UNIVERSITY OF DELAWARE
LASER SAFETY MANUAL CONTENTS

TABLE OF SELECT ACRONYMS USED IN THIS DOCUMENT

ANSI	American National Standard Institute
LSO	Laser Safety Officer
LSC	Laser Safety Committee
MPE	Maximum Permissible Exposure
NHZ	Nominal Hazard Zone
SOP	Standard Operating Procedure

I. Introduction

The purpose of this manual is to ensure the safe use of lasers in research and instructional laboratories at the University of Delaware. To achieve this goal, the University has developed a safety program based upon the American National Standard for Safe Use of Lasers, ANSI Z136.1-2007. ANSI Z136.1-2007 is the recognized standard for laser safety throughout the United States.

Many lasers are capable of causing eye injury from the direct beam and specular reflections. Class 4 lasers are also capable of causing eye injury from diffuse reflections, burning exposed skin, igniting combustible materials and generating hazardous air contaminants. Equipment used to produce the lasing action and control and direct the laser beam may introduce additional hazards associated with high voltage, high pressure, cryogenics, noise, radiation and toxic gases.

Individuals can minimize the risk of a laser injury if they adhere to the requirements of this manual, obtain both formal and hands-on training in safe laser use, and follow the established laser Standard Operating Procedures.

Throughout this document the use of the word “shall” indicates a requirement and the use of the work “should” indicates a recommendation.

II. Scope

The contents of this manual apply to all University personnel, employees, students and visitors, who operate lasers or work in locations where lasers are used.

III. Definitions

Accessible emission limit (AEL). The maximum accessible emission level permitted within a particular laser hazard class. The AEL is used to classify lasers into hazard classes.

Alignment. The process of adjusting the laser beam (using mirrors, lenses, etc.) so that it travels along its desired path.

American National Standard for Safe Use of Lasers (ANSI Z136.1). Document that provides guidance for the safe use of lasers and laser systems by defining control measures for each of four laser classifications. The University of Delaware has adopted this standard as the basis for its safety program.

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

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

Aversion response. Closure of the eyelid, eye movement, papillary constriction, or movement of the head to avoid an exposure to a noxious or bright light stimulant. Aversion response to an exposure from a bright, visible, laser source is assumed to limit the exposure of an individual's retina to 0.25 second or less.

Baseline Eye Exam. A pre-assignment exam recommended (but not required) by the ANSI standard for Class 3B and Class 4 laser operators. The ANSI baseline eye examination consists of an Ocular history evaluation, a Visual acuity test, an Amsler grid test, and a Color vision test.

Collateral radiation. Any electromagnetic radiation, except laser radiation, emitted by a laser or laser system that is physically necessary for its operation.

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

Continuous wave (CW). The output of a laser that is operated in a continuous rather than a pulsed mode. For purposes of safety evaluation, a laser operating with a continuous output for a period > 0.25 s is regarded as a CW laser.

Controlled area. An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser radiation and related hazards.

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

Embedded Laser. An enclosed laser with an assigned class number higher than the inherent capability of the laser system in which it is incorporated, where the system's lower classification is the result of engineering features which limits the accessible emission.

Failsafe 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.

Infrared radiation. Electromagnetic radiation with wavelengths that lie within the range 0.7 μm to 1 mm.

Intrabeam viewing. The viewing condition whereby the eye is exposed to all or part of a laser beam.

Irradiance (E). Radiant power incident per unit area upon a surface, expressed in watts per centimeter squared.

Joule (J). Unit of energy or work, equal to the energy used to accelerate a body with a mass of one kilogram using one Newton of force over a distance of one meter. 1 joule = 1 watt · second Commonly used to characterize the output from pulsed lasers.

Laser-Controlled Area. The area that confines the nominal hazard zone (NHZ) or regulates access to the NHZ. In some cases, the walls, ceiling and floor of the room often define the laser-controlled area. Laser curtains and free-standing laser barriers are sometimes used to limit the size of the laser-controlled area.

Laser Operator. Individuals approved by the Laser Supervisor to operate, align, or maintain laser equipment. In this manual, the term "operator" does not include non-university laser service personnel.

Laser Safety Officer (LSO). One who has the authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards. The LSO for the University of Delaware is on the staff of DEHS.

Laser Supervisor. One who is responsible for, and enforces, the safe use of a laser. The Laser Supervisor controls who uses the laser and how it will be used. In most cases this is a UD faculty member.

Laser system. An assembly of electrical, mechanical, and optical components that includes one or more lasers.

Laser workstation enclosure. An enclosure completely surrounding a laser and associated experimental elements designed to limit accidental physical access to the beam and/or to attenuate reflected beams to harmless levels. May or may not be designed with failsafe interlocks. Not to be confused with a Protective Housing.

Maximum permissible exposure (MPE). The level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin. MPE is expressed in terms of either radiant exposure (Joules/cm^2) or irradiance (Watts/cm^2).

Mode-Locked laser. Laser that emits extremely short duration (picoseconds to femtoseconds), high power pulses by means of mode-locking. Mode-locking is achieved by inducing a fixed phase relationship between the modes of a laser's resonant cavity.

MPE. See **Maximum permissible exposure**.

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

Operation. The performance of the laser or laser system over the full range of its intended functions (normal operation). Does not include Maintenance or Service.

Optical density. The logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength. The higher the optical density, the lower the transmittance.

Peak Irradiance. Peak power incident per unit area on a surface, expressed as watts per cm^2.

Peak power. The maximum occurring optical power in units of watts. For mode-locked lasers, the peak power can exceed 10 gigawatts.

Photochemical effect. A biological effect produced by a chemical action brought about by the absorption of photons by molecules that directly alter the molecule. Primarily produced by ultraviolet and some blue wavelengths.

Protective Housing. Enclosure that surrounds a laser or laser system preventing access to laser radiation above the MPE and access to electrical hazards. Laser manufacturers are required to provide protective housings for all

classes of lasers. Fail-safe interlocks which interrupt the laser beam when the housing is opened are required on Class 3B and Class 4 lasers.

Pulse duration. The time interval (in seconds) between the half-power points on the leading and training edges of a laser pulse.

Pulse-repetition frequency (PRF). Number of pulses occurring per second, expressed in Hertz (Hz).

Pulsed laser. A laser that delivers its energy in the form of a single pulse or a train of pulses. The duration of a pulse is regarded to be < 0.25 seconds.

Q-switched laser. A laser that emits short (~10 to 250ns), high power pulses by means of a Q-switch (Q-switch enhances the storage and dumping of electronic energy in and out of the lasing medium).

Radiant exposure (H). Surface density of the radiant energy received, expressed in units of joules per centimeter squared.

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

Reversible bleaching. The absorbing filter of laser eyewear may become temporarily saturated from an ultrashort laser pulse, causing the beam to pass through.

Service. The performance of procedures, typically defined as repair, to bring the laser or laser system back to full and normal operational status. Normally performed by qualified technical personnel provided by the manufacturer or other service companies.

Shall. In this manual “shall” indicates that the action is mandatory

Should. In this manual, “should” indicates that the action is recommended but not mandatory.

Specular reflection. A mirror-like reflection.

Standard Operating Procedure (SOP). Formal, written description of the safety and administrative procedures to be followed in performing a specific task.

Ultraviolet radiation. Electromagnetic radiation with wavelengths smaller than those of visible radiation; for the purpose of this manual, 0.18 to 0.4 µm.

Visible radiation (light). Electromagnetic radiation that can be detected by the human eye. This term is commonly used to describe wavelengths that lie in the range 0.4 to 0.7 µm.

Watt (W). The unit of power, used to express the rate at which energy is emitted, transferred, or received. 1 watt = 1 joule per second

IV. Laser Classification

Lasers and laser systems are classified based on their capability of injuring personnel. Lasers with a higher laser hazard class value are more capable of injuring exposed and unprotected individuals.

