Laser Safety Manual

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Applies To: Employees, Students, Others
For More Information contact: EHS, Radiation Safety Manager at 860-486-3613

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I. Purpose

The primary objective of the University of Connecticut's (UConn) 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 related to laser use. 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.

II. Scope

The policies and procedures contained in this manual apply to all departments, laboratories, and persons using and possessing Class 3B and 4 lasers or lower class lasers used in a system that produces an output which qualifies it as a Class 3B or 4 laser system. This manual applies to the University of Connecticut campuses located at Storrs, Mansfield Depot, Avery Point, Hartford, Stamford, and Waterbury. The Environmental Health and Safety Laser Safety Officer shall be contacted to confirm whether or not a laser or laser system is classified as Class 3B or 4.

III. Policy Statement

The University of Connecticut's (UConn) Laser Safety Program is based on the American National Standards Institute (ANSI) Z136.1 2014, *Safe Use of Lasers*, and any other pertinent standards, as well as other applicable federal and state regulations.

This Laser Safety Manual is intended to be a guide to the implementation of the UConn Laser Safety Program, the ANSI Z136.1 2014, *Safe Use of Lasers*. Recommendations of ANSI Z136.1 not specifically referenced in this manual are to be considered in effect unless specified otherwise by this Laser Safety Manual. Additional laser safety policies and procedures as set forth by the University are incorporated into this manual.

IV. Enforcement

The University of Connecticut's (UConn) Laser Safety Program will be overseen by the Associate Vice President for Research Compliance and Integrity and implemented and enforced by the Laser Safety Officer (LSO) and the Laser Safety Committee (LSC).

Class 3B and 4 lasers or Class 3B or 4 laser systems which are not in use or do not have approved Standard Operating Procedures (SOPs), proper safety controls, or appropriate protective eyewear will be blocked out and tagged out by the LSO until they are in place and verified.

Violations of this program may result in appropriate disciplinary measures in accordance with University Laws and By-Laws, General Rules of Conduct for All University Employees, applicable collective bargaining agreements, and the UConn Student Conduct Code.

V. Procedures/Forms

Laser Safety Lab Based Training Check List
Laser Safety SOP (Single Laser)
Laser Safety SOP (2 Laser System)
Equipment Form
University Surplus Procedures

VI. Laser Safety Organization and Responsibilities

a. Laser Safety Committee (LSC)
The University of Connecticut (UConn) Laser Safety Committee (LSC) will consist of members with expertise in laser technology or in the assessment of laser hazards representing departments possessing Class 3B or Class 4 lasers or laser systems. The Chair and Department representatives are appointed or removed by, and the Committee is directly responsible to, the Associate Vice President for Research Compliance and Integrity. A representative from the University's Administration and the Director of Environmental Health and Safety (EHS) shall be ex officio members. The Laser Safety Officer (LSO) shall be a voting member of the committee. Members are appointed for a three-year term and may be reappointed.

Duties and responsibilities of the committee are:

1. Establish and maintain policies and practices for the evaluation and control of laser hazards within the university.
2. Make recommendations for appropriate laser safety training programs and materials and SOPs.

3. Maintain an awareness of all applicable new or revised laser safety standards.
4. Facilitate compliance within their respective Departments with laser safety standards, including federal and state regulations, and non-regulatory standards as outlined in the American National Standards Institute (ANSI) Z136 series of laser safety standards.
5. Review reports from the LSO or other individuals with delegated responsibilities for health and safety practices of the university involving laser radiation sources, including personnel training records, laser hazard control measures, laser safety inspections, and other matters concerning use and operational hazards of lasers.
6. Assist in investigating alleged infractions of safety rules or improper use of laser equipment brought to its attention by the LSO or other responsible personnel, and recommend remedial action to correct such infractions.

b. Laser Safety Officer (LSO) and Deputy Laser Safety Officer (DLSO)

