UNIVERSITY of CONNECTICUT

Laser Safety Manual

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Revised: July 29, 2003

1. Laser Safety Organization and Responsibilities

1.1 Introduction

The University of Connecticut Laser Safety Program is based on the recommendations of the American National Standards Institute (ANSI) Z136.1 2000, *Standard for the Safe Use of Lasers* (or latest version thereof), and any other pertinent standards, as well as other applicable federal and state regulations.

The primary objective of the University of Connecticut Laser Safety Program is to ensure that no laser radiation in excess of the maximum permissible exposure (MPE) limit reaches the human eye or skin. Additionally, the program is designed to ensure adequate protection against non-beam hazards. Non-beam hazards include the risk of electrical shock, fire hazard from a beam, chemical exposures from the use of toxic gases, dyes, solvents, and vaporization of targets.

This Laser Safety Manual is intended to supplement, clarify, and modify, applicable to the University of Connecticut Laser Safety Program, the ANSI Z136.1 2000, *Standard for the Safe Use of Lasers* (or latest version thereof). Recommendations of ANSI Z136.1 not specifically referenced in this manual are to be considered in effect unless specified otherwise by the Laser Safety Committee. Additional laser safety policies and procedures as set forth by the Laser Safety Committee are incorporated into this manual.

1.2 Laser Safety Committee (LSC)

The Laser Safety Committee is composed of members appointed by the President of the University. It shall be composed of University faculty and staff laser users, a representative of the University administration, and Environmental Health & Safety Department representatives including the designated Laser Safety Officer. It has jurisdiction over safety issues related to laser equipment and activities at all campuses of the University of Connecticut with the exception of the University of Connecticut Health Center, which maintains its own program.

The responsibilities and authority of the committee include:

1. Facilitating, advising, and supporting the safe use of lasers.
2. Ensuring the University's compliance with laser safety regulations promulgated by Federal and State Agencies, and relevant ANSI standards.
3. Establishing and maintaining adequate policies and practices for the control of laser hazards including training and inspections.
4. Providing direction and advice to the Department of Environmental Health and Safety Radiation Safety Section's designated Laser Safety Officer on matters regarding laser safety policy.
5. Maintaining an awareness of all applicable new or revised laser safety standards.
6. Receiving and reviewing periodic reports from the Laser Safety Officer on monitoring, safety, and personnel exposure.
7. Reviewing significant, and or continued, instances of alleged infraction of use and safety procedures with the Laser Safety Officer and the responsible individuals and directing corrective actions regarding same.
8. Reviewing requests and making recommendations for "seed" money intended for the acquisition of laser safety-related materials, equipment, renovations, etc.

9. Completing and submitting reports to the University Administration, regulatory agencies, etc. as required.

1.3 Laser Safety Officer (LSO)

The Department of Environmental Health and Safety Radiation Safety Section's designated Laser Safety Officer is the operational arm of the Laser Safety Committee at The University of Connecticut. This position is responsible for:

1. Implementing policy decisions of the Laser Safety Committee.

2. Ensuring the University's compliance with laser safety regulations promulgated by Federal and State Agencies, and relevant ANSI standards.

3. Providing consultative services to laser users on laser hazard evaluation, controls, and personnel training programs.

4. Conducting periodic safety audits/inspections of all class 3b and 4 laser equipment, associated personnel, and facilities.

5. Assuring that adequate safety education and training are provided to all personnel who may be exposed to laser energy levels above the Maximum Permissible Exposure limits.

6. Assuring that the prescribed control measures are in effect, recommending or approving substitute or alternate control measures when primary ones are not feasible or practical. This shall include, but not be limited to, such actions as establishing an Nominal Hazard Zone (NHZ), approving standard operation procedures (SOPs), avoiding unnecessary or duplicate controls, selecting alternate controls, conducting periodic facility and equipment audits, and training.

7. Classifying, or verifying classification of lasers and laser systems used at The University of Connecticut.

8. Approving establishment of Nominal Hazard Zones (NHZs) in laser work areas.

9. Approving laser systems operations to include standard operating procedures (SOPs), alignment procedures, maintenance, and servicing.

10. Recommending protective equipment that may be required to assure personnel safety.

11. Approving wording on area signs and equipment labels.

12. Ensuring that required medical surveillance is available as necessary.

13. Maintaining an inventory of all Class 3b and Class 4 lasers at The University of Connecticut.

14. Recommending corrective actions to the LSC if a violation persists.

15. Ensuring necessary records required by applicable government regulations are maintained.

16. Investigating, and submitting written reports on, known or suspected accidents involving laser equipment.

17. The Laser Safety Officer is empowered by the Laser Safety Committee to immediately terminate laser operations found to be an immediate threat to health, safety, or property.

1.4 Primary Laser Researcher (PLR)

Primary Laser Researchers are University of Connecticut faculty/staff members with appropriate training and experience relative to the use of lasers in their respective research activities. PLRs are responsible for all aspects of their laboratory's laser safety compliance program including, but not limited to:

1. Supervising the safe use of lasers and ancillary equipment.

2. Registering all Class 3b and 4 lasers with the LSC through EH&S.

3. Notifying the LSC and EH&S of the intent to acquire or fabricate Class 3b or Class 4 lasers.

4. Creating and implementing laser systems operations to include standard operating procedures (SOPs), alignment procedures, maintenance and servicing operations.

5. Ensuring that lab associated laser users and laser non-users have satisfactorily completed laser safety training (both general and laser/lab specific) prior to work in a laser work area NHZ.

6. Meeting LSC requirements for posting, access control, personal protective equipment, and medical surveillance.

7. Reporting to the Laser Safety Officer known or suspected accidents involving laser equipment.

1.5 Individual Laser Users/Operators

Scientists, research personnel, technical personnel, students, and other workers engaged in laboratory research and research support, which involves the use and operation of either Class 3b or Class 4 lasers. These personnel are responsible for the following:

1. Wearing appropriate personal protective equipment, attending required training, following SOP's, and conducting laser activities in a safe manner.

2. Completing appropriate eye examinations prior to initial use of Class 3b or Class 4 lasers.

1.6 Individual Laser Non-users and Incidental Personnel

Personnel whose work makes it possible (but unlikely) that they may be exposed to laser energy sufficient to damage their skin or eyes, e.g., non-laser using researchers, custodial, maintenance, and clerical personnel.

