Laser Safety Manual

The University of Texas at Austin
304 E 24th St., Ste. 202
Austin, TX. 78712

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1.0 Purpose

The procedures and policies set forth herein are intended to provide for the control of lasers to ensure the safety and preservation of employees, the general public, and the environment. Furthermore, this document establishes the means for demonstrating compliance to Texas Administrative Code (TAC) 25 §289.301 and ANSI Z136.1.

2.0 Scope

The requirements listed herein are applicable to all personnel who possess, or work with Class 3B and/or 4 Lasers or Laser Systems at The University of Texas at Austin. All employees involved with the purchasing, receiving, handling, use, storage, and disposal of lasers shall comply with the procedures in this manual. Standards for laser and laser system classification can be found in Appendix A: Laser Classification.

The Laser Safety Officer (LSO) is the person designated to implement the laser safety program and maintenance of the license and associated records, and is the primary contact with the Texas Department of Health in administering the respective licenses & registrations. The LSO has been delegated the authority to set laser safety policy, suspend activities deemed unsafe, and require and direct remedial action where necessary.

3.0 Related Documents

3.1 EHS-LAS-F-001 – Laser SOP Template
3.2 EHS-LAS-F-002 – Laser Inspection Form
3.3 EHS-LAS-F-003 – Laser Registration Form
3.4 ANSI Z136.1 – Safe Use of Lasers
3.5 ANSI Table C1: Typical Laser Classification - Continuous Wave Lasers
3.6 ANSI Table C2: Typical Laser Classification - Single Pulse Lasers
3.7 ANSI Table 5: MPE for Ocular Exposure to a Laser Beam
3.8 ANSI Table 6: Parameters and Correction Factors
3.9 ANSI Table 7: Maximum Permissible Exposure for Skin Exposure to a Laser Beam
3.10 Texas Administrative Code (TAC) 25 TAC §289.301

4.0 Roles & Responsibilities

4.1 Principal Investigator (P.I.) or Permittee - The P.I. is responsible for:

4.1.1 Registering all Class 3B and 4 lasers with the University by completing EHS-LAS-F-003 – Laser Registration Form and submitting to the Laser Safety Office. No work may be performed until authorization is received. Any proposed changes in the original authorization must be submitted in writing to the Laser Safety Office for approval.

4.1.2 Documenting a written Standard Operating Procedure for all active Class 3B and

4 lasers. The SOP should be documented EHS-LAS-F-001 – Laser SOP Template. SOPs are to be attached to the laser unit listing within the UT HERD system.

4.1.3 Instructing all students or employees in the lab specific operation and safe practices for the laser system.

4.1.4 Maintaining an accurate inventory of Class 3B and 4 lasers within UT HERD.

4.1.5 Reporting any transfers of ownership of Class 3B and 4 lasers to the Laser Safety Office by completing EHS-LAS-F-004 – Laser Transfer Form.

4.1.6 Ensuring all current lab members are attached to the laser permit within UT HERD, and that all personnel with unescorted access to a Class 3B or 4 laser have completed the OH-304 training.

4.1.7 Using UT Direct for the purchase of lasers or laser systems.

4.1.8 Assuring that all lasers for disposal are properly reported to the Laser Safety Office prior to disposing of the unit.

4.1.9 Assuring that lasers or laser systems are secured from unauthorized access and use.

4.1.10 Providing laser energy measuring equipment capable of determining the power and irradiance of the laser or laser system in use.

4.1.11 Providing laser protective eyewear to laser users.

4.2 Laser Worker (End User) – The Laser Worker or End User is responsible for:

4.2.1 Following laboratory administrative, alignment, safety, and standard operating procedures while operating the laser.

4.2.2 Keeping the Laser Safety Supervisor fully informed of any departure or deviation from established safety procedures.

4.2.3 Attending such training and medical surveillance activities as are required.

4.2.4 Ensuring that all personnel within the NHZ adhere to safety policies and procedures including wearing the appropriate PPE when lasers are in use.

4.2.5 Ensuring that entrances to laser use areas remain closed and access only granted to authorized personnel.

4.2.6 Ensuring that engineering controls are in operating condition and that they are used as prescribed such as beam blocks, audible and visual alarms, security access doors.