Environmental Health and Safety (EHS) Radiation Safety Section's designated Laser Safety Officer (LSO) is the operational arm of the Laser Safety Program at the University of Connecticut (UConn). ANSI Z136.1-2014 defines the LSO as one who has the authority and responsibility to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards. This position is responsible for:

1. Implementing Laser Safety policy.
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 (at least once a year).
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 a Nominal Hazard Zone (NHZ), approving Standard Operating 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 UConn.
8. Approving establishment of NHZs in laser work areas.
9. Approving laser systems operations to include 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. Effect medical examinations when necessary.
13. Maintaining an inventory of all Class 3B and Class 4 lasers at UConn.
14. Recommending corrective actions 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 LSO shall have final authority in determining laser control measures and may approve alternate controls when these are appropriate based on the judgment of the LSO. Class 3B and class 4 lasers shall be operated only with the written approval of the LSO. The LSO shall have the authority to terminate laser operations at any time.
18. The LSO may appoint a Deputy Laser Safety Officer (DLSO) and may delegate duties to the DLSO in accordance with ANSI Z136.1. The DLSO has the authority to independently act on behalf of the LSO to implement the UConn Laser Safety Program.

c. Primary Laser Researcher (PLR)

Primary Laser Researchers (PLRs) are University of Connecticut (UConn) 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 or Class 3B or 4 laser systems with Environmental Health and Safety (EHS). Lasers are registered by notifying the Laser Safety Officer (LSO). The LSO will then arrange to meet with the PLR to complete the registration process. Lasers should be purchased and registered in accordance with Section VII of this manual.
3. Notifying EHS 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 for Class 3B or 4 lasers or laser systems.
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 Nominal Hazard Zone (NHZ).
6. Meeting University requirements for posting, access control, personal protective equipment, and medical surveillance.
7. Reporting to the LSO known or suspected accidents involving laser equipment.
8. Completing and submitting the University's Equipment Form, found on the EHS website, prior to moving, purchasing or acquiring a laser. The LSO should be notified in advance to assess the intended space in advance to ensure minimum requirements for a Class 3B or 4 laser laboratory are met.
9. Notifying the LSO prior to modifications to lasers, changes in procedures, and/or changes in control measures.
10. Notifying the LSO prior to disposal of a laser in accordance with Section VII of this manual.

d. Individual Laser Users/Operators

Scientists, research personnel, technical personnel, students, and other workers engaged in laboratory research and research support, which involves working in the laser laboratory when the lasers may be operating or involves the use and operation of either Class 3B or Class 4 lasers or laser systems. These personnel are responsible for the following:

1. Wearing appropriate personal protective equipment.
2. Completing required training.
3. Following Standard Operating Procedures (SOPs).
4. Conducting laser activities in a safe manner.

e. 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) must satisfactorily complete appropriate laser safety training.

VII. Laser Acquisition, Registration, and Tracking

All Class 3B and 4 laser purchases made by the University of Connecticut (UConn) through the University's Kuali Financial System (KFS), must be done by using the Environmental Health and Safety (EHS) Restricted Equipment code for lasers and be registered with EHS. In general, registrants (i.e. the Primary Laser Researcher (PLR) must be full time faculty or staff of UConn. If a laser is obtained from another source (e.g. homemade, salvage, government loans, or other university) it must also be registered with EHS prior to or upon acquisition and prior to use. Lasers are registered by notifying the Laser Safety Officer (LSO). The LSO will then arrange to meet with the PLR to complete the registration process. Lasers may not be used until Standard Operating Procedures (SOPs) are approved and the registration process is completed.

The PLR or designee must notify the LSO or Deputy Laser Safety Officer (DLSO) prior to moving, transferring, or disposing of a Class 3B or 4 laser. The LSO or DLSO will provide further instructions regarding the required forms and/or procedures to be followed. For disposal or transfer of a laser through University Surplus, the PLR must also comply with the procedures and associated documentation specified on the University's Surplus website.