1. Satisfactorily completing appropriate laser safety training.

2. Training

Prior to the initial use of Class 3b or Class 4 lasers all laser users, including the PLR, must complete an appropriate University of Connecticut laser safety training program as approved by the Laser Safety Committee. The training consists of two parts. The first requires successful completion of an on-line laser safety training program administered by the Department of Environmental Health and Safety. The second part entails a PLR provided laboratory-based training program specific to use of lasers under their responsibility. The PLR must also conduct laboratory-based training for their non-laser using research, clerical, and maintenance personnel who, despite controls to prevent otherwise, may be exposed above the MPE.

Guests/visitors of the University of Connecticut who request to use either Class 3b or Class 4 lasers must contact the LSO regarding the training requirement for non-UConn personnel. New employees and guests may use lasers under the direct supervision of a PLR until satisfactorily completing the training requirements. The LSO will be notified of these new employee or guest laser users.

The on-line portion of the laser safety training program is offered on-demand via UConn's WEBCT on-line classroom service. Completion of both the on-line course and the laboratory-based training satisfies the training requirements necessary to commence using either Class 3b or Class 4 lasers.

Laser safety training for incidental personnel not directly associated with a laser lab, e.g., University facilities/maintenance and housekeeping, will be conducted annually by the LSO.

Laser users must participate in periodic retraining. The Laser Safety Committee based upon the specific needs of the PLR and their designated laser users will determine the frequency of retraining. The retraining interval will not exceed four years. The retraining requirement may be met through successful repeating of the on-line programs and/or laboratory-based training.

3. Medical Surveillance

Personnel working with either Class 3b or Class 4 lasers or laser systems are required to obtain a pre-assignment laser use base-line eye examination. As a part of this examination the intended laser user is required to report any medical conditions that could cause the an increased risk of chronic laser exposures. These medical conditions could include, but are not limited to, photosensitivity of the skin, use of photosensitizing medications, and dermatological abnormalities of the skin. Medical screening eye examinations are also required following any suspected laser injuries and at the time of departure from the University.

At the discretion of the laser user, any of the required eye examinations may be formally declined by completion of the Laser Safety Medical Surveillance Declination Form.

Arrangements for eye examinations may be made via the LSO.

4. Laser Acquisitions

Primary Laser Researchers are required to notify the LSO of any decision to purchase, fabricate, or otherwise acquire either Class 3b or Class 4 lasers. The LSO will review with the user the hazards of the proposed operation and make recommendations regarding the specific safety requirements that pertain to the proposed use, including requirements for SOPs, laser control areas, training, and personnel protective equipment. Frequently, lasers are embedded in laser products or systems with a lower hazard rating. For example, laser printers, CD players, and laser scanning confocal microscopes are Class 1 laser products, but they contain Class 3b or Class 4 lasers. When the laser system is used as intended, the controls for the system's class apply. When the system is opened (e.g., for service or alignment) and the embedded laser beam is accessible, a temporary control area must be established. The controls for the temporary control area must be based on the classification of the embedded laser. The user and LSO must determine adequate controls.

Confirmation of a system classification is the responsibility of the LSO, and therefore, necessitates registering the system. An abbreviated SOP may be required, as in the case of such commercially available enclosed laser systems as a laser scanning confocal microscope.

5. Laser Classification

To provide a basis for laser safety requirements, all lasers and laser systems and/or devices in the U.S. are classified according to their hazard potential. Corresponding labels are affixed to the laser or laser system to positively identify the class; the user can then follow the necessary safety precautions. Understanding the laser classification is a fundamental prerequisite for any discussion of laser safety.

Laser classifications are contained in ANSI Z136.1-2000, ANSI Z136.3, and the Federal Laser Products, Performance Standard, 21 CFR 1040. OSHA references the ANSI Z136.1 standard. The Center for Devices and Radiological Health (CDRH), a part of the Food and Drug Administration (FDA) enforce 21 CFR 1040.10 and 1040.11. The FDA requires the manufacturer to classify and appropriately label lasers prior to sale. For custom-built and modified lasers, the LSO can assist with classification.

The following sections describe chiefly continuous-wave (CW) lasers. The same hazard levels apply to pulsed lasers; however, the classification criteria are more complex. Details of the classification of pulsed lasers are in the American National Standard for the Safe Use of Lasers, ANSI Z136.1, and Laser Products Performance Standard, 21 CFR 1040.10. Ultrashort-pulsed laser systems, which operate in the sub-nanosecond time domain, require special safety considerations. Contact the LSO for specific information.

<u>Class 1 Lasers</u>

Class 1 lasers do not emit harmful levels of radiation during normal operation and are, therefore, exempt from control measures. As a matter of good practice, unnecessary exposure to Class 1 laser light should be avoided.

Class 1 lasers can be used without restriction in the manner intended by the manufacturer and without special training or qualification of operating personnel. Personnel should not be exposed to laser light unnecessarily.

<u>Class 2 Lasers</u>

Class 2 lasers emit accessible laser light in the visible region and are capable of creating eye damage through chronic exposure. In general, the human eye will blink within 0.25 second when exposed to Class 2 laser light. This blink reflex provides adequate protection. It is possible, however, to overcome the blink reflex and to stare into a Class 2 laser long enough to cause damage to the eye. The upper power limit for Class 2 lasers is 1 milliwatt (mW). Class 2 lasers are commonly utilized during alignment applications.

Class 2 lasers can be used without restriction in the manner intended by the manufacturer and without special training or qualification of operating personnel. Personnel should not be exposed to laser light unnecessarily.

<u>Class 3a Lasers</u>

Class 3a lasers and laser systems are normally not hazardous when viewed momentarily with the unaided eye, but they pose severe eye hazards when viewed through optical instruments (e.g., microscopes and binoculars). The upper power limit for Class 3a lasers is 5 milliwatts (mW).

Class 3a lasers are governed by the same criteria as Class 1 and Class 2 lasers for normal operations. If the laser light is to be viewed through optical instruments (e.g., binoculars, telescopes, or microscopes), contact the LSO for a hazard review. Special control measures may be needed.

<u>Class 3b Lasers</u>

Class 3b lasers and laser systems may be hazardous under direct and specular reflection. The upper power limit for Class 3b lasers is 500 mW continuous wave (CW) or less than 0.03 Joule (J) pulsed with a pulse width less than 0.25 second. Specific control measures covered in this chapter must be implemented.

Class 4 Lasers

Class 4 lasers include all lasers with power levels greater than 500 mW CW or greater than 0.03 J for a pulsed system. They pose eye hazards, skin hazards, and fire hazards. Viewing of the beam and of specular reflections or exposure to diffuse reflections can cause eye and skin injuries. Class 4 lasers may also produce laser-generated air contaminants (LGAC) and hazardous plasma radiation. All of the control measures explained in this document must be implemented.