Lasers manufactured after August 1, 1976 must be classified and labeled by the manufacturer. The Laser Supervisor shall classify lasers and laser systems that are constructed or modified in the laboratory. Upon request, the Laser Safety Officer can assist the Laser Supervisor with this task.

There are five laser hazard classes:

Class 1 or 1M lasers and laser systems cannot emit accessible levels of radiation that are capable of causing eye injury under any normal operating condition. (A more hazardous laser may be embedded in a Class 1 product that is not accessible during normal operating conditions, but may be during service and maintenance.) Class 1M lasers may pose an eye hazard if viewed with collecting optics such as an eye-loupe or telescope.

Class 2 or 2M lasers and laser systems are lasers that emit wavelengths in the 400 to 700 nm range and are incapable of causing eye injury unless intentionally viewed directly for an extended period. The normal aversion response to bright light (such as blinking) protects the eye from a momentary exposure. Class 2M lasers may be hazardous if viewed with certain collecting optics.

Class 3A or 3R lasers and laser systems do not generally pose an eye hazard unless the eye is appropriately focused and stable but the probability of actual injury is small.

Class 3B lasers and laser systems pose a serious eye hazard from viewing the direct beam or specular reflections. They are not normally a diffuse reflection or fire hazard.

Class 4 lasers and laser systems pose a serious eye hazard from viewing the direct beam and specular reflections. Diffuse reflections may also be hazardous. Class 4 lasers and laser systems may also pose skin and fire hazards or generate air contaminants.

Converting High Hazard Class Lasers or Laser Systems to a Class 1 Laser System

If Class 3B and/or Class 4 lasers are embedded into an appropriate protective housing, they may be reclassified as a Class 1 laser system and the control measures established in this manual will no longer apply. However, whenever the protective housing is removed, a temporary laser controlled area must be established and control measures applicable to the class of the embedded laser(s) must be implemented.

Laser Supervisors who wish to convert a Class 3B and/or Class 4 laser into a Class 1 laser system shall consult with the Laser Safety Officer to ensure that all the requirements of a Class 1 laser system will be met.

Some of the requirements for a Class 1 protective housing are listed below.

- Completely confines the laser beam or limits the emitted beam to a level below that of the applicable Class 1 Accessible Emission Limit (AEL) as defined in Appendix C of the ANSI Z136.1 Standard
- Prevents access to the embedded laser(s) during normal operations
- Equipped with safety interlocks wherever the protective housing can be opened, removed or displaced
- Safety interlocks designed to prevent access to laser radiation above the Maximum Permissible Exposure (e.g. terminates laser power or activates a beam-blocking shutter)
- Safety interlock is fail-safe (the use of redundant electrical series-connected interlocks would fulfill this requirement)
- Labeled in accordance with ANSI Z136.1-2007

V. Laser Beam Bio-Effects

Laser exposure exceeding the Maximum Permissible Exposures (MPEs) may cause eye and skin injury which is sometimes permanent and debilitating. The MPE for each wavelength and exposure situation can be found in the ANSI Z136.1 Standard. Consult with the Laser Safety Officer if you require assistance determining the MPE for the laser you operate.

The probability that biological damage will occur and the tissue of the body at risk depend on a number of factors including: the laser wavelength, the power or energy of the beam, the beam diameter at the exposure site, the exposure duration, pulsed beam characteristics, etc.

The tables below summarize the risks to the eye and skin for different laser wavelengths.

Eye

Spectral Region	Structure of the Eye at Risk	Biological Effect
UV-C (200-280 nm)	Cornea	Photokeratitis
UV-B (280-315 nm)	Cornea	Photokeratitis
UV-A (315-400 nm)	Lens	Cataract
Visible (400-780 nm)	Retina	Retinal injury*
IR-A (780-1400 nm)	Retina, Lens	Retinal burn, cataract
IR-B (1400-3000 nm)	Cornea, Lens	Corneal burn, cataract
IR-C (3000-1000000 nm)	Cornea	Corneal burn
* Retinal injury can be thermal, acoustic or photochemical.		

Skin

Spectral Region	Biological Effect
UV-C (200-280 nm)	Erythema, cancer, accelerated aging
UV-B (280-315 nm)	Erythema, increased pigmentation, cancer, accelerated aging
UV-A (315-400 nm)	Erythema, increased pigmentation, skin burn
Visible (400-780 nm)	Photosensitive reactions, skin burn
IR-A (780-1400 nm)	Skin burn
IR-B (1400-3000 nm)	Skin burn
IR-C (3000-1000000 nm)	Skin burn

VI. Responsibilites

Laser Supervisors have a responsibility to :

1. Supervise the use of lasers under their control.
2. Comply with the UD policy on the Safe Use of Lasers.
3. Implement and enforce the requirements outlined in this manual.
4. Register all Class 3B and Class 4 lasers with the Department of Environmental Health and Safety.
5. Develop standard operating procedures (SOPs) for their Class 3B and Class 4 lasers/laser systems and submit them to the Laser Safety Officer. Review the SOPs at least annually.
6. Ensure that Class 3B and Class 4 laser operators attend laser safety training from the Department of Environmental Health and Safety prior starting laser work and at the required frequency thereafter.
7. Provide Class 3B and Class 4 laser operators with training in procedures to operate, align, maintain, and service their lasers.
8. Provide laser safety awareness training to individuals working around, but not with, their lasers.
9. Ensure that all lasers in their laboratories are properly classified and labeled.
10. Post proper laser warning signs at the entrances to their laboratories.
11. Ensure that the required engineering controls are present and that procedural controls are followed.
12. Ensure that effective, properly-fitting laser safety spectacles and/or goggles are available. Replace eyewear in damaged or poor condition.
13. Notify the Department of Environmental Health and Safety immediately in the event of a laser-related injury and assist the Laser Safety Officer with an investigation into the cause of the injury.
14. Review the plans of lab staff members fabricating lasers and provide close supervision throughout the fabrication process.
15. Consult with the Laser Safety Officer if planning to convert a Class 3B or Class 4 laser to a Class 1 laser system.
16. Inform the Department of Environmental Health and Safety before disposing of a laser or transferring a laser to a new owner.
17. Respond to communications from the Laser Safety Officer and the Laser Safety Committee.

Laser Supervisors may delegate laser safety tasks to qualified members of their staff but remain ultimately responsible for performance of those tasks.

Laser Operators have a responsibility to:

1. Attend laser safety training from the Department of Environmental Health and Safety prior to beginning Class 3B and Class 4 laser operations and at the required frequency thereafter.

2. Obtain training from the Laser Supervisor or his/her qualified designee in procedures to operate, align, maintain, and service the lasers to be used.

3. Follow the standard operating procedures (SOPs) approved by the Laser Supervisor and inform the Laser Supervisor prior to any planned departure from the SOPs.

4. Comply with the requirements outlined in this manual.

5. Wear the correct laser safety eyewear as dictated by the requirements of this manual and by the standard operating procedure approved by the Laser Supervisor. Inform Laser Supervisor when eyewear needs replacement.

6. Do not defeat or bypass any safety interlock or engineering control device unless so directed by a written SOP approved by the Laser Supervisor. Return interlock/device to functioning status at completion of procedure.

7. Discontinue use of lasers if malfunctioning laser safety devices are observed and report such problems to the Laser Supervisor.

8. Immediately notify the Laser Supervisor and/or the Department of Environmental Health and Safety in the event of any laser-related injury or incident.

9. Inform their Laser Supervisor if they are aphakic (no lens in eye), have a history of photosensitivity, or use photosensitizing medications (such as phenothiazines and psoralens) and work with, or around lasers emitting ultraviolet radiation.

Laser Safety Officer (LSO) has a responsibility to:

1. Work cooperatively with Laser Supervisors and Laser Operators to ensure the safe use of lasers at the University.

2. Conduct safety audits of all laser facilities. Inform Laser Supervisors of conditions or practices that do not meet the requirements of the laser safety program as outlined in this manual. [Note: The LSO is empowered by executive administration to order the immediate termination of any laser operation that he/she believes presents an imminent and serious hazard to personnel.]

