NATIONAL ACCELERATOR LABORATORY

**ENVIRONMENT, SAFETY & HEALTH DIVISION**

*Chapter 10: Laser Safety*

# Quick Start Summary

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URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/laserQuickstart.pdf

## 1 Who needs to know about these requirements

The requirements of Laser Safety apply to workers who use low-power lasers, operate high-power lasers, or access labs where such lasers operate; their line management, supervisors, points of contact, and ESH coordinators; project managers; *laser facility program managers*, *system laser safety officers (SLSOs)*, directorate laser leads, and the *laser safety officer (LSO)*; and Occupational Health and Purchasing.

## 2 Why

High-power lasers (Class 3B and Class 4) used at SLAC can damage the eye and burn skin and expose workers to electrical currents, explosions, and fires; toxic materials and laser-generated air contaminants; and collateral radiation, noise, and ultraviolet light. Low-power lasers can create a startle hazard and temporary flash-blindness, after images, and glare responses.

## 3 What do I need to know

- Lasers are classified (Class 1, Class 2, Class 3R, Class 3B, or Class 4) based on the level of accessible radiation and the associated ability 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. Hazard controls are based on the class.
- Work involving Class 3B or Class 4 lasers requires *qualified laser operators (QLOs)* (or, for limited work, *laser controlled area workers*) under the supervision of approved SLSOs, in *laser controlled areas (LCAs)* with *engineering* and *administrative controls* developed by line management and the SLSO and approved by the LSO.
- Use of other classes of lasers, including laser pointers, must meet basic safety requirements.

## 4 When

These requirements take effect 5 May 2023.

## 5 Where do I find more information

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

- Chapter 10, “Laser Safety”

Or contact the program manager.

NATIONAL ACCELERATOR LABORATORY

ENVIRONMENT, SAFETY & HEALTH DIVISION

*Chapter 10*

# Laser Safety

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## 1 Purpose

The purpose of this program is to mitigate the hazards posed by optical lasers, which operate at wavelengths between 180 nm and 1 mm. High-power lasers (Class 3B and Class 4) are used at SLAC in research and accelerator operations. The primary hazard associated with their operation is potential eye damage; other potential hazards include skin burns, electrical currents, explosions, fires, toxic material, laser-generated air contaminants, collateral radiation, noise, and ultraviolet light. Low-power lasers (Class 2 and Class 3R) include laser pointers and alignment lasers; they are safe when used as intended, but require some controls.

This program covers the setup and operation of high-power lasers, encompassing operation approval of *laser controlled areas (LCAs)*, approval of *system laser safety officers (SLSOs)* assigned to the LCAs, approval for two classes of laser workers: *qualified laser operators (QLOs)* and *laser controlled area workers (LCA workers),* and designation of directorate laser leads. It also covers the operation of low-power lasers.

It applies to workers who use low-power lasers, operate high-power lasers, or may access facilities where such lasers operate; their line management, supervisors, points of contact, project managers, and ESH coordinators; and *laser facility program managers*, SLSOs, directorate laser leads, the *laser safety officer (LSO)*, and Radiation Protection, Occupational Health, and Purchasing.

## 2 Roles and Responsibilities

Functional roles and general responsibilities for each are listed below. More detailed responsibilities and when they apply are provided in the procedures and requirements.

The roles may be performed by one or more individuals and one individual may play more than one role, depending on the structure of the organizations involved. Responsibilities may be delegated.

### 2.1 Worker

- Becomes acquainted with all potential laser hazards in his or her work area
- Learns and follows the requirements of this chapter and the laser safety policies, procedures, and hazard control methods appropriate for the class of laser being used
- Follows work planning and control requirements, including requesting or conducting pre-job briefings as appropriate

## 2.2 Qualified Laser Operator

Class 3B or 4 lasers may only be used in approved LCAs, by *qualified laser operators (QLOs)* (or laser controlled area workers, see Section 2.3).

- Is approved and authorized by the SLSO, the LSO, and his or her administrative supervisor. May only work in an LCA after being approved.
- Follows procedures and requirements in the general and *lab-specific standard operating procedures (SOPs)* and *job safety analysis (JSA)* for the work area, including wearing the appropriate *personal protective equipment (PPE)*
- Stops work and seeks instruction from the SLSO when encountering a circumstance that appears unsafe or is not clearly covered in an SOP or JSA document
- Notifies SLSO of new or increased laser hazards in the workplace
- Informs the SLSO if a laser safety control or procedure should be changed or improved
- In the event of a known or suspected accident involving a laser, disables the laser hazard, then follows SLAC's incident response procedures, which include getting appropriate medical assistance and notifying supervisors, including the SLSO and the LSO

Generally, a QLO may only work in the *laser facility* for which he or she was approved. However, a QLO may enter a laser facility without becoming a QLO for that facility and perform short-term *service* work (including alignment), measurements, or experiments in Class 4 mode, subject to the following conditions:

- The visiting QLO, called a *service QLO*, must have approval from his or her administrative supervisor and the SLSO (or their designees) for the facility being visited.
- The visiting service QLO must be escorted by one of the facility's QLOs/LCA workers.
- There must be a pre-job briefing between the service QLO and the escorting QLO/LCA workers for the work to be performed.

Unescorted work in Class 4 mode may only be done by the laser facility's own QLOs.

## 2.3 Laser Controlled Area Worker

*Laser controlled area workers* perform support work such as controls electronics, data acquisition, and accelerator operations. To do so they receive limited approval to be allowed access to laser facilities. They have the same responsibilities as QLOs but are not authorized to perform laser alignment work, and, depending on the facility, may be restricted from changing operation mode or opening shutters.

LCA workers may enter and perform service work in laser facilities not their own subject to the same conditions that apply to visiting QLOs (see Section 2.2).

## 2.4 Affected Worker

*Affected workers* are personnel other than QLOs, LCA workers, laser service subcontractors, or the LSO who may need to perform work in a facility that houses Class 3B or Class 4 lasers.

- Must receive appropriate training about laser hazard controls if relying on the transport shutters as a machine guard
- Must work outside the envelope of the *laser safety system (LSS)* components
- May request to apply lockout/tagout (LOTO) for his or her work

## 2.5 System Laser Safety Officer

Each Class 3B or Class 4 laser facility will have a designated *system laser safety officer (SLSO)*, to whom the line management and supervision responsibilities for laser safety are assigned.

- Is designated by the laser facility program manager and approved by the LSO
- Is knowledgeable of SLAC's laser safety policies and implements the required controls
- Is a QLO for the laser facility to which he or she is assigned
- Ensures adequate work planning and control for safe laser operations
- Ensures adequate safety controls of laser hazards for all personnel, including visitors and the general public, before permitting the operation of a laser
- Is familiar with management walkaround (MWA) requirements and performs frequent walkarounds of laser facilities under his or her authority
- Suspends the operation of a laser when there is inadequate control of laser hazards
- Together with administrative supervisors, approves QLOs, service QLOs, and LCA workers and holds them accountable for meeting laser safety requirements. SLSOs should minimize the number of QLOs approved for a specific laser facility by taking advantage of the service QLO and LCA worker designations.
- For LCA workers, SLSOs should implement the following controls:
  - Limit their number to only those that are essential and may need unescorted laser facility access
  - Limit their scope of work, including limiting radio-frequency identification (RFID) authorization for the laser safety control panel
  - Conduct periodic refresher *on-the-job training (OJT)*
  - Conduct pre-job briefings prior to their laser work and determine if their work needs to be supervised by a regular QLO
  - Determine if any additional LCA or *nominal hazard zone (NHZ)* controls are needed to accommodate their work
  - Avoid scheduling their work during Class 4 laser operations as much as practical, in particular if laser alignment will be taking place
- Designates and qualifies at least one acting SLSO to perform SLSO functions when not available
- Prepares and submits for LSO approval a *lab-specific SOP* before permitting Class 3B or Class 4 laser operations. The SLSO will also prepare and submit for LSO approval any additional JSAs that may be required for laser operations not adequately described in the SOP. The SLSO will ensure that these documents adequately describe the control of laser hazards in the laser facility and comply with SLAC policy.

- Creates and has overall responsibility for *configuration control forms (CCFs)* when required; ensures approvals and notifications are obtained before start of work; and approves completion of work under the CCF
- Determines appropriate training requirements for laser workers and ensures that all are appropriately trained on the specific lasers they will operate, including appropriate site-specific and laser-specific OJT. The SLSO must conduct refresher OJT annually.
- In the event of a known or suspected accident involving a laser, disables the laser hazard, then follows SLAC's incident response procedures, which include getting appropriate medical assistance and notifying line management and the LSO
- Acts as equipment custodian for laser systems
- Maintains a current inventory of all lasers within his or her responsibility. The inventory will include the classification, wavelength, power, manufacturer, model designation, and serial number or SLAC property control number of the laser.
- Maintains laser safety documentation on his or her laser facility's Laser Safety SharePoint, in the Laser Safety Tool, or in a laser safety binder at the laser facility. This documentation includes the SOP, JSAs, and CCFs and other laser safety documentation, such as interface control documents, OJT documentation, certification procedures, and laser inventory.
- Shares with the laser facility program manager and the ESH coordinator responsibility for reviewing and addressing non-laser safety issues when approving laser facilities

## 2.6 Acting System Laser Safety Officer

- Is designated by the SLSO to perform SLSO functions when the SLSO is not available
- Meets all requirements for an SLSO, including being a QLO for the laser facility in question and completing all SLSO training

## 2.7 Directorate Laser Lead

- Is designated by the associate laboratory director for their directorate
- Must be notified for all CCFs at laser facilities in their directorate
- At discretion of LSO, may be required to approve a CCF; if required to approve a CCF, will review it and advise the LSO and SLSO if any changes should be made
- Must be knowledgeable of requirements for CCFs

## 2.8 ESH Coordinator

- Shares with the laser facility program manager and the SLSO responsibility for reviewing and addressing non-laser safety issues when approving laser facilities
- Assists with the qualification and work planning and control processes for laser service subcontractors

## 2.9 Administrative Supervisor / SLAC Point of Contact

*Note* *SLAC employees report directly to their administrative supervisor, and non-employees report to a SLAC point of contact, as described in Chapter 1, "General Policy and Responsibilities". Administrative supervisors and SLAC points of contact have line management responsibility for their assigned workers. Line management for laser work of assigned workers is matrixed between the administrative supervisor and the SLSO.*

- Assigns appropriate ESH laser safety training courses for assigned workers using the SLAC Training Assignment (STA)
- Discusses with the SLSO shared supervisory responsibilities, covering laser work to be performed by his or her assigned workers, required ESH laser safety training courses, and any required site-specific OJT
- Conducts periodic discussions about laser work with his assigned workers and the SLSO
- Has line management responsibility for the conduct of his assigned workers
- Together with the SLSO, holds QLOs and LCA workers accountable for meeting laser safety requirements

## 2.10 Project Manager

- Coordinates the qualification and work planning and control processes for laser service subcontractors

## 2.11 Laser Facility Program Manager

Each Class 3B or Class 4 laser facility must have a designated program manager, who has line management responsibility for the facility.

- Designates an SLSO for each Class 3B or Class 4 laser facility under his or her control
- Assigns line management responsibility for laser safety in the facility to the SLSO
- Periodically discusses the facility's laser operations with the SLSO
- Shares with the SLSO and ESH coordinator responsibility for reviewing and addressing non-laser safety issues when approving laser facility

## 2.12 Radiation Protection Department

- Reviews for ionizing radiation hazards laser operations over a certain intensity (1015 W/cm$^2$ or 1013 W/cm$^2$ under certain conditions)

## 2.13 Purchasing Department

- Notifies the LSO before an order is placed for laser eyewear protection or for a Class 3B or Class 4 laser

## 2.14 Occupational Health Center

- Conducts laser medical eye examinations, ESH Course 253ME, Laser Worker Baseline Medical Exam (ESH Course 253ME), for all employees, students, and users before they use Class 3B or 4 lasers at SLAC
- For any injury or suspected injury, conducts a laser medical eye exam and arranges for an ophthalmology exam if needed.
- For all reportable laser incidents, must meet with affected personnel even when there are no symptoms and inform them of the availability of laser eye exams
- Conducts additional tests for SLAC employees if results of the baseline examination indicate an abnormality. For non-employees, SLAC requests that home institutions perform the required medical eye examination and send results to the SLAC Occupational Health Center for review.
- Follows SLAC's incident response procedures and notifies the LSO immediately if an eye injury due to a laser accident is reported, suspected, or confirmed

## 2.15 Laser Safety Committee

- Advises the LSO on laser safety matters and recommends improvements; also provides oversight and periodic review, as requested
- Provides expertise in forming laser safety policy
- Maintains an awareness of all applicable laser safety policies

## 2.16 Laser Safety Program Manager / Laser Safety Officer

- Is assigned by the laboratory director
- Reports to the chief safety officer (CSO) and advises him or her on laser safety policies and requirements
- Establishes and maintains adequate policies for the control of laser hazards that comply with applicable federal regulations and accepted industry standards
- Approves
  - Operation of all Class 3B and Class 4 lasers
  - The lab-specific SOP and JSA required for operation of a Class 3B or Class 4 laser
  - CCFs
  - All QLOs and LCA workers
- Determines when new laser facilities or major changes to a laser facility should be reviewed by the Laser Safety Committee
- Has authorization to stop any operation for which he or she perceives the laser safety to be inadequate and can be overruled only by the CSO or the laboratory director
- Has authorization to inspect and monitor all laser operations and enforce laser safety control of hazards
- Classifies or verifies classification of all laser systems

- Consults on laser hazard evaluation and controls and assists SLSOs in developing SOPs and JSAs
- Reviews wording on laser area warning signs and equipment labels
- Ensures that the general laser safety training is adequate and available to all workers operating Class 3B and Class 4 lasers
- Performs an annual laser safety inspection of each Class 3B and Class 4 laser facility to review the facility's laser systems, laser hazard controls, and compliance with the safety requirements given in the lab-specific SOP and JSA. The LSO will write an inspection report and submit the results to the SLSO, laser facility program manager, and ESH coordinator.
- Performs a hazard analysis for possibility of a hazardous exposure for all reportable incidents, and informs the Occupational Health Center of results
- Tracks and reviews laser safety items entered into the SLAC Issues and Improvements Management System (SIIMS) and other lessons learned items related to laser safety. Periodically performs a trending analysis for these items.
- Is an ex officio member of the Laser Safety Committee

# 3 Procedures, Processes, and Requirements

These documents describe the detailed requirements for this program and how to implement them.