All requirements of the University of Connecticut Laser Safety Program apply to Class 3b and Class 4 lasers, unless documented equivalent procedures and control measures have been approved by the LSO.

6. Standard Operating Procedures (SOP)

An approved written SOP must be provided by the PLR for all Class 3b and Class 4 laser systems. This SOP will cover laser operations (i.e. description of activities, hazard identification and mitigation, routine alignment procedures, schematics of laser set-up) and other relevant hazards in the laser environment. The University of Connecticut general laser SOP template is available from the LSO or as a PDF on the Environmental Health and Safety web site. The template provides a guide for the PLR in identifying the characteristics of the laser operation and collateral hazards, and in formulating set-up and alignment procedures. For assistance in developing appropriate control measures and completing the SOP, users may contact the LSO.

In the case of enclosed systems (laser scanning confocal microscopy) an abbreviated SOP can be applied. This abbreviated SOP will follow the standard SOP approval process. This approach can only be used after an experimental review by the LSO, who will then determine the required sections of the abbreviated SOP.

All SOPs will be reviewed at least annually by the LSO as part of a routine laser audit/inspection. However, regular review by personnel working with lasers to ensure the accuracy of the procedure(s) is highly recommended. If no new hazards have been added to the system, the users can perform the review without notifying the LSO. If new hazards (use of a sub-nanosecond laser system, for example) have been added to the experiment, a review by the LSO is necessary to assure all applicable safeguards have been satisfied.

A specified time period, agreed upon by both the PLR and the LSO, will be established between the setting up of the laser equipment and the submittal of the SOP draft document. With the assistance of the PLR the LSO will develop a set of documented conditions for the laser user to operate the laser during the interim. These conditions will be posted in the laser environment and sent to the appropriate departmental safety coordinator.

7. Class 3b Control Areas

Class 3b (and Class 4) lasers may be operated only in designated laser control areas approved by the LSO. The purpose of laser control areas is to confine laser hazards to well-defined spaces that are under the control of the laser user. This is an attempt to prevent injury to those visiting and working near the control area. All personnel who require entry into a Class 3b (and Class 4) laser controlled area during laser operations, maintenance, or servicing shall be appropriately trained. Class 3b laser control areas must meet the following administrative and operational control requirements:

7.1 Nominal Hazard Zone (NHZ)

In situations requiring open laser beams it is necessary to define an area, within the Control Area, of potentially hazardous laser radiation. This area is referred to as the Nominal Hazard Zone (NHZ), which is defined as a space within which the level of direct scattered, or reflected laser radiation exceeds the Maximum Permissible Exposure (MPE). The purpose of a NHZ is to define the area in which control measures (e.g. laser eyewear) are required. The LSO and PLR will determine the NHZ. The NHZ may in some situations comprise the entire Control Area.

7.2 Posting

The Control Area must be posted with appropriate warning signs that indicate the nature of the hazard. The wording on the signs will be specified by the LSO and conform to the ANSI Z136.1 guidelines. Such signs shall be posted at all entrances to the laser control area.

7.3 Authorization

Only personnel who have been authorized may operate the laser. Personnel may be authorized upon compliance with the requirements identified in the section on training. At a minimum, authorized personnel have met all training requirements stipulated for the class laser they wish to operate. The Primary Laser Researcher may stipulate additional authorization requirements.

7.4 Beam Stop

All laser beams, other than those applied to tissue for surgical or therapeutic purposes, must be terminated at the end of their useful paths by a material that is non-reflective and fire resistant (beam stop).

7.5 Eye Protection

Lasers should be mounted so that the beam path is not at eye level for standing or seated personnel (i.e. above 6.5 feet or below 3 feet). Laser protective eyewear of adequate optical density and threshold limit for the beam(s) under manipulation must be provided to all present individuals and worn at any point where the laser exposure could theoretically exceed the MPE. Procedures and practices must ensure that optical systems and power levels are not adjusted upstream during critical open beam operations, such as beam alignment. In clinical use, patients must also be provided with eye protection. The need for laser eye protection must be balanced by the need for adequate visible light transmission. It is the responsibility of the Primary Laser Researcher to obtain appropriate laser protective eyewear. For assistance in selecting laser eye protection, contact the LSO. The LSO can assist the user in determining the proper parameters of such eyewear, and can provide contact numbers for vendors. Laser eye protection should be inspected periodically to ensure that it is in good condition.

7.6 Light Containment

Laser light levels in excess of the MPE must not pass the boundaries of the control area. All windows, doorways, open portals, and other openings through which light might escape from a laser control area must be covered or shielded in such a manner as to preclude the transmission of laser light. Special rules apply for outdoor use and laser control areas that do not provide complete containment. Contact the LSO for details.

8. Class 4 Control Areas

Only appropriately trained personnel may enter a Class 4 laser controlled area during the time a procedure utilizing the active beam is in progress. All personnel within the control area must be provided with appropriate protective equipment and are required to follow all applicable administrative controls. Class 4 laser control areas must meet all of the Class 3b control area requirements listed in Section 7 of this manual in addition to the following requirements:

8.1 Emergency Conditions

For emergency conditions there shall be a clearly marked "Panic Button" available for deactivating the laser or reducing the output to levels at or below the MPE.

8.2 Rapid Egresses and Emergency Access

There must be provisions for rapid egress from a laser control area under all normal and emergency conditions. Any control area interlock system must not interfere with emergency egress. In addition, access control measures must not interfere with the ability of emergency response personnel (fire, paramedical, police) to enter the laser control area in the event operating personnel become injured or incapacitated.

8.3 Entryway Controls

Procedural area or entryway controls must be in place to prevent inadvertent entry into a laser control area, or inadvertent exposure to the active laser beam.

The Class 4 laser Control Area shall incorporate one of the following alternatives:

- Non-defeatable (non over-ride) Area or Entryway Safety Controls:
  - Non-defeatable safety latches, entryway or area interlocks (e.g. electrical switches, pressure sensitive floor mats, infrared, or sonic detectors) shall be used to deactivate the laser or reduce the output to levels at or below the applicable MPE in the event of unexpected entry into the laser Control Area.
- Defeatable Area or Entryway Safety Controls:
  - Defeatable safety latches, entryway or area interlocks shall be used if non-defeatable area/entryway safety controls limit the intended use of the laser or laser system.
- Procedural Area or Entryway Safety Controls:
  - Where safety latches or interlocks are not feasible the following shall apply:
    - All authorized personnel shall be adequately trained and adequate personal protective equipment shall be provided upon entry.
    - A door, blocking barrier, screen, curtains, etc. shall be used to block, screen, or attenuate the laser radiation at the entryway.
    - At the entryway there shall be a visible lighted laser warning sign or audible signal indicating that the laser is energized and operating.

