## Table of Contents

Introduction ......................................................................................................................... 2

**Section 1: Organization and Responsibilities** ...................................................................... 3

- 1.1 Chancellor ......................................................................................................................... 3
- 1.2 Laser Safety Committee .................................................................................................... 3
- 1.3 Environment, Health and Safety ....................................................................................... 3
- 1.4 Laser Safety Officer .......................................................................................................... 3
- 1.5 Departmental Chairs ......................................................................................................... 4
- 1.6 Principal Investigator ........................................................................................................ 4
- 1.7 Individual Users ................................................................................................................ 5
- 1.8 Purchasing ........................................................................................................................ 5
- 1.9 Medical Surveillance ........................................................................................................ 5
- 1.10 Laser Use Authorization (LUA) ...................................................................................... 6
- 1.11 Audits ............................................................................................................................. 7
- 1.12 Equipment Forms .......................................................................................................... 7

**Section 2: Laser Hazard Control Measures** ...................................................................... 8

- 2.1 General Considerations ..................................................................................................... 8
- 2.2 Control Measures .............................................................................................................. 8
- 2.3 Engineering Controls ....................................................................................................... 8
  - Protective Housing .............................................................................................................. 8
  - Interlocks on Protective Housing ....................................................................................... 8
  - Service Access Panel .......................................................................................................... 9
  - Key Control ........................................................................................................................ 9
  - Viewing Portals .................................................................................................................. 9
  - Collecting Optics .................................................................................................................. 9
  - Totally Open and Limited Open Beam Path ......................................................................... 9
  - Remote Interlock Connector ............................................................................................... 9
  - Beam Stop or Attenuator ...................................................................................................... 9
  - Activation Warning System ................................................................................................ 9
  - Emission Delay .................................................................................................................... 10
  - Indoor Laser Controlled Area ............................................................................................. 10
  - Class 3b Indoor Laser Controlled Area .............................................................................. 10
  - Class 4 Indoor Laser Controlled Area .................................................................................. 10
  - All Outdoor Laser Controlled Area .................................................................................... 11
- 2.4 Administrative and Procedural Controls ....................................................................... 11
  - Standard Operating Procedural Controls ......................................................................... 11
  - Output Emission Limitations ............................................................................................... 12
  - Education and Training ....................................................................................................... 12
  - Authorized Personnel ......................................................................................................... 12
  - Alignment Procedures ........................................................................................................ 12
  - Protective Equipment ......................................................................................................... 12
  - Spectators .......................................................................................................................... 13
  - Service Personnel .............................................................................................................. 13
  - Laser Optical Fiber ............................................................................................................. 13
  - Protective Windows ............................................................................................................ 13
  - Protective Barriers and Curtains .......................................................................................... 14
  - Other Protective Equipment ............................................................................................... 14
  - Warning Signs, Labels, and Postings .................................................................................. 14
Introduction

This Laser Safety Manual describes UCSD’s laser safety program and provides guidance for the safe use of lasers and laser systems. The safe use of lasers is readily achieved by following nationally recognized standards, provided in the American National Standard for the Safe Use of Lasers (ANSI Z136.1 – 2000). These standards are outlined and expanded upon in this manual.

In addition, this manual also describes the roles and responsibilities of the Chancellor, Laser Safety Committee, EH&S, and authorized laser users in terms of operating lasers or laser systems safely at UCSD. This manual should be available for reference by all laser users. It is the responsibility of the Principle Investigator to maintain this manual for reference purposes. All persons using lasers shall be familiar and comply with all requirements of this manual.
Section 1: Organization and Responsibilities

1.1 Chancellor

The Chancellor is responsible for the existence of a laser safety program and ensures that all lasers are used in accordance with UCSD policies and the American National Standards Institute (ANSI).

The Chancellor is empowered to and has delegated his responsibility for the laser safety program to the Laser Safety Committee (LSC), departments and individuals as follows:

1.2 Laser Safety Committee

The Laser Safety Committee advises the Chancellor of the University, through the Vice Chancellor or Business Affairs on all matters related to laser safety. The Committee recommends such policies and procedures as it may deem appropriate to ensure an adequate laser safety program.

Organization of the LSC

The LSC consists of at least six members appointed by the Chancellor, and a Laser Safety Officer (LSO) experienced in the safe practice of laser use.

Activities of the Committee are directed by its Chair. The Chair of the LSC shall be a member of the Academic Senate. The Chair shall convene the Committee as often as is necessary to consider all aspects pertinent to laser safety. A quorum shall consist of at least three members, including the Chair and LSO.

The LSC shall be the ultimate reviewing and authorizing agent for the use of all lasers. It shall set policies and establish the rules and regulations to be monitored by the LSO. It shall receive and review all pertinent reports and records of Environment, Health and Safety (EH&S) and shall keep and maintain a record of all its transaction and meetings. The LSC shall consider the liabilities of the University in all hazardous activities involving lasers.

1.3 Environment, Health and Safety

Environment, Health and Safety is responsible for the surveillance of laser usage and shall provide consultation, laser safety services and guidance in conformance with policies and standards set forth in this manual, governmental regulations and national laser safety standards.

EH&S is also responsible for the review of University policies on laser safety and for informing the Chancellor and the Laser Safety Committee on matters related to laser safety.

1.4 Laser Safety Officer

The Laser Safety Officer is responsible for operation of the laser safety program, for assuring that use of lasers is in conformance with the University policies applicable with
the national standards, and referring issues to the LSC for its review and approval. The LSO is a member of the LSC.

The LSO’s responsibilities include:

- Providing knowledgeable consultation and evaluation of laser hazards, and approving written Laser Safety Procedures (LSP’s) or Standard Operating Procedures (SOP’s).
- The authority (in consultation with the LSC) to suspend, restrict or terminate the operation of a laser system if he/she considers the laser hazard controls inadequate.
- Ensuring maintenance of the necessary records, including medical surveillance records, required by applicable government standards.
- Classifying or verifying the classification of lasers or modified laser systems.
- Recommending or approving laser protective equipment such as eyewear and warning signs.
- Inspecting and auditing; teaching and research set-ups involving the user of lasers as frequently as deemed necessary, but not less than annually.
- The LSO shall ensure that adequate safety training is provided to staff, students and others using Class 3b and Class 4 lasers and lasers system. The LSO shall maintain records for each person, indicating that appropriate training has been provided.
- Investigating any real or suspected accidents or incidents resulting from laser operation, and initiate appropriate action(s).

1.5 Departmental Chairs

Department Chairs are responsible for the review and approval of proposed uses of lasers within their jurisdiction. Such approval signifies that the department will assist in the enforcement of pertinent University and governmental standards and regulations.

1.6 Principal Investigator

The principal investigator (PI) is responsible for compliance with UCSD and national standards as they pertain to his/her authorized use of lasers or any use under his/her supervision. Specific responsibilities include:

- Laser specific training - the PI shall provide or arrange for appropriate instructions on safety and hazards control to all personnel scheduled to work with lasers under his/her supervision. This instruction shall include making personnel and visitors familiar with laboratory safety policy, the relevant sections of the appropriate ANSI standards, and the LSP/SOP for each laser system to be used. This instruction shall be documented and maintained by the PI, with a copy to the LSO.
- He/she shall prepare a written LSP/SOP, including all pertinent information relating to his/her laser equipment uses and safety measures, and make it available to the LSO for review and approval.
- Ensure that only procedures outlined in a LSP/SOP, and approved by the LSO are carried out.
- He/she shall notify the LSO of plans for the modification of a laser system, which could result in additional laser hazards.
The LSO must be notified in writing when a PI takes an extended leave of his responsibilities for lasers under his/her control (such as a sabbatical). This notification should also designate an alternate person responsible for all laser use operations in his/her absence. The PI also has the option to appoint a full time lab manager for the laser system(s), which shall be the person of contact for the LSO.

The PI shall insure that personnel using Class 3b and Class 4 lasers undergo an eye examination, meeting protocol outlined in ANSI Z136.1-2000 at the following times as described in Section I, Part 1.9.
1. Prior to initial participation in laser work.
2. After completion of laser work or upon leaving UCSD.
3. Immediately after a suspected laser eye injury.

Conduct periodic surveys of authorized work places to assure compliance with LSP guideline and general safety requirements.

At no time permit the operation of a laser unless there is adequate control of laser hazards to researchers, visitors, and others.

Ensure that all visitors have received appropriate instruction in laser safety, and have been issued appropriate protective equipment.

Ensure that all maintenance and repair work is performed by a certified, trained individual.

When a PI knows of or suspects an accident resulting from a laser operated under his/her supervision has occurred, he/she shall discontinue the laser operation, making sure that the laser is off, notify the LSO immediately and assist in obtaining appropriate medical attention for the person involved. He/she shall also preserve the scene of the accident (see section 2.4, Emergency Procedures).

1.7 Individual Users

All authorized laser users have the responsibility to:

- Comply with written LSP/SOP and safety guidelines, i.e., use of recommended protective equipment.
- Maintain proper “housekeeping” habits in the laboratory in order to prevent potential accidents.
- Immediately report the details of any accidents involving lasers to the PI and the LSO.
- Comply with all laboratory safety requirements stipulated by the PI responsible for laser use.

1.8 Purchasing

The Purchasing Department shall notify the Laser Safety Officer, EH&S, of all laser purchase requests via a copy of the original requisition form or express card invoice, excluding laser printers bar code readers, and laser pointers.

1.9 Medical Surveillance

Medical surveillance is required for individuals using Class 3b, and Class 4 laser systems to provide a baseline against which damage (primarily ocular) can be measured in the event of an accidental injury, and identifies certain individuals who
might be at special risk from chronic exposure to selected continuous-wave lasers. Visiting scientists or other visitors will be required to comply with the medical surveillance requirements if their use of lasers is to exceed two weeks at UCSD facilities. Termination medical examinations shall be performed prior to exiting the university.

Laser operators of Class 3b, and Class 4 laser systems should have at least, at a minimum, a baseline examination of the following, as specified in ANSI Z136.1:

- Ocular history
- Visual acuity
- Macular function
- Color vision
- Ocular Fundus with an Ophthalmoscope
- Skin

The eye examinations above can be done at the Shiley Eye Center by contacting (858) 534-6290 for an appointment. The PI is responsible for all costs associated with medical surveillance.

Any individual with a known or suspected eye injury shall be immediately referred to an ophthalmologist. Individuals with skin injuries shall promptly be seen by a physician. It is the PI’s responsibility to contact Occupational Health, (619) 294-6206, in an event of an incident.

Copies of all medical records, including specific test results, must be provided to EH&S and should be retained for at least 30 years.

1.10 Laser Use Authorization (LUA)

Each Principal Investigator (PI) will submit a Laser Use Authorization (LUA) Application form to EH&S, after approval by the Department Chair, or equivalent. All personnel working under the proposed LUA must submit a Laser Use Enrollment form. The LUA may be amended subsequent to its initial approval.

LUA will be due for renewal one year after its initial approval. Renewals will be approved by the Department Chair (or equivalent), the LSC Chair, and the LSO. Part of the renewal process will be a review of laboratory specific issues and audit results will be discussed with the PI and all authorized users.

An LUA may remain active during sabbatical leave of the PI as long as an authorized user is designated as the laboratory contact.

An LUA may remain inactive for no longer than one year. Reactivation within the one year period will be processed as an amendment. If an LUA remains inactive for more than one year, it will be deactivated. An inactive LUA laboratory may not energize any class 3b or 4 lasers without prior notice for the proper inspection of the facility and approval by the LSO.
1.11 Audits

EH&S will periodically conduct audits of all activities and areas under the LUA. The frequency of this audit will be annually with a 30 day follow up on any laboratory deficiency or other issues requiring corrective actions. Additional audits may be conducted at the discretion of the LSC, PI, or LSO.