3. Provide Laser Supervisors and Laser Operators with assistance in any laser-related matter.

4. Disseminate information regarding new laser safety products or techniques to Laser Operators.

5. Assist Laser Supervisors in laser classification and labeling and the posting of laser warning signs.

6. Maintain records of campus laser information including a listing of lasers and laser operators.

7. Assist laser operators in the selection of laser safety equipment.

8. Conduct laser safety training for all personnel working with lasers.

9. Review standard operating procedures (SOPs).

10. Participate in accident investigations involving lasers.

11. Help coordinate the disposal of unwanted lasers.

12. Report laser activities to the Laser Safety Committee at quarterly meetings.

13. Report laser activities to University executive administration on behalf of the Laser Safety Committee.

Laser Safety Committee (LSC) has a responsibility to:

1. Establish and maintain adequate policies and practices for the evaluation and control of laser hazards.
2. Fulfill the responsibilities defined in the UD policy on the Safe Use of Lasers and the Laser Safety Committee Charter.
3. Meet quarterly to receive and discuss the Laser Safety Officer's activity report which includes: new laser registrations and standard operating procedures, laser accident investigations, and safety audit results.
4. Assist the Laser Safety Officer in efforts to encourage Laser Supervisors to promptly address deficiencies identified during laser safety audits.
5. Amend and update Laser Safety Program requirements and the Laser Safety Manual as necessary.
6. Provide the Laser Safety Officer assistance in technical matters as needed.
7. Report to University executive administration in matters related to the laser safety program.

VII. Personnel Training and Qualifications

Only qualified personnel are permitted to operate a laser. The Laser Supervisor determines who is a qualified person based on departmental training, technical training and other appropriate learning experience. Laser Supervisors must obtain authorization from the Laser Safety Officer in writing before allowing a minor (person who is less than 18 years of age) to operate a Class 3B or Class 4 laser.

All individuals planning to operate a Class 3B or Class 4 laser are required to be properly trained in the safe use of lasers prior to working with lasers.

Before operating a Class 3B or Class 4 laser, laser operators shall:

1. Review the University of Delaware Laser Safety Manual.

2. Attend a live training presentation in the safe use of lasers provided by the Department of Environmental Health and Safety (DEHS).

3. Receive training from the Laser Supervisor (or the Laser Supervisor's qualified designee) covering safe operation of the laser to be used, administrative procedures, alignment procedures, and any other applicable standard operating procedure (SOP).

4. Review any operating and safety instructions furnished by the laser manufacturer.

Each calendar year after their initial training, laser operators must complete a "refresher" laser safety training session provided by the Department of Environmental Health and Safety in order to retain authorization to use Class 3B or Class 4 lasers. Should an operator fail to complete a refresher session by the end of the calendar year, their authorization is terminated and the operator must cease laser activities. The operator must complete a refresher training session to regain authorization.

Individuals working in Class 3B or Class 4 laser facilities who are not laser operators must be trained in the following topics: laser hazards, methods to work safely around lasers, how to identify unsafe laser conditions, and what to do in the case of laser injury. The training must occur before the individual is allowed access to the Class 3B or Class 4 laser facility. It is the responsibility of the Laser Supervisor to ensure that such individuals receive the training. The training may be provided directly by the Laser Supervisor or by his/her qualified designee.

Ancillary personnel (e.g. custodial and maintenance personnel) will generally not be permitted to enter laser facilities without an escort when open, or partially open, beams from Class 3B or Class 4 lasers are present. In cases where this is necessary, such individuals may be trained by the Laser Supervisor, the Laser Safety Officer, or the Laser Safety Officer's designee in the topics listed in the paragraph above.

Visiting, short-term, laser operators are those individuals who are conducting research or otherwise working at the University for less than four consecutive weeks. In place of requirement to attend a live training presentation provided by DEHS, such individuals may submit to the Laser Safety Officer written documentation from their home institution that they have been trained in the safe use of lasers. If this is not possible, the individual may contact the Laser Safety Officer and request a private training session. Laser safety staff will conduct such training subject to their availability. The following requirements must be completed:

1. Review the University of Delaware Laser Safety Manual.

2. Receive training from the Laser Supervisor (or the Laser Supervisor's qualified designee) covering safe operation of the laser to be used, administrative procedures, alignment procedures, and any other applicable standard operating procedure (SOP).

3. Review any operating and safety instructions furnished by the laser manufacturer.

VIII. Laser Registration

The Laser Supervisor shall register all Class 3B and Class 4 lasers. The Laser Supervisor shall update his/her laser registry when-- 1) new lasers are purchased, accepted as donations, or otherwise acquired, and 2) lasers are taken out of storage for re-use. Lasers can be registered by using the form in Appendix C or by submitting an electronic form found at-- http://www.udel.edu/ehs/formindex.html

IX. Baseline Eye Examinations

Individuals working with, or around, lasers are not required to obtain a baseline eye exam. Such exams are not a mandatory requirement of the ANSI Z136.1 Standard for Safe Use of Lasers.

X. Suspected or Actual Laser-Induced Injuries

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. For injury to the eye from lasers operating in the retinal hazard region (wavelengths from 400 to 1400 nm), examinations should be performed by an ophthalmologist. Individuals with a skin injury should be seen by a physician.

For injuries that require immediate medical assistance, the UD Department of Public Safety shall be contacted by dialing **911** from any campus **land-line** phone or by using a campus emergency phone. Dialing 911 using a cell phone will not connect you to the UD Department of Public Safety! (If you use a cell phone for an emergency call, dial 302-831-2222.) If it is a serious injury, request the ambulance immediately; otherwise request that a Public Safety officer transport you to the appropriate medical office as listed below:

- Students: Student Health Services, Laurel Hall, 831-2226
- Employees: Christiana Care Environmental Health Services, 200 Hygeia Drive, Newark, 302-428-4250 (“Employees” include Funded Graduate Students, Teaching Assistants, Miscellaneous Wage Student Employees, and other individuals who are compensated for their activities at the University)

The University of Delaware Policy 7-3 regarding injuries can be found at--
http://www.udel.edu/ExecVP/polprod/7-03.html

The injured individual shall notify the Laser Supervisor and the Department of Environmental Health and Safety (302-831-8475) as soon as practical after a suspected injury or adverse effect from a laser exposure occurs. Accident investigations will be conducted by the Laser Safety Officer together with the Laser Supervisor and injured individual. The results of the investigation will be reported to the Laser Safety Committee for review.

XI. Control Measures

The purpose of control measures is to reduce the possibility of exposure of the eye and skin to hazardous levels of laser radiation and to protect individuals from non-beam hazards.

1. *Engineering controls* are those items incorporated into the laser by the manufacturer or designed into the laser installation by the owner which isolates or prevents access to hazardous radiation. This is typically the most effective method of protecting individuals working with, or around, lasers. One example is the use of an interlocked laser enclosure that terminates power to the laser when opened.
2. *Administrative and Procedural controls* are employed when engineering controls are impractical or inadequate to completely eliminate the risk of laser injury. Safety instruction and written standard operation procedures are examples of such controls.
3. *Personal Protective Equipment (PPE)* are items (e.g. laser safety eyewear) that protect individuals when engineering, administrative, and procedural controls fail.
4. A complete safety program in a laser facility will generally include a combination of engineering controls, procedural controls, and PPE use.

Below are the causes of most reported laser incidents. Adherence to the established control measures will minimize the probability of such incidents.

1. Eye exposure during alignment
2. Misaligned optics and upwardly directed beams
3. Available eye protection not worn or incorrect eye protection worn
4. Improper methods of handling high voltage
5. Operators unfamiliar with laser equipment or safety practices
6. Unanticipated eye or skin exposure during laser usage
7. Failure to follow standard operating procedures
8. Fires resulting from ignition of materials

XII. Engineering Controls

A. Protective Housing

Lasers of any class are required to have a protective housing to prevent access to optical and electrical hazards inside the laser. For Class 3B and Class 4 lasers the housing must be interlocked in a manner to eliminate the hazard if the housing is removed or opened.