Locking or blocking entryway doors by unapproved mechanisms (i.e. chains, hasp-locks, etc.) as a means of access control is not acceptable, because it is contrary to the principle of permitting rapid egress or emergency access (see 8.2 above).

9. Temporary Laser Control Areas

Temporary laser control areas can be created for the servicing and alignment of embedded lasers, enclosed lasers, and in special cases where permanent laser control areas cannot be provided. They are subject to the normal SOP approval process.

10. Substitution of Alternate Control Measures

Upon documented review by the LSO, the engineering control measures recommended by ANSI Z136.1 for Class 3b and Class 4 lasers or laser systems may be replaced by administrative or other alternate engineering controls that provide equivalent protection. Approvals of these controls are subject to the same review procedure as described in this chapter.

11. Viewing Laser Radiation

The figures below illustrate intrabeam viewing of direct (primary) and diffusely reflected (secondary) beams.

Fig. 11.1. Intrabeam viewing of direct (primary) beam. This type of viewing is most hazardous. Note that the diagrams also illustrate that a laser beam diverges as it propagates.

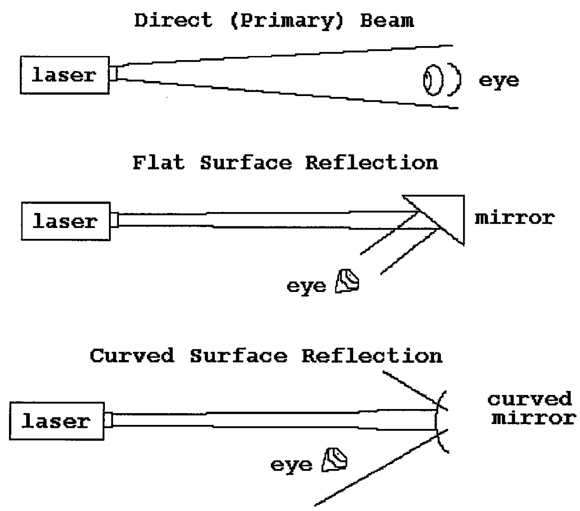
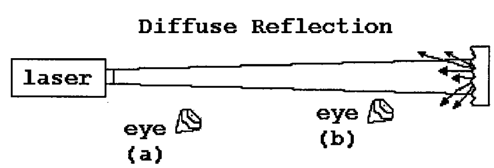


Fig. 11.2. Diffuse Reflection viewing of a specularly reflected (secondary) beam from an irregular surface reflector.



Note: Large source (diffuse reflection) viewing at (eye a) large distance corresponds to a small source, while (eye b) viewing the same source, close-up, produces a large retinal image.

12. Beam Hazards

The most prominent safety concern with lasers is the possibility of eye damage from exposure to the laser beam, as outlined below. The nature of the damage and the threshold level at which each type of injury can occur depends on the beam parameters. These include wavelength, output power, beam divergence, beam diameter, and exposure duration. For pulsed lasers, the parameters include pulse energy, pulse duration, pulse repetition frequency, and pulse train characteristics.

Where feasible, the laser user is required to keep all laser beams within the operating field, on the optical table or within the experimental envelope at all times. To maintain this control it is essential to be aware of all beams, including stray beams and/or reflections, and to terminate them with beam stops at the end of their useful paths. When a beam traverses to other tables or across aisles, the beam must be enclosed or the access to the aisle must be blocked to prevent personnel from exposure to the beam.

Since IR and UV laser beams are not within the boundaries of normal human vision, they possess a higher hazard potential than visible light lasers. Because of the invisible nature of the optical radiation, the use of laser eyewear that will protect against worst-case exposures is required at all times.

Infrared laser beams (> 700 nm) must be terminated by a highly absorbent, non-specular backstop. Note that many surfaces that appear dull are excellent IR reflectors and would not be suitable for this purpose. Beam terminators for Class 4 IR laser beams must be made of a fire-retardant material, or of a material that has been treated to be fire-retardant.

12.1 Retina

Laser light in the visible (400 nm - 780 nm) and near infrared (NIR) (700 nm - 1400 nm) regions that enters the eye is focused on the retina. This can result in the following types of damage:

12.2 Thermal Burn (Retina)

Normal focusing by the eye results in an irradiance amplification of approximately 10,000; therefore, a 1-mW/cm2 beam entering the eye will result in a 100 W/cm2 exposure at the retina. The most likely effect of intercepting a laser beam of sufficient irradiance with the eye is a thermal burn that destroys the retinal tissue. The ANSI Maximum Permissible Exposure (MPE) values are set well below the threshold level for thermal burns.

12.3 Acoustic Damage (Retina)

Laser pulses of duration less than 10 microseconds (μs) induce a shock wave in the retinal tissue that causes a rupture of the tissue. This damage is permanent, as with a retinal burn. Acoustic damage is potentially more destructive than a thermal burn. Acoustic damage usually affects a greater area of the retina, and the threshold energy for this effect is substantially lower. The ANSI MPE values are reduced for short laser pulses to protect against this effect.

12.4 Photochemical Damage

Laser light having wavelengths below 400 nm is absorbed by the lens and cornea and does not reach the retina. Depending on the level of exposure, this may cause immediate thermal burns or the development of cataracts over a period of years.

The light can be laser output, ultraviolet (UV) from the pump light, or blue light from a target interaction. The effect is cumulative over a period of days. The ANSI standard is designed to account only for exposure to the laser light. If UV light from a pump light or blue light from a target interaction is emitted, additional precautions must be taken.

12.5 Other Eye/Skin Hazards

The cornea and the conjunctiva tissue surrounding the eye can also be damaged by exposure to laser light. Damage to the cornea and conjunctiva tissue usually occurs at greater power levels than damage to the retina; therefore, these issues only become a concern for those wavelengths that do not penetrate to the retina (i.e., UV and FIR radiation).

Since the skin is the largest organ of the body, it has the greatest risk of coming into contact with a laser beam. When discussing the skin we will almost always speak in terms of arms, hands, or head. These three body parts are most likely to accidentally move into the beam during alignment or other operations requiring close proximity to the beam. If the beam is of sufficient energy the skin can experience thermal burns, acoustic lesions, and photochemical changes from laser exposure. These effects are almost entirely independent of the coherent nature of the laser light but are aggravated by the high power density of lasers. Also, the wavelength of the beam determines the layer of the skin that will be affected. When dealing with lasers that have the potential to cause burning of the skin, personnel should observe common-sense safety practices such as wearing long-sleeved shirts and gloves of fire-resistant or fire-proof material and using low powered lasers for alignment purposes. Some medications, including tetracycline, doxycycline, tricyclic antidepressants, and methotrexate, can increase a person's risk to UV radiation.