1.12 Equipment Forms

All class 3b and 4 lasers or laser systems within UCSD jurisdiction must be registered with EH&S through an equipment registration form. Any new class 3b or 4 lasers must also be registered prior initial use (see section 5.7).
Section 2: Laser Hazard Control Measures

2.1 General Considerations

Control measures should be devised to reduce the possibility of exposure of the eye and skin to hazardous levels of laser radiation, as well as other hazards associated with the operation of laser devices during normal operation and maintenance.

The LSO shall have the authority to evaluate, monitor and enforce the control of laser hazards.

For all users of lasers and laser systems, it is recommended that the minimum laser radiation level required for the application be used. The laser beam height shall be maintained at a level other than the normal sitting or standing position of a person.

Review of reported incidents have demonstrated that accidents to the eye and/or skin exposures to laser radiation, and accidents related to the ancillary hazards of a laser or laser system, are most often associated with personnel involved with the use of these systems under the following conditions:

- Unanticipated eye exposure during alignment
- Misaligned optics
- Eye protection not used
- Equipment malfunction
- Improper methods of handling high voltage
- Unintentional exposure of unprotected personnel
- Operators unfamiliar with laser equipment
- Lack of protection for ancillary hazards
- Improper restoration of equipment following service

2.2 Control Measures

Control measures may be broken down into the following categories.

- Engineering (e.g., enclosures, interlocks, beam stops etc.)
- Administrative and Procedural (e.g., LSP/SOP, warning signs, eyewear, training, etc).

2.3 Engineering Controls

Protective Housing
Required on all laser classes. In certain instances, operation of a laser or laser system without a protective housing may be necessary. In such case, the LSO will conduct a hazard analysis and assure that other means of controls are used.

Interlocks on Protective Housing
Class 3b and 4 lasers are required to have interlocked protective housing, which is activated upon removal of the protective housing during operation and maintenance. The interlock is designed to prevent access to the beam above the applicable Maximum Permissible Exposure (MPE).
**Service Access Panel**
This panel allows access to Class 3b or Class 4 lasers and should only be removed for servicing purposes by authorized service personnel. These panels must be either interlocked or require a special tool for their removal. A label must be affixed to the panel with the appropriate laser hazard.

**Key Control**
Only an appropriate supervisor or authorized operator of the laser shall have the key or code to enable the operation of laser or laser system. This master switch is to be disabled when the laser is no longer in use.

**Viewing Portals**
All viewing windows and diffuse display screens, which are a part of a laser or laser system shall incorporate a suitable means (such as interlocks, filters, attenuators) to maintain the laser radiation at the viewing position at or below the applicable MPE.

**Collecting Optics**
All collecting optics (lenses, telescopes, microscopes, etc.) intended for viewing use with a laser or laser system shall incorporate suitable means (interlocks, filters, attenuators) to maintain the transmitted laser radiation at levels at or below the appropriate MPE.

**Totally Open and Limited Open Beam Path**
In cases of Class 3b or Class 4 laser or laser system where the laser beam is either partially exposed or totally exposed, a laser hazard analysis shall be conducted by the LSO to establish the Nominal Hazard Zone (NHZ) if not furnished by the manufacturer.

High power lasers or laser systems require more stringent control measures due to the obvious risk of injury from the direct beam or specular reflections. However, there is a greater risk from diffuse reflection along the entire beam path, which must be controlled.

**Remote Interlock Connector**
A Class 3b laser or laser system should and Class 4 laser or laser system shall be provided with remote interlock connector. These interlocks facilitate an electrical connection to an emergency master switch. When the terminals of the connector are open circuited, the accessible radiation shall not exceed the appropriate MPE levels.

**Beam Stop or Attenuator**
A Class 3b laser or laser system should and Class 4 laser or laser system shall be provided with permanently attached beam stop or attenuator. The beam stop or attenuator shall be capable of preventing laser radiation in excess of the appropriate MPE level. In some cases, such as service, where the beam stop or attenuator is placed over the beam aperture, and the laser radiation is below the applicable MPE level, the LSO may deem that laser eye protection is not required.

**Activation Warning System**
Activation warning systems include audible sound (bells or chimes), warning lights, verbal count down, all of which notify personnel that the laser either about to be activated or deactivated.
**Emission Delay**
The laser activation warning system is emission delay activated, which allows the operator sufficient time to control exposure to laser radiation prior to laser activation.

**Indoor Laser Controlled Areas**
An analysis including determination of the NHZ, shall be established by the LSO. If the analysis determines that the classification is a Class 3b or Class 4, a laser controlled area shall be established and adequate control measures instituted.

**Class 3b Indoor Laser Controlled Areas**
Class 3b lasers shall be used in areas where entry by unauthorized personnel can be controlled. Entry into an area by personnel untrained in laser safety may be permitted by the laser operator if they are made aware of the safety requirements and are provided with protective eyewear as required. It is the responsibility of the PI to supervise all untrained personnel in the laser controlled area.

The following control measures are mandatory for class 3b lasers and advisory for class 3a:

- **Training:** All persons using Class 3b lasers are required to attend a general laser safety seminar through EH&S in addition to specific training provided by the PI or manufacturer.
- **Engineering controls:** Priority shall be given to the incorporation of appropriate safety mechanisms (i.e., shutters, interlocks, enclosures, beam stops, beam enlarging systems, etc.) as an integral part of the laser system.
- **Laser controlled area:** Only authorized personnel shall operate laser systems. Spectators shall not be permitted into the laser controlled area unless the LSO approval has been obtained and protective measures have been taken. If the laser beam is not enclosed, special emphasis shall be placed on control of the path of the laser beam.
- **Alignment procedures:** Alignment of a Class 3 laser beam shall be performed in such a manner that the primary beam or a specular reflection of a primary beam does not expose the eye to radiation levels above the MPE (Maximum Permissible Exposure).
- **Optical viewing aids:** Special care shall be taken when using optical systems such as lenses, telescopes and microscopes. Filters or interlocks shall be provided to prevent ocular exposure above the MPE.
- **Equipment labeling:** Class 3 lasers shall have a warning label with the appropriate cautionary statement affixed to a conspicuous place on the laser housing.
- **Key-switch master interlock:** Class 3 lasers shall be provided with an operative keyed master interlock or switch device. The key shall be removable and the laser shall not be operable when the key is removed. The key shall be removed when the laser is no longer in use or is unattended. The key must be maintained by either the PI or an authorized user of the laser.

**Class 4 Indoor Laser Controlled Areas**
High-power lasers require more rigid control measures not only because of the high risk of injury from the direct or specular reflected beam, but because there is a greater risk of injury from hazardous diffuse reflections. The entire beam path capable of producing
hazardous diffuse reflections shall be controlled. Every measure of control should be considered when working with Class 4 lasers or laser systems. In addition to the control measures outlined above under Class 3b lasers, the following Class 4 control measures shall also be applied:

- **Laser controlled area**: Class 4 laser devices shall be optically isolated in an area designed solely for laser operation and access to such an area shall require appropriate authorization.

- **Interlocks**: Safety latches or interlocks shall be used to deactivate the laser in the event of an unexpected entry into laser controlled areas. The design of interlocks shall be such as to allow both rapid egress by the laser personnel and admittance under emergency conditions. The person in charge of the laser controlled area shall be permitted to momentarily override the room access interlocks, which will not allow automatic re-energizing of the power supply, but shall be designed so that the power supply of the shutter must be reset manually. A control-disconnect switch ("panic button") shall be available for deactivating the laser.

### All Outdoor Laser Controlled Areas

All class 3b and 4 lasers or laser systems destined to be energized outdoors for entertainment or scientific purpose must be inspected and approved by the LSO prior initial use. Proper documentation indicating permission to operate the lasers or laser systems outdoor within UCSD premises must be submitted prior to initial use to EH&S at mail code 0035.

- **Laser controlled area**: This area must be designed to prevent any scatter or reflected laser radiation from exiting the controlled area. The beam path must be set up so it is inaccessible to audience/pedestrian. Power source and wires also must be secured to prevent tripping or any inadvertent accidents.

### 2.4 Administrative and Procedural Controls

#### Standard Operating Procedural Controls

Each laser or laser system shall have a Laser Safety Procedure (LSP) or Standard Operating Procedure (SOP) readily available to all individuals involved with the laser. These SOPs shall be maintained in close proximity of the laser or laser system, for reference by the operator and service personnel. It shall contain at least:

- Name of PI responsible for the laser or laser system.
- List of authorized users with documentation of their training.
- Emergency call list
- Description of safety features.
- A complete description of protective equipment to be used by all operators of the laser or laser system.
- Specific operating procedures (submitted by the PI for approval by the LSO), from start-up to shut down.
- Specific alignment procedures as applicable (submitted by the PI and approved by the LSO).
- A safety checklist either provided with the equipment or created by the PI.
- Emergency instructions.
Output Emission Limitations
If in the opinion of the LSO, excessive radiation is emitting from the laser or laser system during normal operation, the LSO shall take appropriate action as required to reduce the power level to that which is commensurate with the required application.

Education and Training
Education and training shall be provided for operators, maintenance, and service personnel for Class 3b and Class 4 lasers or lasers systems. Training should also be provided for operators, maintenance, and service personnel who are working with Class 1, 2, and 3a lasers or laser systems containing embedded Class 3b or Class 4 lasers. Training shall be offered by EH&S (RSVP at (858) 534-6418) and is mandatory for all who operate a Class 3b or Class 4 laser or laser system. The following topics are covered in the training via CD_ROM, provided by EH&S:

- Fundamental of laser operations.
- Laser classifications.
- Biological effects of laser radiation.
- Laser hazards: direct and non-direct.
- Control measures.
- The PI shall provide supplemental training specific to the laser being used.
- The manufacturer of the laser should provide training for that specific laser or laser system.
- Refresher training is encouraged for operators of Class 3b or Class 4 laser systems.
- CPR (optional or at the discretion of the PI).

All training shall be documented and maintained for future reference by EH&S as well as the principal investigator.

Authorized Personnel
Class 3b and Class 4 lasers or laser systems shall be operated, maintained, and serviced only by authorized personnel listed on the LUA or manufacturer's rep.

Alignment Procedures
Alignment of Class 2, 3a, 3b, 4 laser optical systems shall be performed in such a manner that the primary beam, specular, or diffuse reflection does not expose the eye above the applicable MPE. The use of low power visible lasers for the path simulation of higher power lasers is recommended for alignment.

Protective Equipment
Eyewear
All laser protective eyewear shall be clearly labeled with the optical density values and wavelength range. Adequate optical density at the laser wavelength of interest shall be weighed with the need for adequate visible transmission. Periodic inspection shall be made of protective eyewear to ensure that pitting, cracking, etc. will not endanger the wearer. The frame of the protective eyewear should also be inspected for mechanical integrity and light leaks.

Important considerations in determining appropriate eyewear are:
- Wavelength of laser output.
- Potential for multi-wavelength operation.
- Optical density.
• Visible light transmission.
• Peripheral vision.
• Need for prescription glasses.
• Degradation of absorbing media, such as photo-bleaching.
• Capacity of the front surface to produce specular reflection.
• Radiant exposure or irradiance and the corresponding time factors at which laser-protective eyewear damage occurs, including transient bleaching.
• Strength of materials (resistant to shock).
• Comfort and fit.

If needed the LSO, along with many optical companies, can advise on the selection of protective eyewear.

Skin Protection
Skin protection may be required if personnel are likely to be chronically exposed to scattered ultraviolet light, such as during excimer laser applications, or acutely exposed to levels greater than the MPE for the skin. Leather gloves, aprons and jackets are generally considered the most desirable protection against UV exposure. Nylon is very ineffective with a transmission of 20% to 40%. This is important to note since many lab coats are nylon based. Laser light can be attenuated by the use of layered clothing.

Class 4 lasers users should wear fire resistant materials as well as the UV considerations.