If it is necessary to temporarily defeat the interlock and operate Class 3B or Class 4 lasers without the housing, operators must follow a written Standard Operating Procedure (SOP) which incorporates measures to protect all present in the laser facility. The SOP must include provisions to:

- Restrict access to the area.
- Control of the beam to prevent the beam and hazardous reflections from extending beyond the area.
- Removal of reflective materials in and near the beam path.
- Wear appropriate laser eye protection.

After the operation that necessitated the interlock bypass is complete, the interlocks shall be restored to their operational condition.

B. Activation Warning System

An activation warning system shall be used with Class 3B lasers and Class 4 lasers during laser activation or start-up. The system may be audible (bells, chimes, buzzer, etc.) or visible (flashing light). An audible countdown by the laser operator may used as an alternate warning method. If this means of warning is selected, it shall be written into the SOP for use of the laser.

C. Beam Stop or Attenuator

Class 4 lasers shall have a permanently attached beam stop or attenuator which is capable of reducing laser radiation to levels below the MPE when the laser output is not required, as in warm-up procedures. Class 3B should have a permanently attached beam stop or attenuator.

For lasers that do not require a warm-up time, the main power switch may be substituted for the requirement of a beam stop or attenuator.

D. Collecting Optics
Lenses, telescopes, microscopes, loupes, etc intended for viewing use with a laser shall incorporate a suitable means (such as interlocks, filters, attenuators) to prevent eye exposure at levels exceeding the MPE.

E. Window Covers

When a laser is in operation and partially or fully exposed Class 3B or Class 4 laser beam paths are present, all windows which allow viewing into the laser facility by passers-by shall be covered with an opaque material or a laser filter material with sufficient optical density to reduce laser radiation to levels below the MPE. When the laser is not in operation the window covers may be retracted or removed.

F. Emergency Stop

For emergency conditions in facilities with Class 4 lasers, there shall be a clearly marked “Emergency Stop” device available for deactivating the laser or reducing the laser output to levels below the MPE. The stop device shall be in close physical proximity to the laser it controls.

G. Laser Workstation Enclosure

When at all practicable the entire laser experiment should be confined within an enclosure when Class 4 lasers are used. When full enclosure is not practicable, beam guide tubes and barriers shall be used to the maximum extent practicable.

H. Nominal Hazard Zone (NHZ)

A NHZ shall be established for Class 3B and Class 4 laser applications which require an open beam. The NHZ is the area in which the level of direct, reflected or scattered laser radiation exceeds the MPE. The Laser Safety Officer defines the NHZ with the assistance of the Laser Supervisor.

I. Laser-Controlled Area

A laser-controlled area shall be established for Class 3B and Class 4 lasers. The laser-controlled area is the area that confines the NHZ or regulates access to the NHZ.

The walls, ceiling and floor of the room often define the laser-controlled area. Laser curtains and free-standing laser barriers may be used to limit the size of the laser-controlled area. Laser Supervisors should consult with the Laser Safety Officer prior to purchasing and installing curtains and barriers to confirm they are compatible with laser operation and will define the laser-controlled area as intended.

J. Entryway Controls

Entryway controls prevent unauthorized individuals from entering a laser-controlled area (especially when the laser is operating unattended) and also prevent authorized individuals with unprotected eyes from entering the laser-controlled area when a potential eye hazard exists at the entryway.

One of the following controls shall be present at the entryway to all Class 4 laser-controlled areas when partial or fully open beam paths are present.

Non-Defeatable Entryway Safety Controls: Non-defeatable safety latches or interlocks (such as pressure sensitive floor mats, infrared detectors, motion sensors) shall be used to deactivate the laser or reduce the output to levels below the MPE in the event of unexpected entry.

Defeatable Entryway Safety Controls: If non-defeatable controls limit the intended use of the laser, defeatable entryway safety controls may be used. Defeatable entryway controls allow authorized personnel to override the controls. Defeatable entryway controls may be used only if there is no laser radiation hazard at the point of entry. Personnel must be properly trained and provided with adequate personal protective equipment.

Procedural Entryway Controls: If safety latches or interlocks are not feasible, procedural entryway controls may be used. When procedural entryway controls are used, the following conditions must be met:

- Appropriate laser eyewear and any other required personal protective equipment shall be accessible prior to entering the laser-controlled area.
- A door, barrier, screen or curtains shall be used to block or attenuate the laser radiation below the MPE at the entryway.
- The entryway shall be equipped with an illuminated laser warning sign or warning light that indicates the laser is operating at Class 4 levels. The sign or light shall be have the follow statement “Dangerous to Enter when Light is ON, NO ONE MAY ENTER except laser operators” (or words with similar intent).
- When a Class 4 laser is operating unattended* and partially or fully open beams are present, unauthorized access to the laser-controlled area shall be limited by the locking a deadbolt lock in addition to the regular entryway lock. The key to the deadbolt lock shall be provided to only those that have received adequate training in laser safety. To allow access in the case of an emergency, such facilities shall have a key to the deadbolt lock stored in an emergency key box located at the entryway.

The key box shall have a breakable window. Deadbolt lock and emergency key box specifications and ordering information can be found in Appendix F.

* ”Unattended” means that no one trained in the use of the laser is physically present to prevent untrained persons (e.g. custodians, repair personnel) from entering the laser-controlled area.

K. Laser Fabrication

A fabricated laser or laser system is one that is built from electronic and optical components as opposed to being obtained, already assembled, from a commercial laser manufacturer or distributor. Fabricated lasers may be lasers built at the University or obtained from research colleagues or other entities.

Fabricated lasers shall be constructed in a manner that complies with the engineering control requirements described in section A., C., and D. above. Lasers fabricated at the University shall comply with these requirements once they are operable and placed in use. During the period of non-compliance with the engineering control requirements, the Laser Supervisor shall develop and enforce alternate control measures that provide an equal measure of safety. Lasers fabricated at a location outside the University shall be modified, as needed, to comply with the engineering control requirements prior to placing them in use.

Fabricated lasers shall also comply with laser labeling requirements described in the section, Warning Signs and Equipment Labels.

XIII. Administrative and Procedural Controls-

A. Standard Operating Procedures (SOPs)

Written standard operating procedures (SOPs) are required for operating, aligning, maintaining and servicing Class 3B and Class 4 lasers or laser systems. The Laser Supervisor is responsible for the development of the SOPs and shall ensure that they are provided to the Laser Safety Officer (LSO). SOPs are reviewed by the LSO. The manufacturer's operating manual is not a substitute for an SOP.

SOPs shall include: (See Appendix D for guidance on developing a SOP)

i. Laser data
ii. Contact information
iii. Laser application
iv. Control measures
v. Personal protective equipment
vi. Start up and shut down procedures
vii. Experimental procedures
viii. Emergency procedures
ix. Storage
x. Non-beam hazards

The Laser Supervisor or his/her qualified designee shall provide training to operators in the SOPs (see section **Personnel Training and Qualifications**).

SOPs shall be stored in a location near the laser or laser system where operators have ready access to them. Operators shall know the location of the SOPs for the laser(s) they operate.

The Laser Supervisor is responsible for revising SOPs as conditions change and submitting revised SOPs to the LSO. The Laser Supervisor is responsible for ensuring that SOPs are reviewed on at least an annual basis.

Operators shall follow the established SOPs. Operators shall discuss any proposed change to an SOP with their Laser Supervisor.