VIII. Training

Prior to the initial use of Class 3B or Class 4 lasers or laser systems all laser users, including the Primary Laser Researcher (PLR), must complete an appropriate

University of Connecticut (UConn) laser safety training. The training consists of two parts. The first requires successful completion of an on-line laser safety training program administered by Environmental Health and Safety (EHS). 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 Maximum Permissible Exposure (MPE).

Guests/visitors of UConn who request to use either Class 3B or Class 4 lasers or laser systems must contact the Laser Safety Officer (LSO) regarding the training requirements for non-UConn personnel. New employees and guests, such as visiting researchers, must satisfactorily complete the training requirements prior to using Class 3B or Class 4 lasers or laser systems under the direct supervision of an UConn PLR. 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 on-line classroom service. Completion of both the on-line course and PLR conducted laboratory-based training satisfies the training requirements necessary to commence using either Class 3B or Class 4 lasers or laser systems.

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, including the PLR, must participate in periodic retraining based upon the specific needs of the PLR and their designated laser users. The retraining interval will not exceed three years. The minimum retraining requirement may be met by successfully repeating UConn's on-line laser safety training program or participating in documented in-lab training conducted by the PLR and approved by the LSO.

IX. Medical Examinations

Medical examinations shall be performed as soon as practical (usually within 48 hours) when a suspected injury or adverse effect from a laser exposure occurs. In addition to the acute symptoms, consideration shall be given to the exposure wavelength, emission characteristics and exposure situation to ensure appropriate medical referral. Appendix F in ANSI Z136.1-2014 contains recommended examination protocol commensurate with the observed symptoms and laser system.

For injury to the eye from lasers operating in the retinal hazard region, examinations shall be performed by an ophthalmologist.

X. Laser Classification

The basis of the hazard classification scheme is the ability of the laser beam to cause biological damage to the eye or skin during use.

Laser classifications are contained in ANSI Z136.1-2014.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. All lasers or laser systems owned or purchased by the University of Connecticut (UConn) shall have these labels to ensure they are legally sold products in the United States. For custom-built lasers these labels are not required and the Laser Safety Officer (LSO) shall be made aware of such systems and verify the classification with the Primary Laser Researcher (PLR). The PLR shall contact the LSO to determine and label the class of any modified laser or laser system. The LSO must verify the classification of manufactured or custom-built lasers and laser systems.

Class 1 laser systems are incapable of producing damaging radiation levels during normal operation and are exempt from any control measures. Class 1 laser systems may contain higher class lasers and may produce laser hazards if operated with interlocks defeated. The interlocked service panels or portions of the protective housing are only intended to be accessed or removed by authorized service personnel. The LSO shall be notified if repairs or adjustments are needed that require defeating the interlocks to ensure program requirements are met.

Class 1M laser systems are incapable of producing hazardous exposure conditions during normal operation unless the beam is viewed with optical instruments.

Class 2 laser systems emit visible light only at a power level equal to 1 milliwatt or less. The normal aversion response to bright light is adequate protection. Staring into the beam of a Class 2 laser is hazardous.

Class 2M laser systems emit visible light only. The normal aversion response to bright light is adequate protection for unaided viewing. However, viewing the beam with optical aids is potentially hazardous.

Class 3R laser systems have a power level greater than Class 1 or 2 but equal to or less than 5 milliwatts, are potentially hazardous under some viewing conditions, but the probability of an actual injury is small, and the control measures for safe use are straightforward. Most laser pointers fall in this class (Most lasers previously classified as class 3a fall in this category).

Class 3B laser systems have a power level greater than Class 1 or Class 2 and equal to or less than 500 milliwatts, are eye hazards for intrabeam viewing and specular reflections, even for momentary exposures, but diffuse reflections are not usually hazardous. Class 3B laser systems shall be operated only in laser controlled areas by authorized operators. Operators of class 3B laser systems shall receive approved laser safety training.

Class 4 laser systems have a power level greater than 500 milliwatts, are eye hazards and skin hazards for intrabeam exposures, specular reflections, and diffuse reflections. They are also fire hazards and may produce laser generated air contaminants. Class 4 laser systems shall be operated only in laser controlled areas by authorized operators. Operators of Class 4 laser systems shall receive approved laser safety training. A written Standard Operating Procedure (SOP) is required for Class 4 laser operation.

