for lower-class lasers.

9.4.1 Signs and Labels

The outside of the laser enclosure shall be posted with hazard warning signs specifying the highest laser class in use. In addition:

- Attach a laser classification label (if no manufacturer label exists) in a conspicuous location on or near the laser housing.
- Post DANGER signs at each entrance to the operating area. The hazard warning sign should indicate that the work area includes Class 3b or Class 4 lasers.
- Keep the signs and labels current and legible.

See Appendix D for requirements for hazard warning signs. Warning signs and labels are available from your area ES&H Team.

9.4.2 Safety Evaluation of Direct Viewing

When direct viewing cannot be avoided, the LSO shall conduct a safety evaluation and specifically approve the work or alignment procedure for direct viewing.

Additionally, when the beam of a Class 2, 3, or 4 laser is viewed directly on purpose, or if it is necessary to work with optical viewing aids close to the beam, the Responsible Individual shall prepare an IWS/SP. In these cases, special provisions (e.g., use of filters or beam expansion) are mandatory to reduce exposure below the MPE.

9.4.3 Beam Alignment

Alignment is the most hazardous laser activity because personnel have to override the engineered and administrative safeguards. Therefore, laser optical systems (e.g., mirrors, lenses, and beam deflectors) shall be aligned in a way that minimizes the possibility of exposing the eye or skin to the laser beam (or the beam's specular or diffuse reflection) above the MPE.

For complex processes the Responsible Individual should develop an alignment procedure for Class 3b and shall develop an alignment procedure for Class 4 laser systems addressing the applicable issues listed in Appendix B. This alignment procedure may either be included in the laser's IWS/SP or kept in an easily accessible place by the laser operators. The alignment procedure shall be reviewed whenever the IWS/SP is reviewed, or when changing laboratory conditions warrant the need for a review. Document 3.4 contains general information on the preparation of safety related procedures.

Laser operators should consider techniques for performing safe alignments, such as the following:

- Viewing the laser with a TV camera.
- Viewing the laser with an image-converter viewer.
- Using a low-power alignment laser.
- Removing watches, rings, badges, and other reflective objects.
- Using beam blocks (secured to the table) to control reflections. This includes blocks for upward-directed beams.
- Wearing laser protective eyewear for all alignments of any laser, except CW lasers with an output of ≤15 mW in the visible wavelengths.
- Having all unnecessary personnel leave the room or area.
- Identifying and controlling stray beams.
- Reducing the primary beam power.
- Inserting fluorescent materials into the beam.

Additionally, the laser operator shall announce that a loose beam is going to be projected into the laser laboratory or area so that others in the area can protect themselves by donning eyewear, leaving the area, or asking for a delay until they can protect themselves. This announcement shall be made even if the area appears empty (unless personnel cannot enter without the operator's knowledge).

Under certain conditions, and after consultation with and approval by the LSO, protective eyewear worn when aligning *visible* lasers at wavelengths greater than 450 nm may be reduced by a maximum of 1.2 OD from the calculated values of OD or those in the "Eyewear OD" column of the lasers table in the IWS/SP (as applicable) to allow the beam to be seen. These special *alignment* glasses shall be conspicuously marked, indicating that they are to be worn for alignment purposes only and stored separately from the other eyewear in the lab.

The laser operator shall take special care to avoid exposure to direct beams or specular reflections because the OD of the alignment eyewear may be sufficiently low that it admits hazardous levels of light from a direct beam or reflection that could permanently damage the eyes.

Measures shall be taken to ensure that no stray hazardous specular reflections are present before the lower-OD eyewear is worn. These measures shall be documented in an alignment procedure. The minimum OD allowed is determined by a calculation for diffuse viewing at 0.5 m. The laser operator should use the highest OD that will permit successful completion of the alignment task, but in no case is eyewear below the diffuse OD to be used.

When the alignment is completed, the normally specified full-OD eyewear shall be worn.

9.4.4 Eye Protection

Everyone within a controlled laser area or a NHZ shall use eyewear that meets the laser eyewear requirements. See Section 5.3.1 for information on the eyewear safety. Purchase new eyewear if there is no available eyewear or if available eyewear has deteriorated.

9.4.5 Remote Operation

The Responsible Individual shall sweep a remotely operated area before it is illuminated to ensure that it is unoccupied. Otherwise, visible and audible warnings of the impending safety-status change shall be made, followed by a countdown to the status change.

9.4.6 Unattended Laser Operation

Except for visible CW 3b lasers ≤15 mW, an operating laser is considered unattended if none of the authorized operators is in the controlled laser area or at the remote operating station. If an unattended laser is not in use, the power supply shall be de-energized and the keys removed from the power switches or master interlocks, or the laser area shall be locked to prevent access.

If an authorized operator is not available, the following requirements for unattended laser operation apply:

- The Responsible Individual shall conduct an analysis with assistance of the ES&H Team to determine the necessary controls and ensure their implementation.
- During other than normal working hours, the operator shall notify the Emergency Management Division (Fire Department) dispatcher (ext. 2-7595). Ask the dispatcher to notify the Fire Department and the off-shift ES&H technician that an unattended laser is operating in your building and room.
- The laser system shall include functional lights and audible signals or signs indicating that it is operating and utilizes an interlock system, if required. See Table 2 for more information.
- In addition to any required laser warning signs, the entrance signs shall indicate who should be notified if an emergency occurs and how to make the area safe (shutdown instructions) if emergency response is required. See Appendix D for unattended laser signs.

If these requirements cannot be met, an IWS/SP is required for unattended laser operations.

9.4.7 Maintenance or Adjustment

Personnel performing maintenance or adjustment tasks on Class 3b or 4 lasers or laser systems shall be informed of the risks involved either by posting signs at the laser system's work area, providing direct supervision, or including warning information for maintenance and service personnel in the maintenance instructions.

9.4.8 System Check

Safety systems that may have been bypassed, tampered with, or de-energized to allow maintenance or adjustments (especially by outside vendors or service representatives) shall be tested or inspected to ensure these systems are working properly before the laser is returned to service. Record this test on the interlock checklist for the laser (see Appendix E).

10.0 Class 1 Laser Systems with More Hazardous Embedded or Enclosed Lasers

A laser system can be converted to a Class 1 system by including in the laser system design all the controls described in this section. These controls will effectively enclose

the laser, prevent personnel contact with the emitted radiation, and permit unrestricted access into the area.

An enclosed laser is a laser contained in its own protective housing or in the protective housing of the laser system in which it is incorporated. Opening or removing the protective housing allows exposure to a higher level of laser radiation (i.e., radiation exceeding the applicable MPE) than is possible with the protective housing in place.

An embedded laser is an enclosed laser that has a higher class number than the laser system in which it is incorporated; the laser system's lower class number is appropriate because of engineering features limiting accessible emission.