A. Beam Control Measures

The following measures apply when working with Class 3B or Class 4 lasers. The use of the word "shall" indicates a mandatory measure; "should" indicates a recommended, but not mandatory, measure.

i. The beam height should not be positioned at the typical eye location of a person who is standing or seated. A beam control device (such as a beam block) shall be used to protect a standing or seated person if the beam must be at those heights.

ii. The laser should not be positioned so that the beam is directed toward entryways or windows. If this is not possible, a beam control device (such as a beam block) shall be used to protect those passing through the entryway or outside the window.

iii. Lasers shall be securely mounted to maintain the beam in a fixed position during operation.

iv. The beam shall be terminated at the end of its useful path with a beam block. The beam block for Class 4 beams shall be composed of fire resistant material.

v. The laser operator shall remove or cover reflective personal jewelry and other objects when working near an open laser beam. This includes (but is not restricted to) rings, bracelets, watches, dangling necklaces, pens, and belt buckles.

vi. Beam blocks shall be positioned behind turning mirrors so the beam is blocked from leaving the perimeter of the optical table if it misses the mirror. Beam blocks are not required if there is another

barrier that will serve the same function (e.g. a laser enclosure, panels affixed to the sides of the optical table, etc.). Beam blocks and barriers used with Class 4 lasers shall be constructed of fire-resistant materials.

vii. Beams and specular reflections shall be confined to the optical table. Diffuse reflections exceeding the MPE shall not extend past a plane extending vertically from the edges of the optical table. Use of a Laser Workstation Enclosure is recommended to achieve this, however, other options include the use of beam guide tubes, beam blocks, beam barriers, partial beam path enclosures, panels affixed to the sides of the optical table, etc. [See vii. for an exception to vi.]

viii. When it is necessary for the beam path to extend beyond the perimeter of the optical table (e.g. to a nearby second optical table) a physical barrier, such as a beam guide tube, shall be used to prevent accidental exposure.

ix. Unnecessary loose items (tools, meters, unused optical components, notebooks, pens, etc.) shall not be stored on the optical table or near the beam path.

x. When feasible, laser operators should consider the use of fiber optical cable for beam delivery as an alternate to open air beams.

B. Other Procedural Control Measures

The following measures apply when working with Class 3B or Class 4 lasers. The use of the word "shall" indicates a mandatory measure; "should" indicates a recommended, but not mandatory, measure.

i. When a laser operator energizes a laser, he/she shall assume responsibility for controlling the laser operation in a manner which is safe for all those present in the laser-controlled area.

ii. The entryway to the laser-controlled area shall be closed when operating a laser.

iii. Operators shall alert others in the laser-controlled area prior to operating the laser. Operators shall inform those that enter the laser-controlled area when the laser is in operation.

iv. Whenever feasible, operators using visible and near-infrared lasers should consider turning all room lights ON to maximize constriction of the pupil and, thereby, reduce the probability of a beam entering the eye and focusing on the retina.

v. Skin coverings, such as gloves, long sleeved shirts/labcoats, and face shields, should be used when manipulating or working near ultraviolet laser beams. Chronic UV exposure may have long term adverse health effects.

C. Control Measures During Alignments of Class 3B and Class 4 Lasers

More laser accidents occur during beam alignment than any other laser operation! Even a brief, unanticipated eye exposure to a Class 3B or 4 laser beam (or beam reflection) during alignment may result in permanent damage to the affected eye. Extreme care must be exercised when conducting beam alignments.

Although this section focuses on beam alignment, operators should recognize that other laser operations may present a hazard similar to alignments if the operations involve manual beam manipulation in close physical proximity to the laser beam. Examples are inserting a glass attenuator plate, a phosphor card, or reflective experimental sample into the beam path. For such operations, many of the techniques below are useful in minimizing the possibility of an injury.

Alignments shall be performed in such a manner that the primary beam, or a specular or diffuse reflection of the beam, does not expose the eye to a hazardous level of laser radiation. **Adherence to the following techniques is the single most important thing laser operators can do to prevent serious eye injuries to themselves and others in the laser area.**

i. Follow the Alignment SOP developed by your Laser Supervisor. Obtain hands-on instruction in alignment procedures from your Laser Supervisor or his/her qualified designee.

ii. Exclude unnecessary personnel from the laser controlled area during alignment.

iii. Be mentally prepared to do the work by being well rested, allocating enough time to align the beam safely, and eliminating visual and audible distractions.

iv. Whenever practical, use one or more of the following methods to reduce the intensity of the laser beam to be aligned to a safe level (i.e. below the MPE) when performing Class 3B or Class 4 laser beam alignments:
- Adjust laser settings to reduce the output intensity of the laser to as low a level as possible while still allowing alignment to take place.
- Use a temporary beam attenuator over the beam aperture to reduce the intensity of the laser beam.
- Perform the alignment using a low-powered visible beam laser (Class 2 or 2M or Class 3A or 3R) instead of the beam from the high-power laser.

v. When the methods described in item iv. (above) cannot be used or when they do not fully reduce the intensity of the laser beam to a safe level (i.e. below the MPE), wear appropriate laser safety eyewear during the alignment. Use of special “alignment” eyewear may reduce unintended laser eye exposure to a safe level and still allow the beam visualization necessary to align a visible laser beam.

vi. Beam display devices (such as, image converter viewers or phosphor cards) may be useful for locating beams during alignment. Use Caution! The reflections from phosphor cards in some circumstances may be hazardous!

vii. Use shutters or beam blocks to block high intensity beams at their source except when needed during the alignment process.

viii. Use beam blocks to block high intensity beams downstream of the optics being aligned.

ix. Use beam blocks or protective barriers when alignment beams could stray into other areas.

x. Place beam blocks behind optics such as turning mirrors to terminate beams that may miss the mirrors during alignment.

xi. Locate and block all hazardous stray reflections before proceeding to the next optical component or section.

xii. Once alignment is complete, confirm that necessary blocks/barriers are in place before initiating laser experiments/measurements.

xiii. Report any problems experienced during an alignment to your Laser Supervisor.

D. Demonstrations Involving Lasers and Tours of Laser Facilities

The safety of participants during demonstrations involving lasers and tours of laser facilities at the University of Delaware is paramount. The Laser Supervisor and Laser Operator share the responsibility for the safety of the individuals involved and shall assure that the following requirements are met.

If the demonstration or tour involves operation of Class 3B or Class 4 laser with open beams, then -

i. The Laser Supervisor shall notify the Departmental Safety Committee and ~~receive approval from~~ the Chair of the Department or the Director of the Program. If minors are involved, the Laser Supervisor must also obtain written approval of the University Laser Safety Officer in advance ~~writing~~.

ii. The Laser Supervisor or Laser Operator shall advise participants or visitors of the hazards present in the laboratory or area involved in the demonstration or tour. Information regarding appropriate ~~Pertinent~~ safety measures shall be provided~~discussed~~.

iii. The Laser Operator shall minimize the laser hazard as much as practicable by reducing laser power, increasing use of barriers, etc. ~~If minors are involved in the tour/demonstration,~~ Whenever possible, open laser beams exceeding the MPE should be avoided; consider mock setups using Class 2 lasers.

iv. Terminate hazardous operations in the demonstration area or lab that are unrelated to the purpose of the demonstration/tour.

v. All participants in the demonstration or tour must be provided, and don, the same level of eye protection that the UD laser safety manual requires for laser operators. This means that, in some cases, the number of participants must be limited to the number of pairs of appropriate laser safety eyewear that is available. The Laser Safety Officer may have appropriate laser safety glasses that can be loaned to the lab.

vi. The Laser Operator shall be continuously present during laser operation and shall monitor and supervise participants at all times. The Laser Operator shall position her/him~~them~~self so she/he~~they~~ can immediately terminate the laser beam, if necessary.

vii. Demonstrations performed off campus or in an area, on or off campus, not designed as a laser facility requires the approval of the University Laser Safety Officer.

XIV. Warning Signs and Equipment Labels

Illuminated Warning Signs

An illuminated warning sign that is activated when the laser is energized shall be located at the entryway(s) to all Class 4 laser-controlled areas that do not have non-defeatable or defeatable entryway safety controls (see Section XII.J.). Exceptions may be requested in certain cases, such as, facilities containing laser scanning microscopes, laser tweezers, and other similar laser-containing devices.