## 3.1 General Requirements for All Laser Classifications

- Laser Safety: General Requirements (SLAC-I-730-0A05S-008). Describes requirements that apply to all classes of lasers, including classification, project management, purchase, hazard analysis, control selection, electrical safety inspection, labeling, and use

## 3.2 Requirements for Class 2 and Class 3R Laser Operations

- Laser Safety: Class 2 and Class 3R Laser Operation Requirements (SLAC-I-730-0A05S-003). Describes requirements for using Class 2 and Class 3R lasers

## 3.3 Requirements for Laser Pointer Use

- Laser Safety: Laser Pointer Requirements (SLAC-I-730-0A05S-010). Describes requirements for using laser pointers and warns about high-power laser pointers and defects observed with some laser pointers

## 3.4 Requirements and Procedures for Class 3B and Class 4 Laser Operations

- Laser Safety: Laser Worker Approval Procedure (SLAC-I-730-0A05C-003). Describes process for approving QLOs and LCA workers, which must be completed before a QLO or LCA worker begins work with Class 3B and Class 4 lasers

- Laser Worker Approval. Documents approvals for QLOs and LCA workers (in the Laser Safety Tool)
- Laser Safety: System Laser Safety Officer Approval Form (SLAC-I-730-0A05J-001). Documents approvals for SLSOs
- Laser Safety: Acting System Laser Safety Officer Approval Form (SLAC-I-730-0A05J-009). Documents approvals for acting SLSOs
- Laser Facility Approval. Documents approvals for locations in which the lasers operate (in the Laser Safety Tool)
- Laser Safety: Class 3B and Class 4 Laser Operation Requirements (SLAC-I-730-0A05S-004). Describes requirements for identifying hazards, developing and implementing controls, authorizing operations and personnel, and use of Class 3B and Class 4 lasers
- Laser Safety Systems Technical Basis Document (SLAC-I-730-0A05Z-001). Provides guidance and criteria for implementing an engineered laser safety system for Class 3B and Class 4 laser facilities and laser systems
- Laser Safety: Class 3B and Class 4 UV Laser Operation Requirements (SLAC-I-730-0A05S-012). Describes additional requirements for setup and use of facilities where Class 3B or Class 4 UV lasers may operate
- Laser Safety: Laser Controlled Area Requirements (SLAC-I-730-0A05S-009). Describes requirements for setting up laser controlled areas (LCAs), which is a designation required when the maximum level of accessible laser radiation is Class 3B or Class 4
- Laser Safety: Class 3B and Class 4 Laser CoHE Requirements (SLAC-I-730-0A05S-005). Describes requirements for control of hazardous energy (CoHE) for Class 3B and Class 4 lasers
- Laser Safety: Core Laser Safety Practices (SLAC-I-730-0A05S-006). Describes core practices for laser workers using Class 3B and Class 4 lasers
- Laser Safety: Class 3B and Class 4 Laser Eyewear Protection Requirements (SLAC-I-730-0A05S-007). Describes requirements for using protective eyewear when operating Class 3B and Class 4 lasers
- Laser Safety: Laster Controlled Area Visitor Requirements (SLAC-I-730-0A05S-011). Describes requirements for visitors to laser controlled areas, including acceptable access controls, operation modes, and escort status
- Laser Safety: Student Requirements (SLAC-I-730-0A05S-002). Lists restrictions on secondary school, college, and university students working with lasers and gives supervisor responsibilities
- Laser Safety: Laser Service Subcontractor Work Planning and Control Procedure (SLAC-I-730-0A05C-001). Describes process for work planning and control (WPC) for laser service subcontractor work on Class 3B and Class 4 laser systems

## 3.5 Other Program Documents and Resources

- Laser Safety Program Site (SharePoint). Contains additional information and documents for implementing laser safety requirements
- Laser Safety Tool. System used for maintaining information on laser personnel and facilities, including approvals of facilities and qualified laser operators and laser controlled area workers
- Laser Safety Committee

- Guidance for SLAC System Laser Safety Officers (SLAC-I-704-701-004-00). Provides guidance for system laser safety officers
- General Laser Laboratory Safety for SLAC QLOs and LCA Workers (SLAC-I-704-701-003-00). Describes hazards and controls that are generally applicable to Class 3B and Class 4 laser laboratories

# 4 Training

## 4.1 Qualified Laser Operator / LCA Worker

Using the SLAC Training Assignment (STA), supervisors and SLAC points of contact assign training for laser workers and ensure that they are appropriately trained in laser hazards and controls before beginning work. General laser safety training courses are provided by the ESH Division. Site-specific on-the-job training (OJT) is provided by SLSOs (or their qualified designees), who also give the ESH Course 253PRA.

SLSOs maintain a record of site-specific training, using the Laser Safety Tool, provided to laser workers, including annual OJT and specific work authorization for each laser worker via an OJT Summary table.

SLAC employees who perform Class 3B or Class 4 laser work at other than SLAC facilities

- Should be approved as a SLAC QLO or LCA worker (can be as an “unaffiliated” laser worker who is not approved for a specific SLAC facility) and be current on training
- Must comply with the training requirements of the host facility

### 4.1.1 General

- ESH Course 120, Work Planning and Control Overview (ESH Course 120)
- ESH Course 253, Laser Worker Safety Training (ESH Course 253) (every 36 months)
  - Transfer credit. SLAC’s 253 course uses a DOE-wide Laser Worker Safety training course. Transfer credit for equivalent courses at other facilities may be approved by the SLAC LSO for courses listed in a training equivalency document on the Laser Safety Program Site. To transfer credit, the equivalent course must have been completed within the previous three years and course completion documentation must be sent to the SLAC LSO.
- ESH Course 131, Laser Accidents and Lessons Learned (ESH Course 131)
- ESH Course 253PRA, Laser Alignment Safety Practical (ESH Course 253PRA) (only required for operators who perform laser alignment; not required for LCA workers)
  - Transfer credit. Transfer credit for equivalent courses at other facilities may be approved by the SLAC LSO for courses listed in a training equivalency document on the Laser Safety Program Site. To transfer credit, course completion documentation must be sent to the SLAC LSO.

The following courses are only required for QLOs and LCA workers if deemed necessary in a laser facility’s SOP document or by the SLSO, for example when average beam powers exceed 10 W and are propagated outside a single laser enclosure.

- ESH Course 108, Fire Extinguisher Training (ESH Course 108) (every 36 months)

- ESH Course 108PRA, Fire Extinguisher Training Practical (ESH Course 108PRA)

### 4.1.2 Baseline Eye Examination

Baseline eye examinations (ESH Course 253ME) are required for all employees, students, and users before they may use Class 3B or 4 lasers at SLAC. They are also required following any suspected laser-induced injury. A voluntary 253ME exit examination is offered to SLAC employees upon employment termination.

The Occupational Health Center assists laser workers in obtaining a baseline eye examinations and issues a medical clearance for laser use if results are satisfactory. Such eye examinations establish a baseline against which suspected eye damage can be measured. If an abnormality is found, an additional funduscopic examination may be required. For non-employees, SLAC requests that home institutions perform the required medical eye examination and send results to the Occupational Health Center for review.

- ESH Course 253ME, Laser Worker Baseline Medical Exam (ESH Course 253ME)

### 4.1.3 Site-specific On-the-Job Training

SLSOs have line management responsibility for providing and documenting *on-the-job training (OJT)* to QLOs and LCA workers. QLOs and LCA workers must also review the applicable SOP documents. To assist this, a template for an OJT syllabus is available from the Laser Safety Program Site. SLSOs use this to develop a facility's syllabus, which is posted on the facility SharePoint. The Laser Safety Tool is used to document annual OJT in a "Laser Worker Summary" table and specific work authorization in an "OJT Summary" table. The LSO will check that OJT is adequately implemented and documented at the annual laser facility audit and during periodic inspections.

#### 4.1.3.1 Refresher OJT

SLSOs must conduct annual refresher OJT with all authorized laser personnel for their laser facility. The training must cover

- Changing operation modes
- Zero energy verification
- Configuration control
- Fire hazards and controls, including how to respond to a fire

The training should cover

- Laser operation modes and associated eyewear requirements
- Current configuration for lasers, safety shutters, and Class 1 enclosures
- Posted signs and procedures
- Recent SOP revision updates, and any JSA documents in use
- RFID permissions and approved operations

The training date must be documented in the "Laser Worker Summary" table in the Laser Safety Tool, and a syllabus must be available. (A syllabus template is available from the Laser Safety Program Site). SLSOs must also update the "OJT Summary" table in the Laser Safety Tool if the work authorizations change.

## 4.2 System Laser Safety Officer / Acting System Laser Safety Officer

SLSOs and acting SLSOs must review the Guidance for SLAC System Laser Safety Officers document, must complete all QLO requirements, and must take the following courses:

- ESH Course 130, Laser Safety for Supervisors (ESH Course 130) (every 36 months)
- ESH Course 157, Control of Hazardous Energy (ESH Course 157) (every 36 months) or ESH Course 136, Control of Hazardous Energy – Affected Employee (ESH Course 136)
- ESH Course 108, Fire Extinguisher Training (ESH Course 108) (every 36 months)
- ESH Course 108 PRA, Fire Extinguisher Training Practical (ESH Course 108PRA)

## 4.3 Affected Worker and Class 2 or Class 3R Laser Operator

This course is recommended for affected workers in areas where Class 3B or Class 4 lasers may operate and for workers who operate Class 2 or Class 3R lasers:

- ESH Course 132, Laser Safety Basics (ESH Course 132) (every 36 months)

# 5 Definitions

*accessible emission limit (AEL).* The maximum accessible emission level permitted within a particular laser class

*aversion response*. Blinking or looking away when exposed to a bright light. The aversion response time is assumed to be 0.25 seconds.

*barrier.* A device used to block or attenuate incident direct or diffuse laser radiation

*beam conduit.* Conduit used to transport a laser beam between two locations

*coherent.* A beam of light characterized by a fixed phase relationship in space (spatial coherence) or in time (temporal coherence) at a given wavelength

*configuration control form (CCF).* A form for documenting changes in the safety configuration or function of a Class 1 enclosure, safety shutter, or component of an engineered LSS

*control hierarchy.* Engineering controls are first line of defense, followed by administrative controls, and finally PPE

*control of hazardous energy (CoHE).* Control measures used to protect workers from exposure to all forms of hazardous energy due to accidental equipment energization or startup, or from working on or near electrical conductors or circuit parts

*control, administrative.* Control measure that administratively mitigates the potential hazards associated with laser use. For example, training, safety approvals, LSO designation, and SOPs.

*control, alternate .* Control measure that takes the place of explicitly specified control(s) in this document

*control, engineering.* Control measures designed or incorporated into the laser or laser system (for example, interlocks, shutters, enclosure, key controls)

*enclosure.* A physical barrier that completely encloses a laser beam, so that the associated laser beam is inaccessible. If an enclosure for a Class 3B or Class 4 laser beam is appropriately secured or interlocked and has appropriate safety labels, it may be approved by the LSO as a Class 1 enclosure.

*enclosure, Class 1.* An enclosure that surrounds a laser or laser system and prevents access to laser radiation levels above the MPE

*energy isolating device.* A mechanical device that physically prevents the transmission or release of energy

*equivalent protection.* Provides the same level of risk mitigation, or reduces risk to an acceptable level, to prevent injury

*eyewear, alignment.* Laser eyewear used in special procedures with visible lasers, which has reduced optical density from full protection eyewear

*eyewear, full protection.* Laser eyewear that has sufficient optical density that its transmission reduces exposure to a level below the MPE for a direct laser beam and specular reflections

*intensity.* The radiant power per unit area, typically measured in $W/cm^2$. Also referred to as *irradiance*.

*interlock, failsafe or redundant .* Interlock that does not permit an unsafe condition if there is a single component failure

*job safety analysis (JSA).* Technique (and document) that identifies the tasks associated with a job and the related hazards and the controls to eliminate or reduce them to an acceptable risk level. The analysis focuses on the relationship between the worker, the task, the tools, and the work environment.

*laser controlled area (LCA).* An area within which potentially hazardous beam exposure from a Class 3B or Class 4 laser is possible. Access and/or occupancy of the area are controlled. This area may be defined by walls, barriers, or other means.

*laser controlled area (LCA), exclusion.* An LCA with engineered controls to ensure no persons are inside the LCA with Class 3B or Class 4 laser beams enabled

*laser facility.* A work area where a Class 3B or Class 4 laser may operate. It may have one or more LCAs, but may also have no associated LCA if it is engineered and approved for fully enclosed Class 1 operation. Also referred to as a *laser lab*

*laser facility program manager.* A manager of a Class 3B or Class 4 laser facility, or an area or building manager for an LCA

*laser safety contract.* A contract between the SLSO, the LCA line management, and the LSO; it describes details of the laser facility and laser operations and the associated hazards and controls. It is part of a single

document for a laser facility, the SOP and Laser Safety Contract document; this is commonly referred to as the *lab-specific SOP*

*laser safety shutter*. A remotely controlled beam block that can be inserted to function as a machine guard (or sometimes as an energy isolating device in a LOTO procedure). It is often used to disable a laser hazard as part of an interlocked access control. It is also sometimes used in an LCA as part of a Class 1 enclosure if it is closed and disabled.

*laser safety system (LSS).* A combination of devices and logic systems that are used at LCAs and for some Class 1 laser systems with embedded Class 3B or Class 4 lasers. The LSS provides engineering controls to restrict access to LCAs and to laser hazards within enclosures, to provide warning devices for indicating laser system status, and to provide permissives and/or control for safety shutters and laser power supplies.

*laser.* A device that produces a coherent, intense, highly directional beam of light of a single wavelength or tunable over a band of wavelengths

*laser, continuous wave (CW)*. A laser operated with a continuous output for a period greater than or equal to 0.25 seconds

*laser, pulsed.* A laser that delivers its energy in a single pulse or a train of pulses, with duration of the pulses less than 0.25 seconds

*laser safety officer (LSO).* An individual designated by the laboratory director having the authority and responsibility to monitor and enforce the control of laser hazards and to effect the knowledgeable evaluation and control of laser hazards

*laser safety officer, system (SLSO).* An individual designated by the laser facility program manager to have line management and supervision responsibilities for safe laser operations in a laser controlled area

*machine guard.* An engineered safety control used to prevent exposure to an energized (or partially energized or enabled) hazardous laser beam (examples include safety shutter, laser key, interlocked cover)

*maintenance.* Performance of those adjustments or procedures (specified in the user information provided by the manufacturer, and considered preventative, to maintain optimal performance of the laser system), which are to be carried out by the laser worker to ensure the intended performance of the product. (Note interlocked covers for protective housings and Class 1 enclosures may be removed for maintenance tasks.)

*master key.* A device (typically a mechanical key) that when removed prevents associated laser(s) from emitting laser radiation above the MPE

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

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

*non-beam hazard.* Any hazard arising from the presence of a laser system, excluding direct human exposure to direct or scattered laser radiation

*normal operation.* The performance of the laser or laser system over the full range of its intended functions. Removable covers for protective housings and Class 1 enclosures are in place. (Note alignment tasks can be performed during normal operation.)

*on-the-job training (OJT).* OJT takes place in a specific LCA where instructions on laser operation and laser safety are given. Instruction may also include, as needed, laser alignment and experimental procedures.

*optical density (OD).* The logarithm, using base ten, of the reciprocal of the transmittance of a material, such as laser eyewear, at a particular wavelength (for example OD1 has a transmittance of 10 percent)

*personal protective equipment (PPE).* Personal safety protective devices used to mitigate hazards associated with laser use (for example, laser eye protection, protective clothing, and gloves)

*plasma radiation*. Black-body radiation generated by a heated material that can result from laser-target interactions. Hot electrons in a plasma may also generate hazardous x-rays under certain conditions at very high laser intensity.

*protective housing.* An enclosure that surrounds the laser or laser system and prevents access to laser radiation levels above the MPE. A protective housing does not include the aperture for the output beam.

*protective housing, walk-in.* See *laser controlled area (LCA), exclusion*

*qualified laser operator (QLO)*. A worker who has completed all the training requirements and has the necessary approvals to be authorized and released for performing laser work with Class 3B or Class 4 lasers in a specific laser facility (see also *qualified laser operator, service* and *worker, laser controlled area*)

*qualified laser operator (QLO), service*. A QLO authorized to perform limited service work in a laser facility other than the one for which he or she was approved

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

*reflection, specular*. A mirror-like reflection

*remote interlock connector.* Part of a laser source that interfaces with an LCA safety interlock system. When the connector contacts are open or faulted, the laser source is disabled from emitting laser radiation above the MPE.

*saturable absorption.* The property of laser eye protection where the absorption of light decreases (OD decreases) with increasing light intensity. This has been shown to occur with certain laser eye protection materials with high-energy sub-nanosecond pulses.

*service.* The performance of procedures, typically defined as repair, to bring the laser or laser system or laser product back to full and normal operational status. (Note non-interlocked covers for protective housings, Class 1 enclosures, and beam conduits may be removed for service tasks.)