Table 12.1. Summary of basic biological effects of laser light.

PhotoBiological Spectral Domain	Eye Effects	Skin Effects
Ultraviolet C (200–280nm)	Photokeratitis	Erythyma (sunburn), Skin Cancer
Ultraviolet B (280-315nm)	Photokeratitis	Accelerated Skin Aging, Increased Pigmentation
Ultraviolet A (315-400nm)	Photochemical UV Cataract	Pigment Darkening
Visible (400-780nm)	Photochemical & Thermal Retinal Injury	Photosensitive Reactions.
Infrared A (780-1,400nm)	Cataract, Retinal Burns	Skin Burn
Infrared B (1,400-3,000nm)	Corneal Burn, Aqueous Flare, IR Cataract	Skin Burn
Infrared C (3,000-10,000nm)	Corneal Burn Only	Skin Burn

13. Non-Beam Hazards

While beam hazards are the most prominent laser hazards, other hazards pose equal or possibly greater risk of injury or death. These hazards must be reviewed by the LSO and addressed in the Standard Operating Procedure (SOP) for the laser operation where applicable.

13.1 Electrical Hazards

Lasers may contain high-voltage power supplies and large capacitors or capacitor banks that store lethal amounts of electricity. In general, systems that permit access to components at such lethal levels must be interlocked; however, during maintenance and alignment procedures such components often become exposed or accessible. This has caused numerous serious and some fatal shocks.

13.2 Laser Dyes

In some laser systems, liquid dye solutions are used as the optically active medium. Laser dyes are often toxic and/or carcinogenic chemicals dissolved in flammable solvents. This creates the potential for personnel exposures above permissible limits, fires, and chemical spills. Frequently, the most hazardous aspect of a laser operation is the mixing of chemicals that make up the laser dye. In addition, hazardous waste disposal concerns need to be addressed. Consult the applicable laser dye Material Safety Data Sheet

(MSDS) for handling and disposal information. Contact Environmental Health and Safety regarding proper labeling and disposal of laser dyes.

13.3 Compressed and Toxic Gases

Hazardous gases may be used in laser applications; i.e. excimer lasers (fluorine, hydrogen chloride). The SOP should contain references for the safe handling of compressed gases such as cylinder restraints, use of gas cabinets, regulators rated for the type of gas to be used, relief valve settings, proper tubing and fittings, etc.

13.4 Cryogenic Fluids

Cryogenic fluids are used in cooling systems of certain lasers, and can create hazardous situations. As these materials evaporate they can replace the oxygen in the air, thereby creating oxygen deficient atmospheres and an asphyxiation hazard. Adequate ventilation must be provided. Cryogenic fluids are potentially explosive when ice collects in valves or connectors that are not specifically designed for use with cryogenic fluids. Condensation of oxygen in liquid nitrogen presents a serious explosion hazard if the liquid oxygen comes in contact with any organic material. While the quantities of liquid nitrogen employed are usually small, protective clothing and face shields must be used to prevent freeze burns to the skin and eyes.

13.5 Laser Generated Air Contaminants (LGAC)

Air contaminants may be generated when certain Class 3b and Class 4 laser beams interact with matter. When the target irradiance reaches a given threshold of approximately 10^7 W/cm^2, target materials including plastics, composites, metals, and tissues may liberate toxic and noxious airborne contaminants. In other words, when laser beams are sufficiently energized to heat up a target, the target may vaporize, creating hazardous fumes or vapors that may need to be captured or exhausted.

13.6 Plasma Radiation

Interactions between very high power laser beams and target materials may in some cases produce plasma, which is the complete dissociation of nuclei and orbital electrons. The plasma generated may contain hazardous "blue light" and UV emissions, which can be an eye and skin hazard. When targets are heated to very high temperatures, as in laser welding and cutting, an intense light is emitted. This light often contains large amounts of short wavelength or blue light, which may cause conjunctivitis, photochemical damage to the retina, and/or erythema (sunburn-like reactions) in the skin.

13.7 UV and Visible Radiation

Laser discharge tubes and pump lamps may generate UV and visible radiation at levels that could present eye and skin hazards.

13.8 Explosion Hazards

High-pressure arc lamps, filament lamps, and capacitors may explode if they fail during operation. These components are to be enclosed in housing, which will withstand the maximum explosive forces that may be produced. Laser targets and some optical components also may shatter if heat cannot be dissipated quickly enough. Consequently, care must be used to provide adequate mechanical shielding when exposing brittle materials to high intensity lasers.

13.9 Ionizing Radiation (X-rays)

X-rays could be produced from two main sources: high voltage vacuum tubes of laser power supplies such as rectifiers and thyratrons and electric discharge lasers. Any power supplies that require more than 15 kilovolts may produce enough x-rays to be a health concern. Contact the UConn Radiation Safety Section for additional guidance.

14. Laser Accidents

14.1 Immediate Response and General Procedures

All laser accidents at the University of Connecticut, no matter how minimal, shall require an accident report. If individuals suspect they have received a laser exposure, they should first seek immediate medical attention. Any incident involving an alleged or suspected laser radiation overexposure will be reported to the LSO. Whenever an alleged or suspected overexposure to laser radiation occurs, the following steps will be taken:

1. The individual(s) exposed should seek medical care without delay. The individual(s) supervisor (PLR) will be notified to ensure action is taken to prevent any further injury to other personnel.

2. The PLR shall notify the LSO at the first opportunity during EH&S normal working hours (M-F 8:30 AM – 4:30 PM) after the initial reporting of the incident.

3. The LSO will inform the LSC and the Department of Environmental Health and Safety of actions being taken or required as part of the incident response.

4. If medical attention was obtained as the result of a University of Connecticut related laser accident the LSC must be provided a record of the medical examination and treatment for the purpose of the accident investigation.

14.2 Incident Reports

An Incident Report is a document intended to provide information to the LSC, which may in turn initiate follow-up corrective actions as deemed necessary. The information included in the report is confidential and is not to be copied for any other person or file. The Incident Report is not to be placed in the patient's medical record at any time.

14.3 Follow-up Procedures by the Laser Safety Officer

The following guidelines describe the initial procedure to be followed by the LSO in the event of a laser accident or incident:

1. If indicated, the LSO will respond on-site to the laboratory reporting the incident.
2. The LSO will document the following information for future review:
   a. Date and time of call.
   b. Name and department of caller.
   c. Name of reporting person's immediate supervisor
   d. Model, serial number, manufacturer, and nomenclature of device.
3. The LSO will contact the caller's supervisor (PLR) to ensure that he/she is informed.