All requirements of the UConn Laser Safety Program apply to Class 3B and Class 4 lasers or laser systems, unless documented equivalent procedures and control measures have been approved by the LSO.

XI. Standard Operating Procedures (SOP)

An approved written Standard Operating Procedure (SOP) must be provided by the Primary Laser Researcher (PLR) for all Class 3B and Class 4 lasers or laser systems prior to use. 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. University of Connecticut general laser SOP templates are available from the Laser Safety Officer (LSO) or as a PDF on the Environmental Health and Safety (EHS) web site. The templates provide 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. Appendix A includes acceptable laser alignment guidelines which may be utilized in the development of the laser SOP.

Continuous wave visible Class 3B lasers verified by the LSO as being at or below 15 mW are exempt from the SOP requirement but are not exempt from training requirements. In the case of enclosed systems (laser scanning confocal microscopy) an abbreviated SOP can be applied if determined necessary by the LSO. 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 prior to implementing the change to assure all applicable safeguards have been satisfied.

In the event an SOP has not yet been approved, at the discretion of the LSO a specified time period, agreed upon by both the PLR and the LSO, may be established between the setting up of the laser equipment and the approval of the SOP. 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 documented conditions will be made readily available to laser users by the PLR.

XII. Class 3B Control Areas

Class 3B and Class 4 lasers or laser systems may be operated only in designated laser control areas approved by the Laser Safety Officer (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:

a. 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 Laser Safety Officer (LSO) and Primary Laser Researcher (PLR) will determine the NHZ. The NHZ may in some situations comprise the entire Control Area.

b. 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 Laser Safety Officer (LSO) and conform to the ANSI Z136.1 guidelines. Such signs shall be posted at all entrances to the laser control area.

c. 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.

d. 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).

e. 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 Maximum Permissible Exposure (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 Laser Safety Officer (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.

f. Light Containment

Laser light levels in excess of the Maximum Permissible Exposure (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 Laser Safety Officer (LSO) for details.

XIII. 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:

a. 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 Maximum Permissible Exposure (MPE).

b. 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.

c. 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:

1. 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.

2. 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.

3. 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).

XIV. 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 Standard Operating Procedure (SOP) approval process.

XV. Substitution of Alternate Control Measures

Upon documented review by the Laser Safety Officer (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.

XVI. Eyewear Policy

Laser safety eyewear is normally required for the operation of Class 4 lasers with exposed beams. Laser safety eyewear is normally required for the operation of all Class 3B invisible lasers or laser systems and for Class 3B visible lasers/systems with powers greater than 15 mW. Eyewear is not required by policy for Class 3B visible lasers/systems with powers of 15 mW or less if other controls are adequate. The Laser Safety Officer (LSO) will require eyewear or approve laser operation without eyewear on an individual basis based on a hazard evaluation performed by the LSO.

XVII. Viewing Laser Radiation

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

Fig. XVI.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 propogates.