*standard operating procedure (SOP).* A pre-approved, job-specific procedure that describes the complete work scope; necessary work instructions, precautions, and prerequisites; hazards associated with the job; and the hazard controls to be implemented in order to prevent accidents, injuries, and property damage

*standard operating procedure (SOP), lab-specific.* A document specific to a given laser facility combining its standard operating procedure and laser safety contract

*visible light transmission (VLT).* The amount of visible light passing through a filter, weighted for the response of the human eye, expressed as a percentage

*visitor, laser controlled area.* Personnel, not including service subcontractors or the LSO, who have not been approved as a QLO in a SLAC laser facility but are visiting one

*worker, affected.* Personnel other than a QLO, LCA worker, laser service subcontractor, or the LSO who may need to perform work in a facility that houses Class 3B or Class 4 lasers

*worker, laser.* See also *qualified laser operator* and *worker, laser controlled area*

*worker, laser controlled area* . Worker who performs support work such as controls electronics, data acquisition, and accelerator operations, for which he or she receives limited approval to be allowed access to laser labs

*worker, service laser controlled area*. An LCA worker authorized to perform limited service work in a laser facility other than the one for which he or she was approved

# 6 References

## 6.1 External Requirements

The following are the external requirements that apply to this program:

- 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)
- Title 8, *California Code of Regulations*, “Industrial Relations”, Division 1, “Department of Industrial Relations”, Chapter 4, “Division of Industrial Safety”, Subchapter 4, “Construction Safety Orders”, Article 34, “Nonionizing Radiation”, Section 1801, “Nonionizing Radiation” (8 CCR 1801)
- Title 8, *California Code of Regulations*, “Industrial Relations”, Division 1, “Department of Industrial Relations”, Chapter 4, “Division of Industrial Safety”, Subchapter 7, “General Industry Safety Orders”,
  - Group 2, “Safe Practices and Personal Protection”, Article 7, “Miscellaneous Safe Practices”, Section 3314, “The Control of Hazardous Energy for the Cleaning, Repairing, Servicing, Setting-Up, and Adjusting Operations of Prime Movers, Machinery and Equipment, including Lockout/Tagout” (8 CCR 3314)
  - Group 6, “Power Transmission Equipment, Prime Movers, Machines and Machine Parts (8 CCR 3940–4086)
  - Group 8, “Points of Operation and Other Hazardous Parts of Machinery” (8 CCR 4184–4647)
- American National Standards Institute (ANSI) Z136.1, “Safe Use of Lasers” (ANSI Z136.1)

## 6.2 Related Documents

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

- Chapter 1, "General Policy and Responsibilities"
- Chapter 2, "Work Planning and Control"
- Chapter 51, "Control of Hazardous Energy"

Other SLAC Documents

- SLAC Occupational Health Center
- SLAC Training Assignment
- On-The-Job (OJT) Training Requirements (200-2P-1)
- SLAC Trainer Guide >Transferring Credit from Another Institution
- SLAC Issues and Improvements Management System (SIIMS)
- Contractor Assurance – Management Walkarounds (MWA)

Other Documents

- American National Standards Institute (ANSI) Z136.8, "Safe Use of Lasers in Research, Development, or Testing" (ANSI Z136.8)
- National Fire Protection Association (NFPA) 115, "Standard for Laser Fire Protection" (NFPA 115)
- Stanford University, Department of Environmental Health and Safety. Laser Safety
- Food and Drug Administration (FDA). Illuminating Facts About Laser Pointers

NATIONAL ACCELERATOR LABORATORY

ENVIRONMENT, SAFETY & HEALTH DIVISION

*Chapter 10: Laser Safety*

# General Requirements

Product ID: 550 | Revision ID: 2590 | Date published: 5 May 2023 | Date effective: 5 May 2023
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 | ▪ Emitted radiation may be visible or invisible<br>▪ Incapable of producing damaging radiation levels<br>▪ May have an accessible laser beam at very low intensity, or may be a fully enclosed laser with no accessible radiation<br>▪ Exempt from any administrative or PPE control measure requirements |
| Class 2 | ▪ Emits visible radiation at wavelengths between 400–700 nm<br>▪ 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.<br>▪ Maximum average power for *continuous wave (cw) lasers* is 1 mW<br>▪ 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 |
| Class 3R<br>(previously called 3a) | ▪ Emitted radiation may be visible or invisible<br>▪ 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.<br>▪ Generally not considered a significant hazard for accidental viewing, but is a potential hazard for direct or *specular reflection* viewing<br>▪ 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 |
| Class 3B<br>(previously called 3b) | ▪ Emitted radiation may be visible or invisible<br>▪ Emitted radiation has intensity greater than Class 3R. Maximum average power is less than 500 mW (can be lower for *pulsed lasers*).<br>▪ Eye hazard for direct or specular reflection viewing; there are associated laser eyewear protection requirements. |
| Class 4 | ▪ Emitted radiation may be visible or invisible<br>▪ Emitted radiation has intensity greater than Class 3B<br>▪ Hazard to eye or skin from direct beam; there are associated laser eyewear protection requirements<br>▪ *Diffuse reflections* may be hazardous<br>▪ Potential for fire hazard from laser intensity exceeding combustibility thresholds of some materials<br>▪ Laser-target interactions may produce laser-generated air contaminants, and hazardous *plasma radiation* at very high intensities |

## 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$^2$)

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)v
  - 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)

NATIONAL ACCELERATOR LABORATORY

ENVIRONMENT, SAFETY & HEALTH DIVISION

*Chapter 10: Laser Safety*

# Class 2 and Class 3R Laser Operation Requirements

Product ID: 545 | Revision ID: 2591 | Date published: 5 May 2023 | Date effective: 5 May 2023
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/laserReqClass2and3R.pdf

## 1 Purpose

The purpose of these requirements is to protect workers from harmful exposure to low-power lasers, which can create a startle hazard and temporary flash-blindness, after images, and glare responses. They cover using Class 2 and 3R lasers and posting of hazards. They apply to workers whenever they are using lasers of this classification and their supervisors.

*Note* *Laser pointers are also classified as Class 2 and 3R but the requirements they are subject to are in Laser Safety: Laser Pointer Requirements. Class 3R lasers were formerly known as Class 3a lasers and may still bear a label with the former classification.*

## 2 Requirements

| Type | Construction Project | Non-construction Project |
|---|---|---|
| Training | Documented training required | Basic laser safety training recommended (such as ESH Course 132) |
| Operation | Unattended operation not permitted | Unattended operation should not be permitted unless additional controls such as appropriate barriers are used |
| Equipment label | Label must be attached to the laser and specify its classification, wavelength, pulse duration (if applicable), and maximum output power | |
| Signage | An area hazard warning sign must be posted when a construction laser is in operation, and should be posted when a non-construction laser is in operation. This sign must indicate type of laser, wavelength, power, and classification. (Templates for labels and signs are available on the Laser Safety Program Site.)<br>▪ Required signal word for Class 2 lasers: CAUTION<br>▪ Required signal word for Class 3R lasers: CAUTION *(Note construction lasers and commercial lasers may use DANGER, which is also acceptable.)* | |

## 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
  - Laser Safety Program Site (SharePoint)

Other SLAC Documents

- ESH Course 132, Laser Safety Basics (ESH Course 132)

Other Documents

- Title 8, *California Code of Regulations*, "Industrial Relations", Division 1, "Department of Industrial Relations", Chapter 4, "Division of Industrial Safety", Subchapter 4, "Construction Safety Orders", Article 34, "Nonionizing Radiation", Section 1801, "Nonionizing Radiation" (8 CCR 1801)

NATIONAL ACCELERATOR LABORATORY

ENVIRONMENT, SAFETY & HEALTH DIVISION

*Chapter 10: Laser Safety*

# Laser Pointer Requirements

Product ID: 552 | Revision ID: 2592 | Date published: 5 May 2023 | Date effective: 5 May 2023
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/laserReqLaserPointer.pdf

## 1 Purpose

The purpose of these requirements is to prevent startle hazard, temporary flash-blindness, after images, glare responses, and permanent eye damage caused by unsafe use of laser pointers, which are hand-held battery-operated devices with a momentary on-off switch typically used as a pointing device during presentations. They cover classifying, selecting, labeling, and using laser pointers, both personal and SLAC owned. The requirements apply to anyone using a laser pointer at SLAC and the *laser safety officer (LSO)*.

## 2 Requirements

### 2.1 Classification, Selection, and Labeling

Laser pointers have a maximum power output of 5 mW and create a low-power visible laser beam, with wavelengths between 400 to 700 nm. These lasers are either Class 2 (< 1 mW) or Class 3R (< 5 mW).

*Note* *Class 3R lasers were formerly designated as Class 3a lasers and may be labeled this way.*

- When choosing a laser pointer it is the best practice to pick a Class 2 laser. Most commercially available laser pointers, however, are Class 3R.
- Laser pointers must be labeled with a CAUTION label (commercial Class 3a or 3R laser pointers may have a DANGER label, which is also acceptable).
- Green, blue/violet, and all non-red laser pointers should be evaluated by the LSO to verify that they do not exceed the Class 3R output limit.
- For a safety evaluation of a laser pointer or if you have questions on laser pointer safety, contact the LSO.

**Warning** Relatively inexpensive battery-operated hand-held laser “pointers” that are Class 3B (some Class 4) are now commercially available, which are well in excess of the 5 mW legal limit for laser pointers. These devices can be very dangerous. Use of all Class 3B and Class 4 lasers at SLAC must be approved by the LSO; LSO approval for a Class 3B or Class 4 laser “pointer” will not be given.

**Warning** Some commercial non-red laser pointers have been observed to be missing an infrared (IR) filter, which results in dangerous emission of IR laser light that the user is unaware of. (Such laser pointers are not simple single-wavelength diode lasers but are a diode-pumped solid-state laser. A non-linear crystal is used to generate the visible wavelength and then an IR filter must be used to block invisible IR wavelengths.)

## 2.2 Use

- Never point a laser pointer at a person. Permanent damage is possible if the beam is stared into, but there is also the possibility of startle hazard, temporary flash-blindness, after images, and glare response.
- Only point at inanimate objects.
- Laser pointers are not toys. Children should not be allowed to use them unless adequately supervised.

# 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"

Other Documents

- Food and Drug Administration (FDA). Illuminating Facts About Laser Pointers

NATIONAL ACCELERATOR LABORATORY

ENVIRONMENT, SAFETY & HEALTH DIVISION

*Chapter 10: Laser Safety*

# Laser Worker Approval Procedure

Product ID: 688 | Revision ID: 2593 | Date published: 5 May 2023 | Date effective: 5 May 2023
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/laserProcedWorkerApproval.pdf

## 1 Purpose

The purpose of this procedure is to ensure that workers in *laser facilities* where Class 3B and Class 4 laser systems are in use are qualified. It covers approval of *laser workers*. It applies to workers, supervisors and points of contact (POCs), *system laser safety officers (SLSOs)*, the *laser safety officer (LSO)*, and Occupational Health.

Class 3B and Class 4 laser operation requires:

- Operation approval from the LSO
- A SLSO assigned responsibility for their safe operation
- A *lab-specific standard operating procedure (SOP)* document describing laser hazards and controls
- A *laser controlled area (LCA)* with access restricted to laser workers and persons they may escort, as described in the SOP, if there may be accessible Class 3B or Class 4 laser radiation. *(Note some lasers may be configured and approved only for Class 1 – Laser Enclosed operation, in which case an LCA may not be required.)*

(See Laser Safety: Class 3B and Class 4 Laser Operation Requirements for details.)

SLAC has two categories of *laser worker*:

1. *Qualified laser operator (QLO)*
2. *Laser controlled area (LCA) worker*

QLOs and LCA workers are generally approved for the laser facility where they will work and receive both general and facility/LCA-specific training so they can access an LCA and perform work there. (Some QLOs and LCA workers are unaffiliated with any facility; they receive general training only. This allows them to perform service work in any facility or to work at off-site, non-SLAC laser facilities.) QLOs receive additional training to become qualified to operate lasers and perform open beam alignment tasks. LCA workers are generally support personnel who need access to an LCA to perform work other than laser alignment tasks, for example to support accelerator or user facility laser operations.

- **Who does this?** Persons who need to perform work in an LCA that cannot be done under the laser controlled area visitor policy described in the SOP for the LCA (see Laser Safety: Laser Controlled Area Visitor Requirements)
- **When?** Before performing work that can only be done by QLOs and LCA workers
- **How?** As detailed in the procedure below, complete requirements for training and document review, and then request approval in the Laser Safety Tool. *(Note accessing this tool requires a SLAC*

*Windows account, so all persons wanting to become a QLO or LCA worker should obtain a Windows account. There is a provision, however, for an SLSO or LSO to submit a request on behalf of a person who does not have a Windows account.)*

# 2 Procedure

| Step | Person | Action |
|---|---|---|
| 1. | Worker | Determine whether you need to become a laser worker:<br>▪ If you need to perform work in an LCA discuss with the SLSO whether you need to be a laser worker. *(Note it is a significant time investment to become a laser worker and for the SLSO to provide the required training and supervision.)*<br>▪ If you may need to become a laser worker but not affiliated with a particular facility/LCA, contact the LSO to determine if this is necessary (for example, SLAC employees who may want to do laser work offsite). |
| 2. | Worker | Get a SLAC system ID number if you do not have one. To verify you have a valid SLAC system ID, check the SLAC Directory.<br>▪ If you do not have a SLAC system ID, ask your supervisor or point-of-contact (POC) to request one. |
| 3. | Worker | Get a SLAC Windows account if you do not have one.<br>▪ If you do not have a SLAC Windows account, a SLAC ServiceNow request can be submitted for this (follow instructions for "SLAC Computer Account Request"). Ask your supervisor/POC for assistance if needed.<br>This allows you to access the<br>▪ SLAC Training Course Catalog, which provides course descriptions and information on how to take the courses, including links for web-based training<br>▪ SLAC Training Assignment (STA), which provides information on your training history and which courses your supervisor or point-of-contact has assigned you<br>▪ Laser Safety Program Site, which has laser facility information, including links to SOP documents, and many other useful resources<br>▪ Laser Safety Tool, where you can request approval to become a laser worker and can view database information for laser workers and laser facilities<br>*Note you can become a laser worker without having a Windows account; steps 4–11 below allow for that. A Windows account is recommended to facilitate your training and access to laser safety resources.* |
| 4. | Worker | Have your supervisor/POC assign required courses on your STA.<br>All laser workers are required to complete the following courses:<br>▪ ESH Course 253, Laser Worker Safety Training (2.5-hour web course)<br>▪ ESH Course 253ME, Laser Worker Baseline Medical Exam (30-minute exam)<br>▪ ESH Course 131, Laser Accidents and Lessons Learned (1.5-hour classroom course)<br>▪ ESH Course 120, Work Planning and Control Overview (30-minute web course) |

