

STANFORD UNIVERSITY LASER SAFETY MANUAL

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1.0 INTRODUCTION

“Stanford University makes all reasonable efforts to:

1. Protect the health and safety of Stanford University faculty, staff, and students.
2. Provide safe work practices - academic, research, and administrative - for faculty, staff and students.
3. Provide information to faculty, staff, and students about health and safety hazards.
4. Identify and correct health and safety hazards and encourage faculty, staff, and students to report hazards.
5. Provide information and safeguards for those on campus and in the surrounding community regarding environmental hazards arising from operations at Stanford University.”¹

To help fulfill this University policy the Laser Safety Program has been developed to provide guidance for the safe use of lasers and laser systems. Program and recommendations are based upon The American National Standards Institute (ANSI) Z136.1-2000 Standard for Safe Use of Lasers.

NOTE: This written program supercedes the 1990 Laser Safety Policies and Procedures Manual.

2.0 RESPONSIBILITIES

2.1 Laser Safety Committee

- 1) Laser safety policy development and oversight
- 2) Oversight of laser safety program

2.2 Laser Safety Officer (LSO)

- 1) Program development and implementation
- 2) Approve Standard Operating Procedures (SOPs), alignment procedures and other procedures that may be subject to administrative and procedural controls
- 3) Conduct Hazard Evaluations for each Class 3b and Class 4 laser
- 4) Classify constructed or modified lasers and laser systems
- 5) Provide laser safety training
- 6) Provide ANSI approved warnings signs and labels
- 7) Periodically audit laser use facilities
- 8) Investigate laser accidents
- 9) Maintain inventory of Class 3b and Class 4 lasers and laser systems, assign a Controlled Laser Authorization (CLA) number for each PI for use of laser and laser system in their laboratory.

¹ Health and Safety at Stanford University - Principles, Responsibilities, and Practices (Adopted by Stanford University Cabinet, April 1991).

2.3 Departments

2.3.1 Supervisors/ Principal Investigators (PI):

- 1) Submit a Registration Form to the LSO for each Class 3b and Class 4 laser or laser system using form in [Appendix B](#)
- 2) Identify laser hazards present in the work area, implement appropriate hazard controls (including ANIS approved signs and labels) and correct any identified unsafe conditions
- 3) Develop and submit to the LSO the current Standard Operating Procedures (SOPs) for each Class 3b and Class 4 laser or laser system using form in [Appendix A](#)
- 4) Identify all authorized personnel who are eligible to operate or maintain a Class 3b or Class 4 laser or laser system
- 5) Provide job specific Tier III training for each laser user (including physical hazards, health hazards, and emergency procedures)
- 6) Conduct annual self-inspection of lasers and laser use area using form in [Appendix C](#)
- 7) Designate a Laser Safety Contact (LSC)
- 8) Ensure that laser users follow established safety procedures
- 9) Keep copies of all current SOPs, trainings, and inspections/investigations
- 10) Maintain a copy of this written program in the workplace

2.3.2 Laser User:

- 1) Know the hazards and the precautionary procedures for laser use in their work area
- 2) Attend required training(s)
- 3) Plan and conduct operations in accordance with established procedures and good safety practices
- 4) Use personal protective equipment in accordance with prescribed training

3.0 LASER CLASSIFICATION

Lasers are divided into a number of classes depending upon the power or energy of the beam and the wavelength of the emitted radiation. Laser classification is based on the laser's potential for causing immediate injury to the eye or skin and/or potential for causing fires from direct exposure to the beam or from reflections from diffuse reflective surfaces. A qualitative description of laser classes can be found below (ANSI Z136.1-2007).

A Class 1 laser system is:

- Considered to be capable of producing exposure conditions during normal operation unless the beam is viewed with an optical instrument such as an eye-loupe (diverging beam) or a telescope (collimated beam), and

- Exempt from and control measures other than to prevent potentially hazardous optically aided viewing; and is exempt from other forms of surveillance.

A Class 2 laser system:

- Emits radiation in the visible portion of the spectrum (0.4 to 0.7 μm), and
- Eye protection is normally afforded by the aversion response.

A Class 2M laser system:

- Emits in the visible portion of the spectrum (0.4 to 0.7 μm), and
- Eye protection is normally afforded by the aversion response for unaided viewing.
- However, Class 2 M is potentially hazardous if viewed with certain optical aids.

A Class 3 laser system (medium power):

- May be hazardous under direct and specular reflection viewing conditions, but is normally not a diffuse reflection or fire hazard.

