

## Chapter 10: [Laser Safety](#)

# General Requirements

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URL: <https://www-group.slac.stanford.edu/esh/eshmanual/references/laserReqGeneral.pdf>

## 1 Purpose

The purpose of these requirements is to ensure applicable controls are in place for each class of laser. They cover classification, project management, purchase, hazard analysis, control selection, electrical safety inspection, labeling, and use of all classes of lasers. They apply to workers using lasers, *system laser safety officers (SLSOs)*, *laser facility program managers*, line management, and the *laser safety officer (LSO)*.

## 2 Requirements

Laser safety requirements depend on three factors:

1. The laser classification: each laser is assigned a classification (Class 1, Class 2, Class 3R, Class 3B, or Class 4) based on the level of its accessible radiation and the associated ability of the laser beam to cause injury to the eye or skin. For example, a Class 4 laser is capable of causing greater injury than a Class 3B laser.
2. The environment in which the laser is used, including access to the beam path (considering such factors as *enclosures* and *barriers*).
3. The personnel who may use or be exposed to laser radiation.

### 2.1 Classification

Lasers are classified according to their accessible radiation during *normal operation*. A commercial laser purchased with a manufacturer-provided hazard classification that is in conformance with the Federal Laser Product Performance Standard (FLPPS, [21 CFR 1040.10](#) and [21 CFR 1040.11](#)) fulfills all classification requirements.

Lasers fabricated for research and without manufacturer's assurance of FLPPS compliance must be classified prior to operation.

The LSO will classify lasers and laser systems when the classification is not provided, the classification is not in accordance with the FLPPS, or the intended use is different from the use recommended by the manufacturer, or engineering control measures are added, deleted, or modified. Laser classes are given in Table 1.

**Table 1** Laser Classes and Hazards

Class	Hazard
Class 1	<ul style="list-style-type: none"> <li>▪ Emitted radiation may be visible or invisible</li> <li>▪ Incapable of producing damaging radiation levels</li> <li>▪ May have an accessible laser beam at very low intensity, or may be a fully enclosed laser with no accessible radiation</li> <li>▪ Exempt from any administrative or PPE control measure requirements</li> </ul>
Class 2	<ul style="list-style-type: none"> <li>▪ Emits visible radiation at wavelengths between 400–700 nm</li> <li>▪ Eye aversion response (blinking or looking away) provides adequate protection, but eye injury is possible if there is an intentional prolonged exposure. The eye aversion response time is assumed to be 0.25 seconds.</li> <li>▪ Maximum average power for <i>continuous wave (cw) lasers</i> is 1 mW</li> <li>▪ Can present a startle hazard and may cause temporary flash-blindness, after images and glare responses; thus some controls are needed to prevent an accidental exposure</li> </ul>
Class 3R (previously called 3a)	<ul style="list-style-type: none"> <li>▪ Emitted radiation may be visible or invisible</li> <li>▪ Visible laser radiation is greater intensity than Class 2 but must be within a factor 5 of the Class 2 accessible emission limit (maximum average power for cw lasers is 5 mW). Invisible laser radiation is greater intensity than Class 1 but must be within a factor 5 of the Class 1 accessible emission limit.</li> <li>▪ Generally not considered a significant hazard for accidental viewing, but is a potential hazard for direct or <i>specular reflection</i> viewing</li> <li>▪ Can present a startle hazard and may cause temporary flash-blindness, after images and glare responses; thus some controls are needed to prevent accidental exposure</li> </ul>
Class 3B (previously called 3b)	<ul style="list-style-type: none"> <li>▪ Emitted radiation may be visible or invisible</li> <li>▪ Emitted radiation has intensity greater than Class 3R. Maximum average power is less than 500 mW (can be lower for <i>pulsed lasers</i>).</li> <li>▪ Eye hazard for direct or specular reflection viewing; there are associated laser eyewear protection requirements.</li> </ul>
Class 4	<ul style="list-style-type: none"> <li>▪ Emitted radiation may be visible or invisible</li> <li>▪ Emitted radiation has intensity greater than Class 3B</li> <li>▪ Hazard to eye or skin from direct beam; there are associated laser eyewear protection requirements</li> <li>▪ <i>Diffuse reflections</i> may be hazardous</li> <li>▪ Potential for fire hazard from laser intensity exceeding combustibility thresholds of some materials</li> <li>▪ Laser-target interactions may produce laser-generated air contaminants, and hazardous <i>plasma radiation</i> at very high intensities</li> </ul>