10.1 Engineered Controls for Class 1 Embedded and Enclosed Lasers

The following engineered controls apply to all Class 1 laser systems with more-hazardous embedded lasers.

10.1.1 Protective Housing

A protective housing that encloses the embedded Class 3b and Class 4 lasers (e.g., beam tubes or covers) and their output shall be used to prevent the escape of laser radiation above the Class 1 MPE level into areas where personnel have access during normal operations.

10.1.2 Housing Interlocks or Alternative Controls

The protective housing and its access panels or doors shall either be interlocked or shall require tools for removal as approved by the LSO. If an enclosure surrounds live, high-voltage parts, it shall be equipped with a fail-safe interlock system that turns off the high voltage when the enclosure is opened.

In instances where a Class 1 embedded laser is housed in a walk-in enclosure, interlocks are required to prevent operation with personnel inside the enclosure. Service adjustments or maintenance work performed on the laser system shall not render the interlocks inoperative or cause exposure levels outside the enclosure to exceed the MPE unless the work is performed in a laser area with limited access, appropriate safeguards, supervision, and controls. Preparation of an IWS may indicate the need for work procedures or a safety plan.

10.1.3 Fail-Safe Design

When interlocks are used, the protective housing and the laser system shall be designed and fabricated so that the system will continue to meet the requirements for a Class 1 enclosed laser operation if a failure occurs.

10.1.4 Attenuated Viewing Windows (Portals)

Viewing windows shall contain a suitable filter material that will attenuate the transmitted laser radiation to levels below the appropriate MPE under all operating conditions.

10.2 Administrative Controls for Class 1 Embedded and Enclosed Lasers

10.2.1 Signs and Labels

The outside of the laser enclosure shall be posted with a label that specifies the laser classification of the embedded laser. Additionally, the service access panels shall have similar labels.

See Appendix D for requirements for hazard warning signs and labels. Warning signs and labels are available from your area ES&H Team. Commercial equipment with embedded lasers will often include warning information in the instruction manual.

10.2.2 Maintenance or Adjustment

Personnel entering the laser enclosure to perform maintenance or adjustment tasks shall be warned of the risks involved. This warning can be in the form of a label on the laser system's protective housing, direct supervision, or warning information included in the user instructions for maintenance and service personnel. Affected personnel shall comply with the control measures for the higher-hazard laser class.

10.2.3 System Check

Safety systems that may have been bypassed, tampered with or de-energized to allow maintenance or adjustments (especially by outside vendors or service representatives) shall be tested or inspected to ensure these systems are working properly before the laser is returned to service. Record this test on the interlock checklist (see Appendix E).

11.0 Optical Fiber Systems

Refer to ANSI Z136.2 for specific guidance for the safe use, maintenance, and service of optical fiber communications systems that use laser diodes or light-emitting diodes operating at wavelengths between 0.4 and 2.6 μm.

Refer to ANSI Z136.1 for guidance for laser-transmitting fibers that do not meet the above criteria. The following engineered and administrative controls apply to all fiber-optic applications.

11.1 Engineered Controls

Lasers or laser systems that use optical cables to transmit light from one laser area to another shall be considered an enclosed system, with the optical cable forming part of the enclosure. If disconnecting a connector results in accessible radiation above the MPE level, then appropriate engineered and administrative controls consistent with the hazard classification shall be applied.

Optical fibers that deliver high-power laser light can burn through standard fiber sheathing if the fiber breaks. Use special design controls to protect the fibers from damage and prevent exposure to laser radiation. Keep flammable and combustible materials away from fibers carrying high-power laser radiation. When practical, fiber-optic cables should have an armored or fireproof cladding. Fireproof conduit should be considered when high power levels need to be transmitted over fiber-optic cables. Trays, cabling, or enclosures should be appropriately identified with a laser hazard label affixed at an interval of 3 m or less.

11.2 Administrative Controls

When hazardous radiation levels may be present at the end of optical fibers, a CAUTION or a DANGER label (as determined by the ES&H Team or LSO) shall be attached near the end of the fiber or fiber holder. The optical fiber shall be capped off when not in use. If disconnection is necessary while a Class 3b or 4 beam is in the fiber, a temporary laser controlled area shall be set up, and an LSO evaluation shall be conducted if not already covered in an IWS/SP.

Work areas where fiber-optic cables are terminated should be covered with black cloth to allow cleaved fibers to be easily seen. The area should have sharps containers to hold cleaved fibers for disposal, and solvent containers shall be properly labeled. Safety glasses shall be worn, and no eating or drinking shall be permitted in the area. Flammables should be kept away from ovens and heaters used to cure the glues or epoxies used, depending on the termination method.

12.0 Laser Use in Public Areas or Uncontrolled Areas

Certain hazardous lasers, including handheld barcode scanners and laser pointers, are commercially available to people with no technical training. LLNL personnel responsible for any of these devices shall read the following paragraphs in this section and the manufacturer's safety instructions.

12.1 Outdoor Use of Lasers

The LSO shall evaluate lasers and laser systems used outside, except for commercially available lasers used in surveying and construction. Lasers that are directed above the horizontal into navigable airspace require advanced notification and approval from the Federal Aviation Administration if there is a possibility of hitting an aircraft with the beam. The LSO can provide assistance in getting this approval.

12.2 Laser Pointers

New laser pointers and barcode scanners now often use Class 3a lasers, as defined by American National Standard Institute (ANSI) Z136.1-2000, "American National Standard for Safe Use of Lasers." Previously, Class 2 lasers were used; these are low-power lasers that are safe to view unless the viewer suppresses the urge to blink and stares into the laser beam.

Class 3a lasers are, however, moderately powerful and can be hazardous even if viewed for only a brief period of time. Class 3a lasers have a DANGER label; Class 2 lasers have a CAUTION label. When handling Class 3a laser pointers, handheld barcode scanners, and other lasers, observe the following precautions:

- Never point a laser at anyone.
- Never stare into the beam.
- Never view a laser beam using an optical instrument (such as binoculars or microscopes) unless the work procedure has been reviewed and is covered by an IWS/SP or hazard assessment. Use of an optical instrument to view a laser beam can sometimes make a safe exposure dangerous.

Class 3b laser pointers may not be sold legally in the United States and shall not be used at LLNL. Class 3b pointers are dangerous lasers with sufficient energy to cause eye injuries, even during brief exposures.

Improper use or modifications of laser pointers may cause injury. However, when laser pointers are used for their intended purpose, personnel exposure is nonexistent because the laser beam is directed away from the audience.

LLNL personnel responsible for meetings, such as chairpersons or session arrangers, shall ensure that the laser is not pointed at the audience. If this occurs, they shall advise presenters that the beam is potentially hazardous and shall not be directed at the audience. Only one laser pointer may be used at a time. Attendees shall not use pointers while seated because members of the audience or the speaker may look into the laser beam.