There are two subclasses:

- A Class 3R laser system is potentially hazardous under some direct and specular reflection viewing condition if the eye is appropriately focused and stable, but the probability of an actual injury is small. This laser will not post either fire hazard or diffuse-reflection hazard.
- A Class 3B laser system may be hazardous under direct and specular reflection viewing conditions, but is normally not a diffuse reflection or fire hazard.

Note: For lasers classified as Class IIIa see Appendix H for guidance.

A Class 4 laser system (high power):

- Is a hazard to the eye or skin from the direct beam, and
- May pose a diffuse reflection or fire hazard
- May also produce laser generated air contaminants (LGAC) and hazardous plasma radiation.

Commercially produced lasers are classified according to the CDRH Federal Standard (FLPPS, 21 CFR 1040) and identified by labels affixed to the laser. **Removal of protective housing or system modification can increase a laser's classification. Contact the LSO for review prior to servicing or system modification.**

4.0 LASER ACQUISITION, TRANSFER AND DISPOSAL

4.1 Acquisition

The PI/LSC must notify the LSO of all Class 3b or Class 4 lasers/laser systems by submitting a Laser Registration form for each laser/laser system to the LSO. A form must be re-submitted when significant modifications are made to the original laser/laser system. The LSO will conduct a hazard evaluation of the laser work area and make necessary recommendations.

Each officially registered laser or laser system will be provided a CLA number and a laser identification tag. The laser identification tag must be placed on laser or laser system by the PI/LSC. Information on the laser identification tag will include:

- 1) The inventory number
- 2) The serial number and location of the laser or laser system
- 3) The contact name (PI/LSC)

4.2 Transfer

The LSO must be notified when a Class 3b or 4 laser is transferred from the jurisdiction of one PI to another PI on-campus. The new PI/LSC must complete a Laser Registration form. A new laser identification tag will be provided. The LSO must also be notified if the laser is transferred off-campus.

4.3 Disposal

The LSO must be notified when a Class 3b or 4 laser is sold or disposed of and will coordinate with the Hazardous Waste Program, as appropriate.

5.0 CONTROL MEASURES

5.1 Class 1, 2, & 3a Laser Systems

When used as intended Class 1, 2, and 3a laser systems are generally low hazard devices; however some requirements still apply.

1. As with any piece of equipment PIs/LSC are responsible for ensuring training on proper use of that equipment.
2. Exposure to laser radiation must be kept below the Maximum Permissible Exposure (MPE) under all conditions of operation or maintenance. See [Appendix G](#) for Definitions.
3. Laser systems must have the appropriate warning labels with the laser sunburst logotype symbol and the appropriate cautionary statement. See Section 7.0.
4. Removal of protective housing or system modification can increase a laser's classification. Contact the LSO for review prior to servicing or system modification.
5. Use of class 3a laser with telescopes, microscopes, or alignment devices should be reviewed by the LSO prior to operation.

5.2 Class 3b and Class 4 Laser Systems

5.2.1 Control Area Requirements

A laser hazard analysis, including determination of the MPE and Nominal Hazard Zone (NHZ), must be made by the LSO. If it is determined that the classification associated with the maximum level of accessible radiation is Class 3b or 4, a

laser-controlled area is established and control measures instituted. Control measures are only required within the NHZ.

5.2.1.1 Class 3b Control Areas

1. Must be controlled to permit lasers and laser systems to be operated only by authorized personnel.
2. Must be posted with the appropriate warning sign(s). See Section 7.0.
3. All area or entryway safety controls must be designed to allow rapid egress by laser personnel and admittance to the laser controlled area under emergency conditions.
4. Must be operated in a manner such that the laser beam path is well defined and projects into a controlled airspace when the laser beam must extend beyond an indoor controlled area, particularly to the outdoors under adverse atmospheric conditions, i.e. rain, fog, snow, etc.
5. Must be under the direct supervision of an individual knowledgeable in laser safety.
6. Must have all windows, doorways, open portals, etc. either covered or restricted in such a manner as to reduce the transmitted laser radiation to levels at or below the applicable ocular MPE.
7. Must have only diffusely reflecting materials in or near the beam path where possible.
8. Must have appropriate personal protective equipment readily available (i.e., eye protection).