Printed Warning Signs

A warning sign is required to be posted at the entryway(s) to Class 3B and Class 4 laser-controlled areas. The sign (example below) shall comply with the design specified in the ANSI Z136.1 Standard. The Laser Safety Officer can provide appropriate printed warning signs upon request.

The signal word “Danger” shall be located in the upper panel.

Above the tail of the sunburst image, one of the following statements shall be present—

- for Class 3B areas “Laser Radiation- Avoid Direct Exposure to Beam”,
- for Class 4 areas “Laser Radiation- Avoid Eye or Skin Exposure to Direct or Scattered Radiation”

(The word “Invisible” shall precede the work “Laser” if the laser is operating at a wavelength that is less than 400nm or greater than 700nm.)
There may also be additional precautionary instructions in this section of the sign.

Below the tail of the sunburst image, the type of laser shall be indicated. The emitted wavelength, pulse duration (if appropriate), and maximum output may also be indicated.

In the lower right-hand corner of the sign, the class of the laser or laser system shall be indicated.

Equipment Labels

All lasers and laser systems shall have a warning label conspicuously affixed to the protective housing that conforms to the ANSI Z136.1 Standard. The label (example below) shall indicate the precautionary instructions or protective actions required, the type of laser or the wavelength, the pulse duration (if applicable), maximum output and the class of the laser or laser system. The label shall incorporate the sunburst symbol.

All removable protective housings shall have a label affixed in a conspicuous location on the housing which indicates the hazards within the housing. This label (example below) does not need to contain the sunburst symbol.

XV.Laser Safety Eyewear

Enclosure of the laser equipment or beam path is the preferred method of control since the enclosure will isolate or minimize the hazard. This may not always be feasible so engineering, administrative, and procedural controls are established. Laser safety eyewear is worn to protect eyes in situations when, for whatever reason, such controls fail to prevent a hazardous laser exposure to the eye.

Most laser eye injuries have occurred when (1) a person was not wearing laser eyewear or (2) a person was wearing incorrect laser eyewear. **The risk of a laser eye injury is greatly reduced when proper laser eyewear is worn.**

When operating a Class 3B laser or laser system, all those present in the laser-controlled area shall wear appropriate laser safety eyewear when-

- a laser beam alignment is being performed (unless laser intensity is sufficiently reduced using the techniques in item D.iv. of the manual section XIII. Control Measures During Alignments of Class 3B and Class 4 Lasers), or
- items are being inserted into the beam which may result in specular reflections, or
- laser operation results in unconfined specular reflections, or
- it is required by the Standard Operating Procedure (SOP) established for use of the laser by the Laser Supervisor.

When operating a Class 4 laser or laser system all those present in the laser-controlled area shall wear appropriate laser safety eyewear when-

- the laser beam path is not completely confined by enclosures, tubes, or barriers that would prevent personnel exposure to stray beams or reflections at levels exceeding the MPE for the eye, or
- a laser beam alignment is being performed (unless laser intensity is sufficiently reduced using the techniques in item D.iv. of the manual section XIII. Control Measures During Alignments of Class 3B and Class 4 Lasers), or
- items of any kind are being inserted into the beam, or
- laser operation results in unconfined reflections exceeding the MPE for the eye, or
- it is required by the Standard Operating Procedure (SOP) established for use of the laser by the Laser Supervisor.

An operator shall not intentionally look directly into a laser beam even if he/she is wearing laser safety eyewear.

The Laser Supervisor is responsible for ensuring 1) that appropriate and properly-fitting laser safety eyewear is available and 2) that workers know when eyewear must be worn.

Individuals are advised to consult with the Laser Safety Officer prior to purchasing laser safety eyewear to confirm that the eyewear to be purchased will offer the desired protection. Eyewear features to be considered when purchasing eyewear include: filters protect against wavelength in use, optical density (OD) is sufficient to reduce laser radiation to safe levels, frames fit face of operator, filter is tested to withstand exposure to ultrafast pulsed laser radiation (if such radiation is present).

Properly-fitting oversized laser safety spectacles or laser safety goggles shall be available for individuals who wear prescription glasses. The Laser Supervisor shall provide prescription laser safety eyewear for such individuals if oversized eyewear does not fit properly.

Prior to putting on eyewear, individuals shall check the wavelength and optical density (OD) markings on the eyewear frame or lens to confirm that the eyewear offers protection for the laser beam present and that the OD is high enough to provide an adequate level of protection. The Laser Safety Officer can assist individuals calculate

the OD requirement. In multi-laser environments where there may be many different pairs of laser safety eyewear, it may be useful to use a color-coding or other marking system to assist in proper eyewear selection.

The filters used in some laser safety eyewear may exhibit non-linear effects such as saturable absorption when exposed to laser beams of ultrashort (e.g. femtosecond) pulse durations. Those working with such lasers should confirm with the manufacturer of their laser eyewear that it has been tested against, and been proven to be effective for, ultrashort pulsed lasers.

Laser operators should use caution when using phosphor cards which reflect radiation at a different wavelength than the incident laser beam radiation. Use laser safety eyewear that also offers protection at the reflected wavelength if the intensity of the reflection exceeds the MPE for the eye.

Eyewear should be periodically cleaned and inspected. Follow manufacturers' instructions when cleaning laser safety eyewear. Eyewear with lenses that are pitted, crazed, cracked, discolored, or otherwise damaged shall be either tested for acceptability or discarded and replaced.

XVI. Non-Beam Hazards

Lasers operators should be aware that there exist other hazards associated with laser use that are not related to the laser beam. In some cases the potential injury associated with non-beam hazards exceeds that posed by the laser beam. This section identifies non-beam hazards and provides safety guidance but does not attempt to fully instruct the laser operator in safe practices. Operators may be required to obtain additional training as dictated by other applicable regulations or University policies. .

Electrical Hazards

Many lasers utilize high-voltage power supplies and/or capacitors that may store lethal amounts of electrical energy. **Most of the fatalities that have occurred during laser use are due to contact with laser energized conductors.** Electrical shock can occur during laser installation, maintenance, modification, and service where protective covers are removed to allow access to active components as required for those activities.

Electrical safety practices include:

- Obtaining the permission of the Laser Supervisor before attempting service or repairs of laser high voltage electrical components.
- Making sure another lab staff member (a “buddy”) is present while working on electrical components.
- Being well trained in the potential electrical hazards and methods to prevent injury and death.
- Ensuring that fabricated (homemade) lasers have no exposed energized electrical components that a laser operator may accidentally touch.
- Replacing illegible or missing electrical hazard warning labels.
- Following the measures below when protective housings or covers are removed to access exposed energized components:
    1. Adhere to Lock Out/Tag Out procedures to prevent unexpected re-energizing of equipment.
    2. Enclose high voltage sources and terminals whenever possible.
    3. Turn off power and ground all high voltage points before working on power supplies.
    4. Check that each capacitor is discharged and grounded prior to working near the capacitor.
    5. Do not wear rings, watches or other jewelry when working with or near energized equipment.

Laser-Generated Air Contaminants (LGAC)

Air contaminants may be generated when Class 4 and some Class 3B laser beams interact with matter. The quantity, composition and chemical complexity of the LGAC depend on the target material, cover gas and beam irradiance. Laser-irradiated materials such as plastics, composites, metals and tissues may release carcinogenic, toxic and noxious air contaminants. Lasers emitting ultra-violet radiation may generate ozone as the beam interacts with air molecules.

Concentrations of LGAC must be maintained below the exposure limits specified by OSHA, NIOSH or ACGIH. There are three major control measures to reduce the concentration of LGAC to acceptable levels:

- Use enclosing exhaust hoods or local exhaust ventilation to remove the LGAC at the point of generation and vent to the building exterior.
- Isolate the process by using physical barriers.
- Wear respiratory protection when engineering controls are not feasible. (Note: Respirators may not be used without first contacting the Department of Environmental Health and Safety.)

The Department of Environmental Health and Safety can assist laser operators determine if their laser operation generates harmful levels of LGAC and recommend the most appropriate control measures.