Make sure all laser pointers retain their DANGER or CAUTION labels. Visible CW lasers generating beams with irradiances or radiant exposures below the 0.25 s MPE (or 2.55 mW/cm^2) shall have CAUTION labels. Lasers generating beams with equal or higher powers shall have DANGER labels. The label should be firmly attached to the laser pointer or the laser's carrying case.

Use the following guidelines when purchasing or using laser pointers:

- Class 2 diode laser pointers are available and should be used instead of Class 3a laser pointers, whenever practical.
- *Never* purchase or use a Class 3b laser pointer at LLNL.
- Never purchase a laser pointer unless it has the FDA-mandated CAUTION or DANGER safety warning label.

13.0 Lasers Sent Offsite

Individuals who ship lasers offsite, including drop shipments, are cautioned to begin the authorization process as soon as they are aware that an offsite movement will be involved so the shipment will not be held up. Authorizations may be required of several institutional organizations, such as the LLNL LSO, the Hazards Control Department, the LLNL Institutional Review Board, Property Management, Procurement, Shipping and, in some instances, the Department of Energy. Depending on the nature of the offsite operation (i.e., contract, subcontract, work agreement, gift, or property transfer), an IWS, offsite IWS/SP, or review may be needed. Offsite activities, for which LLNL has full or partial management responsibility, or if LLNL will be the primary operator of the laser, require preparation of an IWS and a Level B safety plan.

13.1 Lasers Provided to Offsite Organizations

On occasion, LLNL lends lasers and laser systems to offsite organizations or individuals or provides them as part of subcontracts, purchase orders, integrated contractor orders, intra-university transactions, consultant agreements, bailments, cooperative agreements, or for disposal. Program personnel requesting lasers to be drop-shipped or acquired by a subcontractor under an agreement shall inform the LSO. Before an LLNL

organization can provide lasers or laser systems to an offsite organization or to an individual, all lasers and laser systems belonging to, or acquired by LLNL (with some exceptions) shall have an LSO evaluation. This evaluation may be documented as an authorization for shipment, and shall be included with both the Shipping and Property Management documentation of the transaction.

Exceptions to the required LSO evaluation involve unmodified, commercially available consumer products, such as laser pointers, laser gun sights, laser printers, compact disk players, and barcode scanners, or units being returned to the original manufacturer or qualified service company for repair, maintenance, warranty work, modification, or similar circumstances.

13.2 LLNL Modifications or Laser Manufacture

LLNL is considered to be a "manufacturer" by federal regulations if one or more conditions below are met:

- LLNL personnel assembled a laser from parts.
- LLNL personnel modified a commercially available laser or laser system so that the output or safety characteristics have been changed (for better or worse).
- LLNL personnel embedded or incorporated a commercially available or LLNL-built laser or laser system into some type of an LLNL-built laser system.

Note that the laser hazard classification (Class 1, 2, 3a, 3b, or 4) is **not** taken into consideration when determining if LLNL is a manufacturer or not.

The Responsible Individual shall notify the LSO when an LLNL-manufactured laser is to be sent offsite. If the LSO's written evaluation determines that any of the conditions above apply, the system shall either be:

- Certified by the FDA/CDRH and shown to comply with federal 21CFR 1040, "Performance Standards for Light Emitting Products,"

OR

- Exempted from the compliance process (21 CFR 1010.5) by the DOE, which has the authority to grant an exemption from the federal product regulations if the laser system is to be used for government purposes (i.e., research, investigations, studies, demonstration, training, or reasons of national security).

Once a requester has identified a need to send an LLNL-manufactured laser offsite, the requester should contact the LSO as soon as possible to ensure the evaluation or DOE exemption process does not hold up the shipment. Information about certification and exemption is available from your area ES&H Team and LLNL LSO. These individuals also can provide assistance in the process.

Note: The LSO shall make an evaluation to determine whether an exemption or certification may apply.

13.3 Shipment Process

Before providing a laser to an offsite organization, the requester shall contact the LSO and obtain written approval. The LSO evaluates the request, prepares documentation outlining the hazards associated with the laser, and concurs with the request. Review and authorization are not required when sending a laser or laser system to the manufacturer or to a repair facility for repair or service.

The requester attaches the LSO's review to documents authorizing the equipment to be sent offsite. Depending on the type of transaction, these documents could include a loan or transfer request, subcontract, intra-university transaction, integrated contractor order, consultant agreement, or any other type of agreement. Drop shipments to offsite organizations shall be evaluated and approved by the LSO.

Offsite organizations that receive a Class 3b or 4 laser but do not have an appointed LSO shall be informed, in writing, of the need to appoint one and to create a Laser Safety Program.

13.4 LLNL Operation of a Laser Offsite

The LSO shall evaluate lasers and laser systems to be operated under the control and custody of LLNL while in use offsite. An IWS and a Level B safety plan shall be prepared for the laser operation (except for laser pointers and barcode scanners, and activities normally performed by the public).

13.5 Joint Operation of a Laser Offsite

An offsite IWS/SP shall be prepared for any LLNL-owned laser system of Class 3a (except for laser pointers and barcode scanners, and activities normally performed by the public), Class 3b, or Class 4 laser jointly operated offsite by LLNL personnel and employees of an offsite organization.

14.0 Return on Site of LLNL Lasers or Laser Systems

LLNL normally expects DOE/LLNL property to be returned for future use at LLNL. Other disposition options are possible if they are more cost effective or if there is a benefit to LLNL and DOE. Property Management and the LSO shall be contacted as soon as possible if you are considering not returning lasers or laser systems to LLNL. However, this optional disposition provision does not apply to DOE-exempted lasers or systems (Section 13.2). DOE-exempted units shall be returned to LLNL and shall not be reused, sold, disposed of, or otherwise introduced into commerce offsite without proper FDA/CDRH certification. Notify the LSO when all laser systems are returned onsite.

15.0 Disposition by the Donation, Utilization, and Sales Group at LLNL

The area ES&H Team should evaluate all lasers and laser systems for toxic or hazardous components prior to their disposal or movement to the Donation, Utilization, and Sales (DUS) salvage yard. Lasers and laser systems shall not be moved offsite or given to any other organizations from DUS without an evaluation by the LSO. The area ES&H Team can contact the LLNL LSO for the evaluation.

16.0 Responsibilities

General responsibilities for all workers are described in Document 2.1. Specific responsibilities for lasers are listed under each title.

16.1 Responsible Individual

Authorizing management shall appoint a Responsible Individual for all areas where Class 2 or higher lasers are operated. The Responsible Individual should:

- Provide workers with an opportunity to participate in the hazards analysis and development of controls.
- Review applicable Lessons Learned.
- Consult with Directorate management and consider maintaining spare keys and a list of active cipher codes for laser laboratories in their areas.