Spectators
Spectators or visitors should not be allowed into a controlled laser area containing a Class 3b laser or laser system and spectators shall not be permitted within a laser controlled area which contains a Class 4 laser or laser system unless:
• Appropriate approval from the supervisor has been obtained.
• The degree of hazard and avoidance procedure has been explained.
• Appropriate protective measures are taken.

Service Personnel
All personnel who are required access to Class 3b or Class 4 lasers or laser systems enclosed within a protective housing or protective area shall comply with the control measures of the embedded laser or laser system. The LSO shall require service personnel to have the proper safety training and education commensurate with the class of the laser or laser system.

Laser Optical Fiber
Laser systems, which employ optical cable, shall be considered enclosed systems with the optical cable forming part of the enclosure. If disconnection occurs and the resulting laser radiation is below the applicable MPE by engineering controls, connection, or disconnection may take place in an uncontrolled area. Disconnection or connection shall take place in an appropriate controlled area during operation if the laser radiation is greater than the applicable MPE.

Protective Windows
Facility windows (exterior or interior) that are located within the NHZ of a Class 3b or Class 4 laser or laser system shall have absorbing material, scattering filter, blocking
barrier or screen which reduces any laser radiation to levels below the applicable MPE level.

**Protective Barriers and Curtains**
A blocking barrier, screen, or curtain, which can block or filter laser radiation should be used inside the controlled laser area to prevent the beam from exiting into an uncontrolled area above the applicable MPE level.

It is important to consider the flammability factor and decomposition of the barrier material. It is critical that the barriers do not contain combustible materials or release toxic fumes during or following a laser exposure.

**Other Protective Equipment**
Respirators, fire extinguishers, additional local exhaust system, and hearing protection may be necessary whenever engineering controls cannot provide protection from ancillary hazards.

**Warning Signs, Labels, and Postings**
Laser warning signs and labels shall be in accordance in dimensions, letter size and color, etc... with American National Standard Specification for Accident Prevention Signs, ANSI Z535 series (latest revision thereof). Signs and labels prepared in accordance with previous standards are considered to fulfill the requirement of the standard.

**Warning signs:** (referenced to figures on the proceeding pages).
All entrances to a controlled laser area shall have the proper warning sign posted with the appropriate language indicating the potential hazards within that area. Pertinent information on the warning signs may be printed or hand written in a legible manner, and shall include:

- The signal word “Danger” shall be used with all signs and labels associated with all Class 3a, 3b and Class 4 lasers and laser systems.
- The signal word “Notice” shall be used on signs posted outside temporary laser controlled area for example, during periods of service.
- At position 1 above the tail of the sunburst, special precautionary instruction or protective action that may be applicable.
  1. Laser protective eyewear required.
  2. Invisible laser radiation.
  4. Do not enter when light is on.
  5. Restricted area.
- At position 2 below the tail of the sunburst, the type of laser (Nd:YAG, Helium-Neon, etc...), or the emitted wavelength, pulse duration (if appropriate) and maximum output.
- At position 3, the class of laser or laser system.

**Warning Labels**
All equipment warning labels shall be conspicuously displayed in a location on the equipment where they best warn personnel.

- At position 1 above the tail of the sunburst, precautionary instructions are required:
1. For all Class 3b lasers and laser systems, “Laser Radiation – Avoid Direct Eye Exposure to Beam.”
2. For all Class 4 lasers and laser systems. “Laser Radiation – Avoid Eye or Skin Exposure to Direct or Scattered Radiation.”

At position two and three, the language shall be the same if not similar to the warning signs.

Emergency Procedures
An emergency procedure should be displayed in a conspicuous area to be followed in event of an accident or injury.

In the event of a laser accident, do the following:
1. Shut down the laser or laser system.
2. Provide for the safety of personnel (first aid, evacuation, etc.). If needed, provide further medical assistance by:

   Non-Eye Injuries:
   Proceed directly to Thornton Hospital Emergency/Urgent Care Unit: (858) 657-7600

   Eye Injuries:
   During normal business hours, first contact: Shiley Eye Center at: (858) 534-6290 and then follow their instructions.
   After normal business hours, proceed to the Thornton Emergency /Urgent Care Unit: (858) 657-7600

   NOTE: If a laser eye injury is suspected, have the injured person keep their head upright and still to restrict any bleeding in the eye. Laser eye injuries should be evaluated by a physician as soon as possible.

3. If necessary, contact the fire department at: 911.
4. Inform your Principal Investigator of the accident as soon as possible.
5. A Worker Compensation Claim must be filed within one business day after the accident. Help and information on filling out a Workers Compensation Claim can be obtained by calling UCSD Risk Management at: (858) 534-0136.
6. Inform the UCSD Radiation Safety Office of the accident as soon as possible.
   During normal business hours, call (858) 534-3660
   After business hours, call the UCSD Police Dept. at: (858) 534-4357
   (They have an emergency call list for EH&S)

Maintenance and Repair of Lasers
All maintenance and repair of lasers shall be performed only by individuals able to document training and education compatible with the laser system in question. Appropriate precautions should be taken by the laser repair personnel to assure his/her safety, as well as the safety of lab personnel and the general public within the vicinity. A sign with the signal word “Notice,” along with the appropriate language and information shall be displayed in a conspicuous manner outside of the laser controlled area for the time of service.
Modification of Laser Systems
When a Principal Investigator (PI) finds it necessary to alter the laser or laser systems and/or control measures previously set, he/she shall request a variance in writing. This request for a variance should be provided to the LSO. Approval for a variance will be given only when alternate safety devices and/or procedures have been evaluated and approved by the LSO.

Transfer of Laser Equipment
If there is a need to move a laser or laser system to a different location on the LUA for a new project, a transfer equipment form (see section 5.7) must be filled out and sent in to the LSO at mail code 0035 prior to the move.

If the new location is not on the LUA, an amendment form must be sent in to add the new location to the LUA. An equipment transfer form must also be sent in to the LSO for the moving of the laser or laser system.

Inoperative Lasers
In the event that a laser(s) is to be disposed of or donated to another party, the laser must be permanently deactivated (i.e. cutting the power cord). If a laser is in need of maintenance, the LSO must be contacted so a label can be attached in an inconspicuous area indicating that the particular laser(s) is out of order. When the laser(s) is repaired, the LSO must be contacted for removal of the inactive label prior to the initial use.

2.5 Special Control Measures for Invisible Radiation
Since infrared and ultraviolet radiation is invisible, particular care must be taken when using these laser systems. In addition to the control measures, which apply to the laser hazard classification, the following controls shall also apply. A visible coaxial aiming beam is desirable. Visible and/or audible warnings should activate when the laser is activated.

Infrared lasers: The beam from a Class 3b infrared (IR) laser should be terminated by a highly absorbent backstop. Class 4 laser beams should be terminated by a fire resistant material. (Note: Many surfaces, which appear “dull” visually can act as a reflector of infrared radiation).

Ultraviolet lasers: In order to minimize exposure to ultraviolet (UV) radiation, appropriate shielding material must be used to attenuate the radiation level below MPE for the specific UV wavelength. Special attention shall be given to the possibility of producing hazardous byproducts, such as ozone, and the formation of skin sensitizing agents. Toxic gasses such as $F^2$, $Cl^2$, $NF^3$, etc. may be produced with the use of UV lasers and should be guarded against when invisible radiation is accessible from a Class 3 or Class 4 laser system. Warning signs and light should be displayed in a conspicuous location warning those in the area when the laser is being operated.
## Engineering Control Measures for the Four Laser Classes

### Table 10 from ANSI Z136.1 – 2000

<table>
<thead>
<tr>
<th>Control Measures</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Engineering Controls</strong></td>
<td>1</td>
</tr>
<tr>
<td>Protective Housing</td>
<td>X</td>
</tr>
<tr>
<td>Without Protective Housing</td>
<td>LSO shall establish Alternative Control</td>
</tr>
<tr>
<td>Interlocks on Protective Housing</td>
<td>∇</td>
</tr>
<tr>
<td>Service Access Panel</td>
<td>∇</td>
</tr>
<tr>
<td>Key Control</td>
<td>-</td>
</tr>
<tr>
<td>Viewing Portals</td>
<td>-</td>
</tr>
<tr>
<td>Collecting Optics</td>
<td>MPE</td>
</tr>
<tr>
<td>Totally Open Beam Path</td>
<td>-</td>
</tr>
<tr>
<td>Limited Open Beam Path</td>
<td>-</td>
</tr>
<tr>
<td>Enclosed Beam Path</td>
<td>None is required if 4.3.1. and 4.3.2. fulfilled in ANSI 136.1</td>
</tr>
<tr>
<td>Remote Interlock Connector</td>
<td>-</td>
</tr>
<tr>
<td>Beam Stop or Attenuator</td>
<td>-</td>
</tr>
<tr>
<td>Activation Warning System</td>
<td>-</td>
</tr>
<tr>
<td>Emission Delay</td>
<td>-</td>
</tr>
<tr>
<td>Indoor Laser Controlled Area</td>
<td>-</td>
</tr>
<tr>
<td>Class 3b Indoor Laser Controlled Area</td>
<td>-</td>
</tr>
<tr>
<td>Class 4 Laser Controlled Area</td>
<td>-</td>
</tr>
<tr>
<td>Laser Outdoor Controls</td>
<td>-</td>
</tr>
<tr>
<td>Laser in Navigable Airspace</td>
<td>-</td>
</tr>
<tr>
<td>Temporary Laser Controlled Area</td>
<td>∇</td>
</tr>
<tr>
<td>Remote Firing and Monitoring</td>
<td>-</td>
</tr>
<tr>
<td>Labels</td>
<td>X</td>
</tr>
<tr>
<td>Area Posting</td>
<td>-</td>
</tr>
</tbody>
</table>

- **X** - Shall
- **•** - Should
- **-** - No requirement
- **∇** - Shall if enclosed Class 3b or Class 4
- **MPE** – Shall if MPE is exceeded
- **NHZ** – Nominal Hazard Zone analysis required
### Administrative Control Measures for the Four Laser Classes

#### Table 10 from ANSI Z136.1 – 2000

<table>
<thead>
<tr>
<th>Control Measures</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative and Procedural Controls</td>
<td>1   2   3a   3b   4</td>
</tr>
<tr>
<td>Standard Operating Procedures</td>
<td>-   -   -   -   X</td>
</tr>
<tr>
<td>Output Emission Limitations</td>
<td>-   -   -   -   LSO Determination</td>
</tr>
<tr>
<td>Education and Training</td>
<td>-   -   -   X   X</td>
</tr>
<tr>
<td>Authorized Personnel</td>
<td>-   -   -   X   X</td>
</tr>
<tr>
<td>Alignment Procedures</td>
<td>-   X   X   X   X</td>
</tr>
<tr>
<td>Protective Equipment</td>
<td>-   -   -   -   X</td>
</tr>
<tr>
<td>Spectator</td>
<td>-   -   -   -   X</td>
</tr>
<tr>
<td>Service Personnel</td>
<td>∇   MPE ∇   MPE ∇   MPE X   X</td>
</tr>
<tr>
<td>Demonstration with General Public</td>
<td>MPE* X X X X</td>
</tr>
<tr>
<td>Laser Optical Fiber</td>
<td>MPE MPE MPE X X</td>
</tr>
<tr>
<td>Laser Robotic Installations</td>
<td>-   -   -   X   NHZ X   NHZ</td>
</tr>
<tr>
<td>Eye Protection</td>
<td>-   -   -   -   MPE X   MPE</td>
</tr>
<tr>
<td>Protective Windows</td>
<td>-   -   -   X   NHZ X   NHZ</td>
</tr>
<tr>
<td>Protective Barriers and Curtains</td>
<td>-   -   -   -   -   -</td>
</tr>
<tr>
<td>Skin Protection</td>
<td>-   -   -   X   MPE X   MPE</td>
</tr>
<tr>
<td>Other Protective Equipment</td>
<td>Use may be required</td>
</tr>
<tr>
<td>Warning Signs and Labels (Design Requirements)</td>
<td>- - - - X X</td>
</tr>
<tr>
<td>Service and Repairs</td>
<td>LSO Determination</td>
</tr>
<tr>
<td>Modifications and Laser Systems</td>
<td>LSO Determination</td>
</tr>
</tbody>
</table>