| Step | Person | Action |
|---|---|---|
| | | ▪ ESH Course 219, Environmental Safety and Health Orientation (1-hour web course)<br>For QLOs only:<br>▪ ESH Course 253PRA, Laser Alignment Safety Practical (1–3 hour classroom course) |
| 5. | Worker | Review Chapter 10, "Laser Safety" |
| 6. | Worker | Complete course training assignments listed above in step 4.<br>▪ Transfer credit for the 253 and 253PRA courses. Transfer credit for equivalent courses at other facilities can be approved by the SLAC LSO for courses listed in a training equivalency document on the Laser Safety Program Site. To transfer credit, course completion documentation must be sent to the SLAC LSO.<br>▪ The web-based courses are accessible from the SLAC Training Course Catalog if you have a Windows account. If you do not have a Windows account or want to take a web course remotely, follow directions for "Manual Login" at SLAC Training: Web Based Training.<br>▪ For 253ME, contact the Occupational Health Center to schedule an appointment. (You should schedule this at least one week in advance.)<br>▪ For 131, this course is given by the LSO. It is scheduled monthly, usually on the first Monday of each month at 2:30–4 pm in B28, RM141. You can register for the class at the course catalog web page, or you can contact the LSO to find when the next class is scheduled. Typically, 1–2 additional classes per month are also scheduled as needed.<br>*Note in some cases, conditional approval to become a laser worker can be granted before this course is completed. This requires a justification, that the person take the next available class, and that the laser worker be supervised until the course is completed; then a 30-day conditional approval can be given after which the person will become inactive if the course is not completed.*<br>▪ For 253PRA, contact the SLSO for the appropriate laser facility/LCA and make arrangements with him or her to take the class or to discuss transfer credit, if applicable. (If you are requesting to be an unaffiliated QLO, contact the LSO.) |
| 7. | Worker | Review the SOP document(s) for the relevant laser facility/LCA.<br>▪ These are accessible from the Laser Safety Program Site and are also available at the facility/LCA. If needed you can contact the SLSO for how to access.<br>▪ Skip this step, if you will request to become a laser worker but not associated with a particular facility/LCA. |
| 8. | Worker | Interview with LSO.<br>▪ If you are requesting to become a laser worker for the first time you need to schedule a 30-minute interview with the LSO. The interview will review features for the different laser classifications (1, 2, 3R, 3B and 4), responsibilities for laser workers, and what to expect for site-specific *on-the-job training (OJT)*. |
| 9. | Worker | Request approval to be a laser worker. |

| Step | Person | Action |
|---|---|---|
| | | ▪ Go to Laser Worker Approval. This requires a Windows account to access. If you do not have a Windows account, you can ask the SLSO to submit the request on your behalf.<br>▪ You will need to enter the following information:<br>  ▪ Type of Work (QLO or LCA worker)<br>  ▪ Facility Name (select "None" if requesting to be an unaffiliated QLO or LCA worker; otherwise select the appropriate facility)<br>  ▪ Preferred Email, if different from SLAC email or if you do not have a SLAC email<br>  ▪ SLAC Affiliation (employee, undergraduate student, graduate student, other non-employee)<br>  ▪ Have read Chapter 10, "Laser Safety" and accept responsibilities<br>  ▪ Have read and agree to comply with Laser Safety: Student Requirements, if applicable<br>  ▪ Have read and understood the lab-specific SOP ("facility SOP"), if applicable<br>▪ The approval tool will query the SLAC Training Database and display information on STA course assignments and course completion status. *(Note STA course assignments shown on this web page are for information only and do not affect approval.)*<br>▪ Select "Submit Request" once the necessary information has been entered. If a requirement has not been met, you will receive a message that the request is denied and a reason will be given describing the action you need to take.<br>▪ If you have completed the necessary requirements, then an e-mail notification will be sent to the LSO, your administrative supervisor/POC, and the SLSO (if applicable) that a laser worker request needs their review and action. You will be copied on the e-mail. |
| 10. | LSO, supervisor/POC, and SLSO (if applicable) | Review request.<br>▪ If the LSO, your administrative supervisor/POC, and the SLSO (if applicable) all approve the request, then you have completed approval as a laser worker and your information will be entered into the Laser Safety Tool database. You will be sent an associated notification e-mail.<br>▪ If any of the LSO, your administrative supervisor/POC, or the SLSO (if applicable) deny the request, a reason for the denial will be provided. You will be sent an associated e-mail notification. |
| 11. | Worker | Complete site-specific OJT (if applicable)<br>▪ This is done with the SLSO, or a QLO they designate, at the laser facility/LCA. The OJT will be documented and the SLSO maintains the documentation for that in the Laser Safety Tool database.<br>▪ The SLSO determines approved activities for the worker and documents this in an OJT Summary Table in the Laser Safety Tool database. |

# 3 Forms

The following forms and systems are required by this procedure:

- Laser Worker Approval. Documents approvals for QLOs and LCA workers and must be completed before a QLO or LCA worker begins work with Class 3B and Class 4 lasers
- Site-specific training documentation for QLOs and LCA workers. An example template for an OJT syllabus is available on the Laser Safety Program Site (SharePoint). A laser facility's OJT syllabus is posted on its SharePoint site, while worker-specific OJT documentation is done by the SLSO for their facility using the Laser Safety Tool database

# 4 Recordkeeping

The following recordkeeping requirements apply for this procedure:

- Worker and facility approval records are maintained in the Laser Safety Tool
- The SLSO maintains OJT documentation for the lab's QLOs and LCA workers in the Laser Safety Tool

# 5 References

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

- Chapter 10, "Laser Safety"
  - Laser Safety: Class 3B and Class 4 Laser Operation Requirements (SLAC-I-730-0A05S-004)
  - Laser Safety: Laser Controlled Area Visitor Requirements (SLAC-I-730-0A05S-011)
  - Laser Safety: Student Requirements (SLAC-I-730-0A05S-002)
  - Laser Safety Program Site (SharePoint)
  - Laser Safety Tool

Other SLAC Documents

- SLAC Occupational Health Center
- SLAC Directory
- SLAC ServiceNow
- SLAC Training Assignment (STA)
- SLAC Training Course Catalog
- SLAC Training: Web Based Training
- SLAC Trainer Guide >Transferring Credit From Another Institution
- ESH Course 219, Environmental Safety and Health Orientation (ESH Course 219)
- ESH Course 120, Work Planning and Control Overview (ESH Course 120)

- ESH Course 131, Laser Accidents and Lessons Learned (ESH Course 131)
- ESH Course 253, Laser Worker Safety Training (ESH Course 253)
- ESH Course 253ME, Laser Worker Baseline Medical Exam (ESH Course 253ME)
- ESH Course 253PRA, Laser Alignment Safety Practical (ESH Course 253PRA)

*Chapter 10: Laser Safety*

# System Laser Safety Officer Approval Form

Product ID: 99 | Revision ID: 2594 | Date Published: 5 May 2023 | Date Effective: 5 May 2023
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/laserFormApprovalSLSO.pdf

The person named below is being appointed the system laser safety officer (SLSO) for the laser facility named below, with SLSO responsibilities and authority as described in Chapter 10, "Laser Safety". An SLSO is required for Class 3B or 4 laser facilities (see Laser Safety: Class 3B and Class 4 Laser Operation Requirements).

The signatures below are required for assignment, acceptance, and approval.

## Laser Facility

| Name | Location |
|---|---|
| | |

## Assignment

| Laser Facility Program Manager | | |
|---|---|---|
| Name | Signature | Date |
| | | |

## Acceptance

| System Laser Safety Officer (SLSO) | | |
|---|---|---|
| Name | Signature | Date |
| | | |



## Approval

| SLAC Laser Safety Officer (LSO) | | |
|---|---|---|
| Name | Signature | Date |
| | | |

*Chapter 10: Laser Safety*

# Acting System Laser Safety Officer Approval Form

Product ID: 664 | Revision ID: 2595 | Date Published: 5 May 2023 | Date Effective: 5 May 2023
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/laserFormApprovalActingSLSO.pdf

The person named below is being appointed the acting system laser safety officer (SLSO) for the laser facility named below, with SLSO responsibilities and authority as described in Chapter 10, "Laser Safety", when the SLSO is not available. An SLSO is required for Class 3B or 4 laser facilities (see Laser Safety: Class 3B and Class 4 Laser Operation Requirements).

The signatures below are required for assignment, acceptance, and approval.

## Laser Facility

| Name | Location |
|---|---|
| | |

## Assignment

| Laser Facility Program Manager | | |
|---|---|---|
| Name | Signature | Date |
| | | |
| Laser Facility System Laser Safety Officer (SLSO) | | |
| Name | Signature | Date |
| | | |

## Acceptance

| Acting System Laser Safety Officer (SLSO) | | |
|---|---|---|
| Name | Signature | Date |
| | | |



## Approval

| SLAC Laser Safety Officer (LSO) | | |
|---|---|---|
| Name | Signature | Date |
| | | |

NATIONAL ACCELERATOR LABORATORY

ENVIRONMENT, SAFETY & HEALTH DIVISION

*Chapter 10: Laser Safety*

# Class 3B and Class 4 Laser Operation Requirements

Product ID: 546 | Revision ID: 2596 | Date published: 5 May 2023 | Date effective: 5 May 2023
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/laserReqClass3Band4.pdf

## 1 Purpose

The purpose of these requirements is to protect workers from harmful exposure to lasers. They cover identifying hazards, developing and implementing controls, and authorizing operations, personnel, and use of Class 3B and Class 4 lasers. They apply to workers using lasers of this classification, *system laser safety officers (SLSOs)*, directorate laser leads, *laser facility program managers*, line management, ESH coordinators, the *laser safety officer (LSO)*, and Radiation Protection.

## 2 Requirements

Class 3B and Class 4 lasers have significant potential to cause injury and require specific control measures, described below.

### 2.1 Approvals

The following approvals must be completed before Class 3B and Class 4 laser operations may begin:

- Laser Facility Approval for the *location* in which the lasers will be operating. The approval request is submitted by the laser facility's SLSO, who must first affirm that annual laser safety certification checks are complete and that any necessary facility SOP updates are complete. The request must be approved by the facility program manager, the ESH coordinator, and the LSO. LSO approval requires that: 1) the SOP, with any needed revisions, is approved, and 2) a facility inspection has been completed and all pre-approval action items are complete. The LSO approval includes an approval expiration date, which is nominally one year from the approval date.
- A System Laser Safety Officer Approval Form for the SLSO, who will have line management and supervision responsibilities for safe laser operations in the facility
- A Acting System Laser Safety Officer Approval Form for the acting SLSO, who performs SLSO functions when the SLSO is not available
- Laser Worker Approval for the facility's *qualified laser operators (QLOs)*, who will operate these lasers
- Laser Worker Approval for the facility's *laser controlled area (LCA) workers*, who perform support work such as controls electronics, data acquisition, and accelerator operations

## 2.2 Engineering Controls

*Engineering controls* are given first priority over *administrative controls* and *personal protective equipment (PPE)*. Additional engineering controls requirements to those described in this document can be found in the following:

- Laser Safety: Laser Controlled Area Requirements
- Laser Safety: Class 3B and Class 4 UV Laser Operation Requirements
- Laser Safety: Class 3B and Class 4 Laser CoHE Requirements
- Laser Safety Systems Technical Basis Document

### 2.2.1 Removable Covers for Protective Housings, Class 1 Enclosures, and Beam Conduits

Engineering controls for these must meet all of the following requirements:

- Covers that may be removed during *normal operation* or *maintenance* must be provided with *failsafe or redundant interlocks*.
- Covers that are only removed during infrequent service tasks must either
  - Be interlocked (failsafe or redundant interlocks not required) or
  - Be secured, requiring a tool to remove
- If defeatable interlocks are used, it must not be possible to replace the cover with the interlock defeated.
- In uncontrolled areas, non-defeatable cover interlocks must be used for *Class 1 enclosure* or *beam conduit* covers that may be removed to enable Class 3B or Class 4 work, except if LSO approval is given to use an administrative configuration control lock.

Engineering controls for these should include each of the following:

- Interlocked covers for SLAC-built lasers if similar commercial lasers would have them because removing the cover exposes a different wavelength hazard
- Interlocks for Class 1 enclosure covers that are frequently removed or may be removed for an extended period, and may expose a different wavelength hazard when removed
- An engineered *laser safety system (LSS)* configured so it is easy to add a new Class 1 cover interlock
- Redundant cover interlocks, if used in an uncontrolled area

*Note* *Interlocked cover controls provide a higher level of engineering control than secured covers; and non-defeatable interlocks provide a higher level of engineering control than defeatable interlocks.*

### 2.2.2 Removable Connectors for Fiber Transport Cables

Removable connectors must either be

- Interlocked, so the laser source is disabled when in the disconnected state, or

- Secured, requiring a tool to disconnect, unless the connector is within a secured or interlocked enclosure

### 2.2.3 Exclusion LCAs and Walk-in Protective Housings

Engineering controls for these must include

- Failsafe or redundant access control interlocks to disable laser hazards in excess of Class 3R if a person enters
- An electronic warning device at the entry to the LCA or walk-in protective housing that indicates a NO ACCESS condition.

*Note* Exclusion LCAs *and* walk-in protective housings *have engineered controls to ensure no persons are inside the LCA with Class 3B or Class 4 laser beams enabled.*

### 2.2.4 Barriers, Beam Path Control, and Beam Termination

Appropriate *barriers*, beam path control, and beam termination are needed to block potential stray beams and prevent accidental placing of objects or parts of one's body in a beam path.

Engineering controls for these must include the following:

- Backstops behind the upper turning mirror in a periscope if there is an upward-going beam
- Beam barriers to contain possible stray beams from optics that can generate out-of-plane beams (for example, periscopes, beam-splitting polarizers, corner cubes, retroreflectors, and diffraction gratings)
- Appropriate beam termination for all primary and stray beams

Engineering controls for these should include the following:

- Backstops behind turning mirrors if other barriers are not adequate to contain stray beams
- Table skirts at the perimeter of laser tables (these are barriers that extend 1 to 2 inches above the nominal height of laser beams on the table)

## 2.3 Procedures

### 2.3.1 Lab-specific Standard Operating Procedure

Each *laser controlled area (LCA)* or *laser facility* must have an associated *standard operating procedure (SOP)* and *laser safety contract*, described in a document referred to as the *lab-specific SOP*. This document identifies potential hazards present and describes controls to mitigate these hazards.

*Note* *Generally, a laser facility has one or more LCAs; a facility approved only for fully enclosed Class 1 operation will have no LCAs. In most cases a single lab-specific SOP will cover all the facility's LCAs; in others each LCA will have its own.*

The lab-specific SOP usually references a general SOP, General Laser Laboratory Safety for SLAC QLOs and LCA Workers. This document describes hazards and controls that are broadly applicable to Class 3B

and Class 4 laser laboratories at SLAC, many of which use a SLAC-built *laser safety system (LSS)* found in most accelerator, Linac Coherent Light Source (LCLS), and research laser labs.

The general and lab-specific SOPs have minimal overlap and requirements in both apply, though the lab-specific SOP takes precedence if there is a conflict.

The lab-specific SOP must include the following:

- Reference to the general SOP, if applicable
- Schematic of the laser facility, which includes identifying the *nominal hazard zone (NHZ)*. The NHZ is the area inside the LCA where there may be accessible laser radiation above the *maximum permissible exposure (MPE)* when lasers are enabled.
- Lasers and laser system specifications
- Laser hazard parameters and associated *optical density (OD)* requirements for laser eyewear
- Description and specification of functional requirements for the engineered LSS and other engineering controls
- Description of the laser operation modes and associated eyewear requirements
- Lab-specific non-beam hazards
- Laser eyewear specifications
- Lab-specific training
- Administrative procedures, including
  - How to set each operation mode (for example, Laser Off, Class 1, Class 4) and any operation mode requirements such as restrictions on unattended Class 1 operation
  - Special or non-routine alignment procedures that have requirements that go beyond what is described in core laser safety practices (for example, during optical parametric amplifier [OPA] alignment)
  - Special requirements if more than one type of laser eyewear protection is used in Class 4 mode. Different eyewear requirements should have different Class 4 operation modes defined.
  - Special requirements for laser maintenance or service work
  - Entry and egress procedure during Class 4 operation

The general SOP document describes the following administrative controls:

- Reference to following core laser safety practices (see Laser Safety: Core Laser Safety Practices)
- How to respond if there is a failure in an LSS component
- Requirements for pre-job briefings
- Requirements for safety configuration control, including for moving safety shutters or other key safety components
- Requirements for satisfying *control of hazard energy (CoHE)* to prevent the unexpected startup or energization of a laser hazard (see Laser Safety: Class 3B and Class 4 Laser CoHE Requirements)

Lab-specific and general SOP documents do not have expiration dates unless specifically indicated. A template for lab-specific SOPs is available on the Laser Safety Program Site.