## 2.2 Hazard Control Hierarchy and Control Requirements

Laser hazards are controlled with a combination of *engineering* and *administrative controls* and *personal protective equipment (PPE)*. Engineering controls are given first priority because they are the most reliable. If possible, they are used to eliminate the laser hazard by fully enclosing the laser beam. Class 3B and Class

4 laser operation requires significant engineering, administrative, and PPE controls. There must be sufficient redundancy of controls to ensure safe laser operations with minimal risk for injury. There should be no single points of failure that could result in a hazardous exposure.

To ensure engineering controls are effective, they must have good integrity, be reliable, and be implemented in accordance with the [SLAC Conduct of Engineering Policy](#).

## 2.3 Hazard Analysis and Requirements for Credited and Non-credited Controls

Laser hazard analysis is performed by the SLSO and the LSO to determine the controls requirements to mitigate the associated risks for injury.

- *Credited controls* must be used to reduce risk to an acceptable level.
- Additional *non-credited* controls should be used to further reduce the risk to a level that is as low as reasonably practicable (ALARP).

Laser hazard analysis and requirements for credited controls follow SLAC's general policy requirements for these in [General Policy and Responsibilities: Hazard Control Selection and Management Requirements](#).

For Class 3B and Class 4 laser operation, all of the following controls are generally considered to be credited controls:

- An engineered *laser safety system (LSS)*
- *Standard operating procedures (SOPs)*, including [Laser Safety: Core Laser Safety Practices](#)
- Laser eyewear PPE
- Laser worker training (see Section 4, "Training", in [Chapter 10, "Laser Safety"](#).)

### 2.3.1 Interfaces between Safety Systems

When an engineered LSS for a Class 3B or Class 4 laser system has an interface with another system (such as a radiation safety system) that affects the LSS safety functions and is the responsibility of a different group, the interface, configuration control, and responsibilities must be described in an interface control document (ICD). Additional requirements for ICDs can be found in the [Laser Safety Systems Technical Basis Document](#).

## 2.4 Project Management Requirements

A project is initiated when implementing a new *laser facility* or laser system or making a significant upgrade to an existing facility or system. As applicable, the [SLAC Conduct of Project Management Policy](#) and the [General Policy and Responsibilities: ESH Project Review Procedure](#) must be followed.

## 2.5 Alternate Controls

*Alternate controls* may be used to replace control requirement(s) in this document, provided all of the following requirements are met:

- They provide equivalent protection as would be accomplished with the specific control(s) not used.
- They are reviewed and approved by the LSO.
- Training on them is provided to all affected laser workers.

Alternate controls may be needed when the primary controls specified in this document are not feasible or not reasonably practicable.

Situations where an alternate control may be needed include

- Acceptance testing of a newly received laser
- Service work by a service subcontractor

Examples of alternate controls include

- No unattended operation
- A guard being posted
- An enclosure, if not interlocked, is secured and has a warning label

## 2.6 Unattended Operation

Only Class 1 lasers or laser systems will be used for unattended operation in unsupervised areas without the implementation of additional control measure requirements.

## 2.7 Exposure Control

The following controls are recommended for all laser classes above Class 1 to minimize the risk from potential exposure to laser beams:

- Use the minimum laser radiation required for the application.
- Avoid eye and skin exposure and direct viewing of the laser beam; maintain the beam at a level other than the eye level of a person sitting or standing.
- Limit potential exposure levels to as far below the *maximum permissible exposure (MPE)* values as is practical (values for the MPE are below known hazardous levels and can be obtained from the LSO or [ANSI Z136.1](#)).