- X - Shall
-● - Should
- - - No requirement
-∇ - Shall if enclosed Class 3b or Class 4
-MPE – Shall if MPE is exceeded
-NHZ – Nominal Hazard Zone analysis required
-* - Applicable only to UV and IR Lasers
DANGER

VISIBLE AND/OR INVISIBLE LASER RADIATION

AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION
LASER PROTECTIVE EYEWEAR REQUIRED

Laser type
Emitted wavelength
Pulse duration (if appropriate)
Max output

Class 4 laser

Sample Warning Sign for Class 4 Lasers
DANGER

VISIBLE AND/OR INVISIBLE LASER RADIATION

AVOID DIRECT EXPOSURE TO BEAM
LASER PROTECTIVE EYEWEAR REQUIRED

Laser type
Emitted wavelength
Pulse duration (if appropriate)
Max output

Class 3b laser

Sample Warning Sign for Class 3b Lasers
NOTICE

LASER ALIGNMENT OR REPAIR IN PROGRESS

DO NOT ENTER
LASER PROTECTIVE EYEWEAR REQUIRED

Laser type
Emitted wavelength
Pulse duration (if appropriate)
Max output

Class __ laser

Sample Warning Sign for Temporary Laser Controlled Area During Periods of Service and Alignment.
Section 3: ANSI Z136.1 Laser Classification

The American National Standards ANSI Z136.1-2000 has established a classification system for lasers according to their relative hazards and specifies appropriate controls for each classification.

The laser hazards classification system is based on the ability of the primary laser beam to cause biological damage to the eye and/or skin during intended use. Other ancillary hazards are discussed in section 4 of this manual.

The Food and Drug Administration requires manufacturers to classify their products. A label is affixed to the laser by the manufacturer, which indicates the hazard class. However, when the laser hazard class is unknown, or when the laser has been modified and the hazard class has changed, the LSO must be contacted to evaluate and classify the laser system.

3.1 Class 1

These lasers are considered safe and are incapable of producing damaging radiation levels during normal operation. Class 1 lasers are exempt from control measures and surveillance. Example – bar code scanner (see chart).

3.2 Class 2 & 2a

Class 2 & 2a lasers are low powered lasers with an output of approximately 1 mW of continuous wave. All class 2 lasers operate in the visible portion of the electromagnetic spectrum (400 nm – 700 nm). Eye protection is usually afforded by aversion response and blink reflex (0.25 seconds). However, a Class 2 laser beam could be hazardous if one were to intentionally expose the eye for longer than 0.25 seconds. Example – helium neon (HeNe) pointer (see chart on pg 23).

3.3 Class 3a & 3b

A Class 3 laser system can emit any wavelength and may be hazardous under direct and specular viewing conditions, but diffuse reflection is usually not a hazard. These lasers are usually not a fire hazard (see section 2 and glossary).

1. Class 3a – Operates at 1-5 mW of continuous wave. Do not view direct beam.
   Example – optical alignment equipment.
2. Class 3b – Operates at 5-500 mW for continuous wave. Engineering and administrative control measures are required to prevent direct or reflected beam viewing (see chart on pg 23).

3.4 Class 4

Class 4 laser systems operate at greater than 500 mW (continuous), can emit any wavelength, and are considered an eye, skin, fire, and diffuse reflection hazard. The most stringent control measures have been established for these lasers. Controls to prevent eye and skin exposure to direct and diffusely reflected beam are required.

Section II provides specific requirement control measures for Class 1, 2, 2a, 3a, 3b, and 4 lasers.
<table>
<thead>
<tr>
<th>Wavelength (µm)</th>
<th>Laser Type</th>
<th>Wavelength (µm)</th>
<th>Class 1* (Watts)</th>
<th>Class 2 (Watts)</th>
<th>Class 3** (Watts)</th>
<th>Class 4 (Watts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultraviolet 0.180 to 0.280</td>
<td>Neodymium: YAG (Quadruple)</td>
<td>0.266 only</td>
<td>≤9.6 x 10^{-9} for 8 hours</td>
<td>None</td>
<td>&gt; Class 1 but ≤ 0.5</td>
<td>&gt;0.5</td>
</tr>
<tr>
<td></td>
<td>Argon</td>
<td>0.275</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultraviolet 0.315 to 0.400</td>
<td>Helium-Cadmium</td>
<td>0.325 only</td>
<td>≤3.2 x 10^{-6}</td>
<td>None</td>
<td>&gt; Class 1 but ≤ 0.5</td>
<td>&gt;0.5</td>
</tr>
<tr>
<td></td>
<td>Argon</td>
<td>0.351, 0.363</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Krypton</td>
<td>0.3507, 0.364</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visible 0.400 to 0.700</td>
<td>Helium-Cadmium</td>
<td>0.4416 only</td>
<td>≤4 x 10^{-5}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Argon (Visible)</td>
<td>0.457</td>
<td>≤5 x 10^{-5}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.476</td>
<td>≤1 x 10^{-4}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.488</td>
<td>≤2 x 10^{-4}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.514</td>
<td>≤4 x 10^{-4}</td>
<td></td>
<td></td>
<td>&gt; Class 1 but ≤ 1 x 10^{-3}</td>
</tr>
<tr>
<td></td>
<td>Krypton</td>
<td>0.530</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Neodymium: YAG (Double)</td>
<td>0.532</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Helium-Neon</td>
<td>0.543</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dye</td>
<td>0.400-0.550</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Helium-Selenium</td>
<td>0.460-0.550</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dye</td>
<td>0.550-0.700</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Helium-Neon</td>
<td>0.632</td>
<td>≤0.4 x 10^{-4}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>InGaAlP</td>
<td>0.670</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ti:Sapphire</td>
<td>0.670</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Krypton</td>
<td>0.6471, 0.6764</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near Infrared 0.700 to 1.400</td>
<td>GaAlAs</td>
<td>0.780</td>
<td>≤5.6 x 10^{-4}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GaAlAs</td>
<td>0.850</td>
<td>≤7.7 x 10^{-4}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>GaAs</td>
<td>0.905</td>
<td>≤9.9 x 10^{-4}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Neodymium: YAG</td>
<td>1.064</td>
<td>≤1.9 x 10^{-3}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Helium-Neon</td>
<td>1.080</td>
<td>≤1.9 x 10^{-3}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.152</td>
<td>≤2.1 x 10^{-3}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>InGaAsP</td>
<td>1.310</td>
<td>≤1.5 x 10^{-3}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Far Infrared 1.400 to 10³</td>
<td>InGaAsP</td>
<td>1.550</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Holmium</td>
<td>2.100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Erbium</td>
<td>2.940</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hydrogen Fluoride</td>
<td>2.600-3.000</td>
<td>≤9.6 x 10^{-3}</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Helium-Neon</td>
<td>3.390 only</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carbon Monoxide</td>
<td>5.000-5.500</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carbon Dioxide</td>
<td>10.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water Vapor</td>
<td>118</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hydrogen Cyanide</td>
<td>337</td>
<td>≤9.5 x 10^{-2}</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Assumes no mechanical or electrical design incorporated into laser system to prevent exposures from lasting to \( T_{\text{max}} = 8 \) hours (one workday); otherwise the Class 1 AEL could be larger than tabulated.

**See 3.3.3.1 in ANSI Z 136.1 for definition of Class 3a.
<table>
<thead>
<tr>
<th>Wavelength (µm)</th>
<th>Laser Type</th>
<th>Wavelength (µm)</th>
<th>Pulse Duration (s)</th>
<th>Class 1* (Joules)</th>
<th>Class 3b (Joules)</th>
<th>Class 4 (Joules)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultraviolet 0.180 to 0.400</td>
<td>Excimer (ArF)</td>
<td>0.193</td>
<td>20 x 10^{-9}</td>
<td>≤2.4 x 10^{-5}</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td></td>
<td>Excimer (KrF)</td>
<td>0.248</td>
<td>20 x 10^{-9}</td>
<td>≤2.4 x 10^{-5}</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td></td>
<td>Neodymium: YAG Quadrupled (Q-sw)</td>
<td>0.266</td>
<td>20 x 10^{-9}</td>
<td>≤2.4 x 10^{-5}</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td></td>
<td>Excimer (XeCl)</td>
<td>0.308</td>
<td>20 x 10^{-9}</td>
<td>≤5.3 x 10^{-5}</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td></td>
<td>Nitrogen</td>
<td>0.337</td>
<td>20 x 10^{-9}</td>
<td>≤5.3 x 10^{-5}</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td></td>
<td>Excimer (XeF)</td>
<td>0.351</td>
<td>20 x 10^{-9}</td>
<td>≤5.3 x 10^{-5}</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td>Visible 0.400 to 0.700</td>
<td>Rhodamine 6G (Dye Laser)</td>
<td>0.450-0.650</td>
<td>1 x 10^{-5}</td>
<td>≤1.9 x 10^{-7}</td>
<td>&gt; Class 1 but ≤0.03</td>
<td>&gt;0.03</td>
</tr>
<tr>
<td></td>
<td>Copper Vapor</td>
<td>0.510, 0.578</td>
<td>2.5 x 10^{-9}</td>
<td>≤1.9 x 10^{-7}</td>
<td>&gt; Class 1 but ≤0.03</td>
<td>&gt;0.03</td>
</tr>
<tr>
<td></td>
<td>Neodymium: YAG Doubled (Q-sw)</td>
<td>0.532</td>
<td>20 x 10^{-9}</td>
<td>≤1.9 x 10^{-7}</td>
<td>&gt; Class 1 but ≤0.03</td>
<td>&gt;0.03</td>
</tr>
<tr>
<td></td>
<td>Ruby (Q-sw)</td>
<td>0.6943</td>
<td>20 x 10^{-9}</td>
<td>≤3.9 x 10^{-6}</td>
<td>&gt; Class 1 but ≤0.03</td>
<td>&gt;0.03</td>
</tr>
<tr>
<td></td>
<td>Ruby (Long Pulse)</td>
<td>0.6943</td>
<td>1 x 10^{-3}</td>
<td>≤3.9 x 10^{-6}</td>
<td>&gt; Class 1 but ≤0.03</td>
<td>&gt;0.03</td>
</tr>
<tr>
<td>Near Infrared 0.700 to 1.4</td>
<td>Ti: Sapphire</td>
<td>0.700-1.000</td>
<td>6 x 10^{-6}</td>
<td>≤1.9 x 10^{-7}</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td></td>
<td>Alexandrite</td>
<td>0.720-0.800</td>
<td>1 x 10^{-4}</td>
<td>≤7.6 x 10^{-7}</td>
<td>&gt; Class 1 but ≤0.033</td>
<td>&gt;0.033**</td>
</tr>
<tr>
<td></td>
<td>Neodymium: YAG (Q-sw)</td>
<td>1.064</td>
<td>20 x 10^{-9}</td>
<td>≤1.9 x 10^{-6}</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td>Far Infrared 1.4 to 10^{3}</td>
<td>Erbium: Glass (Q-sw)</td>
<td>1.540</td>
<td>10 x 10^{-9}</td>
<td>≤7.9 x 10^{-3}</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td></td>
<td>Co: Magnesium-Fluoride</td>
<td>1.8-2.5</td>
<td>80 x 10^{-6}</td>
<td>≤7.9 x 10^{-4}</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td></td>
<td>Holmium</td>
<td>2.10</td>
<td>250 x 10^{-6}</td>
<td>≤7.9 x 10^{-4}</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td></td>
<td>Hydrogen Fluoride</td>
<td>2.600-3.000</td>
<td>0.4 x 10^{-6}</td>
<td>≤1.1 x 10^{-4}</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td></td>
<td>Erbium</td>
<td>2.940</td>
<td>250 x 10^{-6}</td>
<td>≤5.6 x 10^{-4}</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td></td>
<td>Carbon Dioxide (Q-sw)</td>
<td>10.6</td>
<td>100 x 10^{-9}</td>
<td>≤7.9 x 10^{-5}</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
<tr>
<td></td>
<td>Carbon Dioxide</td>
<td>10.6</td>
<td>1 x 10^{-3}</td>
<td>≤7.9 x 10^{-4}</td>
<td>&gt; Class 1 but ≤0.125</td>
<td>&gt;0.125</td>
</tr>
</tbody>
</table>

* Assuming that both eye and skin may be exposed, i.e., 1.0 mm beam (area of limiting aperture = 7.9 x 10^{-3} cm^2).