### 2.3.2 Job Safety Analysis

A *job safety analysis (JSA)* is sometimes used to extend the description of laser hazards and controls given in a lab-specific SOP. For example, it may be used when a particular experiment is being done that is short-lived and it does not make sense to revise the SOP, or it may be used for specialized procedures that only a few of the facility's QLOs will perform.

JSA approval includes an expiration date. Sample JSAs are available on the Laser Safety Program Site.

### 2.3.3 Configuration Control Form

Work that modifies the safety configuration or function of a Class 1 enclosure, a safety shutter, or a component of the engineered LSS requires a configuration control change process to be followed, resulting in an approved *configuration control form (CCF)*. A CCF is also required for other work that modifies the laser safety configuration or laser safety functionality for a Class 3B or Class 4 laser system in a way that is outside the scope of what is described in a laser facility's approved SOP and JSA documents. Use of a CCF should be described in a lab-specific SOP or JSA, but the CCF may also be used as a standalone procedure document if approval is given by the LSO.

The SLSO has overall responsibility for creating the CCF, submitting it to the LSO for review/approval, making notifications and obtaining approvals required before the start of work, following WPC protocols to release the work, and then approving each stage of the work as described in the CCF.

*Note* *Some simple actions that are adequately described in an SOP or JSA may be exempt from this requirement. Consult the LSO on such exemptions.*

Example actions that would require a CCF are

- Changing a Class 1 enclosure in any manner that changes its safety function
- Relocating a safety shutter or interlocked laser power supply (except for very simple changes if LSO approval is given)
- Bypassing any required laser safety interlock (except for defeatable interlocks if used as described in the SOP)
- Re-starting laser operations for portable laser systems following a change in location or following a long period of non-use.
- Applying or removing a configuration control padlock

The CCF must include the following information:

- Description of work to be performed and its purpose
- Determination by the LSO whether lockout/tagout (LOTO) is required to protect a worker performing a maintenance or servicing task from an unexpected laser hazard during their work under the CCF. If LOTO is required, then its requirements described in Chapter 51, "Control of Hazardous Energy", must be followed.
- Requirements and safety checks needed before starting the work
- Safety requirements needed while laser system is in a modified state; when laser system is in a modified state, a copy of the CCF must be posted, preferably at the laser control panel and/or laser entry door

- Work completion requirements and description of safety checks needed to close out the CCF
- Names and dates for persons performing the work and validation checks

A CCF template and instructions are available on the Laser Safety Program Site. The instructions include the following:

- The SLSO must approve the CCF description and completion of requirements stated in the CCF.
- The LSO must review and approve the CCF and determine what additional notifications and approvals are required.
- The directorate laser lead must be notified of all CCFs for facilities in their directorate; they must approve all CCFs for which LOTO is required. *(Note: directorate laser leads are appointed by their associate laboratory director.)*

Validation checks by a second QLO must be done to confirm that requirements before starting work and requirements for closing out the CCF are completed.

### 2.3.4 Annual Inspections by the LSO

Annual inspections of Class 3B and Class 4 LCAs must include the following:

- Verification that the current SOP document(s) accurately reflects current laser operations
- Verification that laser system interlock functionality checks have been completed
- Review of the list of authorized laser workers, and verification that their training is current
- Review of lasers in use and verification that their operations are adequately described in the SOP (and JSA) document(s)
- Verification that LCA entryway postings meet requirements
- Inspection of eyewear and eyewear storage location to verify that requirements are met, including that the eyewear is not damaged and that only approved laser eyewear is present
- Checking that barriers and beam containment are adequate
- Checking that housekeeping is adequate
- Review of status of open action items from last inspection

### 2.3.5 Laser Worker Approval

Laser workers, both qualified laser operators (QLOs) and laser controlled area (LCA) workers, must complete formal and on-the-job training and a medical exam and be approved by the LSO, his or her administrative supervisor or point-of-contact (POC), and the SLSO (if applicable) before beginning work with Class 3B and Class 4 lasers.

See the Laser Safety: Laser Worker Approval Procedure.

## 2.4 Equipment Labels

Templates for equipment labels are available on the Laser Safety Program Site.

### 2.4.1 Protective Housings

An equipment label must be affixed to a conspicuous place on the housing and provide hazard information for the output laser beam (class, wavelength, pulse duration if appropriate, maximum power and appropriate WARNING or DANGER signal word).

An equipment label must also be placed on the control panel if it is separated from the housing by more than 2 meters.

If there is an output aperture, there should be an associated aperture label.

### 2.4.2 Removable Covers on Protective Housings and Class 1 Enclosures

A warning label identifying the highest class of laser radiation contained within the enclosure or housing must be affixed to each removable cover. The label must include the following text (or equivalent):

- If the cover has no defeatable interlocks
  - CLASS 3B LASER RADIATION WHEN OPEN or
  - CLASS 4 LASER RADIATION WHEN OPEN
- If the cover has defeatable interlocks
  - CLASS 3B LASER RADIATION WHEN OPEN AND INTERLOCKS DEFEATED or
  - CLASS 4 LASER RADIATION WHEN OPEN AND INTERLOCKS DEFEATED

### 2.4.3 Removable Fiber Connectors

A warning label identifying the highest class of laser radiation contained within the fiber must be affixed to each removable fiber connector. The label must include the warning statement (or equivalent):

- HAZARDOUS LASER RADIATION MAY BE ACCESSIBLE WHEN DISCONNECTED

### 2.4.4 Long-distance Beam Conduits and Fiber Transport

On long-distance beam conduits and fiber transport, a warning label must be placed approximately every 3 meters. The label text must include a WARNING or DANGER signal word and the following text (or equivalent):

- CLASS 3B LASER RADIATION ENCLOSED or
- CLASS 4 LASER RADIATION ENCLOSED

## 2.5 Unsupervised and Unattended Laser Operation

### 2.5.1 Unsupervised Laser Operation

Unsupervised laser operation is not permitted.

*Note* *Unsupervised laser operation would be operation of a Class 3B or Class 4 laser without authorization from an assigned SLSO, which is not permitted per the requirements in Section 2.1.*

### 2.5.2 Unattended Laser Operation

Class 3B and Class 4 lasers or laser systems that are only used as part of a LSO-approved Class 1 laser system are exempt from the requirements in this section.

The unattended use of Class 3B or Class 4 lasers or laser systems is permitted only when these conditions are met:

- The SLSO has ensured that control measures, consistent with the hierarchy of controls, provide adequate protection to those who may enter the LCA during times of unattended use.
- The SOP, or JSA if applicable, does not prohibit unattended operation.

*Note* *The engineered LSS for many SLAC laser facilities permits unattended laser operation, with an associated door interlock bypass capability whose functionality is described in the SOP.*

*Requirements for engineering controls for LCA entryways (for example, locked and interlocked door) are described in Laser Safety: Laser Controlled Area Requirements.*

## 2.6 Training

SLSOs have line management responsibility for providing and documenting *on-the-job training (OJT)* to QLOs and LCA workers. This includes the SLSO maintaining an OJT syllabus for site-specific training for each worker. The SLSO must conduct an annual refresher for this training.

A template for an OJT syllabus is available on the Laser Safety Program Site. SLSOs use this to develop a facility's syllabus, which is posted on the facility SharePoint. The Laser Safety Tool is used to document annual OJT in a "Laser Worker Summary" table and specific work authorization in an "OJT Summary" table.

## 2.7 Control of Hazardous Energy (CoHE)

CoHE requirements prevent the accidental startup or energization of energy sources. See

- Laser Safety: Class 3B and Class 4 Laser CoHE Requirements

## 2.8 Laser Eyewear Protection

When using Class 3B or Class 4 Lasers, the following requirements must be met:

- Laser Safety: Class 3B and Class 4 Laser Eyewear Protection Requirements

## 2.9 Safety Evaluation of Non-beam Hazards

*Non-beam hazards* result from factors other than direct human exposure to a laser beam but are associated with laser equipment or laser operations. Non-beam hazards include

- Electrical (laser power supplies, high voltage connections)
- Fire and explosion (flammable solvents in dye lasers, high pressure arc lamps, capacitor banks). (Fire safety is particularly important for Class 4 lasers; requirements are described in the following Section 2.10.)
- Chemicals
- Pressure vessels
- Compressed gases
- Cryogenics
- Mechanical (associated with robotics)
- Collateral radiation (x-rays from electrical equipment operating above 15 kV, or ultraviolet (UV) radiation from flashlamp operation)
- Hazards from laser-target interactions (laser-generated air contaminants, combustion of flammable materials, plasma radiation, and, at very high irradiance, ionizing radiation).

The SLSO, laser facility program manager, and ESH coordinator are responsible for appropriate evaluation of and safety controls for non-beam hazards and all non-laser safety issues. Evaluation and safety controls for non-beam hazards must be described in the lab-specific SOP or in a JSA.

The LSO will assist in evaluating hazards and controls for non-beam hazards and consult with other ESH program managers and subject matter experts as needed.

### 2.9.1 Safety Evaluation of Ionizing Radiation Hazard from Laser-Target Interactions

Review by SLAC's Radiation Protection Department is required for the following laser operations:

- Laser beam is focused to intensities > $10^{15}$ W/cm$^2$, or
- Laser beam is focused to intensities > $10^{13}$ W/cm$^2$, if all the following conditions are also met:
  - Laser beam average power > 0.5 W
  - Focused beam is or may be incident on a *renewable* solid or liquid target
  - Focused beam is not enclosed in a vacuum chamber or pressure vessel

The target is considered *renewable* if

1. The laser beam is rastered or otherwise moved on a solid target, or
2. A solid target is rastered or otherwise moved during laser beam exposures, or
3. The laser beam is incident on a liquid target

At the high intensities capable of generating an ionizing radiation hazard, the laser beam will ablate a solid target and in this situation the radiation hazard will not be sustainable unless the target is renewable. (For example, an accident scenario that results from a high intensity focused laser beam mis-steered onto a barrier would not produce a sustainable radiation hazard.)

## 2.10 Fire Safety Requirements

Fire prevention control measures must be implemented for all Class 4 lasers and for all lasers with average beam irradiance of 0.5 W/cm$^2$ or greater. These controls must include all of the following:

- Minimize combustible materials.
- Route and secure cables and plastic tubing carefully so they cannot be exposed to a laser beam.
- Use appropriate materials for beam dumps, shutters, and barriers. For high average power laser hazards (>~100 W), water-cooled shutters and beam dumps may be needed. Perform damage and acceptance tests for beam dumps and shutters as applicable.
- Verify correct placement, securing, and beam alignment for shutters and beam dumps.
- Ensure portable fire extinguishers are accessible within 75 feet.
- Ensure an emergency shutdown switch is located near the laser equipment. The EMERGENCY OFF button described in Laser Safety: Class 3B and Class 4 Laser Controlled Area Requirements can be used for this.
- Annual OJT on fire hazards and controls for all QLOs and LCA workers, including the following:
  - Locations for fire alarms and fire extinguishers
  - Emergency entry and egress
  - Emergency Off
  - Response to a fire:
    - Perform Emergency Off if practical, and exit area
    - Ensure someone calls 911 or pulls a fire alarm
    - Only use fire extinguisher if all of the following are satisfied: fire is small and is not growing quickly; ESH Course 108 is current; and the fire extinguisher is the correct type.
    - Notify supervisor and the area or building manager.

*Note* *Additional guidance on fire safety for laser systems can be found in* NFPA 115.

Additional controls are needed for laser equipment utilizing flammable or reactive gases, or ignitable liquids. The ESH coordinator, fire marshal, and LSO must be informed if these are used.

## 2.11 QLO and LCA Worker Service Work in Laser Labs

Generally, a QLO or LCA worker may only work in the facility for which he or she has been approved. However, a QLO or LCA worker may enter and work in another laser facility without becoming a QLO or LCA worker for that facility in order to perform short-term *service* work, measurements, or experiments, subject to the following conditions:

- The visiting QLO or LCA worker, called a *service QLO* or *service LCA worker*, must have approval from his or her administrative supervisor and the SLSO (or their designees) for the laser facility being visited.
- The visiting service QLO/LCA worker must be escorted by one of the facility's QLOs or LCA workers.
- There must be a pre-job briefing between the service QLO/LCA worker and the escorting QLO/LCA worker for the work to be performed.

Unescorted work in Class 4 mode may only be done by the laser facility's own QLOs/LCA workers.

*Note* *SLSOs should minimize the number of QLOs approved for a specific laser facility by taking advantage of this service QLO (and LCA worker, described below) designation.*

## 2.12 Laser Controlled Area Worker

*Laser controlled area (LCA) workers* perform support work such as controls electronics, data acquisition, and accelerator operations. To do so they receive limited approval to be allowed access to laser facilities. They have the same responsibilities as QLOs but are not authorized to perform laser alignment work, and, depending on the facility, may be restricted from changing operation mode or opening shutters.

SLSOs should implement the following controls for these workers:

- Limit their number to only those that are essential and may need unescorted laser facility access.
- Limit their scope of work, including limiting radio-frequency identification (RFID) authorization for the laser safety control panel.
- Conduct periodic refresher OJT.
- Conduct pre-job briefings prior to their laser work and determine if their work needs to be supervised by a regular QLO.
- Determine if any additional LCA or NHZ controls are needed to accommodate their work.
- Avoid scheduling their work during Class 4 laser operations, in particular if laser alignment will be taking place.

## 2.13 Laser Controlled Area Visitor Policy

*Laser controlled area visitors* are personnel who have not been approved as a QLO/LCA worker in a SLAC laser facility. (This does not include service subcontractors or the LSO). Visitor access when Class 3B or Class 4 lasers may be in operation is strongly discouraged but may be allowed if adequate controls are present. For requirements see Laser Safety: Laser Controlled Area Visitor Requirements.

# 3 Forms

The following forms and systems are required by these requirements:

- Laser Safety Tool. System used for maintaining information on laser personnel and facilities, including approvals of facilities and qualified laser operators and laser controlled area workers

- Laser Facility Operations Approval. Documents approvals for Class 3B and Class 4 laser facility operations (in the Laser Safety Tool)
- Laser Worker Approval. Documents approvals for QLOs and LCA workers (in the Laser Safety Tool)
- Laser Safety: System Laser Safety Officer Approval Form (SLAC-I-730-0A05J-001). Documents approvals for SLSOs
- Laser Safety: Acting System Laser Safety Officer Approval Form (SLAC-I-730-0A05J-009). Documents approvals for acting SLSOs
- Site-specific training documentation for QLOs and LCA workers. A template for an OJT syllabus is available on the Laser Safety Program Site (SharePoint). SLSOs use this to develop a facility's syllabus, which is posted on the facility SharePoint. The Laser Safety Tool is used to document annual OJT in a "Laser Worker Summary" table and specific work authorization in an "OJT Summary" table
- Lab-specific SOP, JSA, and CCF documents: templates and examples for these are available on the Laser Safety Program Site (SharePoint).

# 4 Recordkeeping

The following recordkeeping requirements apply for these requirements:

- The SLSO must maintain the following records for the laser facility to which he or she is assigned:
  - Lab-specific SOP, and any supplemental JSAs or CCFs in use
  - SLSO/acting SLSO approval forms
  - OJT documentation for the facility's QLOs and LCA workers, maintained in the Laser Safety Tool
  - Inventory of lasers, laser keys, and keys issued to QLOs
  - Alignment eyewear approval forms and log forms, if alignment eyewear is used
  - Documentation for tests and certification of the LSS
  - Documentation for audits and facility reviews, such as the annual laser safety inspection conducted by the LSO
- Worker and facility approval records are maintained in the Laser Safety Tool
- All current safety documentation records must be available as:
  - Printed copies in the laser safety binder at the laser facility, or
  - Electronically accessible on the Laser Safety Program Site or in the Laser Safety Tool.