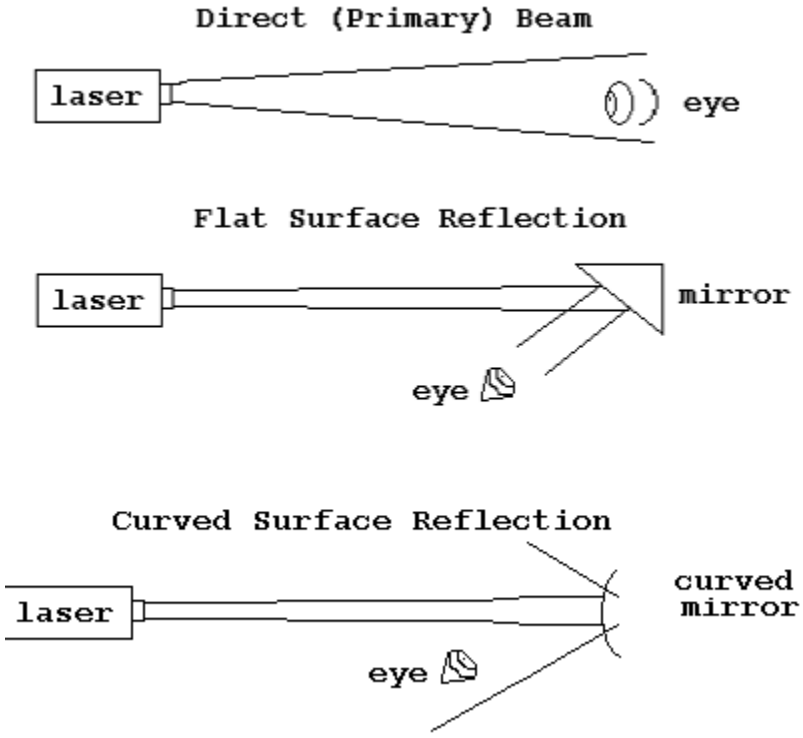
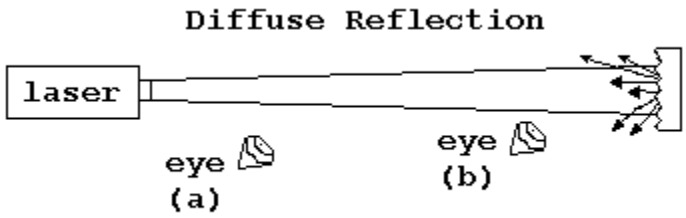

Direct (Primary) Beam
laser
eye
Flat Surface Reflection
laser
mirror
eye
Curved Surface Reflection
laser
curved mirror
eye

Fig. XVI.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.

XVIII. 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.

a. Retina

Laser light in the visible (400 nm - 700 nm) or near infrared (700 nm - 1400 nm) regions that enters the eye is focused on the retina. This can result in either thermal burns or acoustic damage.

b. Thermal Burn (Retina)

Normal focusing by the eye results in an irradiance amplification of approximately 100,000; therefore, a 1-mW/cm^2 beam entering the eye will result in a 100 W/cm^2 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.

c. 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.

d. 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.

e. 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 XVII.1: Summary of basic biological effects of laser light.

PhotoBiological Spectral Domain	Eye Effects	Skin Effects
Ultraviolet C (180–280nm)	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 (400-700nm)	Photochemical & Thermal Retinal Injury	Photosensitive Reactions.
Infrared A (700-1,400nm)	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

XIX. 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 Laser Safety Officer (LSO) or appropriate Environmental Health and Safety (EHS) representative and addressed in the Standard Operating Procedure (SOP) for the laser operation or as a separate procedure where applicable. Contact the LSO or the appropriate EHS representative regarding non-beam hazards related to chemicals, biological agents, fiber optic fragments, respiratory or hearing protection, and electrical or other physical workplace hazards (such as ergonomics or limited work spaces) to ensure proper procedures and training are complied with.

a. 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. Electrical hazards may include electric shock, resistive heating, electric spark ignition of flammable materials, and arc flash. Where these hazards may exist, an EHS electrical safety technical expert shall be consulted by the Primary Laser

Researcher (PLR) to ensure proper training and required controls measures are in place.

b. 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 Safety Data Sheet (SDS) for handling and disposal information. Refer to the University of Connecticut Chemical Hygiene Plan or contact Environmental Health and Safety (EHS) Chemical Safety regarding proper labeling and disposal of laser dyes.

c. Compressed and Toxic Gases

Hazardous gases may be used in laser applications; i.e. with excimer lasers (fluorine, hydrogen chloride). As required by the standard, the Standard Operating Procedure (SOP) shall contain a procedure for, or reference to, 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. All compressed gases having a hazardous material information system (HMIS) health, flammability, or reactivity rating of 3 or 4 shall be contained in an approved and appropriately exhausted gas cabinet that is alarmed with sensors to indicate potential leakage conditions. Sensors may also be installed in other locations as appropriate, including exhaust ventilation ducts. Exhaust ductwork should be of rigid construction, especially for hazardous gases. Contact the Laser Safety Officer (LSO) to arrange for a review of the hazardous gas installation and procedure.