** Class 3b AEL varies from 0.033 to 0.480J corresponding to wavelengths that vary between 0.720 and 0.800µ.
### Maximum Permissible Exposure (MPE) for the Eye

#### Table A1. Small Source MPE’s for Commonly Used Lasers

<table>
<thead>
<tr>
<th>Laser Type</th>
<th>Wavelength (µm)</th>
<th>MPE (W/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>T*=0.25 s</td>
</tr>
<tr>
<td>CO₂</td>
<td>10.6</td>
<td>-</td>
</tr>
<tr>
<td>Nd:YAG (CW)</td>
<td>1.33</td>
<td>-</td>
</tr>
<tr>
<td>Nd:YAG</td>
<td>1.064</td>
<td>-</td>
</tr>
<tr>
<td>Nd:YAG Q-switched</td>
<td>1.064</td>
<td>-</td>
</tr>
<tr>
<td>GaAs (diode)</td>
<td>0.840</td>
<td>-</td>
</tr>
<tr>
<td>InGdAlP (diode)</td>
<td>0.670</td>
<td>2.5 x 10⁻³</td>
</tr>
<tr>
<td>HeNe</td>
<td>0.633</td>
<td>2.5 x 10⁻³</td>
</tr>
<tr>
<td>Krypton</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.647</td>
<td>2.5 x 10⁻³</td>
</tr>
<tr>
<td></td>
<td>0.568</td>
<td>2.5 x 10⁻³</td>
</tr>
<tr>
<td></td>
<td>0.530</td>
<td>2.5 x 10⁻³</td>
</tr>
<tr>
<td>Argon</td>
<td>0.514</td>
<td>2.5 x 10⁻³</td>
</tr>
<tr>
<td>XeF³</td>
<td>0.351</td>
<td>-</td>
</tr>
<tr>
<td>XeCl³</td>
<td>0.308</td>
<td>-</td>
</tr>
</tbody>
</table>

*T is the exposure duration

*a* Operating at less common 1.33 µm

*b* Pulsed operation at 11Hz, 12-ns pulsed, 20MJ/pulse

*c* When repeated exposure levels are anticipated the MPE must be reduced by a factor of 2.5

### Table A2. MPE for the Eye for Selected Single Pulse Lasers

<table>
<thead>
<tr>
<th>Laser Type</th>
<th>Wavelength (µm)</th>
<th>Pulse Duration (s)</th>
<th>MPE (J cm⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excimer (ArF)</td>
<td>0.193</td>
<td>2 x 10⁻⁸</td>
<td>3 x 10⁻³</td>
</tr>
<tr>
<td>Excimer (XeCl)</td>
<td>0.308</td>
<td>2 x 10⁻⁸</td>
<td>6.7 x 10⁻³</td>
</tr>
<tr>
<td>Ruby (pulsed)</td>
<td>0.694</td>
<td>1 x 10⁻³</td>
<td>1 x 10⁻⁵</td>
</tr>
<tr>
<td>Nd:YAG (pulsed)</td>
<td>1.064</td>
<td>1 x 10⁻³</td>
<td>5 x 10⁻⁵</td>
</tr>
<tr>
<td>Nd:YAG (Q-Switched)</td>
<td>1.064</td>
<td>5-100 x 10⁻⁹</td>
<td>5 x 10⁻⁶</td>
</tr>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>10.6</td>
<td>1 x 10⁻³</td>
<td>10 x 10⁻³</td>
</tr>
</tbody>
</table>
Section 4: Non-Beam Hazards

In addition to direct hazards to the skin and eyes with exposure to the laser beam, it is also important to consider other related hazards with the use of lasers. These classes of hazards may include: electrical, fire, explosion, other optical radiation hazards, compressed gases, cryogenic, toxic and carcinogenic materials, ionizing radiation, and noise. Associated hazards must be evaluated and included in SOPs by each Principal Investigator (PI) for their specific laser applications with approval by the LSO.

4.1 Electrical Hazards

Electrocution is most common when the laser, or laser system, is going through installation, maintenance, modification, and service, where the protective covers are often removed to allow access to active components. To prevent electrical injuries, all personnel should be adequately trained and the “buddy system” used whenever working around high voltage laser power supplies. Training in Cardiopulmonary Resuscitation (CPR) is recommended for all laser service, research personnel, and their assistants. Periodic refresher courses are also encouraged.

All laser systems shall be installed in accordance with manufacturer specifications and/or as required in the National Electrical Code (ANSI NFPA 70). The following are frequently identified as potential electrical problems during laser facility audits:

- Uncovered electrical terminals.
- Improperly insulated electrical terminals.
- Hidden “power-up” warning lights.
- Lack of personnel trained in current cardiopulmonary resuscitation practices, or lack of refresher training.
- “Buddy system” or equivalent safety measure not being practiced during maintenance and service.
- Failure to properly discharge and ground capacitors.
- Non earth-grounded or improperly grounded laser equipment.
- Non-adherence to the OSHA lock-out standard (29CFR 1910.147).
- Excessive wires and cables on floor that create fall or slip hazards.

4.2 Fire Hazards

Class 4 laser beams represent a fire hazard. Irradiances exceeding 10 W cm\(^{-2}\) or beam powers exceeding 0.5 W, flame resistant materials should be used for such cases.

4.3 Explosion Hazards

High-pressure arc lamps, filament lamps, and capacitor banks in laser equipment shall be enclosed in housings, which can withstand the maximum explosive pressure. The laser target and elements of the optical train which may shatter during laser operation shall also be enclosed, or equivalently protected, to prevent injury to the operator and/or observers. Explosive reactions of chemical laser reactants, or other laser gases, may be of concern in some cases.
4.4 Compressed Gases

Presently, many hazardous gases, (eg. chorine, fluorine, hydrogen chloride, and hydrogen fluoride), are being used in lasers or laser systems. In cases where hazardous gases are present in a laser system, procedure for their safe handling shall be developed and incorporated into the Standard Operating Procedure (SOP).

4.5 Laser Dye and Solvents

Laser dyes are organic compounds which, when mixed in solution with certain solvents, form a lasing medium for dye lasers. Certain dyes are highly toxic or carcinogenic. Since these dyes need to be changed frequently, special care must be considered when handling, preparing solutions, and operating dye lasers. An MSDS for dye compounds shall be available to all appropriate workers. Contact the EMF for disposal at 4-2753.

4.6 Optical Radiation – (other than laser beam hazards)

Ultraviolet radiation emitted from a laser’s discharged tubes and pumping lamps (i.e., not part of the primary laser beam) must be suitably shielded so that personnel exposures are maintained within the threshold limit values specified by the American Conference of Governmental Industrial Hygienists (ACGIH).

Plasma emissions created during a laser-welding process may have sufficient ultraviolet and/or blue light content (0.2 to 0.55 μm) to raise concern for operators viewing a laser-welding process on a long-term basis without additional protection for the plasma emission.

4.7 Industrial Hygiene Considerations

Industrial hygiene concerns include hazards associated with compressed gases, cryogenic materials, toxic and carcinogenic material, noise, and ionizing radiation. Adequate local exhaust ventilation shall be installed to reduce potentially hazardous fumes and vapors produced by laser welding, cutting, and other laser target interactions to levels below those used for non-laser conventional cutting, e.g., flame cutting, and welding of the same material.

4.8 Ionizing Radiation

Section 5: Appendices

5.1 Laser Fundamentals

A laser is a device which produces an intense, coherent directional beam of light by stimulating electronic or molecular transitions to higher energy levels. LASER is an acronym for Light Amplification by Stimulated Emission of Radiation. A laser system is an assembly of electrical, mechanical, and optical components which includes a laser. Laser light is uniquely different from more common light sources due to four important properties: monochromaticity, directionality, radiance, and coherence.

Monochromaticity
The color of light is dependent upon the wavelength used. Violet has the shortest wavelength, red has the longest and white light is the combination of all visible colors or wavelengths. Laser light consists of only a single color of light. Wavelengths, while not uniform in length, occur within a very narrow range, producing a beam of only one color.

Directionality - Collimation
Light from an ordinary source radiates in an omni-directional manner. This divergence makes these sources useful for lighting homes and work places. Laser light, however diverges very slowly as it radiates away from the source. The laser light is concentrated into a narrow cone of divergences, which propagates outward from the source in a single direction.

Radiance
Radiance is closely related to the directionality characteristic, and describes the amount of power radiated by the laser within the narrow cone of divergence. The significant factor is the ability of the laser to be focused (with lens) down into a very small, intense area.

Coherence
The coherence of laser light actually contributes to most aspects of the other three characteristics and is based on the wave properties of light. Light waves generated by an ordinary light source, such as a fluorescent bulb, are incoherent, i.e., a mixture of different frequencies and wavelengths of light, not in step with one another.

Light waves generated by a laser are all of the same frequency, i.e., “hills and valleys” all occur at the same time, and waves are all in step with one another.

The relationship between coherence and the other three properties are listed below:

- Coherent light waves are monochromatic.
- Since coherent light waves are all in phase with one another as they travel through space, the beam is highly directional with very low divergence.
- Since power is concentrated within this narrow cone of divergence, radiance is very high.

Laser sources operate within four primary regions of the electromagnetic spectrum.

- Ultraviolet (100 to 400 nm), wavelengths are shorter than the visible portion of the spectrum.
Visible (400 to 700 nm), visible wavelength ranging from the blue to the red spectrum respectively.
- Near Infrared (0.7 to 1.4 μm), wavelengths are longer than the visible portion of the spectrum.
- Far Infrared (1.4 to 10^3 μm), where heat is predominantly radiated by material objects and terminates where the microwave portion of the spectrum begins.

5.2 The Lasing Process

All lasers are comprised of four basic elements:
- The Active Medium – the collection of atoms or material that can be excited to a state of population inversion.
- The Excitation Mechanism – the source of energy to move atoms from ground state to an excited state to create the population inversion.
- The Feedback Mechanism – the system that returns a fraction of coherent laser light produced in the active medium back to an active medium.
- The Output Coupler – by making one of the mirrors partially transmitting, a portion of the coherent light is then allowed to escape.

In brief, the lasing process occurs as follows:
- The Excitation Mechanism supplies sufficient energy to create a population inversion.
- Excitation atoms in the active medium emit the laser wavelength in all directions by spontaneous emission. The resulting incoherent light is called fluorescence.
- Photons are emitted traveling perpendicular to mirrors at the ends of the active medium and cause stimulated emission as photons are reflected back and forth through the active medium.
- The reflection of photons continues and builds up optical standing waves inside the active medium that are composed of photons of the same wavelength, direction of travel, and coherence. Some photons escape through the output coupler to form the laser beam.
- Laser emission may be either cw (continuous wave) or pulsed, with pulse repetition frequencies ranging from 1 to 10^{10} pulse per second. The pulse duration will typically range from a few milliseconds, 10^{-3} seconds, to several picoseconds, 10^{-12} seconds.