After the LSO has verified that the exposed individual(s) has been afforded the opportunity to obtain medical care, and that the appropriate administrative personnel have been notified of the incident, the LSO will continue to investigate the circumstances of the accident by obtaining the following information:

1. Name(s) of individual(s) alleged or suspected to have been overexposed.
2. Laser nomenclature, characteristics and operating parameters at the time of the incident (wavelength, peak and average power, pulse width and frequency, beam diameter and divergence, etc.).
3. Date, location, and time of the incident, as well as the duration of the exposure and the individual's position relative to the laser.
4. Description of what happened. If possible, obtain a signed brief description from all individuals who have first-hand knowledge of the incident.

5. Protective equipment and clothing in use at the time of the accident, and eyewear transmission characteristics at the wavelength of the laser.
6. Facility configuration at the time of the event.
7. The name and telephone number of the attending physician.

Within a reasonable amount of time following the initial reporting of the alleged or suspected overexposure, the LSO will coordinate with appropriate organizations to prepare a detailed report of the incident. This report shall consist of a summary of the estimated exposure, timetable of medical evaluations, recommendations to prevent recurrence of the incident, and discussion of further medical follow-up recommendations.

15. Key Switches

For those laser systems equipped with a key switch to prevent unauthorized use, the key must not be left in the switch when the laser system is unattended.

16. Outdoors Use of Lasers

The use of Class 3b or Class 4 lasers outdoors shall be conducted in compliance with ANSI Z136.6 2000, *Standard for the Safe Use of Lasers Outdoors* (or latest version thereof). Contact the LSO for additional information.

17. Laser Demonstrations

Special control measures shall be employed for those situations where lasers or laser systems are used for educational demonstration, artistic display, entertainment, or other related uses at the University of Connecticut where the intended viewing group is the general public. Contact the LSO for additional information.

18. Spectators

Spectators are not permitted within a laser control area during periods of active laser use unless:

1. Appropriate approval from the PLR has been obtained.
2. The degree of hazard and avoidance procedure has been explained to the spectator.
3. Appropriate protective measures are taken.

19. Laser Pointers

The power limit for laser pointers used at the University of Connecticut shall not exceed 5milliwatts.

The users of laser pointers should observe the following safety guidelines:

1. Never look directly into the beam or point a laser at anyone else.
2. Never point a laser at a mirror or other equally reflective surface.
3. Limit laser pointer use to devices with laser radiation labels citing Class 2 or 3, and wavelengths between 630 nm and 680 nm.

Note: Several States have enacted laws regarding the use of laser pointers in a manner inconsistent with their intended use as a tool to indicate, mark, or identify a specific position, place, item, or object.

20. Glossary

Absorb To transform radiant energy into a different form, with a resultant rise in temperature.

Absorption Transformation of radiant energy to a different form of energy by the interaction with matter, depending on temperature and wavelength.

Accessible Emission Level: The magnitude of accessible laser (or collateral) radiation of a specific wavelength or emission duration at a particular point as measured by appropriate methods and devices. Also means radiation to which human access is possible in accordance with the definitions of the laser's hazard classification.

Accessible Emission Limit (AEL): The maximum accessible emission level permitted within a particular class. In ANSI Z 136.1, AEL is determined as the product of accessible emission Maximum Permissible Exposure limit (MPE) and the area of the limiting aperture (7 mm for visible and near-infrared lasers).

Aperture: An opening through which radiation can pass.

Argon: A gas used as a laser medium. It emits blue-green light primarily at 448 and 515 nm.

Attenuation: The decrease in energy (or power) as a beam passes through an absorbing or scattering medium.

Aversion Response: Movement of the eyelid or the head to avoid an exposure to a noxious stimulant, bright light. It can occur within 0.25 seconds, and it includes the blink reflex time.

Beam: A collection of rays that may be parallel, convergent, or divergent.

Beam Diameter: The distance between diametrically opposed points in the cross section of a circular beam where the intensity is reduced by a factor of e-1 (0.368) of the peak level (for safety standards). The value is normally chosen at e-2 (0.135) of the peak level for manufacturing specifications.

Beam Divergence: Angle of beam spread measured in radians or milliradians (1 milliradian = 3.4 minutes of arc). For small angles where the cord is approximately equal to the arc, the beam divergence can be closely approximated by the ratio of the cord length (beam diameter) divided by the distance (range) from the laser aperture.

Blink Reflex: See aversion response.

Brightness: The visual sensation of the luminous intensity of a light source. The brightness of a laser beam is most closely associated with the radio-metric concept of radiance.

Carcinogen: An agent potentially capable of causing cancer.

Carbon Dioxide: Molecule used as a laser medium. Emits far infrared energy at 10,600 nm (10.6 μm).

Closed Installation: Any location where lasers are used which will be closed to unprotected personnel during laser operation.

CO_2 Laser: A widely used laser in which the primary lasing medium is carbon dioxide gas. The output wavelength is 10.6 μm (10600 nm) in the far infrared spectrum. It can be operated in either CW or pulsed.

Coherence: A term describing light as waves that are in phase in both time and space. Monochromaticity and low divergence are two properties of coherent light.

Collimated Light: Light rays that are parallel. Collimated light is emitted by many lasers. Diverging light may be collimated by a lens or other device.

Collimation: Ability of the laser beam to not spread significantly (low divergence) with distance.

Continuous Wave (CW): Constant, steady-state delivery of laser power.

Controlled Area: Any locale where the activity of those within are subject to control and supervision for the purpose of laser radiation hazard protection.

Cornea: The transparent outer coat of the human eye, covering the iris and the crystalline lens. The cornea is the main refracting element of the eye.

Diffuse Reflection: Takes place when different parts of a beam incident on a surface are reflected over a wide range of angles in accordance with Lambert's Law. The intensity will fall off as the inverse of the square of the distance away from the surface and also obey a Cosine Law of reflection.

Divergence: The increase in the diameter of the laser beam with distance from the exit aperture. The value gives the full angle at the point where the laser radiant exposure or irradiance is e-1 or e-2 of the maximum value, depending upon which criteria is used.

Embedded Laser: A 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 to the engineering features limiting accessible emission.

Emission: Act of giving off radiant energy by an atom or molecule.

Enclosed Laser Device: Any laser or laser system located within an enclosure that does not permit hazardous optical radiation emission from the enclosure. The laser inside is termed an "embedded laser."