The Responsible Individual shall:

- Verify that individuals working in the area have received proper training in laser safety and other applicable safety classes for the operation.

- Verify that personnel receive eye examinations when required.
- Specifically authorize individuals to operate each Class 3b or Class 4 laser or laser system.
- Prepare an IWS/SP when a Class 2, 3, or 4 laser must be intentionally viewed or if it is necessary to work with optical viewing aids close to the beam.
- Develop alignment procedures for Class 3b and Class 4 laser systems involved with complex processes.
- Sweep a remotely operated area before it is illuminated to ensure that it is unoccupied.
- Conduct a hazard analysis of any unattended laser operation with the assistance of the ES&H Team to determine the necessary controls and ensure their implementation.
- Notify the LSO whenever an LLNL-manufactured laser is to be sent offsite.
- Provide PPE and ensure that it is used properly. This includes determining the appropriate laser eyewear in consultation with the LSO or DLSO.

The Responsible Individual shall ensure:

- The safe operation of lasers in the area assigned.
- That payroll supervisors are notified of the need to have designated personnel scheduled for baseline laser eye examinations prior to beginning work with lasers.
- Pre-work planning is accomplished before the initial use of a laser or laser system.
- Completion of designated tasks as part of the hazards analysis for the IWS.
- All individuals, including outside service contractors, understand the hazards associated with lasers and comply with all training, safety, and medical surveillance requirements and IWS/SPs. Contractors shall certify compliance.
- That visitors do not enter laser areas without a briefing on the hazards and controls used in the controlled area and the permission of the laser operator.
- Changes to IWS/SPs under their responsibilities are submitted when conditions warrant (e.g., when new lasers are added or the hazard level changes).
- When appropriate, a hazards assessment is documented on the IWS or safety plan to identify the appropriate PPE for use with lasers.

- That the installation, operation, and maintenance of electrical equipment and systems conform to the standards in Document 16.1.
- That OD properties of plastic used for safety enclosures are available.

16.2 Facility Management

- Inform the Responsible Individual, operators, and workers of any facility-specific hazards and controls that may interfere with the safe operation of the lasers to be installed or used in the facility.
- Evaluate the IWS to ensure that the laser operation is within the facility safety envelope and is compatible with other work activities in the area.
- Coordinate with the Responsible Individual if facility modifications are required for work involving the proposed lasers.

16.3 Payroll Supervisors

- Ensure that individuals working in the area have received proper training in laser safety and other applicable safety classes for the operation.
- Ensure personnel receive eye examinations when required.

16.4 Laser Operator

- Take laser safety training.
- Comply with the applicable IWS/SPs, procedures, requirements, and controls given in this document.

16.5 Workers

- Keep the Responsible Individual assigned to their area fully informed of any departure from established IWS/SPs.
- Make sure they are current in laser safety and related training.
- Report the following events to their area ES&H Team and the Responsible Individual, and go to the Health Services Department
    - — All laser exposures to the eye or skin that are greater than the MPE for the actual exposure duration. Workers shall contact the LSO through the ES&H Team for the appropriate MPE.

— Exposures that cause a burning sensation or a change in the condition of the skin, visual afterimage, blurring, obstruction of vision, headaches, or other pain.
— Any injury caused by laser support equipment, such as electric shock or exposure to dye solution.

If any of these events occur after normal working hours, workers shall contact the Emergency Management Division dispatcher at 911.

16.6 ES&H Team

- Assists the Responsible Individual in assuring that safety requirements are followed in evaluating and controlling hazards.
- Recommends proper PPE.

16.7 Health Services Department

The Health Services Department is responsible for the Laser Medical Monitoring Program. Examinations shall be compliant with requirements for medical surveillance found in ANSI Z136.1-2000.

16.8 Laser Safety Officer

- Oversees the LLNL Laser Safety Program.
- Evaluates laser hazards and installations.
- Establishes laser control measures.
- Assists the Responsible Individual in determining appropriate laser safety eyewear and approves all laser eyewear purchases.
- Conducts a comprehensive safety review for every Class 2 or higher laser system where direct beam viewing cannot be avoided.
- Establishes an NHZ in the space around a Class 3a or higher laser operated outdoors or in open areas within buildings in which exposure to laser light can exceed the MPE limit.
- For temporary installations, performs a documented initial safety evaluation unless the temporary installation is already described in an IWS/SP.
- Reviews laser-related IWS/SPs.
- Approves PPE.

- Assures that adequate training courses are being provided to personnel using lasers.
- Conducts self-assessments of the Laser Safety Program.
- Remains current with and serves as the subject-matter expert (SME) for the applicable Work Smart Standards (WSS).
- Evaluates and approves modifications to lasers and lasers being moved offsite (see Section 13.0).

The LSO may delegate these duties to an industrial safety engineer assigned to an ES&H Team, who shall serve as a DLSO. Formal Laser Safety Officer training is required; see the LSO for details. The DLSO may be reached through the area ES&H Team.

16.9 Directorate/Program Laser Safety Officer

Directorates or programs may request that one or more of their personnel be designated as a Directorate/Program Laser Safety Officer. The Directorate Associate Director (or designated representative) shall nominate personnel for this position based upon their experience and knowledge of lasers, applicable codes, and standards. The LLNL LSO reviews the nominees' qualifications and either accepts or rejects the nominees. Formal Laser Safety Officer training is required; see the LLNL LSO for details. Directorate/Program Laser Safety Officers, under the direction of the LLNL LSO, may exercise the roles, responsibilities, and authorities listed for the LSO (except for overseeing LLNL Laser Safety Program, interacting with external agencies, and serving as the SME for the WSS).

17.0 Work Smart Standards

21 CFR 1002, "Records and Reports."

29 CFR 1910 Subpart J, General Environmental Controls (1910.141 to 1910.147)

29 CFR 1910 Subpart S, Electrical (1910.301 to 1910.399) App A

ANSI Z136.1-2000, American National Standard for Safe Use of Lasers, with exception of Sections 4.3.7, 4.3.8, 4.3.10.2.1, 4.4.2, 4.5.1, 4.6.5.2, 4.6.5.3, 4.6.5.4, and all appendices; replace "approve" with "review" in Sections 1.3.2.4, 1.3.2.7, and 4.4.1; in Section 4.3.4 exempt all portions except the last paragraph dealing with lock and tag of power sources.

ANSI Z136.2-1997, Safe Use of Optical Fibers Communication Systems Utilizing

Laser Diode &LED Sources

DOE O 440.1A, "Worker Protection Management for DOE Federal and Contractor Employees," Attachment 2, "Contractor Requirement Document," Sections 1–11, 13–16, 18 (delete item 18.a), 19 (delete item 19.d.3), and 22.