4.2.7 Ensuring that the key or coded access to Class 3B or 4 lasers remains secured from unauthorized use and or access.

4.3 Laser Safety Officer (LSO) - The Laser Safety Officer is responsible for:

4.3.1 Reviewing all proposals for use of lasers and laser systems.

4.3.2 Preparing license applications, amendment applications, and required reports as well as acting as the contact point for all correspondence with State and Federal Radiation Health Agencies.

4.3.3 Prescribing special conditions and requirements as may be necessary for safe and proper use of all laser systems.

4.3.4 Preparing and disseminating information on Laser Safety for the use of and guidance of staff and students.

4.3.5 Monitoring laser use activities for the purpose of assessing compliance with laser safety guidelines and requirements.

4.3.6 Investigating unusual laser exposures, incidents, and accidents and reporting corrective action to the appropriate party.

4.3.7 Review and advise in the design of all new facilities using lasers or constructed for the purpose of providing protection against laser exposure.

4.3.8 Completing a laser hazard analysis for all Class 3B and 4 lasers.

4.3.9 Provide laser warning signage as prescribed in ANSI Z136.1.

4.4 Laser Safety Committee (LSC) - The LSC is responsible for:

4.4.1 Assisting the Laser Safety Officer in providing oversight to all uses of laser radiation that poses a hazard because of its ionizing, photochemical, or thermal action as well as the possession, handling and storage of lasers and laser systems.

4.4.2 Recommending policies, procedures and practices it considers advisable for safely working with laser systems to the University Safety and Security Council and to the President.

4.4.3 Updating, as necessary, of this approved relevant safety material.

4.4.4 Recommending qualified persons individually for inclusion in the University's license to use lasers and laser systems.

4.4.5 Respond to any safety issues involving the use of lasers which may be communicated to the Committee by the University Safety and Security Council or by academic or administrative authorities.

4.4.6 Perform all functions required of an RSC by statutes and regulations. Should the RSC duties under applicable statutes and regulations conflict with any RSC duties outlined in this Policy Memorandum, then such statutes and regulations will control.

4.4.7 Meeting annually to provide oversight of, and advice to, the LSO.

5.0 Standards & Procedures

5.1 Administrative

5.1.1 Procurement

5.1.1.A All applications for possession and use of Class 3B or 4 lasers or laser systems shall be completed and submitted to the LSO prior to obtaining the laser or laser system.

5.1.1.B Applications for possession and use of radioactive material shall be made on form EHS-LAS-F-003 - Laser Registration Form.

5.1.1.C Changes in equipment, facilities, or procedures shall be submitted to the LSO for approval prior to implementation.

5.1.1.D All applications for lasers or laser systems are subject to approval by the LSO.

5.1.1.E Applications for possession and use of laser or laser systems shall contain the following information:

1. The name and position of the applying Permittee, including department and contact information.
2. The name and position of the Laboratory Laser Safety Supervisor (LSS) if different from the Permittee.
3. The location of the laser, with room number or lab and a drawing if required.
4. The manufacturer of the laser. (If the laser is manufactured by University personnel, state as such).
5. The model and serial number of the laser.
6. The general type of laser (Dye, gas, solid state, semiconductor, etc.).
7. The specific type of laser active material.
8. The operating wavelength(s) or wavelength range (nm) of the laser.
9. The excitation mechanism (optical, electrical, chemical, etc.).
10. The time dependent operating properties of the laser (CW, pulse, repetitively pulsed, mode-locked, etc.).
11. The maximum capable energy level of the laser in Joules. This shall include any modifications which have been made to the equipment since its original manufacture or assembly.
12. If the laser is a pulsed laser:
13. The minimum pulse duration if the laser is a pulsed laser.

14. The maximum pulse frequency per second.
15. The maximum capable energy of the laser in Joules.
16. The beam diameter at the exit from the laser.
17. The beam divergence, if known.
18. The designated controlled area for laser operation (add sketch if useful)
19. The method of safety compliance expected (interlocks, enclosure, etc.)
20. Other information including a brief description of the purpose of the laser (Doppler measurements, fluorescence, etc.), frequency of use, expected primary users, etc. Include any information which may have a bearing on safety related issues

5.1.2 Transfer

5.1.2.A All transfers of possession of Class 3B or 4 lasers or laser systems shall be submitted to and approved by the Laser Safety Office prior to transferring ownership of the laser or laser system.

5.1.2.B Applications for transfer of Class 3B and 4 lasers shall be made on the form EHS-LAS-F-004 - Laser Transfer Form.