5.3 Types of Lasers

There are four important types of lasers with differentiation based on active medium type, pumping method, and the character of the output beam.

**Solid Crystal Lasers**

Solid Crystal Lasers employ a solid Crystalline material as an active medium such as Ruby (crystalline Aluminum oxide doped with Chromium) or Neodymium: YAG (triply ionized Neodymium doped with Yttrium Aluminum Garnet). The active medium is a cylindrical rod with ends cut plane-parallel to each other then polished. The pumping method is usually a tungsten filament lamp coupled with an AC power supply (for Ruby).
Gas Lasers
Gas Lasers use gas or a gas mixture such as Argon or Helium-Neon as an active medium and are contained within a sealed glass tube called a plasma tube. Mirrors are either attached to the ends of the plasma tube or are mounted externally. The pumping method is usually DC discharge within the plasma tube and may be either continuous or pulsed.

Liquid Lasers
Liquid Lasers employ liquid as an active medium such as, complex organic dyes in alcohol solutions (Rhodamine 6G). Dye solutions circulate through the glass tube. Different chemicals are fed into the reaction chamber.

The feedback mechanisms are mirrors mounted externally to the glass tube or reaction chamber.

The output wavelength can be varied by changing the dye’s concentrations, and the pumping method could be high intensity flashlamp or a second laser. Liquid lasers can be pulsed or continuous wave, ultraviolet, infrared or visible.

Semiconductor Lasers
Semiconductor Lasers, which are also called laser diodes or injection lasers, employ an active medium that is a p-n junction between slabs of semiconductor material such as Gallium/Arsenide.

The feedback mechanism is provided by cleaving sides of slab along crystal planes to form parallel mirror surfaces.

The pumping method is an application of power supply across p-n junction where the intensity of light is controlled by varying power applied. The output is generally in the infrared end of the electromagnetic spectrum.

Excimer Lasers
Excimer (an abbreviation for Excited Dimer) Lasers operate using reactive gases such as chlorine and fluorine mixed with inert gases, such as argon, krypton, or xenon. The combinations, when electrically excited, produce a pseudo molecule or “Dimer” with an energy level configuration that allows the generation of a specific laser wavelength in the UV spectra.

Free-Electron Lasers
The Free-Electron Lasers are similar in many respects to a microwave oscillator tube. The photon emission occurs between continuum states of free electrons. The transition wavelength is determined by momentum conservation in the interaction with an “undulator” magnet. The undulator magnet consists of a transverse magnet field which varies sinusoidally along the electronic beam trajectory. An electron transversing such a magnet is free to scatter a virtual photon from the magnet into a real proton.

5.4 Biological Effects of Laser Radiation

Laser radiation should not be confused with ionizing radiation, such as X-rays and gamma rays, although very high irradiances have been known to produce ionization in air and other materials. The biological effects of laser radiation are essentially the
action of visible, ultraviolet or infrared radiation upon tissues. However, radiant intensities typically produced by lasers are of magnitudes that could previously be approached only by the sun, nuclear weapons, burning magnesium, or arc lights. Typically, the radiant exposure of the retina is 100,000 times that of the iris in the visible spectrum. That is, the lens of the eye concentrates the power of the laser beam by up to 100,000 times.

This is one of the important properties that make lasers potentially hazardous. Laser radiation incident upon biologic tissue will be reflected, transmitted, and/or absorbed. The degree to which each of these effects occurs depends upon various properties of the tissues involved. Absorption is selective, as in the case of visible light; darker material such as melanin or other pigmented tissue absorbs more energy. The macula lutea is the area in the eye of greatest visual acuity (central vision). A lesion resulting from a laser strike in the macula lutea area could “blind” an individual by destroying the central vision. This is why lasers should never radiate at eye level. Q-switched lasers pose a greater hazardous threat due to the substantial radiant exposure per time period.

**Eye Effects**
The eye is the organ most critical in evaluating laser hazards. For laser hazard purposes, the important components of the eye are the cornea, the lens, and the retina. The cornea is the transparent outer covering of the eye and it is composed of a regular arrangement of transparent fibers. Physiologically, it is part of the skin; however, it does not have the melanin pigment associated with the skin. Its response to radiation, therefore, is very similar to the skin. Any misalignment of the regular order of the fibers can cause the cornea to become opaque. Because the cornea lacks the skin’s pigmentation, it is very sensitive to ultra-violet radiation.

Visible and near infrared lasers pose a critical hazard on the retina. Infrared-A is transmitted by the cornea to the lens and then focused upon the retina. Far infrared B&C is absorbed by the cornea and damages that part of the eye. The macula lutea is the area on the retina of greatest visual acuity (central vision). A lesion resulting from a laser strike in the macula lutea area could “blind” an individual by destroying the central vision. Whether or not damage occurs depends on the wavelength and the energy density at the eye. These considerations have been taken into account when establishing the maximum permissible exposures (MPE) of ANSI Z136.1, for the eye and skin.

Specifically, lasers can produce the following biological effects based on wavelength:

**Ultraviolet Radiation (100-400 nm)**
Actinic ultraviolet radiation, UV-B (200-315 nm) and UV-C (100-200 nm), can produce symptoms similar to those observed in arc welders. It may cause severe acute inflammation of the eye and conjunctiva. UV-B and UV-C radiation does not reach the retina. Near ultraviolet radiation, UV-A (315-400 nm), is absorbed principally in the lens which causes the lens to fluoresce. Very high doses can cause corneal and lenticular opacities. Insignificant levels of UV-A reach the retina. The most hazardous wavelength for cataract production appears to be 300 nm.
Visible Light (400-700 nm) and Near-Infrared (IR-A) Radiation (700-1400 nm)
Adverse laser effects are generally believed to be limited largely to the retina in this spectral region. The effect upon the retina may be a temporary reaction without residual pathologic changes, or it may be more severe with permanent pathologic changes resulting in a permanent scotoma. The mildest observable reaction may be simple reddening; as the retinal irradiance is increased, lesions may occur which progress in severity from edema to charring, with hemorrhage and additional tissue reaction around the lesion. Very high radiant exposures will cause gases and mechanical compression waves (acoustic transients) to form near the site of absorption, which may disrupt the retina and may alter the physical structure of the eye. Portions of the eye other than the retina may be selectively injured, depending upon the region where the greatest absorption of the specific wavelength of the laser energy occurs and the relative sensitivity of tissue affected. Lasers and light sources in the blue-green wavelengths area potentially are more hazardous than other visible lasers because of the high absorption properties of melanin in the blue-green region. Blue laser radiation has caused retinal lesions in monkeys at approximately 1/1000 the irradiance necessary to produce thermally induced retinal lesions using red laser radiation. The action spectrum for such retinal lesions may include the UV region around 400 nm. There is no reason to believe that UV could not photochemically or thermally induce retinal lesions if the ocular spectral transmission of the species in question allows the near ultraviolet to reach the retina.

Far-Infrared Radiation IR-B (1.4-3 μm) and IR-C (3-1000 μm)
Absorption of far-infrared radiation produces heat with its characteristic effect on the cornea and the lens of the eye. The 10.6 micrometer wavelength from the carbon-dioxide laser is absorbed by the cornea and conjunctiva and may cause severe pain and destructive effects.

Skin Effects
Skin injuries are not as consequential as eye injuries. Skin reflects most visible and IR-A radiation, where as it is highly absorbing at UV-B, UV-C, IR-B and IR-C. Adverse thermal effects resulting from exposure of the skin to radiation from 315 nm to 1 mm may vary from mild reddening (erythema) to blistering and charring, depending upon the exposure dose rate, the dose (amount of energy) transferred, and conduction of heat away from the absorption site. Adverse skin effects resulting from exposure to UV-B radiation vary from erythema to blistering depending upon the wavelength and total exposure dose.

There is a large variation in individual sensitivity to skin injuries. Maximum permissible exposure limits are therefore indicated for the exposure that most individuals can tolerate without sustaining tissue injury or adverse biological damage.
5.5 Photosensitizing Agents

There are certain medical conditions, xeroderma pigmentosum, herpes simplex, and agents, which may lower the MPE threshold for biological effects in the skin, cornea, lens and retina from exposure to ultraviolet and near ultraviolet radiation. Certain chemicals, known as photosensitizing agents, can increase skin sensitivity from ultraviolet exposure. Below is a representative list of photosensitizing agents from ANSI Z136.1-2000:

<table>
<thead>
<tr>
<th>Agent</th>
<th>Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Sulfanomide</td>
<td>Phototoxic</td>
</tr>
<tr>
<td></td>
<td>Photoallergic</td>
</tr>
<tr>
<td>2 Sulfonylurea</td>
<td>Phototoxic</td>
</tr>
<tr>
<td>3 Chlorthiazides</td>
<td>Papular and Erosive Eruptions</td>
</tr>
<tr>
<td>4 Phenothiazines</td>
<td>Exaggerates Sunburn</td>
</tr>
<tr>
<td></td>
<td>Urticaria</td>
</tr>
<tr>
<td></td>
<td>Gray-Blue Hyperpigmentation</td>
</tr>
<tr>
<td>5 Antibiotics, e.g., Tetracycline</td>
<td>Exaggerates Sunburn</td>
</tr>
<tr>
<td></td>
<td>Phototoxic</td>
</tr>
<tr>
<td>6 Griseofulvin</td>
<td>Exaggerates Sunburn</td>
</tr>
<tr>
<td></td>
<td>Phototoxic</td>
</tr>
<tr>
<td></td>
<td>Photoallergic</td>
</tr>
<tr>
<td>7 Nalidixin Acid</td>
<td>Erythema</td>
</tr>
<tr>
<td></td>
<td>Bullae</td>
</tr>
<tr>
<td>8 Furocoumarins (Psoralen)</td>
<td>Erythema</td>
</tr>
<tr>
<td></td>
<td>Bullae Hyperpigmentation</td>
</tr>
<tr>
<td>9 Estrogens/Progesterones</td>
<td>Melasma</td>
</tr>
<tr>
<td></td>
<td>Phototoxic</td>
</tr>
<tr>
<td>10 Chlordiazepoxide (Librium)</td>
<td>Eczema</td>
</tr>
<tr>
<td>11 Triazetyldiphenolisatin (Laxative)</td>
<td>Eczematous Photoallergic Reaction</td>
</tr>
<tr>
<td>12 Cyclamates</td>
<td>Phototoxic</td>
</tr>
<tr>
<td></td>
<td>Photoallergic</td>
</tr>
<tr>
<td>13 Porphyrins (Porphyria)</td>
<td>Phototoxic</td>
</tr>
<tr>
<td>14 Retin-A (Retinoic Acid)</td>
<td>Exaggerates Sunburn</td>
</tr>
<tr>
<td></td>
<td>Photoallergic</td>
</tr>
</tbody>
</table>
absorption. Transformation of radiant energy to a different form of energy by interaction with matter.

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

accessible optical radiation. Optical radiation to which the human eye or skin may be exposed for the condition (operation, maintenance, or service) specified.

administrative control. Control measures for the safe use of lasers or laser systems, which involve the application of SOP, warning signs, eyewear....

alpha max ($\alpha_{\text{max}}$). The angular limit beyond extended source MPEs for a given exposure duration are expressed as a constant radiance or integrated radiance. This value is defined as 100 mrad.

alpha min ($\alpha_{\text{min}}$). See limiting angular subtense.

aperture. An opening or window through which radiation passes.

aphakic. Term describing an eye in which the crystalline lens is absent.

apparent visual angle. The angular subtense of the source as calculated from source size and distance from the eye. It is not the beam divergence of the source.

attenuation. The decrease in the radiant flux as it passes through an absorbing or scattering medium.

authorized personnel. Individuals approved by management to install, operate, or service laser equipment.

average power. The total energy in an exposure or emission divided by the duration of the exposure or emission.

aversion response. Closure of the eyelid, or movement of the head to avoid an exposure to an noxious stimulant or bright light. In this manual, the aversion response to an exposure from a bright laser source is assumed to occur within 0.25 s, including the blink reflex time.

beam. A collection of rays characterized by direction, diameter, (or dimension), and divergence (or convergence).

beam diameter. The distance between diametrically opposed points in the cross-section of a beam where the power per unit area is $1/e \times 0.368$ times that of the peak power per unit area.

beam divergence (\(\phi\)). See divergence.

blink reflex. See aversion response.