UCRL-AR-129189, Rev.1, *LLNL Occupational Medicine Standard: Medical Evaluation of Employees*.

NFPA 70, "National Electrical Code."

18.0 Resources for More Information

18.1 Contacts

For further information on laser safety, contact your area ES&H Team or the LSO by calling the Hazards Control Department.

18.2 Applicable Lessons Learned

Lessons Learned pertaining to laser issues can be found at the following Internet address:

http://www-r.llnl.gov/llnl_only/es_and_h/lessons/lessons.shtml

18.3 Other Sources

21 CFR 1010, "Performance Standards for Electronic Products."

21 CFR 1040, "Performance Standards for Light Emitting Products."

ANSI Z535.2-1998 "American National Standard for Environmental and Facility Safety Signs."

ANSI Z535.4-1998 "American National Standard for Product Safety signs and labels."

NFPA 115 (1995), "Recommended Practice on Laser Fire Protection."

Appendix A

Additional Nevada Test Site Requirements

The following additional requirements apply only to Class 3b and 4 laser operations at the NTS.

All Class 3b and 4 lasers or laser systems shall be registered with ES&H Team 1 at NTS, using a copy of the attached Laser Registration Form (Figure A-2). Submit the completed form to the Nevada Test Organization (NTO) Hazards Control Team 1 DLSO at NTS, M/S 777.

The LLNL-NTO Team 1 DLSO shall submit the Laser Registration form along with the OSP or FSP to the Bechtel Nevada (BN) ES&H LSO for review and approval at National Nuclear Security Administration/Nevada (NNSA/NV) facilities. NNSA/NV has delegated the approval of all Class 3 and Class 4 laser and laser systems to the BN ES&H LSO. The LLNL NTO LSO shall forward these registrations to the appropriate BN LSO.

All Class 3b or 4 lasers or laser systems shall have an approved OSP, IWS/SP, or an appendix to the FSP where the laser or laser system will be operated. The OSP or appendix to the FSP should be developed in accordance with Document 3.3.

The basic requirements for any laser operation at NNSA/NV facilities are summarized in the table below. The requirements exclude non-experimental use Class 3a lasers such as laser pointers, levels, barcode scanners, gun sights, and other activities normally performed by the public.

Laser Operation Requirements at NNSA/NV

Laser Class	SOP Required	Registration with BN Laser Registration Officer Required	Flashing Red Beacon at Laser Controlled Area Access Point Required	Posting/Labeling in Accordance with ANSI z136.1-2000 Required	Administrative Control Required (e.g., Sweeps)	Interlocked Laser Access Control Points Required	Red / Amber / Green Warning Light Panel Required At Laser Area Access Control Point For Class 3a, 3b, and 4 Lasers	
							Red Warning Lights Required During Laser Operation	Amber Warning Lights Require During Laser Operation
3a	No	No	No	Yes	No	No	No	Yes
3b	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No

The red, amber, and green warning lights on the standard warning light panel have the following designation:

Red: Class 3b or 4 laser in operation. Do Not Enter.

Amber: Class 1 through 3a lasers in operation. Contact the laser operator upon entry.

Green: No laser in operation. Permission from laser operator not required to enter.

Figure A-1 shows an example of the standard warning panel

Figure A-1. Standard warning panel.

LAWRENCE LIVERMORE NATIONAL LABORATORY

NUCLEAR TEST OPERATIONS

LASER REGISTRATION

(Class IIIb and IV)

LASER INFORMATION Prepared By:_____

Date:_____

Organization:_____ Date Use of Laser to Begin:_____

Model/Type:_____ Date Use of Laser to Cease:_____

Manufacturer:_____

Serial No.:_____ Physical Location of Use:_____

Person in Charge:_____ Phone No.:_____

Intended Use:_____

Laser Type: Material:_____Continuous:_____Pulse:_____

Pulse Rate Frequency:_____Pulse Length:_____*Peak Power:_____

Average Power (If CW Laser):_____Wave Length:_____

Aperture Diameter:_____*Beam Divergence:_____

Laser Class:_____

*Method Of Determination: ☐ Manufacturers Specifications ☐ Actual Measurement

Other (Explain):_____

Particular Precautions: **DO NOT LOOK DIRECTLY INTO LASER APERTURE OR REFLECTION PATHWAYS WHILE LASER IS ON**

Hazards to Aircraft: (Describe): _____

Operation Safety Procedure (OSP) Attached? **Note:** Laser not to be operated until OSP is approved.

(Class IIIb and above)

☐ YES ☐ NO

Laser to be used at the NTS? ☐ YES ☐ NO

Remarks:_____

Approved By: LLNL-NTO Hazards Control Team 1

Laser Safety Officer: Name:_____

Date:_____

BN ES&H Laser Safety Officer: Name:_____

Date:_____

Figure A-2. Laser Registration Form.

Appendix B

Example of Written Procedures for Laser Beam Alignment

The text starting on the next page may be used as the basis for written procedures for specific laser beam alignment operations. The Responsible Individual and DLSO may edit the text in the sections "Procedural Considerations" and "Alignment Methods to Be Used for This Laser" as appropriate to tailor it to their particular setup.

Written Procedures for Laser Beam Alignment

The techniques for laser alignment listed below are to be used to help prevent accidents during alignment of this laser or laser system.

The requirements for alignment procedures for Class 2 and above lasers and laser systems, specified in Document 20.8, "Lasers," in the *ES&H Manual* and in ANSI Z136.1, do not apply to laser pointers, surveying equipment, barcode scanners, handheld laser diagnostic equipment, or similar general-industry equipment.

Procedural Considerations

- To reduce accidental reflections, watches, rings, dangling badges, necklaces, reflective jewelry are taken off before any alignment activities begin. Use of nonreflective tools should be considered.
- Access to the room or area is limited to authorized personnel only.
- Consider having at least one other person present to help with the alignment.
- All equipment and materials needed are present prior to beginning the alignment.
- All unnecessary equipment, tools, combustible materials (if the risk of fire exists) have been removed to minimize the possibility of stray reflections and non-beam accidents.
- Persons conducting the alignment have been authorized by the Responsible Individual.
- A NOTICE sign is posted at entrances when temporary laser control areas are set up or unusual conditions warrant additional hazard information be available to personnel wishing to enter the area.

Alignment Methods to Be Used for This Laser

- There shall be no intentional intrabeam viewing with the eye. (This statement shall remain. Do not delete.)
- Coaxial low-power lasers should be used when practical for alignment of the primary beam.
- Reduce beam power with ND filters, beam splitters, or dumps, or by reducing power at the power supply. Whenever practical, avoid the use of high-power settings during alignment.