5.2.1.2 Class 4 Control Areas

Class 4 laser control areas **must incorporate all Class 3b control measures, plus the following:**

1. Control area interlocks or alternate controls to preclude the entry of unprotected personnel while Class 4 laser radiation is present in the control area. The interlock system may be designed to preclude entry while the laser is operating or to terminate laser operation when the door is opened without deliberate overriding of the interlock by a trained laser user.

or

- (a) Blocking barrier, screen, curtains, etc. must be used to block, screen, or attenuate the laser radiation levels so that the MPE is not exceeded at the entry point.
- (b) At the entryway there must be a visible or audible signal indicating that the laser is energized and operating at Class 4 levels. A lighted laser warning sign or flashing light (visible through protective eyewear) are acceptable entryway warning light alternatives.

- (c) Personnel trained on entryway procedures and adequate personal protective equipment provided upon entry.

5.2.2 Engineering Controls

The engineering control measures required for Class 3b and 4 lasers are listed below. Where specific engineering controls are infeasible they may be replaced with specific administrative and procedural controls and personal protective equipment (PPE) with prior review by the LSO. Alternative controls and PPE requirements must be documented in a written SOP. See Appendix G for additional explanation of each feature.

| Engineering Controls ✓ Required + Recommended | Laser Class | |
|--|--------------------|---|
| | 3b | 4 |
| Protective Housing – for active laser work with housing off, contact LSO for hazard analysis and appropriate controls | ✓ | ✓ |
| Interlocks on Protective Housing | ✓ | ✓ |
| Service Access Panels Interlocked or tool required and appropriate warning label on the panel | ✓ | ✓ |
| Key Control | + | ✓ |
| Remote Interlock Connector | + | ✓ |
| Beam stop or Attenuator | + | ✓ |
| Laser Activation Warning System | + | ✓ |
| Emission Delay | | ✓ |
| Remote Firing and Monitoring | | + |
| Panic Button | | ✓ |
| Viewing windows, diffuse display screens, or collecting optics (lenses, microscopes, etc.) are controlled with interlocks, filters, or attenuators to maintain laser radiation at the viewing position at or below the applicable MPE. | ✓ | ✓ |
| Enclosed Beam Path | + | + |

5.2.3 Administrative and Procedural Controls

Administrative and procedural controls are methods or instructions that specify rules, or work practices, or both, which implement or supplement engineering controls. Necessary administrative and procedural controls for 3b and 4 laser and laser systems include, but are not limited to:

1. Standard Operating Procedures (SOPs) – written laser specific SOPs should be developed for Class 3b lasers and laser systems. Written SOPs are required for Class 4 lasers and must include procedures for operation, maintenance, and other relevant safety considerations.

2. Authorized Personnel – PI/LSC must identify authorized personnel and ensure that those personnel are the only ones that operate maintain, or service a Class 3b or 4 laser or laser system. See Section 8 for training requirements.
3. Alignment Procedures – ensure SOPs specify alignment procedures. See [Appendix D](#) for alignment guidelines.
4. Use minimum laser radiation required for the application. If necessary, the LSO may require the reduction of levels of accessible power or radiant energy during the operation or maintenance of a Class 3b or Class 4 laser system.
5. Lasers or laser systems must have the appropriate warning labels. See Section 7.0 for warning label requirements.
6. Maintain beam height at a level other than the normal position of the eye of a person in the standing or seated position.

6.0 PROTECTIVE EQUIPMENT

Personal protective equipment may have serious limitations and must be used only in conjunction with engineering and administrative controls, when working with Class 3b and Class 4 lasers and laser systems.

6.1 Personal Protective Equipment

6.1.1 Eye Protection

Appropriate eye protection devices must be worn when working with Class 3b and Class 4 lasers or laser systems. Laser protective eyewear is usually not required for Class 2 or Class 3a lasers or laser systems, except in conditions where intentional long-term (>0.25 seconds) direct viewing is required. Eyewear must be specifically selected to withstand either direct or diffusely scattered beams and shall meet all provisions of ANSI Z87.1-1989. (4.6.2.3) Refer to [Appendix E](#) for Eyewear Selection Chart.

Eyewear must be inspected before each use, and replaced if necessary, to maintain the eyewear in good condition. Contact the LSO for assistance in selecting protective eyewear.