d. 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.

e. 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. Environmental Health and Safety (EHS) must pre-approve the method of ventilation utilized to capture or exhaust the LGACs.

f. 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.

g. 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.

h. 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.

i. 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 Environmental Health and Safety (EHS) Radiation Safety for additional guidance.

j. Nanoparticles

The use of nanoparticles can pose a hazard to lungs, tissues and organs. Processes that produce laser-generated nanoparticles shall be engineered so as to avoid the entry of the particles into the body via inhalation, ingestion, or absorption processes.

k. Biological Agents

Infectious materials may survive irradiation and become airborne. Contact Environmental Health and Safety (EHS) Biological Safety for additional guidance.

XX. Laser Accidents

The major causes of laser accidents in the laboratory are:

- Eye exposure during alignment
- Misaligned optics and upwardly directed beams
- Available eye protection not used
- Equipment malfunction
- Improper methods of handling high-voltage circuits
- Intentional exposure of unprotected personnel
- Operators unfamiliar with laser equipment
- Lack of protection from ancillary hazards
- Improper restoration of equipment following service
- Eyewear worn not appropriate for laser in use
- Unanticipated eye/skin exposure during laser usage
- Inhalation of laser generated air contaminants and/or viewing laser generated plasmas
- Fires resulting from the ignition of materials
- Eye or skin injury of photochemical origin
- Failure to follow Standard Operating Procedures (SOPs)

Ensuring all beam and non-beam hazards are addressed appropriately prior to working with Class 3B or 4 lasers or laser systems is critical to the prevention of accidents. Appropriate engineering controls, SOPs, training, Personal Protective Equipment (PPE) and other safety measures, as required by this manual, must be in place to safeguard workers. Should an accident occur with the laser beam or a non-beam hazard, the following outlines the proper procedures.

a. Immediate Response and General Procedures for all Laser Beam and Non-Beam Accidents

1. All laser accidents involving an injury from a laser beam or a non-beam hazard at the University of Connecticut (UConn), no matter how minimal, requires a report of the injury. Injury reporting requirements and network information are found at: http://hr.uconn.edu/workers-comp/ . Filing a completed First Report of Injury form (Form WC 207)*/* and the supervisor (Primary Laser Researcher (PLR)) calling the injury in to the injury report line is what generates the claim number (within 24-48 hours). For questions, contact:

   Tiffanie Klick
   Workers' Compensation Administrator
   University of Connecticut
   Department of Human Resources
   9 Walters Ave, U-5075
   Storrs, CT 06269
   Direct 860-486-2598
   Fax 860-486-0406

2. If an individual suspects they have received a laser exposure or other non-beam injury, they should first seek immediate medical attention without delay.
3. When possible, close the laser beam shutter and/or turn off the laser system.
4. If there is a fire, pull the fire alarm, evacuate the building and contact 911.
5. The supervisor (PLR) of the injured individual(s) should be notified to ensure action is taken to prevent any further injury to other personnel.
6. After the initial reporting of the incident, the PLR shall notify the Laser Safety Officer (LSO) at the first opportunity during Environmental Health and Safety (EHS) Radiation Safety's normal working hours (M-F 8:00 AM – 4:00 PM) at 860-486-3613 or after hours by contacting the Public Safety Dispatch at 860-486-4925.

7. Do not resume laser operations without LSO approval.

b. Immediate Response and General Procedures for Laser Beam Accidents

1. The individual(s) exposed should seek medical care without delay**.**
2. **For eye injuries or suspected eye injuries, an Ophthalmologist must evaluate laser eye injuries within 48 hours of the suspected injury.**
3. For injuries at the Storrs campus, the exposed individual should contact the Windham Eye Group immediately to schedule an exam appointment with an Ophthalmologist.