- Laser protective eyewear shall be worn at all times during the alignment, within the parameters and notes specified in the accompanying laser table.
- The LSO has authorized eyewear with reduced OD to allow the beam spot to be seen. Measures shall be taken and documented to ensure that no stray hazardous specular reflections are present before the lower-OD eyewear is worn. Maximum-OD eyewear, as listed in the laser table, is to be worn again once alignment is complete. The reduced-OD eyewear is labeled as alignment eyewear and is stored in a different location than the standard laser eyewear for this operation.
- Skin protection should be worn on the face, hands, and arms when aligning at UV wavelengths.
- The beam is enclosed as much as practical. The shutter is closed as much as practical during course adjustments. Optics and optics mounts are secured to the table as much as practical. Beam stops are secured to the table or optics mounts.
- Areas where the beam leaves the horizontal plane shall be labeled.
- Any stray or unused beams are terminated.
- Invisible beams are viewed with IR/UV cards, business cards, card stock, craft paper, viewers, 3 × 5 cards, thermal fax paper, or Polaroid film or by a similar technique. Operators are aware that such materials may produce specular reflections or may smoke or burn.
- Pulsed lasers are aligned by firing single pulses when practical.
- Intra-beam viewing is not allowed unless specifically evaluated and approved by the LSO/DLSO. Intrabeam viewing is to be avoided by using cameras or fluorescent devices.
- Normal laser hazard controls shall be restored when the alignment is completed. Controls include replacing all enclosures, covers, beam blocks, and barriers and checking affected interlocks for proper operation.

This document is to be reviewed in 1 year from the date of the IWS or IWS/SP or as conditions warrant, which ever is the shorter time period

Reviewed by:

LSO/DLSO	Date

Appendix C

Ordering Laser Eyewear

Laser eyewear can be purchased in various frame styles, with or without a prescription, adjustable or nonadjustable. Contact your area ES&H Team industrial safety engineer to find the frame style best suited to your needs. Your ES&H Team DLSO, program LSO, or LLNL LSO can also recommend vendors that have reputable quality assurance programs in place for the eyewear that they sell. Before use, individuals shall check and verify that the eyewear received meets the specifications of what was ordered.

C.1 Prescription Orders for Safety Glasses

Prescription eyewear is issued to a single individual and requires a prescription no older than one year from your ophthalmologist or optometrist.

Step	Person Performing Task	Task to Be Performed
1	Laser experimenter, laser operator and area Deputy (or program) LSO	Calculate or confirm the required OD. Select the appropriate frame style.[a]
2	Laser experimenter, laser operator	Fill out two forms: • "Information Needed To Obtain Laser Eyewear" (Figure C-1). • Form LL 2588, "Authorization for Safety Glasses" (Figure C-2). This form is also available at the following Internet address: http://www-r.llnl.gov/eforms/eforms_lib.html
3	Technical Release Representative (TRR)	• Approves purchase of laser glasses by filling in an account number and signing the forms. • Sends the form to Safety Glasses Office, L-723.
4	Safety Glasses Office/ industrial optometrist	Reviews completed forms and orders safety glasses.
5	Safety Glasses Office/ technician	• Receives the glasses from the manufacturer. • Schedules a fitting. At the fitting appointment: • Checks the glasses for the proper prescription and optical density. • Discusses proper care and use of the laser eyewear.

[a] **The industrial safety engineers have access to various frame styles that can be fitted with glass or plastic lenses as well as styles that can be worn over your present glasses and are trained to help you select the frame style that provides the best fit for the best protection.**

Prescription laser eyewear is exclusively ordered through the Safety Glasses Office Technical Release Representative (TRR) and is to be properly fitted by the industrial optometrist at the Safety Glasses Office.

C.2 Ordering Nonprescription Safety Glasses or Glasses With Special Frames

Nonprescription laser eyewear may be worn by more than a single individual, possibly over the wearer's prescription glasses, and be adjusted for fit by the wearer. Any TRR may order this type of eyewear, following evaluation and approval by the area DLSO, program LSO, or the LLNL LSO. Nonprescription eyewear that uses specialty frames (such as wire frames) or specially made glass that is not be prescription must be purchased through the TRR at the Safety Glasses Office (SGO). When the SGO receives this type of nonprescription eyewear, they will contact you to pick it up, at which time they will adjust the frames to properly fit you.

Step	Person Performing Task	Task to Be Performed
1	Laser experimenter, laser operator, and area Deputy (or program) LSO	• Calculate or confirm the required OD. • Select the appropriate frame style.[a]
2	Laser experimenter, laser operator	Fill out two forms: • "Information Needed To Obtain Laser Eyewear" (Figure C-1). • Form LL 2588, "Authorization for Safety Glasses" (Figure C-2). This form is also available online at http://www-r.llnl.gov/eforms/eforms_lib.html
3	TRR	• Approves purchase of laser glasses by filling in the account number and signing. • Sends the form to the industrial safety engineer who processed the request.
4	Safety Glasses Office	Reviews completed forms and orders safety glasses.
5	Safety Glasses Office	• Receives ordered glasses from the manufacturer. • Schedules an appointment. • Checks the glasses for the proper OD. • Discusses proper care and use of the laser eyewear.

[a] **The DLSOs and the Safety Glasses Office have access to various frame styles that can be fitted with glass or plastic lenses, as well as styles that can be worn over your present glasses, and can help you select the frame style that provides the best fit for the best protection.**

Information Needed to Obtain Laser Eyewear

*Please fill in a separate sheet for **each** type of eyewear you seek.*

I. Optical density and wavelength information is essential. Please fill in the following table for the eyewear you want:

	Laser or wavelength 1	Laser or wavelength 2	Laser or wavelength 3	Laser or wavelength 4
Laser name				
Wavelength				
CW or pulsed?				
Output power (CW)				
Pulsed only				
Output energy per pulse				
Pulse duration				
Pulse repetition rate				

NOTE: Be sure to account for unexpected exposures to fundamentals/harmonics when specifying eyewear for frequency-converted lasers.

Is this laser operation covered by a Safety Plan (SP) or IWS? Yes ☐ No ☐

If it is covered by an SP, what is the number of the SP? _____

II. User needs and preferences should be discussed with the Laser Safety Officer before ordering eyewear. The following information is needed:

A. Prescription (check one) No ☐ Single vision ☐ Bifocal ☐

B. *Goggles* or *spectacles* (check one) Goggles ☐ Spectacles ☐

C. For *spectacles*, should opaque side shields or translucent side shields that will still block the laser wavelengths will be ordered? (check one)

Opaque side shield ☐ Translucent side shield ☐

D. Do you want glass lenses or plastic lenses?

1. Glass lenses are usually heavier, but usually let through more light and are more resistant to damage when struck directly by a beam.