Collateral and Plasma Radiation

Collateral radiation (radiation not associated with the primary laser beam) may be produced by system components such as power supplies, discharge lamps and plasma tubes. Radiation may be in the form of X-rays, UV, visible, IR, microwave and radiofrequency (RF). When high power pulsed laser beams (peak irradiance of 10^{12} W/cm^2 or greater) are focused on a target, plasma is generated that may also emit collateral radiation. Contact the LSO for evaluation of these hazards. The Radiation Safety Officer can help evaluate hazards associated with ionizing radiation.

Fire Hazards

Class 4 laser beams can ignite flammable solvents, gases and combustible materials. Fire safety practices include:

- Terminating laser beams with non-combustible materials.
- Storing only necessary materials in the vicinity of the laser beam path.
- Storing flammable and combustible solvents and materials properly and away from the laser beam.
- Being aware of the location of the closest fire extinguisher and obtaining instruction in its proper use from the Department of Environmental Health and Safety (www.udel.edu/ehs/ehstrainsched99.html).

Compressed Gases

There exist certain risks associated with the use of high pressure gas cylinders. Safe practices when working with such cylinders include:

- Obtaining training in the safe use of compressed gas from the Department of Environmental Health and Safety (www.udel.edu/ehs/ehstrainsched99.html).
- Securely strapping or chaining cylinders to a wall, heavy bench, etc. High pressure compressed gas cylinders can become “missiles” in the lab should the cylinder valve shear off as the cylinder falls.
- Refraining from storing cylinders near doorways and emergency exits.
- Storing cylinders containing hazardous gases (e.g. chlorine, fluorine, hydrogen chloride and hydrogen fluoride) in ventilated gas cabinets or enclosures.
- Using tubing and connectors that are compatible with the gas being delivered to the laser system.

Laser Dyes, Solvents, and Chemicals

Laser dyes are complex fluorescent organic compounds that are dissolved in a solvent to form a lasing medium. Some dyes are highly toxic or carcinogenic. Most solvents suitable for dye solutions are flammable and toxic by inhalation and/or skin absorption. Hazardous chemicals are sometimes used to clean optics and for other laser-related activities.

The use of hazardous chemicals generates hazardous waste which must be managed correctly to protect workers and the environment and to prevent regulatory non-compliance and potential costly fines.

Safe use and management of chemicals in laser facilities include:

- Obtaining chemical hygiene training each year from the Department of Environmental Health and Safety or the Lab Supervisor **(www.udel.edu/ehs/trainingrequirements.html**).
- Obtaining chemical waste training each year from the Department of Environmental Health and Safety (www.udel.edu/ehs/trainingrequirements.html).
- Storing in the lab a copy of the material safety data sheet (MSDS) for each chemical used.
- Preparing and handling dye solutions in a fume hood.
- Wearing a lab coat, safety glasses and gloves. The Department of Environmental Health and Safety can be contacted for assistance with glove selection.
- Installing spill pans under dye pumps and reservoirs.

- Knowing and following the correct disposal method for chemical wastes.
- Knowing the location of the closest eyewash and safety shower.
- Reporting chemical spills and personal chemical exposures immediately to the Department of Environmental Health and Safety.

Laser Optical Tables

Laser optical tables often weigh in excess of 3000 pounds and the legs of the table are often unattached to the table top. Forcibly pushing against the table may cause the table to topple resulting in considerable table and facility damage and possibly serious personal injuries as well. Lifting of the tabletop may result in the falling of heavy unsupported leg supports also potentially injuring individuals. When planning the relocation of laser optical tables, individuals should always first seek approval of the Laser Supervisor. Proper lifting and moving equipment should be used.

XVII. Laser Safety Assessments and Audits

Pre-Construction Assessment: Prior to construction or renovation of a laser facility containing Class 3B and/or Class 4 lasers, the Laser Supervisor should consult with the Laser Safety Officer to discuss the proposed laser operation and to determine the facility requirements necessary to comply with the UD laser safety program.

Pre-Operational Assessment: Prior to placing a new Class 3B or Class 4 laser into routine operation, the Laser Supervisor (or his/her qualified designee) shall inform the Laser Safety Officer and schedule a pre-operational laser safety assessment to determine whether all the requirements of the UD laser safety program have been met. The Laser Safety Officer shall promptly communicate to the Laser Supervisor, in writing, any changes that must be made to the laser facility or operation before routine laser activities can begin.

Safety Audits: Laser safety staff shall periodically conduct safety audits of each laser facility. The audit is designed to determine whether the facility is successfully meeting the requirements of the laser safety program as defined in the UD Laser Safety Manual. A report of the findings of the audit shall be provided to the Laser Supervisor, his/her departmental safety committee, and the UD Laser Safety Committee. The Laser Supervisor is expected to correct any deficiencies within the time frame noted in the audit report. Laser safety staff are committed to assisting laser personnel, when they request help, to achieve compliance. A copy of the Laser Safety Audit form can be found in Appendix G. The procedure for addressing deficiencies that are not corrected can be found in Appendix H.

XVIII. Imminent Laser Hazards

The Laser Safety Officer (LSO) is empowered by University executive administration to order the immediate termination of any laser-related activity that he/she believes to be a serious and imminent health and/or safety hazard. An example would be the presence of a Class 4 laser specular reflection through a window into a public area.

When the LSO terminates an operation, he/she shall attempt to immediately inform the Laser Supervisor in-person of the reason for termination. The LSO shall also inform the Laser Supervisor, in writing, within 24 hours.

The LSO shall promptly report the circumstances of the termination to members of the Laser Safety Committee (LSC) and within 5 working days the Committee shall meet to consider whether to uphold the LSO's decision to terminate the operation. The affected Laser Supervisor shall be invited to attend the meeting to provide information for the Committee's consideration. In lieu of attendance, the Laser Supervisor may provide information in writing.

The Laser Supervisor may resume the terminated laser operation once he/she is provided with written notice from the LSO that the condition of concern has been satisfactorily rectified. The LSO shall also provide members of the LSC with a copy of this notice.

The Laser Supervisor may also resume the terminated laser operation if he/she is not provided, in writing within 5 working days of termination, with a statement that the Laser Safety Committee has met and has upheld the LSO's decision to terminate the operation.

XIX. Servicing of Lasers

When on-site servicing or repair of lasers or laser systems is conducted by non-university personnel (e.g. laser manufacturer representative), such personnel are expected to perform their activities in compliance with the requirements of the American National Standard for Safe Use of Lasers (ANSI Z136.1). Depending on the type of service and the laser, this may include the establishment of a temporary laser-controlled area, the posting of a NOTICE warning sign (example below) and/or the erection of temporary barriers.

Laser operators shall immediately inform the Laser Supervisor or the Laser Safety Officer if they observe unsafe behavior by those serving or repairing lasers.

The Laser Supervisor or his/her qualified designee shall confirm that, after servicing, all engineering controls that may have been bypassed or disconnected (e.g. protective housing interlock) have been returned to normal operation.

XX. Transfer and Disposal of Lasers

The Laser Supervisor shall inform the Laser Safety Officer when a laser has been transferred to another UD Laser Supervisor or to an individual or entity off-campus.

When a Laser Supervisor terminates an affiliation with the University and lasers formerly under his/her supervision remain on campus, the departmental Chair or other pertinent authority shall promptly transfer control of those lasers to a Laser Supervisor who will take steps to prevent their unauthorized use until the lasers are permanently re-assigned or disposed.

Prior to the disposal of an unwanted laser, the Laser Supervisor shall ensure that the Laser Safety Officer has been informed. The LSO will help facilitate proper disposal of the laser.

Appendix A

[Hold for Future Use]

Appendix B

Laser Safety Committee Charter

Meetings:

The committee meets on a quarterly basis to conduct business. Additional meetings may be called at the discretion of the Chair or the Laser Safety Officer.