Factors in selecting appropriate eyewear:

- 1) Laser power and /or pulse energy
- 2) Wavelength(s) of laser output
- 3) Potential for multi-wavelength operation
- 4) Radiant exposure or irradiance levels for which protection (worst case) is required
- 5) Exposure time criteria
- 6) Maximum permissible exposure
- 7) Optical density requirement of eyewear filters at laser output wavelength

- 8) Angular dependence of protection afforded
- 9) Visible light transmission requirement and assessment of the effect of the eyewear on the ability to perform tasks while wearing the eyewear
- 10) Need for side-shield protection and maximum peripheral vision requirement
- 11) Radiant exposure or irradiance and the corresponding time factors at which laser safety filter characteristics change occurs, including transient bleaching especially for ultra short pulse lengths
- 12) Need for prescription glasses
- 13) Comfort and fit
- 14) Degradation of filter media, such as photo bleaching
- 15) Strength of materials (resistance to mechanical trauma and shock)
- 16) Capability of the front surface to produce a hazardous specular reflection
- 17) Requirement for anti-fogging design or coatings

6.1.2 Skin Protection

Skin protection can best be achieved through engineering controls. If potential skin damaging exposures exist, skin covers and or “sun screen” creams are recommended.

Minimize exposure to UV radiation by using beam shields and clothing (opaque gloves, tightly woven fabrics, laboratory jacket or coat) which attenuate the radiation to levels below the MPE for specific UV wavelengths. Consider flame-retardant materials for Class 4 lasers

Special attention must be given to the possibility of producing undesirable reactions in the presence of UV radiation (formation of skin sensitizing agents, ozone, etc.).

6.2 Facility Window Protection

Exterior or interior windows that are located within the NHZ of a Class 3b or Class 4 laser or laser system must be provided with appropriate absorbing filter, scattering filter, blocking barrier or screen to reduce any transmitted laser radiation to levels below the applicable MPE level. Important factors for selection include: ability to withstand direct and diffusely scattered beams, flammability and decomposition products of the window material.

6.3 Laser Protective Barriers and Curtains

A blocking barrier, screen or curtain which can block or filter the laser beam at the entryway should be used inside the controlled area to prevent Class 3b or Class 4 laser light from exiting the area at levels above the applicable MPE level. Important factors for selection include: ability to withstand direct and diffusely scattered beams, flammability and decomposition products of the protective barrier or curtain.

7.0 WARNING SIGNS AND EQUIPMENT LABELS

ANSI/IEC approved signs and labels are provided by the LSO and must be conspicuously displayed in locations where they best serve to warn onlookers. Personnel who do not read/understand the English language and who may need to enter areas where lasers are used, must be provided appropriate instructions as to the meaning of warning signs and labels. The PI/LSC is responsible for identifying and training such personnel.

7.1 Warning Signs

Laser controlled areas must be posted with the appropriate warning signs at the entryway(s) and if necessary, within the laser controlled area.

- **Danger:** Must be used with all signs and labels associated with all Class 3a lasers and laser systems that exceed the appropriate MPE for irradiance, and all Class 3b and Class 4 lasers and laser systems.
- **Caution:** Must be used with all signs and labels associated with Class 2 lasers and laser systems, and all Class 3a lasers and laser systems that do not exceed the appropriate MPE for irradiance.
- **Notice:** Must be used on signs posted outside a temporary laser controlled area. The area within the temporary controlled area must also have appropriate signs posted (danger warning for Class 3b or Class 4).

7.2 Equipment Label

All lasers or laser systems (except Class 1) must have appropriate warning labels affixed to a conspicuous place on both the housing and the control panel (if separated by more than 2 meters).

Class 2 lasers and laser systems, “Laser Radiation – Do Not Stare into Beam”

Class 3a lasers and laser systems (accessible irradiance does not exceed MPE based upon 0.25 second exposure for wavelengths between 0.4 and 0.7 μm), “Laser Radiation – Do Not Stare into Beam or View Directly with Optical Instruments”

All other Class 3a lasers or laser systems, “Laser Radiation – Avoid Direct Eye Exposure”

Class 3b lasers or laser systems, “Laser Radiation – Avoid Direct Exposure to Beam”

Class 4 lasers or laser systems, “Laser Radiation – Avoid Eye or Skin Exposure to Direct or Scattered Radiation”

7.3 Labeling of Protective Equipment

7.3.1 Labeling of Protective Eyewear

All eyewear must be clearly labeled with the optical density and wavelength. Color-coding or other distinctive identification is recommended in multi-laser environments.

7.3.2 Labeling of Laser Protective Windows and Collecting Optic Filters

All laser protective windows must be labeled with the optical density and wavelength(s) for which protection is afforded, and should be labeled with the threshold limit and exposure time for which the limit applies, and the conditions under which protection is afforded.

7.3.3 Labeling of Laser Protective Barriers

All laser protective barriers must be labeled with the barrier threshold limit and exposure time for which the limit applies, and beam exposure conditions under which protection is afforded. Contact LSO for any assistance.