2. Glass lenses are used when average output ≥100 W and for prescriptions.

   (check one) Glass filters? ☐ Plastic filters? ☐

E. *For eyewear to be worn over existing glasses*: Goggle or wraparound laser eyewear can be used, but some goggles may be too small for some fashionable big-lens street spectacles. (Check one)

   Doesn't apply ☐ Prefer goggles ☐ Prefer wraparounds ☐

F. *For multiple wavelengths requiring several filter layers* (glass filters only):

1. The two filter materials can be glued together so protection is always provided against multiple wavelengths.
2. Alternatively, when exposures to one wavelength occur more frequently, the filters for the wavelength with fewer exposures can be provided as a *flip up* or *clip on*. (Check one of the following)

   Single wavelength/band only ☐ Flip up ☐ Clip on ☐ Glued together ☐

III. How many pairs do you need? _____

Figure C-1. Information Needed to Obtain Laser Eyewear Form.

University of California
Lawrence Livermore National Laboratory

AUTHORIZATION FOR SAFETY GLASSES (Health & Safety Manual Section 10.07)

Complete this form and call extension 2-5190 for an appointment

Date

Name (Last, First, MI)	A	Emp#	ge	L-Code	Bldg	Extension	Pager	Cost Acct #

Job Title	Department/Division/Program

Employment Status (check one)	☐ Permanent ☐ Summer	☐ Consultant ☐ Contract	Supervisor Name (Type or Print)	Extension

Resource Manager (type or print)	E	xtension

Job Exposure (*Check all that apply*)

☐ Impact ☐ Bright Light ☐ Infrared ☐ Glassblowing
☐ Chemical ☐ Ultraviolet ☐ Welding/Soldering ☐ Other _____

Hours exposed per week	Do you wear contact lenses? ☐ No ☐ Yes	Contact Lens Type ☐ Hard ☐ Soft	Have you been previously issued LLNL glasses? ☐ No ☐ Yes	Date of most recent eye exam

Prescriptions more than one year old WILL NOT be accepted. Replacement glasses and lenses will not be issued on expired prescriptions or on prescriptions that are more than two years old.

Reason for replacement or repair

☐ Scratched lenses ☐ Broken frame ☐ Lost
☐ New prescription ☐ Broken lenses ☐ Other _____

Does this employee work on exposed, energized electrical equipment >50V? ☐ No ☐ Yes	Other Glasses Requested ☐ Sun ☐ Computer *	(Approx Progressive Lens Add'l Cost) ☐ Progressive Lenses $60.00

*

Request for Safety Glasses require the following signatures	Supervisor Approval	Cost Account Approval	Computer Glasses Approval

Special Glasses

All requests for safety glasses other than those designated above, require Industrial Safety Engineer approval.

Check type of lenses required:
☐ Welding Calobar ☐ Didymium ☐ Other (specify below) _____
☐ Laser ☐ Respirator _____

Industrial Safety Engineer Approval

An authorization sheet is not required for personal safety glasses that are purchased. Call the Safety Glasses Office for an appointment. Payment by check or money order only is required on the day of the order. NO CASH PLEASE.

SAFETY GLASSES OFFICE USE ONLY

Date Safety Glasses Ordered	Ordered By	Eye Size
		☐44 ☐46 ☐47 ☐48 ☐49 ☐50 ☐51 ☐52 ☐53 ☐54 ☐55 ☐56 ☐57 ☐58 ☐59 ☐60 ☐61

Bridge Size	Lens Color
☐14 ☐15 ☐16 ☐17 ☐18 ☐20 ☐22 ☐24 ☐26	☐Clear ☐Cal ☐Pink ☐Gray

Cat Number	Temple Sizes
	☐135 ☐140 ☐145 ☐150 ☐Other ☐5-1/4 ☐5-1/2 ☐5-3/4 ☐6 ☐6-1/4 ☐6-1/2 ☐6-3/4 ☐7

Special

LL2588# v3.0 (01/02)

Figure C-2. Authorization for Safety Glasses.

Appendix D

General Layout of Laser Warning Signs

Examples of typical laser signs are shown below in a typical 8.5 x 11-in. horizontal format. Signs shall be conspicuously displayed in locations where they best will serve to warn onlookers. A pragmatic alternative to expensive commercial or laminated signs are signs that can be generated and readily updated with very specific messages using a color printer and mounted in protective viewgraph sleeves. Signs should be approved by an LSO or DLSO and may be obtained from your local ES&H Team. Equipment labels follow basically a similar format as the signs described below. These may also be obtained from your local ES&H Team.

D-1 Sign Types

- The DANGER sign indicates an imminent hazard that, if not avoided, ***will*** result in serious injury or death.
- The CAUTION sign indicates a hazardous situation that ***could*** result in minor or moderate injury if not avoided.
- The WARNING sign may be used outside an area or an enclosure that contains a danger-level hazard. The ***hazard could potentially*** result in serious injury or death if not avoided.
- A WARNING sign is not a replacement for the required DANGER sign.
- The NOTICE sign indicates a statement related to personnel or property protection. It shall not be used solely in place of the previously mentioned signs.

Figure D-1 displays a generic sign with the following general characteristics (from top to bottom): at the top is a colored signal-word panel with a safety-alert symbol (exclamation point within an equilateral triangle) and a signal word; below this is a word message designated as Position 1; this is followed by a graphic symbol (in this case, a laser-sunburst symbol); Positions 2 and 3 are final word messages. Older signs that conformed to ANSI standards shall remain valid; however, all new signs shall conform to the new sign standards described in ANSI Z535.x-1998 ("x" refers to standards 1–5).

Figure D-1. Layout of laser warning signs.

D-2 Type Format

The signal word shall be large type and in all uppercase letters (in this case 108 point), comparable in size to the safety-alert symbol. The word and symbol shall be on the same baseline. The text messages for Positions 1, 2, and 3 shall be 18 or 24 point, left justified using upper and lowercase black letters. Only words that need to be emphasized should be in all capital letters. Do not overfill the space with large type because sufficient "white space" makes the messages more readable. Both the signal word and the messages shall be in bold, sans-serif fonts (Helvetica or Geneva).

D-3 Panels and Symbols

The upper colored, signal-word panel shall be red to signify DANGER, yellow for CAUTION, orange for WARNING, and blue for *NOTICE*. The signal word type shall be white for DANGER and *NOTICE*, and black for CAUTION and WARNING. Note that only the *NOTICE* word is printed in italic font. The safety-alert symbol uses the corresponding colors as the colored panel; the exclamation point utilizes the same color as the panel; and the equilateral triangle uses the same color as the signal word. The safety-alert symbol is used only to indicate a potential personnel injury hazard, not to alert potential property damage. Hence, the NOTICE sign does not use a safety alert symbol. The body of the sign may incorporate many different kinds of graphic symbols depending on the hazard type. The examples in Figure A-1 show only the laser sunburst symbol, which shall be black for all signs except the DANGER sign, which shall be red. The NOTICE sign may use a black or blue symbol. The backgrounds for all signs shall be white, except for the CAUTION sign, which uses yellow. In the latter case, the yellow background and signal word panel merge together.