# 5 References

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

- Chapter 10, "Laser Safety"
  - Laser Safety: Laser Worker Approval Procedure (SLAC-I-730-0A05C-003)
  - 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: Class 3B and Class 4 Laser CoHE Requirements (SLAC-I-730-0A05S-005)
  - Laser Safety: Laser Controlled Area Requirements (SLAC-I-730-0A05S-009)
  - Laser Safety: Class 3B and Class 4 Laser Eyewear Protection Requirements (SLAC-I-730-0A05S-007)
  - Laser Safety: Core Laser Safety Practices (SLAC-I-730-0A05S-006)
  - Laser Safety: Laser Controlled Area Visitor Requirements (SLAC-I-730-0A05S-011)
  - General Laser Laboratory Safety for SLAC QLOs and LCA Workers (SLAC-I-704-701-003-00)
  - Laser Safety Program Site (SharePoint)
- Chapter 51, "Control of Hazardous Energy"

Other SLAC Documents

- On-The-Job (OJT) Training Requirements (200-2P-1)
- ESH Course 108, Fire Extinguisher Training (ESH Course 108)

Other Documents

- National Fire Protection Association (NFPA) 115, "Standard for Laser Fire Protection" (NFPA 115)

*Chapter 10: Laser Safety*

# Class 3B and Class 4 UV Laser Operation Requirements

Product ID: 662 | Revision ID: 2597 | Date published: 5 May 2023 | Date effective: 5 May 2023
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/laserReqClass3Band4UV.pdf

# 1 Purpose

The purpose of these requirements is to minimize skin exposure to ultraviolet (UV) radiation. They cover setup and use of facilities where Class 3B or Class 4 UV lasers may operate. They apply to workers in these facilities, visitors to them, and *system laser safety officers (SLSOs)*, *laser facility program managers*, and the *laser safety officer (LSO)*.

# 2 Requirements

## 2.1 Hazard Overview

Eye and skin *maximum permissible exposures (MPEs)* are the same in the UV and in the infrared IR outside of the retinal hazard region. In the retinal hazard region between 400–1400 nm, eye MPEs are less than skin MPEs; for example, for a 1000s exposure eye MPEs are ~×100–1000 less than skin MPEs.

- MPEs in the UV are the same for coherent (laser) and incoherent sources.
- MPEs in the UV depend on the cumulative exposure. For example the MPE is 3mJ/cm$^2$ between 180–300 nm for exposures from 10$^{-9}$s to 1000s. The potential hazard from long exposures to *diffuse reflections* must be considered.
- Skin injuries are less serious than eye injuries:
  - Vision impairment has much higher consequences
  - Skin injuries are usually self-repairing
- Skin injuries are much more probable than eye injuries:
  - Large surface area
  - Hands close to laser beams

# 2.2 Controls

## 2.2.1 Engineering Controls (Enclosures and Barriers)

Skin protection can best be achieved with engineering controls: enclose UV laser beam paths as much as practical. When there are open beams, primary protection to accessible diffuse reflections is provided by *personal protective equipment (PPE)* for eye and skin protection.

- Enclose UV laser beam paths to the extent practical. If the beam paths cannot be enclosed, then implement adequate barriers to minimize potential skin exposure from chronic exposure to beam losses and other sources of diffuse reflections.
- Beam dumps. Design barriers or enclosures for beam dumps to minimize potential exposure to diffuse UV reflections from them.

## 2.2.2 Administrative Procedures

- Attenuate laser beams to the minimum power required when there are open UV laser beams, in particular when alignment is done.
- Use remote steering controls and diagnostics as much as practical for aligning UV laser beams.
- Plan work to minimize time with potential skin exposure to hazardous UV laser beams.
- Keep exposed skin as far as practical from open beams.

## 2.2.3 PPE for Skin

- Wear long-sleeved shirts.
- Use gloves when working with hands near accessible laser beams (direct beam exposure hazard for primary or stray beams).
- Use gloves when diffuse reflection *nominal hazard zone (NHZ)* > 20 cm if hands may be within this distance of an open beam path when diffuse reflections may not be well shielded, for example, for beam powers above 10 mW at wavelengths less than 300 nm.
- Use a face shield when diffuse reflection NHZ > 1m if working within this distance of an open beam path when diffuse reflections may not be well shielded: for example, for beam powers above 250 mW at wavelengths less than 300 nm.

## 2.2.4 Medical Exams

- Skin exams for laser personnel can be performed by the Occupational Health Center. Laser personnel should request a skin exam if they experience any symptoms from exposure to UV laser beams.
- Periodic skin exams are recommended for laser personnel who may have chronic exposures exceeding MPE values.

## 2.2.5 Site-specific Training and Procedures

- Lab-specific *on-the-job training (OJT)* and *standard operating procedures (SOPs)* must describe the potential for skin injury and the controls to use. These need to emphasize barriers and enclosures for UV beams and when to use skin PPE.

# 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: Class 3B and Class 4 Laser Operation Requirements (SLAC-I-730-0A05S-004)
  - Laser Safety Program Site (SharePoint)
  - PPE – Eye-Skin Protection

*Chapter 10: Laser Safety*

# Laser Controlled Area Requirements

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URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/laserReqControlledArea.pdf

## 1 Purpose

The purpose of these requirements is to prevent untrained and unprotected personnel from entering areas where Class 3B and Class 4 laser radiation is present and to ensure that *qualified laser operators (QLOs)* can enter and exit areas safely, by warning them of the laser hazards present inside the area prior to entry and what the current operation mode and entry requirements are. They cover setting up *laser controlled areas (LCAs)*, which is a designation required when the maximum level of accessible laser radiation is Class 3B or Class 4. They apply to the *laser safety officer (LSO)*, *system laser safety officer (SLSO)*, and *laser facility program managers*.

For information on operating requirements for Class 3B and Class 4 lasers, see Laser Safety: Class 3B and Class 4 Laser Operation Requirements.

## 2 Requirements

Class 3B and Class 4 laser operation may only take place inside an LCA. The LCA description will be given in the associated *lab-specific standard operating procedure (SOP)* or *job safety analysis (JSA)*.

The *laser safety system (LSS)* generally provides most of the engineering controls required for LCAs. Additional LSS requirements to those described in this document can be found in the Laser Safety Systems Technical Basis Document.

An LCA must

- Allow both emergency entry and rapid exit. The emergency entry procedure, including a description of how the laser hazard is disabled, must be posted at the LCA entry. An emergency entry must automatically disable laser hazards via interlocks unless additional controls are in place, such as no unattended operation.
- Have a master controller located inside the LCA that permits laser light in the LCA above the *maximum permissible exposure (MPE)* level only when it is enabled and its input interlocks are satisfied. *(Note for simple installations, the master controller and associated master key may be the laser power supply [one or more] and associated key[s].)*
- Have a *master key* that enables the master controller operation. Removal of the master key will disable all Class 3B and Class 4 laser beams in the LCA and can be used for configuration control by the SLSO or as part of an *administrative lock and tag procedure*. Access to the master key is restricted to QLOs. (See Laser Safety: Class 3B and Class 4 Laser CoHE Requirements.)
- Have an illuminated warning sign, interfaced to the LCA master controller or engineered *laser safety system (LSS)*, to indicate when hazardous laser beams above the MPE may be present in the LCA. This

LCA warning device must be installed at the LCA entry so it is visible prior to entry. It must also be installed inside the LCA, where it should be easily viewable to persons within.

- Have a minimum of one interlocked and one locked door to gain entry. An unauthorized access must trip the door interlock, which then disables the laser hazards. Access entry to the LCA through the locked door is restricted by key or coded access to QLOs. In some situations, though, the LCA entry may be unlocked if there is a guard posted at the entry. The means for restricted access must be specified in the lab-specific SOP or JSA.
- Be effectively light tight. If it is not light tight, an appropriate hazard analysis will be conducted by the LSO. Windows, doorways, and open portals will need curtains or covers to reduce laser radiation outside the LCA to levels below the MPE.
- Have an entryway with one of the following to ensure no laser hazard exists at the entryway during entry or exit:
  - A non-defeatable entry interlock that disables laser hazards in the LCA to be below the MPE during entry
  - A defeatable entry interlock that temporarily allows entry or exit without disabling laser hazards in the LCA, if barriers are in place to prevent a laser radiation hazard at the entry
  - Alternative controls such as a posted guard, if approved by the LSO, if interlocks are not feasible or inappropriate. Entryway must be configured such that no laser hazard exists at the entry point during an entry or exit (for example, with the use of overlapping laser curtains).
- For LCAs where there is a work area (for example, computer work station or optics preparation area) outside the *nominal hazard zone (NHZ)* an additional barrier must be implemented at the NHZ entryway to remind entering personnel to don laser eyewear protection during Class 3B or Class 4 laser operation. Engineered barriers are to be given priority over administrative barriers such as a sign. (An interlocked proximity sensor with an audible/visual alarm is one way to implement this NHZ entryway control.)
- Have a clearly marked and easily accessible EMERGENCY OFF button within the LCA that will reduce accessible laser light levels below the MPE
- Have an audible alarm during laser startup or activation (such as when a *laser safety shutter* is about to be opened) to notify personnel within the LCA. An emission delay (typically 10 to 15 seconds, during which the audible alarm sounds) following a request to start up the laser (for example, a request to open a laser safety shutter) is required before the laser beam energization occurs. If the LCA does not have such an audible alarm, then the lab-specific SOP or JSA must specify how verbal notification will be used instead. (See Laser Safety: Class 3B and Class 4 Laser CoHE Requirements.)
- Have all interlock faults be latching. Reactivating the laser will be done manually. It is recommended that reactivating the laser following an interlock fault require authorization (for example, by using a radio-frequency identification [RFID] key or coded access) from a QLO. (See Laser Safety: Class 3B and Class 4 Laser CoHE Requirements.)
- Have the following signs posted at the entryway location (templates for these are available on the Laser Safety Program Site):
  - Laser hazard warning sign, which gives the laser classification, laser parameters, and *optical density (OD)* requirements for laser eyewear
  - Contact information for responsible line management personnel and for phone within the LCA
  - Emergency entry procedure

  - LCA visitor policy, if visitors are permitted when Class 3B or Class 4 lasers are enabled (see Laser Safety: Laser Controlled Area Visitor Requirements)
- Have a Core Laser Safety Practices poster displayed (available on the Laser Safety Program Site)
- Have the following signs/procedures (or equivalent) posted at the laser control panel location for changing operation modes (templates for these are available on the Laser Safety Program Site):
  - All laser labs that have both Class 1 and Class 4 operation modes must post the Setting Class 1 (Laser Enclosed) Operation Mode procedure
  - All laser labs that have a Class 4 operation mode must post the Setting or Changing Class 4 Operation Mode procedure
  - All LCLS hutches that have LCAs must post the Hutch Search Procedure to Set Class 4 Laser Operation

*Note* *SLSOs may modify the template procedures, with the approval of the LSO. SLSOs must review these procedures as part of on-the-job training.*

## 2.1 Recommendations

An LCA should

- Have a Class 1 operation mode, where beams are enabled but fully enclosed in an approved, engineered *Class 1 enclosure*. Laser eyewear protection would not be required in this mode. Unattended operation should not be permitted in this mode unless the associated removable panel covers are interlocked or secured by administrative configuration control locks.
- Use partitions or laser curtains to allow regions inside the LCA to be outside of NHZ. Outside the NHZ no accessible Class 3B or Class 4 laser beams are present and laser eyewear protection is not required. This can be useful to accommodate a computer workstation, an optics preparation area, and an entryway area where laser eyewear is stored and put on. (If such areas are set up, an additional barrier must be implemented at the NHZ entryway to remind entering personnel to don laser eyewear protection during Class 3B or Class 4 laser operation. See Section 2.)
- Have normal entry and exit not challenge interlocks. Where practical, *engineering controls* rather than *administrative controls* should be used for this.
- Have emergency lighting installed
- Have ambient lighting capable of providing at least 500 lux
- Have a phone inside the LCA

# 3 Forms

The following are signs to be posted at the LCA that are described in these requirements (templates for these are available on the Laser Safety Program Site [SharePoint]):

- Laser hazard warning sign
- Emergency entry procedure
- LCA visitor policy

- Core Laser Safety Practices poster

# 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: 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 Laser CoHE Requirements (SLAC-I-730-0A05S-005)
  - Laser Safety: Laser Controlled Area Visitor Requirements (SLAC-I-730-0A05S-011)
  - Laser Safety Program Site (SharePoint)

NATIONAL ACCELERATOR LABORATORY

ENVIRONMENT, SAFETY & HEALTH DIVISION

*Chapter 10: Laser Safety*

# Class 3B and Class 4 Laser CoHE Requirements

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# 1 Purpose

The purpose of these requirements is to prevent the unexpected energization or startup of machines or equipment, or release of stored energy. They cover *control of hazardous energy (CoHE)* for Class 3B and Class 4 lasers. They apply to workers, *system laser safety officers (SLSOs)*, and the *laser safety officer (LSO)*.

# 2 Requirements

## 2.1 Overview

Class 3B and Class 4 laser radiation is considered hazardous energy because of the potential for serious eye injury. Therefore careful consideration of CoHE is needed to protect workers. Key CoHE practices are especially important to follow if laser eyewear protection is not being worn when working – workers need very good assurance that laser hazards have been adequately disabled and controlled.

There are three general approaches to meeting SLAC's CoHE program requirements:

1. **Lockout/tagout (LOTO).** When *service* or *maintenance* is performed on equipment, de-energization of the equipment is the preferred method for achieving CoHE. When this is done, LOTO requirements apply (see Chapter 51, "Control of Hazardous Energy").
2. **Alternative energy controls.** If service or maintenance on a laser is being done and LOTO is not applied, then alternative energy control methods must be used. Such methods must utilize appropriate *machine guards* (for example, laser *master key* and *laser safety shutters*). This is the method used to satisfy CoHE requirements for most laser service and maintenance. It is subject to the requirements noted in Section 2.3.
3. **Administrative lock and tag.** If a laser system needs to be shut down or secured (for example securing a *barrier* to ensure Class 1 operation) for purposes of configurational or operational control, not for the personal protection of the person applying the lock, then an administrative lock and tag procedure may be used (see Chapter 51, "Control of Hazardous Energy").

Routine daily tasks by *qualified laser operators (QLOs)* and *laser controlled area (LCA) workers* in laser facilities are usually considered *normal operations* with energized or partially-energized laser equipment. Laser alignment and optics work by QLOs, including creating new beam paths and replacing damaged optics, are generally considered tasks that are "routine, repetitive and integral to normal operations" for laser workers.

Service and maintenance work by QLOs often require energized or partially energized (that is, enabled) laser beams, in which case laser eyewear protection is used in addition to other alternative energy controls to prevent an accidental exposure.

## 2.2 Energy Isolating Devices

SLAC's CoHE program requires equipment to have *energy isolating device(s)* with appropriate LOTO capability. For laser systems this includes an easily verifiable closed position for a lockable beam block if a beam block is used. *(Note it may not be necessary for a laser safety shutter to satisfy a LOTO capability requirement if cord-and-plug control can be used to disable the laser hazard or if an alternating current [a.c.] circuit breaker can be locked out.)*

If a laser safety shutter or a laser beam block is used not as a machine guard, but as an energy isolating device to protect a worker performing a non-routine maintenance or service task from an unexpected laser hazard, then it must satisfy LOTO requirements. An equipment-specific lockout procedure (ELP) will need to be developed and approved (unless cord-and-plug control is applicable). The ELP will need to include a description of the location and operation of the energy isolating device. The ELP must also describe how *zero energy verification (or energy isolation)* is done. (See Chapter 51, "Control of Hazardous Energy".)