8.0 TRAINING

PIs/LSC are responsible for ensuring that staff and students receive appropriate training on the hazards in their work area and that documentation of that training is maintained. Before operating a Class 3b or Class 4 laser or laser system, all users must:

- 1) Read the Laser Safety Program,
- 2) Receive laser safety training from EH&S (Contact LSO)
- 3) Receive laboratory-specific safety training (including a thorough review of the laser equipment, administrative and engineering controls, and alignment and standard operating procedures) from the LSC or PI, and
- 4) Read and sign a copy of the applicable SOPs.

Laser users must be re-trained whenever a new hazard is introduced into the work area.

9.0 MEDICAL SURVEILLANCE

To communicate pre-placement ophthalmologic exams available to laser users, contact Stanford University Occupational Health Center at 725-5308 to schedule an appointment for individuals who may be exposed to Class 3b or Class 4 radiation. Refer to EH&S Medical Surveillance for more information.

Eye exams must be performed after a suspected eye injury (see Section 12.0- Laser Accidents).

10.0 NON-BEAM HAZARDS

Non-beam hazards often exist in laser-related operations and can pose significant health and safety risks. In addition to being evaluated by EH&S, non-beam hazards must be adequately addressed in SOPs where applicable ([Refer to Appendix F](#)).

11.0 SPECIAL CONSIDERATIONS

11.1 Service of Embedded Class 3b or Class 4 Lasers

Access to Class 3b or Class 4 lasers or laser systems enclosed within a protective housing or protected area enclosure is limited to properly trained individuals and by specific engineering and administrative controls. Contact LSO for more information.

11.2 Outdoor Control Measures

Projection of Class 3a, 3b, or 4 lasers beams in the outside environment requires prior review by the LSO. Contact LSO for additional information.

11.3 Additional Laser Uses

Lasers may also be used in optical fiber transmission systems and robotic installations. Contact the LSO for more information regarding applicable control measures.

12.0 LASER ACCIDENTS

12.1 Response/Reporting Procedures

All accidents/exposures are to be reported to supervisor as soon as possible.

12.1.1 Serious Injury/Illness

For health-threatening injuries/illnesses, call x9-911 or proceed immediately to the Stanford Hospital Emergency Department

Supervisor is to **immediately** contact EH&S @ 725-9999 to report deaths, or serious injury or illness.

Cal/OSHA defines an injury or illness as “serious” if it:

- Requires inpatient hospitalization for a period in excess of 24 hours for other than medical observation; or
- An employee suffers a loss of any member of the body; or
- An employee suffers any serious degree of permanent disfigurement.

12.1.2 All Other Injuries

For treatment of all other injuries, proceed to:

- For Students, **Vaden Student Health Service** (866 Campus Dr., x8-2336)

- For Employees, **Alliance Occupational Medicine** (2737 Walsh Ave., Santa Clara, (408) 228-8400 and 315 S. Abbott Ave., Milpitas, (408) 790-2900), and **US Health Works** (201 Arch St., Redwood City, 556-9420) http://www.stanford.edu/dept/Risk-Management/docs/su_occupational_med_pro.doc

12.1.3 Standardized Forms for Accident/Exposures

- Supervisors are to provide Employee's Claim for Workers' Compensation Benefits (Form DWC-1) to injured employee immediately. Supervisors and employees are to complete within 24 hours.
- The SU-17 Accident, Incident or Exposure Report (for all incidents/injuries/exposures) has two sections: one for the supervisor and one for the employee to complete. To be completed within 24 hours and sent to Risk Management.
- Cal-OSHA 5020 to be completed (typed) within 24 hours by the supervisor (for cases when one or more workday is lost by an employee or when treatment of the employee is required by a physician in a medical facility).
- SU-16 Workers' Compensation Lost Workdays Report is completed by the supervisor when an employee has one or more workdays lost.
- All forms are available from the Stanford University Office of Risk Management.

12.1 Accident Investigation

Upon notification of an accident, LSO will conduct an investigation. Steps of the investigation include:

- 1) LSO interviews injured workers and witnesses
- 2) LSO examines workplace for factors associated with the accident/exposure
- 3) LSO determines the possible causes of the accident/exposure
- 4) Supervisor takes corrective action to prevent the accident/exposure from recurring
- 5) Supervisor records the findings and corrective actions taken

13.0 RECORD-KEEPING

The PI/LSC is responsible for maintaining all laser safety-related records (i.e., laser safety training, SOPs, inspections/ audits, medical surveillance) for each employee for a minimum of one year [per Cal/OSHA, Title 8 CCR 3203 (b)]. For general purposes, recommend records be maintained as long as the employee works with that laser or laser system.