## 2.8 Protective Housing

A laser must be contained in its appropriate *protective housing* to reduce potential exposure. The aperture through which the useful beam is emitted is not part of the protective housing. Special safety procedures may be required when protective housings are removed.

The protective housing must

- Limit the maximum accessible laser radiation to a level that defines the classification
- Have classification labels affixed on a conspicuous part of the laser housing

- Limit access to other associated radiant energy emissions and to electrical hazards associated with components and terminals

## 2.9 Laser Equipment Labels

All lasers must have equipment labels on the protective housing that specify their classification, wavelength, pulse duration (if appropriate), and maximum output power.

Equipment labels have an associated signal word:

- CAUTION for Class 2 and Class 3R lasers (Note commercial lasers may use DANGER for Class 3R, which is acceptable.)
- WARNING for Class 3B and for most Class 4 lasers (Note commercial lasers may use DANGER for Class 3B and Class 4, which is acceptable.)
- DANGER for Class 4 lasers that have very high power, pulse energy or irradiance (for example, >100 W average power, >1 J pulse energy, or  $>10^{16}$  W/cm<sup>2</sup>)

Templates for labels are available on the [Laser Safety Program Site](#).

## 2.10 Work Planning and Control

Laser operations must comply with SLAC *work planning and control (WPC)* requirements (see [Chapter 2, “Work Planning and Control”](#)). WPC requirements for laser safety when working with Class 3B and Class 4 lasers include the following:

- Work by *qualified laser operators (QLOs)* and *laser controlled area workers* in their own laser facility is considered resident-area, yellow work. Authorization and release is granted by the workers being qualified and approved (via the [Laser Safety Tool](#), which also documents the workers’ facility-specific work authorizations). When working outside their home facilities, they are limited to *service* work and additional requirements apply. (See [Laser Safety: Class 3B and Class 4 Laser Operation Requirements](#).) Work performed by *service* subcontractors is considered red work and is authorized and released following [Laser Safety: Laser Service Subcontractor Work Planning and Control Procedure](#).
- A *lab-specific SOP* or *job safety analysis (JSA)* is used to describe hazards and controls associated with the work. Laser work may only begin after these documents and the laser laboratory itself have been approved.
- Pre-job briefings must be held as appropriate, and are recommended for new tasks, unfamiliar or infrequently performed tasks, significant configuration changes, or returning system to operation following a downtime or power outage.

Additional requirements apply when laser work is performed by service subcontractors (see [Laser Safety: Laser Service Subcontractor Work Planning and Control Procedure](#)).

For details, see [Laser Safety: Class 3B and Class 4 Laser Operation Requirements](#).

## 2.11 Purchasing Lasers and Laser-protective Eyewear

The LSO must be notified of all purchases of Class 3B and Class 4 lasers and of laser eyewear protection.

*Note      Online purchase requisitions have a section for the requester to complete on whether the purchase includes a Class 3B or Class 4 laser purchase or service, or the purchase of laser protective eyewear; with an affirmative response the LSO will be notified automatically.*

Purchased laser products must meet the Food and Drug Administration (FDA) requirements in [21 CFR 1040.10](#) and [21 CFR 1040.11](#), except as described in [FDA Laser Notice 25](#) and [FDA Laser Notice 56](#).

*Note      Laser components are exempt from FDA requirements (see [21 CFR 1040.10](#))*

### 2.11.1 FDA Laser Notice 25 Products

Laser products that utilize [FDA Laser Notice 25](#) are required to

- Have an equipment label stating the exemption and that the product should not be used without adequate protective devices and should not be disposed of through excess or regular surplus property channels
- Include, to the extent practical, the safety provisions of [21 CFR 1040.10](#) and [21 CFR 1040.11](#). Adequate alternative safety controls are to be provided wherever this is not practical.
- Have written authorization from the Department of Energy (DOE) to the laser manufacturer to sell or transfer each exempt laser product

The LSO must be informed of laser purchases utilizing FDA Laser Notice 25, and SLAC must submit annual reports to DOE on such purchases.