## 2.3 Alternative Energy Controls

Alternative energy controls must use the necessary combination of *engineering controls* (machine guards such as safety shutters, interlocks, and key control), warning and alert systems, *administrative controls*, training, and *personal protective equipment (PPE)* such as laser eyewear to achieve effective CoHE protection for workers. These controls must be documented in the *lab-specific standard operation procedure (SOP)* or *job safety analysis (JSA)*, with review and approval by the LSO.

The LSS generally provides most of the engineering controls required when alternative energy controls are used for CoHE. Additional LSS requirements to those described in this document can be found in the Laser Safety Systems Technical Basis Document.

### 2.3.1 Master Keys

Each Class 3B and Class 4 laser requires an associated master key. The master key must be removable and the laser must not be operable when the key is removed.

### 2.3.2 Laser Safety Shutters and Safety Beam Blocks

Laser safety shutters and safety beam blocks are remotely (for safety shutters) or manually (for safety beam blocks) controlled and can be inserted to function as a machine guard, or sometimes as an energy isolating device in a LOTO procedure. Safety shutters are often used to disable a laser hazard when the engineered *laser safety system (LSS)* detects a fault condition (for example, LCA access violation or *Class 1 enclosure* cover removal). Safety shutters and interlocked safety beam blocks are sometimes used as part of a Class 1 enclosure; in Class 1 operation mode laser eyewear protection is not required.

*Note* *Safety shutters and safety beam blocks with IN position sensors provide a higher level of engineering control when they are interfaced to an engineered LSS that can disable laser*

*hazards when certain interlock requirements (for example, for LCA access control, LCA operation mode or a Class 1 enclosure) are not met.*

The following requirements apply to laser safety shutters and safety beam blocks:

- Each independent laser system should have an associated safety shutter or a dedicated safety beam block (safety shutters are recommended for this). When used as such, shutters or blocks must be placed directly at the source laser output aperture or as close as practical. Safety enclosures associated with them should be as small as practical to limit how often the shutter may be accessible.
- Safety shutters or dedicated safety beam blocks should be used at the input to devices that can generate other wavelength hazards (for example, harmonics crystals, optical parametric amplifiers [OPAs], or OPCPA [optical parametric chirped-pulse amplifiers [OPCPAs]). Safety shutters are recommended for this and should only be enabled when needed for a particular Class 4 operation mode.
- Safety shutters and safety beam blocks must have an IN readback sensor with an associated display signal available for monitoring by laser personnel.
- Safety shutters should have independent readback sensors (and associated displays) for the IN and OUT positions.
- Safety shutters should have independent control and readback (for example, to assist with a LOTO or administrative lock and tag procedure).
- Safety shutters must close when control signals or power are deactivated or removed.
- When there is an inconsistency between the requested state and the (IN or OUT) position sensors, the laser safety system should give an alarm warning and, if possible, inhibit the laser upstream of the safety shutter or safety beam block.
- Safety shutters' manufacturing information must be described in the lab-specific SOP or JSA, including an evaluation of their ability to withstand the maximum laser irradiance.
- Safety shutters and safety beam blocks must be labeled LASER SAFETY DEVICE. Safety labels should be placed over the securing bolts for safety shutters and indicate that SLSO approval is required to move or modify. SLSOs should also consider use of a special tool, administrative lock, or interlock to address safety configuration control for safety shutters.
- Correct safety shutter (and, if applicable, interlocked safety beam block) operation and interlock functionality must be tested at least once per year as part of a laser safety certification procedure.
- Control shutters should not share common hardware, such as a controller interface chassis, with safety shutters and should not be controlled by the LSS. *(Note control shutters are used to enable beam paths for operational needs rather than safety.)*

### 2.3.3 Activation Warning System Requirements

An audible or visual emission indicator is required to indicate the possible presence of an accessible Class 3B or Class 4 laser beam. An appropriate audible or visual indicator is also required just before laser emission to allow actions to avoid exposure. Laser safety shutters usually require an audible warning 10 to 15 seconds before opening; this must be described in the lab-specific SOP or JSA.

### 2.3.4 Requirements for Laser Safety System Interlocks

Interlocks for access doors, protective covers, service access panels, and enclosures must be open normally. Doors and covers must be closed to satisfy (close) the interlocks.

Power failure to an interlock circuit or removing an interlock connector must cause the laser system to go into, or remain in, a safe state by closing shutters or disabling power.

All interlock faults must be latching.

### 2.3.5 LCA Search Required Before Enabling Laser Hazards

Before turning on the beam and making it accessible, the responsible QLO must

- Search the LCA to ensure that only qualified laser personnel are present and that all wear appropriate protective eyewear
- Warn personnel present of the laser hazard being enabled

This procedure must be described in the lab-specific SOP or JSA.

## 2.4 Laser Transport Safety Shutters

When a laser safety shutter is used as a machine guard (for example, as part of a Class 1 enclosure or as a beam block) to prevent transport of a Class 3B or Class 4 laser beam to an area that has unrestricted access to *affected workers* (personnel other than QLOs, LCA workers, laser service subcontractors, and the LSO), the following requirements apply:

- Two redundant transport shutters must be installed to act as an effective machine guard.
- A shutter acceptance test must be done to verify the mechanical integrity of the shutter system to be an effective machine guard, and the LSO must review and approve the test (a template for this test is available on the Laser Safety Program Site).
- An illuminated display sign must be used to communicate the laser hazard status (for example, Laser Off mode or Class 1 mode).
- Affected workers who rely on the transport shutters as a machine guard must receive appropriate training information about the laser hazard controls (in some cases the area hazard analysis document may be used for this).
- Work by affected workers must be outside the envelope of the LSS components.
- Requests by affected workers to apply LOTO for their work need to be respected and accommodated.

## 2.5 Zero Energy Verification

If the LSS is being used as a machine guard to disable the laser hazard so that laser eyewear protection can be removed, a *zero energy (or energy isolation) verification* must be done before removal of the eyewear. This may be done by verifying the IN status of a laser safety shutter or by using an appropriate laser beam power meter or diagnostic. Zero energy verification procedures should be described in the SOP or JSA.

## 2.6 Service and Maintenance Procedures

The lab-specific SOP or JSA must define *service* and *maintenance* work. Examples include work done by service subcontractors and work done when interlocked protective covers or service access panels are removed.

- A NOTICE sign must be placed at the LCA entry when service subcontractor work is in progress.
- When an interlocked cover or service access panel is removed, the LSS must be evaluated for any changes in its normal functions (for example to prevent laser hazards by inserting shutters and to provide an activation warning system with emission delay). If some of the normal LSS functions are absent, additional controls may be needed to provide equivalent protection as during normal operation.
- The SLSO is responsible to identify if any work activity may need a CCF or LOTO and will then consult with the LSO to make a determination.

## 2.7 Equipment Custodian Requirements

The lab-specific SOP, JSA, or Laser Safety Program Site must describe who is responsible for the laser equipment.

## 2.8 Training

Workers who rely on alternative energy controls to provide effective CoHE protection against an accidental laser exposure must receive appropriate training from the SLSO or designee. For QLOs and LCA workers this is done as part of their OJT and site-specific training.

In addition, the SLSO is required to take one of the following courses:

- ESH Course 157, Control of Hazardous Energy (ESH Course 157)
- ESH Course 136, Control of Hazardous Energy – Affected Employee (ESH Course 136)

## 2.9 Fiber Optics Connectors

Class 3B and Class 4 laser sources to the fiber transport cables must be blocked or disabled before connecting or disconnecting the fiber.

If a fiber transport cable is disconnected and the laser source enabled, an LCA must be established and protective eyewear worn.

If the fiber terminations are to be directly inspected, then the laser hazard must be disabled – protective eyewear may never be relied on to permit direct intrabeam viewing. The QLO performing this task may disable the laser hazard by removing the laser enabling key (master key) if he or she is in control of this key; if this cannot be done, then LOTO must be used unless cord-and-plug control can be used. Whatever method is used to disable the laser hazard, zero energy (or energy isolation) verification must also be done.

*Note* *Additional engineering and equipment label requirements can be found in Laser Safety: Class 3B and Class 4 Laser Operation Requirements.*

## 2.10 Affected Worker

*Affected workers* are personnel other than QLOs, LCA workers, laser service subcontractors, or the LSO who may need to perform work in a facility that houses Class 3B or Class 4 lasers.

- Work should be done in Laser Off mode with the master key removed to disable laser hazards as part of an administrative configuration control or administrative lock and tag control. Such work can be done without requiring LOTO if the workers are not doing service or maintenance on laser equipment and are adequately informed of how the lasers are disabled.
- Work may be done in Laser On mode (may be Class 1 or Class 4), if all the following requirements are satisfied:
  - Workers are not doing service or maintenance on equipment associated with the LSS.
  - Work should be done in Class 1 mode rather than Class 4 mode.
  - Laser visitor requirements are satisfied as described in Laser Safety: Laser Controlled Area Visitor Requirements.
  - While LOTO is not generally required, if affected workers request to apply LOTO for their work to satisfy CoHE, then such requests need to be respected and accommodated.

# 3 Forms

The following forms and systems are required by these requirements:

- Shutter Acceptance Test Form (available on the Laser Safety Program Site [SharePoint])
- Fiber Optic Connector Label (available on the Laser Safety Program Site [SharePoint])

# 4 Recordkeeping

The following recordkeeping requirements apply for these requirements:

- Transport shutter acceptance test documents will be maintained by the SLSO.

# 5 References

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

- Chapter 10, "Laser Safety"
  - 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 Laser Eyewear Protection Requirements (SLAC-I-730-0A05S-007)
  - Laser Safety: Laser Controlled Area Visitor Requirements (SLAC-I-730-0A05S-011)
  - Laser Safety Program Site (SharePoint)

- Chapter 51, "Control of Hazardous Energy"

Other SLAC Documents

- ESH Course 157, Control of Hazardous Energy (ESH Course 157)
- ESH Course 136, Control of Hazardous Energy – Affected Employee (ESH Course 136)

# Class 3B and Class 4 Laser Eyewear Protection Requirements

Product ID: 549 | Revision ID: 2600 | Date published: 5 May 2023 | Date effective: 5 May 2023
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/laserReqClass3Band4Eyewear.pdf

# 1 Purpose

The purpose of these requirements is to protect workers from harmful exposure to lasers. They cover use of protective eyewear when operating Class 3B and Class 4 lasers. They apply to workers whenever they are using lasers of this classification and, *laser facility program managers*, *system laser safety officers (SLSOs)*, line management, and the *laser safety officer (LSO)*.

# 2 Requirements

## 2.1 General

Laser eyewear protection must meet all the following requirements:

- Must be worn within the *nominal hazard zone (NHZ)* when the *master key* enables the laser hazards and the *laser controlled area (LCA)* is in a Class 3B or Class 4 laser operation mode
  - In work areas that are outside the NHZ, but within the LCA, *qualified laser operators (QLOs)* and *LCA workers* should carry eyewear protection (by use of a lanyard, for example)
- Must provide full protection unless an LSO-approved exception exists (see Section 2.1.1). Full protection eyewear has sufficient *optical density (OD)* to reduce exposure from an enabled laser beam (either direct beam or *specular reflection*) to a level below the *maximum permissible exposure (MPE)*. (The MPE and OD requirement must be evaluated for each enabled laser beam.)
- Must be labeled with wavelength-dependent OD information
- Must have sufficient *visible light transmission (VLT)* for tasks to be performed. From a practical standpoint, when the VLT is less than 20 percent additional lab lighting may be required to perform the intended tasks.
- Must be evaluated for *saturable absorption* and for material damage due to potential power density from a direct hit
- Must fit properly when used, to provide adequate protection. **Peeking over or under laser eyewear is not allowed.**
- Must be approved by the LSO as part of the approval process for a *lab-specific standard operating procedure (SOP)* or *job safety analysis (JSA)* document. The LSO will also perform periodic inspections of the eyewear in use.

- Must be adequately maintained and cleaned
- Must be adequately labeled, stored, and organized to avoid confusing different types of eyewear that may be used
- Must be inspected before each use to verify correct selection for the hazards enabled and to check for possible damage. Damaged eyewear must be discarded if the damage could compromise the required protection. (*Note if reflective eyewear with dielectric coatings is used, even small scratches to the filter may cause damage and compromise the required protection.)*

### 2.1.1 Exceptions to Full Protection Eyewear Requirement

Exceptions to the full protection eyewear requirement within the NHZ are allowed if at least one of these five conditions exists:

1. Laser beams are fully enclosed in an approved, engineered *Class 1 enclosure*.
2. A limited open beam path exists with no credible possibility of a beam exposure.
3. A visible, open laser beam is present during an approved alignment eyewear procedure.
4. An approved administrative procedure is used to disable the laser hazard, which includes verification that the hazard has been disabled.
5. The LSO gives approval for the exception, with documented justification.

Exceptions must be documented in the lab-specific SOP or JSA.

## 2.2 Alignment Eyewear Requirements

For all routine laser operations and for most laser alignment procedures, *full protection eyewear* must be used. *Alignment eyewear*, defined as protective eyewear with reduced OD from full protection, may only be used for specific alignment procedures that have been appropriately evaluated, documented, and authorized. **Use of alignment eyewear is therefore a highly regulated and authorized activity.**

Laser safety training emphasizes the critical importance of wearing appropriate laser eyewear.

**Caution**

1. The most common scenario for laser accidents in a research and development environment involves not wearing adequate protective eyewear during alignment procedures.
2. While alignment eyewear and the associated procedures may be adequate for the diffuse reflection hazard, adequate consideration also needs to be given to possible unintended stray beams, which can be a greater hazard. The diffuse reflection irradiance hazard at 0.5 m viewing distance is typically a factor of 10,000 less hazardous than the direct beam hazard, but stray beams may be present at more hazardous levels (for example, partial transmission through dielectric mirrors or partial reflection from an uncoated optic).

All the following alignment eyewear requirements must be met:

- A technical note or JSA describing the alignment procedure must be approved by the LSO. It must include

  - Justification for why full protection eyewear cannot be utilized for completing the alignment task. Appropriate consideration must be given to using remote viewing with charged-couple device (CCD) cameras (or other electronic devices) to operate the laser at lower power and to use low power alignment lasers.
  - A schematic
  - Calculations specifying the required OD for the alignment eyewear. The minimum OD allowed will be determined by a calculation for diffuse viewing at 0.5 m. The laser operator should use the highest OD (up to the full protection OD) that will permit successful completion of the alignment task. For most alignment eyewear procedures, a reduction of OD1 or OD2 from full protection should be adequate.
  - A step-by-step procedure for the alignment that also details the hazard controls. Measures must be taken to ensure that no stray hazardous diffuse or specular reflections are present before the lower-OD alignment eyewear is worn. The procedure should avoid creation of new beam paths and insertion of material in or near the beam path when this eyewear is worn with the laser beam present. Appropriate *beam blocks* must be used. Appropriate consideration for satisfying *control of hazardous energy (CoHE)* requirements must also be given (see Laser Safety: Class 3B and Class 4 Laser CoHE Requirements).
  - Description of a NOTICE sign that must be placed at the LCA entry when this alignment procedure is in progress.