A quorum for meetings consists of a majority of the membership; the Laser Safety Officer and Chair must also be present. The Chair may designate one of the technical members to serve as Chair in his/her place when he/she is unable to attend a meeting.

Motions are carried when 50% or more of the attending membership vote for approval.

Membership:

Members of the committee are appointed by the Provost or his designee, typically the Vice Provost for Research. For the purposes of this charter, this individual will be referred to as the Executive Administrator.

The committee is composed of the Laser Safety Officer (who acts as Secretary), representatives of the administration, and technical members. The technical membership of the committee is comprised of faculty and professional staff from the various university departments that use lasers. Technical members shall have substantial hands-on experience in the use of lasers. Sixty-five percent or more of the membership shall be technical members.

The Laser Safety Officer (LSO) is that staff member of the Department of Environmental Health and Safety appointed by the Executive Administrator to act as LSO. Representatives of the administration include the Vice Provost for Research (or his/her designee) and any others appointed by the Executive Administrator.

A technical member acts as the Committee Chair. The Chair is elected by the members of the committee.

Committee Responsibilities:

With executive administration and the Laser Safety Officer, assume the responsibility for developing and maintaining an effective university program to protect laser operators and others from hazards associated with lasers operations.

Establish policies for the management of the laser safety program. Establish requirements for safe laser use based upon the ANSI standard. Revise the policies and requirements as necessary.

Keep laser operators, departmental Chairpersons, and other appropriate academic and administrative officers advised of changes in rules and recommendations of various governmental and professional agencies concerned with laser safety.

Arrange for and/or conduct a periodic management audit of the Laser Safety Program whose purpose is to review the overall effectiveness of the program. An audit report shall be presented to the Executive Administrator.

Meet at least on a quarterly basis to conduct business that includes the activities listed below. Maintain minutes of its meetings and communicate its activities to the Executive Administrator.

- Review the LSO's summary of laser registrations and standard operating procedures (SOPs) submitted to him/her for approval.
- Review the results of safety audits conducted by the LSO and other safety staff members.

- Review the findings of the LSO's investigation of laser accidents.

Communicate to Departmental Chairs, College Deans, and other administrative officers, as necessary, when lasers continue to be used in a non-compliant manner after Laser Supervisors have been advised of laser safety deficiencies.

Meet within 5 days of the date that the LSO has terminated a laser operation that he/she considered to be a serious and imminent health and/or safety hazard and either uphold or reverse the LSO's decision.

Other responsibilities as defined in the Laser Safety Manual.

Reviewed and approved by the Laser Safety Committee:

Dr. Murray Johnston, Chair — Date: 1-28-2010

Reviewed and approved by the Executive Administrator:

Dr. Mark Barteau — Date: 2/16/10

Appendix C

Laser Registration Form (also found at http://www.udel.edu/ehs/formindex.html)

UNIVERSITY OF DELAWARE

LASER REGISTRATION FORM

Instructions: All Class 3b and 4 lasers are required to be registered with the University of Delaware Laser Safety Committee. Complete this form for each laser to be registered and forward to

Laser Safety Officer, Environmental Health and Safety fax: 831-1528

Principal Investigator: _____ Phone: _____

Laser Manufacturer: _____

Model Name/Number: _____

Serial Number: _____

UD Property Tag Number: _____

Laser Location: _____
Building Department Room Number

Laser Type (Nd:YAG, HeNe, etc): _____

Classification (3b or 4): _____

Wavelength(s) (nm): _____

Beam Diameter at laser output (mm): _____

Beam Divergence (mrad): _____

☐ Continuous Wave: Average Power (Watts): _____

or

☐ Repetitively Pulsed: Energy (Joules per pulse): _____
Pulse duration (s): _____
Pulse repetition frequency (Hz): _____

or

☐ Single Pulse Pulse duration (s): _____
Energy (Joules per pulse): _____

Purpose or Use: _____

Comments:

_____ _____
Principal Investigator's Signature Date

Appendix D

Laser Standard Operating Procedure (SOP) Template

[still to be developed]

Appendix E

References and Additional Sources of Laser Safety Information

[still to be developed]

Appendix F

Ordering Information for Deadbolt Lock and Emergency Key Box

[still to be developed]

Appendix G

Laser Safety Audit Form

University of Delaware
Environmental Health & Safety
Laser Safety Audit

Date	
Department	
Laser Location(s)	
Laser Supervisor	
Lab Laser Contact (if not PI)	
DEHS Auditor	William Fendt, Laser Safety Officer (LSO) wfendt@udel.edu

	Y	N	Comment
Are laser warning signs properly posted?			
Is access to the laser-controlled area restricted to authorized persons?			
Have all laser operators attended laser safety training?			
Are all Class 3B and Class 4 lasers registered by the PI with the Laser Safety Committee?			
Has a written operating procedure for each laser been developed and is it accessible to all operators?			
Were lasers labeled with required warning signs and labels?			
Is a copy of the Laser Safety Manual present and accessible to operators?			
When lasers are in use, is the laser operator always physical present to control laser operation? If no, how is unauthorized access prevented?			
Are beam blocks, barriers, curtains, and/or enclosures in place to prevent laser exposures outside the immediate experimental area?			
Is appropriate laser safety eyewear present, in good condition, and worn at appropriate times?			
Was the facility free of any laser-related, non-beam hazardous conditions?			

NOTES:

Appendix H

Procedure for Addressing Laser Program Deficiencies

The procedure below outlines the steps that will be followed when deficiencies are identified. The Laser Safety Officer (LSO) and his/her designees within the Department of Environmental Health and Safety (DEHS) will assist Laser Supervisors in the identification of deficiencies and lend assistance to Supervisors, if requested, to resolve them.

[The procedure below does not apply if the Laser Safety Officer believes that an identified deficiency represents a serious and imminent health or safety hazard. In this situation the procedure specified in the chapter entitled **Imminent Laser Hazards** shall be followed.]

A. Deficiencies identified by Laser Operators or others present in a laser facility shall be promptly corrected. In some cases it may be necessary for those individuals to seek the guidance and assistance of the Laser Supervisor when correcting the deficiency. The LSO shall assist those requesting help with resolving a self-identified deficiency.

B. If a deficiency is identified during a Laser Safety Audit by the LSO or a DEHS auditor, it will be noted on the Laser Safety Audit Report. A copy of the report shall be provided to the Laser Supervisor and his/her departmental safety committee. The Laser Supervisor is expected to correct the deficiency within the time frame noted in the audit report. DEHS staff are committed to assisting the Laser Supervisor correct the deficiency, when help is requested. A follow-up audit shall be conducted by the LSO or a DEHS auditor after the time period for the correction of the deficiency has passed.

C. If the follow-up audit identifies that the deficiency has been corrected, this finding shall be noted on a Laser Safety Audit Report, a copy of which shall be provided to the Laser Supervisor and his/her departmental safety committee. If the follow-up audit identifies that the deficiency has not been corrected, this finding shall be noted on a Laser Safety Audit Report and a new time frame for correction of the deficiency shall be noted. A copy of the report, along with a letter from the Laser Safety Committee encouraging the Laser Supervisor to correct the deficiency, shall be sent to the Laser Supervisor, his/her departmental safety committee, and his/her departmental Chair/Director. In some cases the college Dean may also be notified. A second follow-up audit shall be conducted by the LSO or a DEHS auditor after the time period for the correction of the deficiency has passed.

D. If the second follow-up audit identifies that the deficiency has been corrected, this finding shall be noted on a Laser Safety Audit Report, a copy of which shall be provided to each individual that received a copy of the previous audit report. If the follow-up audit identifies that the deficiency has still not been corrected, the Laser Safety Officer and/or Laser Safety Committee shall contact the Senior Vice Provost for Research and Strategic Initiatives (or other senior member of administration) to determine the best course of action to correct the deficiency which could include suspension of the Laser Supervisor's authorization to use lasers.

E. Throughout the entire process outlined above, the Laser Safety Officer shall make all reasonable attempts to resolve deficiencies in a cooperative manner with the Laser Supervisor.