Energy (Q): The capacity for doing work. Energy is commonly used to express the output from pulsed lasers and it is generally measured in Joules (J). The product of power (watts) and duration (seconds). One watt second = one Joule.

Erythema: The medical term for redness of the skin due to congestion of the capillaries.

Excimer: An abbreviation for *excited dimer*. A gas mixture used as the active medium in a family of lasers emitting ultraviolet light.

Exposure Duration: The total amount of time the ocular structures or skin are exposed to the laser beam.

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.

Gas Discharge Laser: A laser containing a gaseous lasing medium in a glass tube in which a constant flow of gas replenishes the molecules depleted by the electricity or chemicals used for excitation.

Gas Laser: A type of laser in which the laser action takes place in a gas medium.

Helium-Neon (HeNe) Laser: A laser in which the active medium is a mixture of helium and neon. Its wavelength is usually in the visible range. Used widely for alignment, recording, printing, and measuring.

Infrared Radiation (IR): Invisible electromagnetic radiation with wavelengths that lie within the range of 0.70 to 1000 μm. These wavelengths are often broken up into regions: IR-A (0.7-1.4 μm), IR-B (1.4-3.0 μm) and IR-C (3.0-1000 μm).

Iris: The annular, pigmented structure that lies behind the cornea of the human eye. The iris forms the pupil.

Intrabeam Viewing: The viewing condition whereby the eye is exposed to all or part of a direct laser beam or a specular reflection.

Irradiance (E): Radiant flux (radiant power) per unit area incident upon a given surface.
Units: Watts per square centimeter. (Sometimes referred to as power density, although not exactly correct).

Joule (J): is a unit of energy (1 joule = 1 Watt-second).

Laser: An acronym for light amplification by stimulated emission of radiation. A laser is a cavity with mirrors at the ends, filled with material such as crystal, glass, liquid, gas or dye. It produces an intense beam of light with the unique properties of coherency, collimation, and monochromaticity.

Laser Accessories: The hardware and options available for lasers, such as secondary gases, Brewster windows, Q-switches and electronic shutters.

Laser Controlled Area: See Controlled Area.

Laser Device: Either a laser or a laser system.

Laser Medium (Active Medium): Material used to emit the laser light and for which the laser is named.

Laser Rod: A solid-state, rod-shaped lasing medium in which ion excitation is caused by a source of intense light, such as a flash lamp. Various materials are used for the rod, the earliest of which was synthetic ruby crystal.

Laser Safety Officer (LSO): Designated Environmental Health and Safety professional who has authority to monitor and enforce measures to control laser hazards and effect the knowledgeable evaluation and control of laser hazards. Serves as the operational arm of the Laser Safety Committee.

Laser Safety Committee (LSC): University appointed individuals generally comprised of members of the research community, Environmental Health and Safety, and Administration. Charged with oversight of laser use at the University of Connecticut.

Laser System: An assembly of electrical, mechanical and optical components that includes a laser. Under the Federal Standard, a laser in combination with its power supply (energy source).

Lens: Curved pieces of optically transparent material, which, depending on its shape is used to either, converge or diverge light.

Light: (see Visible Radiation)

Limiting Aperture: The maximum circular area over which radiance and radiant exposure can be averaged when determining safety hazards.

Macula: The small, uniquely pigmented and specialized area of the retina.

Maintenance: Performance of those adjustments or procedures specified in user information provided by the manufacturer with 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 glossary.

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. MPE is expressed in terms of either radiant exposure (joules/cm^2) or irradiance (watts/cm^2).

Nd: Glass Laser: A solid-state laser of neodymium: glass offering high power in short pulses. A Nd-doped glass rod used as a laser medium to produce 1064 nm light.

Nd: YAG Laser Neodymium: Yttrium Aluminum Garnet. A synthetic crystal used as a laser medium to produce 1064 nm light.

Neodymium (Nd): The rare earth element that is the active element in Nd: YAG lasers and Nd: Glass lasers.

Nominal Hazard Zone (NHZ): The nominal hazard zone describes 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.

Ocular Fundus: The back of the eye. The ocular fundus may be seen through the pupil by use of an ophthalmoscope.

Optical Cavity (Resonator): Space between the laser mirrors where lasing action occurs.

Optical Density: A logarithmic expression for the attenuation produced by an attenuating medium, such as an eye protection filter. (OD = -logT, where T is the transmittance)

Optical Fiber: A filament of quartz or other optical material capable of transmitting light along its length by multiple internal reflections and emitting it at the end.

Optical Pumping: The excitation of the lasing medium by the application of light rather than electrical discharge.

Optical Radiation: Ultraviolet, visible, and infrared radiation (0.35-1.4 μm) that falls in the region of transmittance of the human eye.

Output Power: The energy per second measured in watts emitted from the laser in the form of coherent light.

Plasma Radiation: Black-body radiation generated by luminescence of matter in a laser generated plume.

Power: The rate of energy delivery expressed in watts (Joules per second). Thus: 1 Watt = 1Joule / 1 Sec.

Protective Housing: A device designed to prevent access to radiant power or energy.

Pulse: A discontinuous burst of laser, light or energy, as opposed to a continuous beam. A true pulse achieves higher peak powers than that attainable in a CW output.

Pulse Duration: The "on" time of a pulsed laser, it may be measured in terms of milliseconds, microseconds, nanoseconds, picoseconds, and femtoseconds as defined by half-peak-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: Laser that delivers energy in the form of a single or train of pulses.

Pump: To excite the lasing medium. See Optical Pumping or Pumping.

Pumped Medium: Energized laser medium.

Pumping: Addition of energy (thermal, electrical, or optical) into the atomic population of the laser medium, necessary to produce a state of population inversion.

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

Radiant Energy (Q): Energy in the form of electromagnetic waves usually expressed in units of Joules (watt-seconds).

Radiant Exposure (H): The total energy per unit area incident upon a given surface. It is used to express exposure to pulsed laser radiation in units of J/cm2.

Reflection: The return of radiant energy (incident light) by a surface, with no change in wavelength.

Refraction: The change of direction of propagation of any wave, such as an electromagnetic wave, when it passes from one medium to another in which the wave velocity is different. The bending of incident rays as they pass from one medium to another (e.g., air to glass).

Resonator: The mirrors (or reflectors) making up the laser cavity including the laser rod or tube. The mirrors reflect light back and forth to build up amplification.

Retina: The sensory tissue that receives the incident image formed by the cornea and lens of the human eye. The retina lines the posterior eye.

Ruby: The first laser type; a crystal of sapphire (aluminum oxide) containing trace amounts of chromium oxide.