D-4 Specific Applications of Laser-Related Signs

For the laser-class signs, the word message in Position 1 is verbatim from Section 4.7.4 of ANSI Z136.1-2000 and is based on the highest class of laser described by a sign. Use of the words "invisible" or "visible", as appropriate, are added for any of the lasers covered. If a sign covers only visible lasers, the words "visible laser radiation" may be replaced by "visible laser light". A separate paragraph at Position 1 can describe precautionary instructions. However, the preferred method is to include the paragraph just below the sunburst at Position 2. This paragraph may include such messages as "Access for authorized individuals only"; "Minimum optical density (OD) eyewear may be required"; "Knock for access permission"; or "Call x-xxxx for access". The paragraph should end with reference to an applicable IWS/SP, FSP, or IWS (see SP xxx.xx or see IWS xxxxxxxx as appropriate).

The lower portion of Position 2 shall describe either (1) laser type or wavelength, pulse duration (if appropriate), and maximum output; or preferably (2) laser type, OD requirement for maximum protection, and applicable wavelength in nm. The latter format is preferred because the OD specification normalizes hazard levels that otherwise would require power (CW) or energy (pulsed), pulse duration and repetition rate as applicable, exposure duration, beam size, divergence, limiting aperture, and wavelength. The data should be presented in tabular form for ease of readability and should not be crowded with overly large type. Position 3 shall show the highest class of laser covered by a sign and be located at the lower right-hand corner.

Specific functions of signs are listed below:

- A DANGER—Class 4 laser sign covers one or more Class 4 lasers that are considered to be at very high power or energy. Typically, a facility described by such a sign will require access interlocks unless other controls are implemented.
- A DANGER—Class 3b laser sign covers one or more Class 3b lasers that are considered to be of moderate to high power or energy. A facility described by such a sign may employ optional access interlocks, particularly if two or more lasers are in operation at the same time, unless other controls are implemented. Visible CW alignment lasers ≤15 mW and with appropriate beam control require no interlocks when they are the only lasers used.
- A DANGER—Class 3a laser sign covers one or more Class 3a lasers that are considered to be of moderate power or energy and exceed the MPE. Typically, a facility described by such a sign will not employ access interlocks.

- A CAUTION—Class 3a laser sign covers one or more visible Class 3a lasers that are considered to be of low power or energy and are expected not to exceed the MPE when viewed without optical viewing aids for ≤0.25 s. This sign is seldom used. No interlocks are required.
- A CAUTION—Class 2 laser sign covers one or more visible Class 2 lasers that are considered to be of low power and do not to exceed the MPE for ≤0.25 s. No interlocks are required.
- A WARNING sign warns of potential harm behind a door or enclosure. This sign may be used to advise of an unattended operation; a high-power or high-energy laser completely embedded as a Class 1 laser; or hazardous, accessible electrical contacts within an enclosure.
- A NOTICE sign is a policy sign conveying information directly or indirectly related to personnel or property protection. The sign may provide notification of inactivity of a facility, equipment, or an interlock system. The sign may also advise of a temporary situation such as when a laser is being serviced without functioning interlocks. In the latter case, the NOTICE sign shall be supplemented with the appropriate DANGER sign.

Appendix E

Interlock Checklist

BUILDING _____ SYSTEM _____

ROOM _____ DIVISION RESPONSIBLE _____

DATE	DOOR INTERLOCKS	RUN/SAFE BOXES	KEY SWITCH	ALARMS (AUDIBLE & VISIBLE)	REMARKS	SIGNATURE

Appendix F

Terms and Definitions

Accessible radiation	Laser radiation to which it is possible for the human eye or skin to be exposed during normal use.
Authorized person	A person who has the approval of the area supervisor or program management to perform a particular function in that area.
Aversion response	Movement of the eyelid or head to avoid exposure to a noxious stimulant or bright light. An aversion response can occur within 0.25 s, including the blink reflex time.
Continuous-wave (CW) laser	A laser operating with a continuous output for a period that is greater than or equal to 0.25 s.
Controlled laser area	An area in which the occupancy and activity of those within are subject to control to protect personnel from hazards.
Commerce	Organizations or individuals that are not part of the DOE or DOE contractors.
CW	See "Continuous-wave (CW) laser."
Diffuse reflection	Spatial distribution of a beam of radiation when it is reflected in many directions by each point on a surface or within a medium.
DLSO	Deputy laser safety officer.
Embedded laser	A laser with an assigned classification higher than the classification of the laser system in which it is incorporated. The system's lower classification is appropriate because engineered features limit accessible emission.

Enclosed laser	A laser that is contained within a protective housing of itself or of the laser or laser system in which it is incorporated. Opening or removal of the protective housing 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.
Failsafe	An electrical or mechanical system where the failure of a single interlock component will cause the system to go into, or remain in, a safe mode.
IR	Infrared.
Irradiance (E)	The optical power per unit area reaching a surface (W/cm^2).
Joule (J)	A unit of energy (1 Joule = 1 Watt-second).
Laser, laser system	A device that produces an intense, coherent, directional beam of light. Also an acronym for Light Amplification by Stimulated Emission of Radiation. A laser system is a device that has an attached laser, lenses, and mirrors or fiber optics, or somehow uses the exposed beam of the attached laser.
Laser Safety Officer (LSO)	The head of the Hazards Control Department appoints the LSO. He or she is charged with the knowledgeable evaluation and control of laser hazards that are due to LLNL operations. If the LSO is unavailable, a DLSO (i.e., an ES&H Team industrial safety engineer who has had formal LSO training) shall perform these functions.
Maximum permissible exposure (MPE)	The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. The LSO can provide guidance on calculating an appropriate MPE or a copy of the standard.
MPE	See "Maximum permissible exposure (MPE)."
NHZ	See "Nominal hazard zone (NHZ)."

Nominal hazard zone (NHZ)	The space around a laser in which exposure to laser light exceeding the MPE is possible. The space boundary shall be clearly indicated by signs, barricades, walls, and ropes, as appropriate (e.g., the laboratory walls and doors typically satisfy this requirement).
Nominal ocular hazard zone (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, during installation or service, is not expected to exceed the appropriate MPE.
OD	Optical Density.
Offsite	Outside the LLNL or Site 300 fence line.
Power	The rate at which energy is emitted, transferred, or received. The unit of measurement used is *watt* or *Joules per second*.
Pulsed laser	A laser that delivers its energy in the form of a single pulse or a train of pulses, with a pulse duration of less than 0.25 s.
Radiant exposure	The optical energy per unit area reaching a surface (Joules/cm^2).
Reflection	The deviation of radiation following incidence with a surface.
Specular reflection	A mirror-like reflection.
UV	Ultraviolet.