$C_A$. Correction factor which increases the MPE values in the near infrared (IR-A) spectral band (700-1400 nm) based upon reduced absorption properties of melanin pigment granules found in the skin and in the retinal pigment epithelium. $C_B$. Correction factor which increases the MPE values in the red end of the visible spectrum (450-600 nm), because of greatly reduced photochemical hazards. $C_E$. Correction factor used for calculating the extended-source MPE for the eye from the small-source MPE, when the laser source subtends a visual angle exceeding $\alpha_{\text{min}}$. $C_p$. Correction factor which reduces the MPE for repetitive-pulse exposure of the eye.

calorimeter. A device for measuring the total amount of energy absorbed from a source of electromagnetic radiation.

carcinogen. An agent potentially capable of causing cancer.

coagulation. The process of congealing by an increase in viscosity characterized by a condensation of material from a liquid to a gelatinous or solid state.

coherent. A light beam is said to be coherent when the electric vector at any point in it is related to that at any other point by a definite, continuous function.
collateral radiation. Any electromagnetic radiation, except laser radiation, emitted by a laser of laser system which is physically necessary for its operation.

collecting optics. Lenses or optical instruments having magnification and thereby producing an increase in energy or power density. Such devices may include telescopes, binoculars, microscope, or loupes.

collimated beam. Effectively, a “parallel” beam of light with very low divergence or convergence.

conjunctival discharge (of the eye). Increased secretion of mucus from the surface of the eyeball.

continuous wave (CW). The output of a laser which is operated in a continuous rather than a pulsed mode. In this standard, a laser operating with a continuous output for a period $\geq 0.25$ s is regarded as a CW laser.

controlled area. An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection form radiation hazards.

cornea. The transparent outer coat of the human eye which covers the iris and the crystalline lens. The cornea is the main refracting element of the eye.

critical frequency. The pulse repetition frequency above which the laser output is considered continuous wave (CW). For a 10 s exposure to a small source, the critical frequency is 55 kHz for wavelengths between 0.4 and 1.05 $\mu$m, and 20 kHz for wavelength between 1.05 and 1.4 $\mu$m.

cryogenics. The branch of physical science dealing with very low temperatures.

denaturation. Functional modification of the properties of protein by structural alteration via heat or photochemical processes.

depigmentation. The removal of the pigment of melanin granules from human tissues.

dermatology. A branch of medical science that deals with the skin, its structure, functions, and diseases.

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

dioptr. A measure of the power of a lens, defined as $1/f_0$, where $f_0$ is the focal length of the lens in meters.

divergence ($\phi$). For the purpose of this standard, divergence is taken as the plane angle projection of the cone that includes $1 - 1/e$ (i.e. 63.2%) of the total radiant energy or power. The value of the divergence is expressed in radians or milliradians.

effective energy ($Q_{\text{eff}}$). Energy, in joules, through the applicable measurement aperture.

effective power ($\phi_{\text{eff}}$). Power, in watts, through the applicable measurement aperture.

electromagnetic radiation. The flow of energy consisting of orthogonally vibrating electric and magnetic fields lying transverse to the direction of propagation. X-ray, ultraviolet, visible, infrared, and radio waves occupy various portions of the electromagnetic spectrum and differ only in frequency, wavelength, and photon energy.

embedded laser. An enclosed laser with an assigned class number higher than the inherent capability of the laser system in which it is incorporated, where the system’s lower classification is appropriate due to the engineering features limiting accessible emission.

enclosed laser. A laser that is contained within a protective housing of itself or of the laser or laser system in which it is incorporated. Opening or removing of the protective housing provides additional access to laser radiation above the applicable MPE than possible with the protective housing in place (an embedded laser is an example of one type of enclosed laser).
endoscope. An instrument utilized for the examination of the interior of a canal of hollow organ.

energy. The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers, and is generally expressed in joules (J).

engineering control. Control measures for the safe use of lasers or laser systems, which are directly related to the laser itself (i.e. enclosures, interlocks...).

epidemiology. A branch of medical science that deals with the incidence, distribution, and control of disease in a population.

epithilium (of the cornea). The layer of cells forming the outer surface of the cornea.

erythema. Redness of the skin due to congestion of the capillaries.

extended source. A source of optical radiation with an angular subtense at the cornea larger than \( \alpha_{\text{min}} \). See small source.

fail-safe interlock. An interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into, or remain in, a safe mode.

focal length. The distance, measured in centimeters, from the secondary nodal point of a lens to the secondary focal point. For a thin lens imaging a distant source, the focal length is the distance between the lens and the focal point.

focal point. The point toward which radiation converges or from which radiation diverges or appears to diverge.

fundus. See ocular fundus.

funduscopic. Examination of the fundus (rear) of the eye.

half-power point. The value on either the leading or trailing edge of a laser pulse at which the power is one-half of its maximum value.

hertz (Hz). The unit which expressed the frequency of a periodic oscillation in cycles per second.

infrared. The region of the electromagnetic spectrum between the long-wavelength extreme of the visible spectrum (about 0.7 \( \mu \text{m} \)) and the shortest microwaves (about 1 mm).

infrared radiation. Electromagnetic radiation with wavelength which lie within the range 0.7 \( \mu \text{m} \) to 1 mm.

installation. Placement and connection of laser equipment at the appropriate site to enable intended operation.

integrated radiance. The integral of the radiance over the exposure duration, expressed in joules-per-square-centimeter per-steradian (J*cm\(^{-2}\)*sr\(^{-1}\)).

intrabeam viewing. The viewing condition whereby the eye is exposed to all of part of a laser beam (See small source viewing).

ionizing radiation. Electromagnetic radiation having a sufficiently large photon energy to directly ionizing atomic or molecular systems with a single quantum event.

iris. The circular pigmented membrane, which lies behind the cornea of the human eye. The iris is perforated by the pupil.

irradiance. Radiant power incident per unit area upon a surface, expressed in watts-per-square-centimeter (W*cm\(^{-2}\)). Synonym: power density.

Jaeger's test. Samples of type of various sizes printed on a card for testing close visual acuity. An analogue of the Snellen chart for distant visual acuity.

joule. A unit of energy. 1 joule = 1 watt*second.

Lambertian surface. An ideal surface whose emitted or reflected radiance is independent of the viewing angle.

laser. A device that produces radiant energy predominantly by stimulated emission. Laser radiation may be highly coherent temporally, or spatially, or both. An acronym for Light Amplification by Stimulated Emission of Radiation.
laser barrier. A device used to block or attenuate incident direct or diffuse laser radiation. Laser barriers are frequently used during times of services to the laser system when it is desirable to establish a boundary for a temporary (or permanent) laser controlled area.


laser pointer. A Class II or Class IIIa laser product that is usually hand held that emits a low-divergence visible beam of less than 5 milliwatts and is intended for designating specific objects or images during discussions, lectures or presentations as well as for the aiming of firearms or other visual targeting practice.

laser safety officer (LSO). Person who has authority to monitor and enforce the control of lasers and laser systems.

laser system. An assembly of electrical, mechanical, and optical components which includes a laser.

lesion. An abnormal change in the structure of an organ or part due to injury or disease.

limiting angular subtense ($\alpha_{\text{min}}$). The apparent visual angle which divides small-source viewing from extended-source viewing. $\alpha_{\text{min}}$ is defined as 1.5 mrad.

limiting aperture ($D_f$). The maximum diameter of a circle over which radiant exposure are averaged for purposes of hazard evaluation and classification.

limiting cone angle ($\gamma$). Angle of acceptance for measurement of photochemical hazard for extended sources with radiance and integrated radiance.

limiting exposure duration ($T_{\text{max}}$). An exposure duration which is specifically limited by the design or intended use(s).

macula. The small uniquely pigmented specialized area of the retina of the eye, which in normal individuals, is predominantly employed for acute central vision (i.e. area of best visual acuity).

maintenance. Performance of those adjustments or procedures (specified in user information provided by the manufacturer of the laser or laser system), which are to be performed by the user to ensure the intended performance of the product. It does not include operation or service as defined in this section.

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

meter. A unit of length in the international system of units; currently defined as the length of a path transversed in vacuum by light during a period of 1/299792458 seconds. Typically, the meter is subdivided into the following units:

- centimeter (cm) = $10^{-2}$ m
- millimeter (mm) = $10^{-3}$ m
- micrometer ($\mu$m) = $10^{-6}$ m
- nanometer (nm) = $10^{-9}$ m

minimum viewing distance. The minimum distance at which the eye can produce a focused image of a diffuse source, usually assumed to be 10 cm.

nominal hazard zone (NHZ). The space within which the level of the direct, reflected, or scattered radiation during normal operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.

nominal ocular hazard distance (NOHD). The distance along the axis of the unobstructed beam from a laser, fiber end, or connector to the human eye beyond which the irradiance or radiant exposure, during installation or service, is not expected to exceed the appropriate MPE.
**non-beam hazard.** A class of hazards that result from factors other than direct human exposure to a laser beam.

**ocular fundus.** The interior posterior surface of the eye (the retina), as seen upon ophthalmoscopic examination.

**operation.** The performance of the laser or laser system over the full range of its intended functions (normal operation). It does not include *maintenance or service* as defined in this section.

**ophthalmoscope.** An instrument for examining the interior of the eye.

**optically aided viewing.** Viewing the laser source with an optical device such as an eye loupe, hand magnifier, microscope, binoculars, telescope, etc. Optically aided viewing does not include viewing with corrective eyewear or with indirect image converters.

**optical density (Dλ).** Logarithm to the base ten of the reciprocal of the transmittance. That is,

\[ D_\lambda = -\log_{10} \tau_\lambda \]

where \( \tau_\lambda \) is the transmittance.

**photophobia.** An unusual intolerance of light. Also, an aversion to light usually caused by physical discomfort upon exposure to light.

**photosensitizers.** Substances which increase the sensitivity of a material to irradiation by electromagnetic energy.

**pigment epithelium (of the retina).** The layer of cells which contain brown or black pigment granules next to and behind the rods and cones.

**plasma radiation.** Black-body radiation generated by luminescence of matter in a laser-generated plume.

**power.** The rate at which energy is emitted, transferred, or received. Unit: watts (joules per second).

**protective housing.** An enclosure surrounding the laser or laser system that prevents access to laser radiation above the applicable MPE level. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing may enclose associated optics and a workstation, and limits access to other associated radiant energy emission and to electrical hazards associated with components and terminals.

**pulse duration.** The duration of a laser pulse, usually measured as the time interval between the half-power points on the leading and trailing edges of the pulse.

**pulse-repetition frequency (PRF).** The number of pulses occurring per second, expressed in hertz.

**pulsed laser.** A laser which delivers its energy in the form of a single pulse or a train of pulses. In this standard, the duration of a pulse < 0.25s.

**pupil.** The variable aperture in the iris through which light travels to the interior of the eye.

**Q-switch.** A laser that emits short (~10-250ns), intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium, respectively.

**Q-switched laser.** A laser that emits short (~10-250 ns), high-power pulses by means of a Q-switch.

**radian (rad).** A unit of angular measure equal to the angle subtended at the center of a circle by an arc whose length is equal to the radius of the circle. 1 radian \( \approx 57.3 \) degrees; \( 2\pi \) radians = 360 degrees.