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

Secured Enclosure: An enclosure to which casual access is impeded by an appropriate means (e.g. door secured by lock, magnetically or electrically operated latch, or by screws).

Semiconductor Laser: A type of laser that produces its output from semiconductor materials such as gallium arsenide (GaAs).

Service: Performance of adjustments, repair or procedures on a non-routine basis, required to return the equipment to its intended state.

Solid Angle: The ratio of the area on the surface of a sphere to the square of the radius of that sphere. It is expressed in steradians (sr).

Source: The term source means either laser or laser-illuminated reflecting surface, i.e., source of light.

Spectator: An individual who wishes to observe or watch a laser or laser system in operation and who may lack the appropriate laser safety training.

Specular Reflection: A mirror-like reflection.

Tunable Laser: A laser system that can be "tuned" to emit laser light over a continuous range of wavelengths or frequencies.

Tunable Dye Laser: A laser whose active medium is a liquid dye pumped by another laser or flash lamps to produce various colors of light. The color of light may be tuned by adjusting optical tuning elements and/or changing the dye used.

Ultraviolet (UV) Radiation: Electromagnetic radiation with wavelengths between soft X-rays and visible violet light, often broken down into UV-A (315-400 nm), UV-B (280-315 nm), and UV-C (100-280 nm).

Viewing Portal: is an opening in an experimental system, allowing the user to observe the experimental chamber. All viewing portals and display screens included as an integral part of a laser system must incorporate a suitable means to maintain the laser radiation at the viewing position at or below the applicable MPE (eye safe) for all conditions of operation and maintenance. It is essential that the material used for viewing portals and display screens not support combustion or release toxic vapors following exposure to laser radiation.

Visible Radiation (light): Electromagnetic radiation that can be detected by the human eye. It is commonly used to describe wavelengths in the range between 400 nm and 700-780 nm.

Watt (W): The unit of power or radiant flux (1 watt = 1 joule per second).

Wavelength: The distance between concentric oscillations of the light wave, usually measured from crest to crest, which determines its color. Common units of measurement are the micrometer (micron), the nanometer, and (earlier) the Angstrom unit.

YAG: Yttrium Aluminum Garnet, a widely used solid-state crystal composed of yttrium and aluminum oxides and a small amount of the rare earth neodymium.

Sample Laser Standard Operating Procedure Template

The University of Connecticut Laser Safety Program

Laser Safety Standard Operating Procedure (SOP)

1. LASER DATA:

Type: Wavelength(s): Classification:

Manufacturer: Model: Serial #:

Location Building: Room:

( ) Pulsed:

Max. Energy per pulse: Pulse Duration: Repetition Rate:

( ) Continuous Wave:

Max. Power:

2. LASER SAFETY CONTACTS:

Primary Laser Researcher (PLR): Department:

Campus Phone: Alternative Phone:

Department of Environmental Health & Safety Laser Safety Officer (LSO):

Campus Phone: 860-486-3613

Emergencies: 911

Notify the Laboratory PLR and University LSO of all laser-related injuries.

3. LASER SAFETY PROGRAM:

Reference the University of Connecticut Laser Safety Manual for the following:

- Responsibilities of the Laser Safety Committee, Laser Safety Officer, Primary Laser Researcher (PLR), and Laser Users.
- Training requirements.
- Class 3b and Class 4 laser registration and disposal/transfer requirements.
- Medical screening (eye examination).
- Personal Protective Equipment (PPE), including protective eyewear.
- Standard Operating Procedures (SOPs).
- Signage and labeling requirements.
- Non-radiation hazards.

4. LASER APPLICATION SUMMARY:

5. HAZARDS:

Check if applicable	Hazard	Control
	Open/accessible laser beam.	
	Laser operations at eye level (standing or sitting).	
	Ultraviolet radiation/blue light exposure.	
	Reflective surfaces.	
	High Voltage.	
	Capacitors.	
	Fumes/vapors.	
	Plasma radiation.	
	Compressed gasses.	
	Hazardous chemicals.	
	Hazardous waste.	
	Fire.	
	Laser maintenance.	
	Housekeeping.	

6. CONTROLS:

Check if applicable	Control	Comments
	Entryway interlocks.	
	Entryway signage.	
	Nominal Hazard Zone (NHZ).	
	Laser master switch (key or computer code).	
	Laser beam enclosure interlocks.	
	Laser housing cover interlocks.	
	Emergency stop (i.e. panic button).	
	Beam attenuators (stops/dumps).	
	Laser secured to base.	
	Laser associated equipment (e.g. reflectors/dumps, etc.) secured to base.	
	Protective barriers.	
	UConn Laser Safety Manual available for reference.	
	Manufacturers' laser manual available for reference.	

7. PERSONAL PROTECTIVE EQUIPMENT (PPE):

Check if required/applicable	PPE	Comments
	Eyewear.	
	Clothing.	
	Other	

8. EYEWEAR SPECIFICATIONS:

Eyewear Criteria	Comments
Adequate pairs available for all needs.	
Eyewear specific to laser wavelength(s).	
Optical Density (OD) appropriate for all ranges of laser energy/power operations.	
Proper fit.	
Free of damage and or excessive scratches.	

Discard damaged or unfit eyewear.

LASER EYEWEAR					
For this laser			Wear this eyewear		
Type of Laser	Wavelength(s) (nm)	Comments	Wavelength(s) attenuated (nm)	Optical Density (OD)	Comments

9. OPERATING PROCEDURES:

- Initial preparation of lab environment and laser for normal laser operation (e.g. key position, interlock activated, outside warning light on, identification of personnel, operational log, etc.).

- Target area preparation:

- Operational procedure (power settings, Q-switched mode, pulse rate, other):

- Shutdown procedure:

- Special procedures (alignment, safety tests, interlock bypass, etc.):

- Emergency procedures:

- Hazardous waste disposal procedures (if applicable):

10. LASER OPERATOR SOP REVIEW:

I have read this Standard Operating Procedure, understand the contents, and will utilize this procedure each time I use the laser or laser system.

Name (print)	Signature	Date

- **This SOP shall be:**
  - **Read and understood by laser users prior to their initial use of the listed laser.**
  - **Reviewed by all laser users following any modifications.**
  - **Reviewed annually by all laser users.**
- **This SOP must be readily accessible and available for reference by laser users.**
- **Modifications to this SOP must be reviewed and approved by both the PLR and the LSO.**

11. PLR REVIEW/APPROVAL:

Date:

Name:

Signature:

Comments:

12. LSO REVIEW/APPROVAL:

Date:

Name:

Signature:

Comments:

June 23, 2003