- Special alignment eyewear must be conspicuously labeled and stored separately from the other eyewear in the lab.
- QLOs wearing full protection eyewear are not allowed to perform laser/optics work when alignment eyewear is being worn by other laser personnel. Such QLOs may only observe or supervise work. Laser personnel not needed for the alignment eyewear procedures should not be present.
- Alignment eyewear may be permitted only for "visible" wavelengths; such wavelengths may be outside the ANSI Z136.1 visible range, defined as 400 to 700 nm. (More careful evaluation and justification will be needed for alignment eyewear at 750 to 800 nm than at 530 nm, however.)
- QLOs must receive special approval and receive appropriate *on-the-job training (OJT)* to use alignment eyewear. (An approval form template for this is available on the Laser Safety Program Site.)
- QLOs must use an alignment eyewear log to document each time an alignment procedure is carried out using alignment eyewear and which QLO performs the task. (A template for this is available on the Laser Safety Program Site).
- For laser *service* subcontractor work, the relevant JSA must identify if alignment eyewear will be worn during the service work. Service subcontractors must satisfy the same alignment eyewear requirements as QLOs. (See Laser Safety: Laser Service Subcontractor Work Planning and Control Procedure.)

The following are recommendations that should be implemented:

- A checklist should be used for performing alignment eyewear procedures.
- The procedure should allow only one QLO at a time to wear alignment eyewear. If the procedure may require more than one QLO to wear alignment eyewear, this must be stated and justified. Other QLOs present during the alignment procedure must wear full protection eyewear.
- Alignment eyewear should be worn for the minimum amount of time possible to safely complete the procedure. Full protection eyewear should be worn to the extent possible. Alignment work and

optimization should be attempted with full protection eyewear first and alignment eyewear worn only if needed.

- When alignment eyewear is worn, the beam power density should be reduced to the minimum needed to perform the task.

# 3 Forms

The following forms and systems are required by these requirements:

- Qualifier Laser Operator Approval for Alignment Eyewear Form (available on the Laser Safety Program Site [SharePoint])
- Alignment Eyewear Usage Log (available on the Laser Safety Program Site [SharePoint])

# 4 Recordkeeping

The following recordkeeping requirements apply for these requirements:

- The SLSO must maintain completed alignment eyewear forms and use logs in the laser facility's safety binder or SharePoint site.

# 5 References

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

- Chapter 10, "Laser Safety"
  - Laser Safety: Class 3B and Class 4 Laser Operation Requirements (SLAC-I-730-0A05S-004)
  - Laser Safety: Class 3B and Class 4 Laser CoHE Requirements (SLAC-I-730-0A05S-005)
  - Laser Safety: Laser Service Subcontractor Work Planning and Control Procedure (SLAC-I-730-0A05C-001)
  - Laser Safety Program Site (SharePoint)

Other Documents

- American National Standards Institute (ANSI) Z136.1, "Safe Use of Lasers" (ANSI Z136.1)

*Chapter 10: Laser Safety*

# Core Laser Safety Practices

Product ID: 548 | Revision ID: 2601 | Date published: 5 May 2023 | Date effective: 5 May 2023
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/laserReqCorePractices.pdf

## 1 Purpose

The purpose of these requirements is to avoid harmful exposure to lasers. They cover using Class 3B or Class 4 lasers. They apply to *qualified laser operators (QLOs)* and *laser controlled area (LCA) workers*.

## 2 Requirements

| Item | Requirement |
|---|---|
| 1 | ▪ Select proper eyewear; check condition before each use<br>▪ Ensure all personnel are wearing appropriate eyewear |
| 2 | ▪ Be knowledgeable of all safety controls and equipment safety features |
| 3 | ▪ Remove or cover jewelry, watches, et cetera if the objects may be near the beam path |
| 4 | ▪ **Communicate:** alert others prior to turning on laser, opening shutters, or creating new beam paths |
| 5 | ▪ Exclude unnecessary personnel during alignment |
| 6 | ▪ Have good diagnostics available for indirect viewing of the laser beam such as fluorescent cards, charged-couple device (CCD) cameras, or infrared (IR) viewers |
| 7 | ▪ Keep primary and stray beams in horizontal plane below eye level when possible<br>▪ Avoid bringing eyes near plane in which the laser propagates |
| 8 | ▪ Check for and block stray beams: when placing a new optical component in the beam, locate and block all stray reflections before proceeding to next step |
| 9 | ▪ Use beam blocks: block the beam upstream until beam is needed; place a block downbeam of optic path being aligned |
| 10 | ▪ Use special caution when using periscopes, beam-splitting polarizers, and other optics that may generate out-of-plane beams: secure appropriate beam blocks to contain possible stray beams |
| 11 | ▪ Use *Class 1 enclosures* to eliminate laser hazards when possible<br>▪ Use barriers, beam tubes, and table enclosures or side shields when possible |
| 12 | ▪ Use irises to aid in alignment |
| 13 | ▪ Use minimum intensity needed, and use low-power alignment lasers when possible |
| 14 | ▪ Secure all optics to table<br>▪ Practice good housekeeping |
| 15 | ▪ Perform *zero energy verification* when disabling a laser hazard such that laser eyewear can be removed, in accordance with the *standard operating procedure (SOP)* |

# 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: Class 3B and Class 4 Laser Operation Requirements (SLAC-I-730-0A05S-004)
  - Laser Safety: Class 3B and Class 4 Laser Eyewear Protection Requirements (SLAC-I-730-0A05S-007)
  - Laser Safety: Class 3B and Class 4 UV Laser Operation Requirements (SLAC-I-730-0A05S-012)

NATIONAL ACCELERATOR LABORATORY

ENVIRONMENT, SAFETY & HEALTH DIVISION

*Chapter 10: Laser Safety*

# Student Requirements

Product ID: 145 | Revision ID: 2602 | Date published: 5 May 2023 | Date effective: 5 May 2023
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/laserReqStudent.pdf

## 1 Purpose

The purpose of these requirements is to ensure the safety of students, secondary, undergraduate, and graduate, working with lasers at SLAC. They cover operating Class 3B and Class 4 lasers in SLAC laser facilities. They apply to students, the persons who supervise them, and *system laser safety officers (SLSOs)*.

## 2 Requirements

Recognizing that

1. Students are not SLAC employees
2. Students may be working at SLAC for a short period (for example, summer students)
3. Students require significant supervision and mentoring

SLAC requires that

1. Secondary school students and students under 18 will not be allowed to work with Class 3B or Class 4 lasers and cannot become *qualified laser operators (QLOs)* or *laser controlled area (LCA) workers*
2. Undergraduate students (for example, university and community college students) working at SLAC for less than 10 weeks may work with Class 3B and Class 4 lasers as QLOs only under direct supervision of an experienced QLO who is present in the laser facility. After 10 weeks of work at SLAC, such students may be evaluated and approved by the SLSO to work unsupervised in a facility with Class 3B and Class 4 lasers present. Undergraduate students may be approved as LCA workers following completion of on-the-job training.
3. Graduate students may be evaluated and approved by the SLSO after four weeks of supervised QLO work (rather than 10 weeks as described above) with Class 3B and Class 4 lasers to work unsupervised in a facility with these lasers present. Graduate students may be approved as LCA workers following completion of on-the-job training.

## 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: Class 3B and Class 4 Laser Operation Requirements (SLAC-I-730-0A05S-004)
  - Laser Safety: Laser Controlled Area Visitor Requirements (SLAC-I-730-0A05S-011)

*Chapter 10: Laser Safety*

# Laser Controlled Area Visitor Requirements

Product ID: 553 | Revision ID: 2603 | Date published: 5 May 2023 | Date effective: 5 May 2023
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/laserReqControlledAreaVisitor.pdf

## 1 Purpose

The purpose of these requirements is to ensure that visitors are aware of conditions under which they can enter a *laser controlled area (LCA)*, and that the LCA will be in a state of minimal hazard during the visit. They cover entering laser controlled areas. They apply to *qualified laser operators (QLOs)*, *laser controlled area workers (LCA workers)*, *laser controlled area visitors*, *system laser safety officers (SLSOs)*, and the *laser safety officer (LSO)*.

## 2 Requirements

*Laser controlled area visitors*, defined as personnel, not including service subcontractors or the laser safety officer (LSO), who have not been approved as a *qualified laser operator (QLO)* or *LCA worker* in a SLAC *laser facility*, may only be permitted access to an LCA if the following requirements are met, unless an exception is approved by the LSO. These conditions must be posted at the laser entry if a laser visitor is permitted in an LCA in Class 1 or Class 4 operation mode.

| Operation Mode | Requirements |
|---|---|
| Laser OFF | ▪ The SLSO or designee is responsible for ensuring that the LCA's lasers are not operating.<br>▪ Unescorted access is permitted. Laser eyewear protection is not required. |
| Class 1 | ▪ Visitors must be escorted by one of the facility's QLOs or LCA workers.<br>▪ Lasers may be operating but the laser beams are fully enclosed in approved Class 1 enclosures and there are no open beams. The escorting QLO or LCA worker is responsible for ensuring Class 1 laser conditions during the visit.<br>▪ Laser eyewear protection is not required. |
| Class 4 | ▪ **Visitor access is strongly discouraged** because high-power laser beams may be accessible. Access may, however, be permitted subject to the following conditions:<br>  ▪ Visitors must be 18 years of age or older.<br>  ▪ A QLO/LCA worker must escort the visitor at all times in the laser facility. **(Approval from the SLSO is required for LCA workers to escort visitors.)**<br>▪ Prior to entry, the visitor and QLO/LCA worker must discuss the visit's purpose, scope, and plan for a safe method of completing the task. WPC requirements must be followed. The QLO/LCA worker will explain relevant aspects of laser hazards and controls for the facility. This generally includes a restriction that no laser alignment takes place during the time the visitor is in the LCA.<br>  ▪ Prior to entry by the visitor, the QLO/LCA worker will check the laser facility to ensure the laser system is in and will stay in a state of minimal hazard during the visit. |

| Operation Mode | Requirements |
|---|---|
| | ▪ Prior to and during entry, the QLO/LCA worker ensures the visitor wears appropriate laser eyewear protection.<br>▪ Visitors are not allowed to operate or manipulate the laser beams or perform work on equipment associated with the *laser safety system*. |

# 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: Class 3B and Class 4 Laser Operation Requirements (SLAC-I-730-0A05S-004)
  - Laser Safety Program Site (SharePoint)

NATIONAL ACCELERATOR LABORATORY

ENVIRONMENT, SAFETY & HEALTH DIVISION

*Chapter 10: Laser Safety*

# Laser Service Subcontractor Work Planning and Control Procedure

Product ID: 483 | Revision ID: 2604 | Date published: 5 May 2023 | Date effective: 5 May 2023
URL: https://www-group.slac.stanford.edu/esh/eshmanual/references/laserProcedSubcontractor.pdf

## 1 Purpose

The purpose of this procedure is to ensure an equivalent level of safety requirements as called for by Chapter 2, "Work Planning and Control", and Chapter 42, "Subcontractor Safety", while accommodating the unique requirements of laser *service* subcontractor work. It covers work planning and control (WPC) for laser service subcontractor work on Class 3B and Class 4 laser systems. It applies to SLAC project managers, *laser facility program managers*, *system laser safety officers (SLSOs)*, buyers, ESH coordinators, the *laser safety officer (LSO)*, and subcontractors.

## 2 Procedures

The LSO reviews the work plans, provides safety oversight, and gives the final work release following a pre-job briefing. WPC for laser service subcontractor work has some differences compared to other high-hazard service work and does not utilize a service manager (SM), but it does utilize many of the same procedures and safety documents and forms, as referenced here.

| Step | Person | Action |
|---|---|---|
| 1. | Project manager | Submits purchase requisition for laser installation (may be part of a laser purchase) or laser maintenance/service, sends notification of purchase requisition to the SLAC LSO<br>The requisition will indicate sole source if applicable, give scope/statement of work, and note that on-site work will be done that requires<br>▪ Site-specific safety plan (SSSP) and *job safety analysis (JSA)* documents<br>▪ A description of laser safety training for subcontractor personnel<br>▪ Approval by the LSO<br>Completes the Subcontractor Safety: Work Classification Form, with assistance if necessary from an ESH coordinator<br>The project manager will be the SLAC point-of-contact (POC) for the subcontractor. |
| 2. | Buyer | Conducts procurement process, utilizing terms and conditions appropriate for on-site service work |
| 3. | Buyer | Awards contract to the selected service subcontractor |

| Step | Person | Action |
|---|---|---|
| 4. | Project manager | Consults with the LSO and starts to put together the required safety documentation in a WPC "red folder" (examples available on the Laser Safety Program Site)<br>At this stage<br>▪ Prepares the SSSP and an associated JSA. (Templates are available on the Laser Safety Program Site, under "Service Subcontractors".) The SSSP and JSA will generally reference the laser facility's SOP document and, if applicable, area hazard analysis; subcontractor personnel follow the same safety requirements as SLAC's qualified laser operators.<br>▪ Sends the SSSP and JSA to the subcontractor for review and for subcontractor to make any needed updates or changes; sends copies to the LSO |
| 5. | Subcontractor | Signs the SSSP and sends it to the buyer and/or the project manager |
| 6. | Project manager | Obtains the necessary signatures for the SSSP, including from the LSO and the SLSO, then submits signed SSSP to the buyer and requests a notice to proceed (NTP) |
| 7. | Buyer | Issues NTP to subcontractor |
| 8. | Project manager | Completes a work integration plan (WIP) document (template available on the Laser Safety Program Site, under "Service Subcontractors"), notifying the ESH coordinator and laser facility program manager of the service work planned |
| 9. | Laser facility program manager | Signs initial release for the work on the WIP |
| 10. | Project manager, subcontractor | Complete site access requirements for badging and training |
| 11. | Project manager, SLSO, LSO, and subcontractor | Pre-job briefing held<br>JSA is updated as needed and then signed by all personnel<br>Pre-job review document is completed and signed by all personnel (template available on the Laser Safety Program Site, under "Service Subcontractors"<br>SLSO signs JSA indicating authorization for the work<br>LSO gives final release as indicated on the WIP document |
| 12. | Subcontractor | Performs work under supervision of project manager<br>Keeps red folder with all the safety documentation available at the job site |
| 13. | LSO | Performs periodic inspections of the work |
| 14. | Project manager | Provides update status to LSO at the end of each day until the work is completed<br>Notifies LSO when any changes may be needed to the JSA (if changes are needed, these require signature approvals, re-authorization by SLSO, and re-release by LSO) |
| 15. | Project manager | Notifies LSO when work is complete |
| 16. | SLSO | Retains appropriate documentation for laser service work in the Laser System Safety Binder |
| 17. | LSO | Updates the spreadsheet summary of laser service work |

# 3 Forms

The following forms and systems are required by this procedure:

- Laser site-specific safety plan (SSSP), job safety analysis (JSA), work integration plan (WIP), and pre-job review templates (available from the Laser Safety Program Site [SharePoint], under "Service Subcontractors")
- Subcontractor Safety: Work Classification Form (SharePoint). Form for documenting classification of project as green or non-green work, and for non-green, initial ESH assessment
- Laser Service Subcontractor Log. Spreadsheet summary of completed laser service work (available from the Laser Safety Program Site [SharePoint], under "Service Subcontractors")

# 4 Recordkeeping

The following recordkeeping requirements apply for this procedure:

- The SLSO retains appropriate documentation for laser service work in the laser facility's safety binder or SharePoint site
- The LSO updates the Laser Service Subcontractor Log of laser service work when the work is complete

# 5 References

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

- Chapter 10, "Laser Safety"
  - Laser Safety Program Site (SharePoint)
- Chapter 2, "Work Planning and Control"
  - Work Planning and Control (includes forms and online tools)
- Chapter 42, "Subcontractor Safety"
- Chapter 55, "Site Access Control"
  - Site Access Control: Site Access by Individual and Area (SLAC-I-720-0A00S-002)