### 2.11.2 FDA Laser Notice 56 Products

Among other requirements, laser products for introduction into United States commerce, including imports, that utilize Notice 56, must

- Comply with [21 CFR 1040.10](#) and [1040.11](#) as applicable
- Be certified and identified in accordance with [21 CFR 1010.2](#) and [1010.3](#)
- Be reported in accordance with [21 CFR 1002.10](#)

Laser products that are not considered a medical device and utilize [FDA Laser Notice 56](#) are required to have a certification label stating

- “Complies with FDA performance standards for laser products except for conformance with IEC 60825-1 Ed. 3., as described in Laser Notice No. 56, dated May 8, 2019.” or
- “Complies with 21 CFR 1040.10 and 1040.11 except for conformance with IEC 60825-1 Ed. 3, as described in Laser Notice No. 56, dated May 8, 2019.”

### 2.11.3 Class 3B and Class 4 Laser Products

FDA requirements for Class 3B and Class 4 laser products include

- Equipment labels, including a certification label
- Protective housing
- Operation manual and servicing procedures
- Key-actuated master control
- Activation warning system and emission indicator
- Remote interlock connector

## 2.11.4 Receiving Laser Products

When purchased laser products are received, the equipment custodian must

- Review the safety section in the laser's manual
- Verify that the required equipment labels are present
- Inspect the laser systems' electrical equipment to determine if the equipment is listed or requires inspection and approval under the Electrical Equipment and Inspection Program before use (see Section 2.12).

## 2.12 Electrical Safety Inspection

Laser systems' electrical equipment should be certified and listed for use in the United States by a Nationally Recognized Testing Laboratory (NRTL) whenever possible. NRTL-listed laser systems that are used within the listing agency and manufacturer requirements are acceptable for use at SLAC without any additional electrical safety inspection.

Non-listed equipment must be inspected according to the requirements of the [Electrical Equipment Inspection Program](#) (EEIP) and must have EEIP approval before use.

Additional guidance for electrical safety requirements for laser purchases can be found in [Guidance for SLAC System Laser Safety Officers](#).

## 2.13 Laser Use for Demonstrations and Events

Lasers used for demonstrations and events at SLAC outside of *laser controlled areas* must meet the requirements listed below, except for laser pointers used for presentations, which are subject to requirements in [Laser Safety: Laser Pointer Requirements](#). Participants at these demonstrations and events can include the general public and SLAC personnel who are not laser workers.

- Lasers will not exceed Class 3R. Class 1, Class 1M, Class 2, Class 2M, and Class 3R lasers are allowed.

*Note*      *Class 3B and Class 4 lasers can only be operated in a laser controlled area with approval from the SLAC LSO*

- Class 2 lasers should be used instead of Class 3R lasers, if practical. Visible lasers (400–700 nm wavelength) should be used unless the point of the demonstration can only be accomplished with an invisible laser.

- Laser use will be supervised by a SLAC laser worker (QLO or LCA worker) or a SLAC employee who has completed ESH Course 132, Laser Safety Basics ([ESH Course 132](#)).
- Requirements in Section 2.7, “Exposure Control”, will be followed.
- Laser beam paths will be controlled and will not be directed towards participants.
- Laser use must be reviewed and approved by the SLAC LSO. The LSO will determine appropriate controls, including any laser safety instruction that must be given to participants.