   Windham Eye Group
   83 Quarry St, Willimantic, CT 06226
   (860) 423-1619

   For injuries at the Avery Point campus, the exposed individual should contact the Norwich Ophthalmology Group immediately to schedule an exam appointment with an Ophthalmologist.

   Norwich Ophthalmology Group
   Wawecus Medical Center
   79 Wawecus Street, suite 105
   Norwich CT 06360
   (860) 886-0161

   The Windham Eye Group and the Norwich Ophthalmology Group are covered under Workers' Compensation and student insurance. The Groups do not require a referral and may be contacted directly.

   For injuries at a regional campus location other than Storrs or Avery Point, or if the Windham Eye Group or the Norwich Ophthalmology Group are not a covered healthcare provider for the injured, another Ophthalmologist may be contacted. Other approved Workers' Compensation Ophthalmologists can be found at the following link: http://hr.uconn.edu/workers-comp/.

4. If the injury or suspected injury is a Workers' Compensation covered accident, inform the Physician during the initial contact.

5. Follow the guidelines in Section a. Immediate Response and General Procedures for all Laser Beam and Non-Beam Accidents.

c. Immediate Response and General Procedures for Non-Beam Accidents

1. Obtain medical assistance for injuries that are not laser exposures within 48 hours (non-beam injuries). If an ambulance is needed, contact 911.
2. Follow the guidelines in Section a. Immediate Response and General Procedures for all Laser Beam and Non-Beam Accidents.

XXI. 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.

XXII. Outdoors Use of Lasers

The use of Class 3B or Class 4 lasers outdoors shall be conducted in compliance with ANSI Z136.6, *Standard for the Safe Use of Lasers Outdoors*. Contact the Laser Safety Office (LSO) for additional information.

XXIII. 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 (UConn) where the intended viewing group is the general public. Contact the Laser Safety Office (LSO) for additional information.

XXIV. Spectators

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

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

XXV. Laser Pointers

The power limit for laser pointers used at UConn shall not exceed 5milliwatts. Laser pointers modified must be labeled with the Class and with "not a laser pointer" or not used as a laser pointer.

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.

Appendices

Appendix A	Laser Alignment Guidelines

Appendix A
LASER ALIGNMENT GUIDELINES
University of Connecticut
Laser Safety Program

Preface: Laser alignment is a challenge and rarely has a standardized methodology to adhere to. **It is also the most likely time for a laser-induced injury/accident to occur!** As such, the University of Connecticut's (UConn) Laser Safety Officer (LSO) recommends the following good practices when performing laser alignments:

- Follow all laser-specific operating requirements stipulated in the designated Standard Operating Procedure (SOP).
- No unauthorized personnel will be in the room or designated laser control area during the alignment procedure.
- Only appropriately trained personnel shall perform, or be physically present during laser alignment operations.
- If applicable, laser safety curtains/partitions shall be put in place.
- Remove all wristwatches, jewelry, I.D. badges, etc. that may cause unintended stray reflections.
- Clear the laser optic table of any unnecessary equipment and or materials.
- Ensure beam blocks and stray beam shields are in place and securely mounted.
- Designated protective eyewear shall be worn. For visible-wavelength-lasers, this may involve designated "laser alignment" eyewear intended to allow the researcher to view the beam while providing a reduced level of eye protection.
- Use the lowest practical power during the alignment process.
- If possible use an alignment laser (e.g. HeNe).
- Utilize appropriate alignment tools (e.g. fluorescence cards, alignment scopes, etc.).
- Avoid having beams cross aisle ways – if this is unavoidable ensure the accessible aisle way is appropriately marked and barricaded during laser operations.
- Avoid beam alignment out of the horizontal plane.
- Establish beam path(s) at safe height(s), below eye level when standing or sitting.
- Whoever moves or places an optical component on an optical table is responsible for identifying and terminating each and every stray beam coming from that component.