**radiance.** Radiant flux or power output per unit solid angle per unit area expressed in watts-per-centimeter squared-per-steradian (W*cm\(^{-2}\)*sr\(^{-1}\)).
radiant energy. Energy emitted, transferred, or received in the form of radiation. Unit: joules (J).

radiant exposure. Surface density of the radiant energy received expressed in units of joules-per-centimeter squared (J/cm²).

radiant flux. Power emitted, transferred, or received in the form of radiation. Unit: watts (W). Also called: radiant power.

radiant intensity. Quotient of the radiant flux leaving a source and propagated into an element of solid angle containing the direction, by the element of solid angle. Radiant intensity is expressed in units of watts per steradian (W/sr⁻¹).

radiant power. Power emitted, transferred, or received in the form of radiation, expressed in watts (W). Synonym: radiant flux.

radiometry. A branch of science that deals with the measurement of radiation. For the purpose of this standard, radiometry will be limited to the measurement of infrared, visible, and ultraviolet radiation.

Rayleigh scattering. Scattering of radiation in the course of its passage through a medium containing particles whose sizes are small compared with the wavelength of the radiation.

reflectance. The ratio of total reflected radiant power to total incident power. Also called reflectivity.

reflection. Deviation of radiation following incidence on a surface.

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

refractive index (of a medium). Denoted by n, the ratio of the velocity of light in vacuum to the phase velocity in the medium. Synonym: index of refraction.

repetitive pulse laser. A laser with multiple pulses of radiant energy occurring in a sequence.

retina. The sensory membrane that receives the incident image formed by the cornea and lens of the human eye. The retina lines the inside of the eye.

retinal hazard region. Optical radiant with wavelengths between 0.4 and 1.4 µm, where the principle hazards is usually to the retina.

safety latch. A mechanical device designed to slow direct entry to a controlled area.

scanning laser. A laser having a time-varying direction, origin, or pattern of propagation with respect to a stationary frame of reference.

scintillation. The rapid changes in irradiance levels in a cross-section of a laser beam.

secured enclosure. An enclosure to which casual access is impeded by an appropriate means, e.g., a door secured by a magnetically or electrically operated lock or latch, or by fasteners that need a tool to remove.

service. The performance of those procedures or adjustments described in the manufacturer’s service instructions which may affect any aspect of the performance of the laser or laser system. It does not include maintenance or operation as defined in this section.

shall. The word “shall” is to be understood as mandatory.

should. The word “should” is to be understood as advisory.

small source. In this document, a source with an angular subtense at the cornea equal to or less than alpha-min (α_min), i.e., ≤ then 1.5 mrad. This includes all sources formerly referred to as “point sources” and meeting small-source viewing (formerly called point source or intrabeam viewing) conditions.

small-source viewing. The viewing condition whereby the angular subtense of the source, α_min, is equal to or less than the limiting angular subtense, α_min.
solid angle. The three-dimensional angular spread at the vertex of a cone measured by the intercepted by the cone on a unit sphere whose center is the vertex of the cone. Solid angle is expressed in steradians (sr).

source. A laser of a laser-illuminated reflecting surface.
spectator. An individual who wishes to observe or watch a laser or laser system in operation, and who may lack the appropriate laser safety traning.

specular reflection. A mirror-like reflection.

steradian (sr). The unit of measure for a solid angle. There are $4\pi$ steradians about any point in space.

standard operating procedure (SOP). Formal written description of the safety and administrative procedures to be followed in performing a specific task.

stromal haze (of the cornea). Cloudiness in the connective tissue or main body of the cornea.
surface exfoliation (of the cornea). A stripping or peeling off of the surface layer of cells from the cornea.
synergism. A condition in which the combined effect is greater than the sum effects of individual contributors.

$T_1$. The exposure duration (time) at which MPEs based upon thermal injury are replaced by MPEs based upon photochemical injury to the retina.

$T_2$. The exposure duration (time) beyond which extended-source MPEs based upon thermal injury are expressed as a constant irradiance.

threshold limit (TL). In this standard, the term is applied to laser protective eyewear filters, protective windows, and barriers. The TL is an expression of the “resistance factor” for beam penetration of a laser protective device. This is generally related by the Threshold Limit (TL) of the protective device (expressed in $W*cm^{-2}$ or $J-cm^{-2}$). It is the maximum average irradiance (or radiant exposure) at a given beam diameter for which a laser protective device (e.g. filter, window, barrier, etc.) provides adequate beam resistance. Thus, laser exposures delivered on the protective device at or below the TL will limit beam penetration to levels at or below the applicable MPE.

$T_{max}$. See limiting exposure duration.

$t_{min}$. For a pulse laser, the maximum duration for which the MPE is the same as the MPE for a 1 ns exposure. For thermal biological effects, this corresponds to the “thermal confinement duration” during which heart flow does not significantly change the absorbed energy content of the thermal relaxation volume of the irradiated tissue.

tonometry. Measurement of the pressure (tension) of the eyeball.

transmission. Passage of radiation through a medium.

transmittance. The ratio of transmitted power to incident power.

ultraviolet radiation. Electromagnetic radiation with wavelengths shorter than those of visible radiation; for the purpose of this standard, 0.18 to 0.4 $\mu$m.

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

viewing window. Visually transparent parts of enclosures that contain laser processes. It may be possible to observe the laser processes through the viewing window.

visible radiation (light). In this standard, the term is used to describe electromagnetic radiation which can be deleted by the human eye. This term is commonly used to describe wavelength which lie in the range 0.4 to 0.7 $\mu$m.

watt (W). The unit of power or radiation flux. 1 watt = 1 joule-per-second.

wavelength. The distance between two successive points on a periodic wave which have the same phase.

work practices. Procedures used to accomplish a task.
5.7 Laser Forms
Laser Use Authorization Application

Name: ___________________________ (Last, First, Middle Initial)  Office Extension: ____________
Academic Title: ___________________  Lab Extension: ____________
E-mail: ___________________________  Mail Code: ____________
Department: ________________________  Index #: ____________
Lab Manager/Contact: _______________________________________
Lab Manager/Contact e-mail: ___________________________________
Eye Protection? Yes ☐ / No ☐  Sign and Posting? Yes ☐ / No ☐
Laser Safety Manual? Yes ☐ / No ☐  SOPs? Yes ☐ / No ☐

List all lasers to be used under this LUA

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Serial Number</th>
<th>Building</th>
<th>Room Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Project Summary

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
All personnel authorized to use lasers and/or laser systems under this LUA must submit a Laser User Enrollment form and be listed below:

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

I hereby certify that all information in this statement is true and correct, and authorize the release of any past laser radiation exposure history from previous employers to UCSD. I have read, understand and will comply with the requirements of UCSDs Laser Safety Manual.

Submitted by: _______________________________  ____/____/______

PI Signature  Date

Approved by: _______________________________  ____/____/______

LSO Signature  Date

Approved by: _______________________________  ____/____/______

Laser Safety Committee Signature  Date

Please attach a copy of your C.V. and copies of current award notices for grants that involve laser(s), and send them to the Laser Safety Officer at mail code 0920 or fax to 858-534-7982.
Laser Use Enrollment Application

Name: ___________________________ (Last, First, Middle Initial)  Office Extension: _________

Employee/Student ID: _______________  Lab Extension: ____________

Date of Birth: ______________________  Mail Code: _______________

Department: ________________________  LUA #: _________________

Principal Investigator: _______________  Gender: _______________

Eye Exam Date: _____________________

UCSD Laser Training Date: ____________

Status: □ Faculty / □ Staff / □ Student / □ Other ____________________

List any education/training specifically applicable to the use of lasers and/or laser systems or laser safety. Include date and location for each.

________________________________________________________________________

________________________________________________________________________

Proposed Use

List all lasers and laser systems to be used at UCSD:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Serial Number</th>
<th>Building</th>
<th>Room Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
List prior experience working with lasers and/or laser systems beginning with the most recent.

<table>
<thead>
<tr>
<th>From: <em><strong><strong>/</strong></strong></em>/_____</th>
<th>To: <em><strong><strong>/</strong></strong></em>/_____</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employer:</td>
<td></td>
</tr>
<tr>
<td>Address:</td>
<td></td>
</tr>
</tbody>
</table>

Describe Laser Use

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Laser Type</th>
<th>Power</th>
<th>Type of Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>From: <em><strong><strong>/</strong></strong></em>/_____</th>
<th>To: <em><strong><strong>/</strong></strong></em>/_____</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employer:</td>
<td></td>
</tr>
<tr>
<td>Address:</td>
<td></td>
</tr>
</tbody>
</table>

Describe Laser Use

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Laser Type</th>
<th>Power</th>
<th>Type of Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

I hereby certify that all information in this statement is true and correct. I have read, understand, and will comply with the requirements of UCSD's Laser Safety Manual.

Submitted by: _________________________________  ___/___/____
             User Signature                    Date

Approved by: _________________________________  ___/___/____
           Principal Investigator Signature    Date

Please send to the Laser Safety Officer at mail code 0920 or fax to 858-534-7982.
Laser Use Authorization Amendment Application

PI: _______________________________  RUA: ________________________
Lab Manager/Contact: _______________  Phone: ________________________

Personnel
To add, submit a Laser Use Enrollment form and list below:

____________________________________________________________________
____________________________________________________________________

To delete, list below.

____________________________________________________________________
____________________________________________________________________

Work Location
To add:

<table>
<thead>
<tr>
<th>Building</th>
<th>Room Number</th>
<th>Room Use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To Delete:

<table>
<thead>
<tr>
<th>Building</th>
<th>Room Number</th>
<th>Room Use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Lasers

To add submit a Laser Safety Registration form and list below:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Serial Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To Delete:

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Serial Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To add a new project summary, describe:

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

Submitted by: ______________________  _____/_____/_____

Principal Investigator Signature   Date

Please send to the Laser Safety Officer at mail code 0920 or fax to 858-534-7982.
Laser Safety Equipment Registration Application

Manufacturer: __________________________  Serial #: __________________________

Laser Classification (3a,3b,4): __________  Type of Laser: __________________________
(i.e.: Argon, HeNe)

Maximum Power: ________ W / ________ J  Model: __________________________

Wavelength: __________________________  □ Continuous wave / □ Pulsed

Laser Status: □ Active / □ Inactive / □ Broken / □ Other: __________________________

□ Shared Between: __________________________  Name of PI

□ On Loan From: __________________________  Department / University

Location (Building and Room Number)

________________________________________________________________________
________________________________________________________________________

Principal Investigator: __________________________

Phone: ______________

Mail Code: __________

Email Address: __________________________

Department: __________________________

I hereby certify that all information in this statement is true and correct.

Submitted by: __________________________  _____/_____/_______

   PI Signature  Date

Approved by: __________________________  _____/_____/_______

   Department Chair Signature  Date

Please send to the Laser Safety Officer at mail code 0920 or fax to 858-534-7982.
Laser Safety Equipment Transfer Application

<table>
<thead>
<tr>
<th>Manufacturer:</th>
<th>Serial Number:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser Type:</td>
<td>Laser Classification:</td>
</tr>
<tr>
<td>Maximum Power:</td>
<td>Continuous Wave / Pulsed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transferred From</th>
<th>Transferred To</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Building and Room Number)</td>
<td>(Building and Room Number)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PI:</th>
<th>PI:</th>
</tr>
</thead>
<tbody>
<tr>
<td>LUA:</td>
<td>LUA:</td>
</tr>
<tr>
<td>Date:</td>
<td>Date:</td>
</tr>
<tr>
<td>Signature:</td>
<td>Signature:</td>
</tr>
<tr>
<td>Printed Name:</td>
<td>Printed Name:</td>
</tr>
<tr>
<td>Phone Number:</td>
<td>Phone Number:</td>
</tr>
</tbody>
</table>

(original for UCSD, one copy for each PI)

**EH&S Use**

Date Entered: _______________

Please send to the Laser Safety Officer at mail code 0920 or fax to 858-534-7982.
References