## 3 Forms

The following forms and systems are required by these requirements:

- None

## 4 Recordkeeping

The following recordkeeping requirements apply for these requirements:

- None

## 5 References

[SLAC Environment, Safety, and Health Manual](#) (SLAC-I-720-0A29Z-001)

- [Chapter 10, “Laser Safety”](#)
  - [Laser Safety: Laser Pointer Requirements](#) (SLAC-I-730-0A05S-010)
  - [Laser Safety: Class 2 and Class 3R Laser Operation Requirements](#) (SLAC-I-730-0A05S-003)
  - [Laser Safety: Class 3B and Class 4 Laser Operation Requirements](#) (SLAC-I-730-0A05S-004)
  - [Laser Safety Systems Technical Basis Document](#) (SLAC-I-730-0A05Z-001)
  - [Laser Safety: Class 3B and Class 4 UV Laser Operation Requirements](#) (SLAC-I-730-0A05S-012)
  - [Laser Safety: Laser Worker Approval Procedure](#) (SLAC-I-730-0A05C-003)
  - [Laser Safety: Laser Service Subcontractor Work Planning and Control Procedure](#) (SLAC-I-730-0A05C-001)
  - [Laser Safety: Core Laser Safety Practices](#) (SLAC-I-730-0A05S-006)
  - [Guidance for SLAC System Laser Safety Officers](#) (SLAC-I-704-701-004-00)
  - [Laser Safety Program Site](#) (SharePoint)
- [Chapter 1, “General Policy and Requirements”](#)
  - [General Policy and Requirements: ESH Project Review Procedure](#) (SLAC-I-720-0A24C-001)
  - [General Policy and Requirements: Hazard Control Selection and Management Requirements](#) (SLAC-I-720-0A24S-001)



- [Chapter 2, “Work Planning and Control”](#)
- [Chapter 8, “Electrical Safety”](#)
  - [Electrical Equipment Inspection Program](#) (SLAC-I-730-0A11A-001)

#### Other SLAC Documents

- [SLAC Conduct of Engineering Policy](#) (ENG-2018-018)
- [SLAC Conduct of Project Management Policy](#) (PM-2018-034)
- ESH Course 132, Laser Safety Basics ([ESH Course 132](#))

#### Other Documents

- Title 21, *Code of Federal Regulations*, “Food and Drugs, Chapter 1, “Food and Drug Administration, Department of Health and Human Services”, Subchapter J, “Radiological Health”, Part 1002, “Records and Reports”, Subpart B, “Required Manufacturers' Reports for Listed Electronic Products”
  - Section 1002.10, “Product Reports” ([21 CFR 1002.10](#))
- Title 21, *Code of Federal Regulations*, “Food and Drugs, Chapter 1, “Food and Drug Administration, Department of Health and Human Services”, Subchapter J, “Radiological Health”, Part 1010, “Performance Standards for Electronic Products: General”
  - Section 1010.2, “Certification” ([21 CFR 1010.2](#))
  - Section 1010.3, “Identification” ([21 CFR 1010.3](#))
- Federal Laser Product Performance Standard (FLPPS): Title 21, *Code of Federal Regulations*, “Food and Drugs, Chapter 1, “Food and Drug Administration, Department of Health and Human Services”, Subchapter J, “Radiological Health”, Part 1040, “Performance Standards for Light-emitting Products”
  - Section 1040.10, “Laser Products” ([21 CFR 1040.10](#))
  - Section 1040.11, “Specific Purpose Laser Products” ([21 CFR 1040.11](#))
- Food and Drug Administration (FDA) Laser Notice 25, “Exemption of Certain Laser Products Used Exclusively by the Department of Energy or its Contractors, and by the National Oceanic and Atmospheric Administration, U.S. Department of Commerce” ([FDA Laser Notice 25](#))
- Food and Drug Administration (FDA) Laser Notice 56, “Laser Products – Conformance with IEC 60825-1 Ed. 3 and IEC 60601-2-22 Ed. 3.1; Guidance for Industry and FDA Staff” ([FDA Laser Notice 56](#))
- American National Standards Institute (ANSI) Z136.1, “Safe Use of Lasers” ([ANSI Z136.1](#))