5.1.2.C No Class 3B or 4 laser or laser system shall be transferred to another party prior to obtaining a copy of the laser registration for Class 3B and 4 lasers and laser systems.

5.1.2.D Transfer of personally owned Class 3B and 4 lasers to a University owned space is prohibited without prior approval from the Laser Safety Office.

5.1.3 Disposal

5.1.3.A All disposals of Class 3B and 4 lasers or laser systems shall be submitted to and approved by the Laser Safety Office prior to relinquishing ownership of the system.

5.1.3.B All Class 3B and 4 lasers or laser systems shall be rendered inoperable prior to disposing of the system.

5.1.3.C After obtaining approval for disposal, the lab shall contact the University's surplus office for pickup of the system.

5.1.3.D Ownership of the Class 3B or 4 laser or laser system shall remain with the current PI until a final disposition of the system can be demonstrated.

5.2 General Laser Laboratory Requirements

5.2.1 All laser beams shall be terminated at the end of its useful path.

5.2.2 Beam paths shall be located at a point other than eye level when standing or sitting at all times.
5.2.3 Lasers and laser systems shall be oriented so that the beam is not directed toward entry points to the Controlled Area or toward aisles or hallways.
5.2.4 Jewelry or other reflective objects shall not be worn when operating a laser or laser system.
5.2.5 Specular reflections shall be minimized to the best extent possible.
5.2.6 Lasers and laser systems shall be securely mounted on the table or platform in which they are used prior to operation.
5.2.7 Beam paths shall be clearly identified to ensure the path does not cross populated, study, desk, or traffic areas.
5.2.8 The beam path shall be cleared of all unused objects and reflective materials prior to operating the laser.
5.2.9 For lasers with cooling systems, condensation shall be removed prior to operating the laser or laser system to prevent specular reflections.
5.2.10 The appropriate eye protection shall be worn at all times when the laser is in operation, including beam alignment and beam shape observation.
5.2.11 Persons in the controlled area shall wear appropriate clothing, gloves, and/or shields to prevent exposure of the skin to levels exceeding the skin MPE.
5.2.12 Each laboratory shall designate a Laser Safety Supervisor (LSS) and identify to the LSO.
5.2.13 The LSS shall be a faculty or staff member that assumes control of the affected area and has the authority to implement corrective actions up to and including the shutdown of laser operations when necessary due to unsafe conditions.

5.3 Class 3B & 4 Laser Laboratory Requirements

5.3.1 Each Class 3B and 4 laser shall only be operated in a Laser Controlled Area (LCA). An LCA shall be established by the Permittee to limit access of personnel to laser radiation. Each LCA shall be posted conspicuously with signs as specified in 25 TAC 289.301(v). Access to the LCA shall be controlled by a door, blocking barrier, screen, or curtain, which attenuates the laser radiation to below the MPE, and individuals who enter the Controlled area shall not experience radiation above the MPE immediately upon entry.
5.3.2 Each Class 3B and 4 LCA shall be secured from unauthorized entry while the laser is in use.
5.3.3 Each Class 3B and 4 laser shall be secured from unauthorized access at all times, including when not in use.
5.3.4 Each Class 3B and 4 laser shall have an interlock on any safety housing that ensures that laser radiation is not accessible above Maximum Permissible Exposure limits, and which is removable without the use of tools.
5.3.5 Safety interlocks shall be provided for any portion of the protective housing that by design can be removed or displaced without the use of tools during normal operation or maintenance, and thereby allows access to radiation above MPE limits.

5.3.6 Adjustment during operation, service, testing, or maintenance of a laser containing interlocks shall not cause the interlocks to become inoperative except where a laser is in a Laser Controlled Area. For pulsed lasers, interlocks shall be designed so as to prevent firing of the laser; for example, by dumping the stored energy into a dummy load and for CW lasers, the interlocks shall turn off the power supply or interrupt the beam (i.e., by means of shutters).

5.3.7 Each Class 3B and 4 laser shall be provided with a key switch or coded access (i.e. computer password). Requests for exceptions to this requirement shall be provided in writing and considered by the LSO on a case-by-case basis

5.3.8 Each person who operates or works with a Class 3B or 4 lasers shall complete OH-304 Laser Safety Training provided by the University as well as lab specific training pertaining to the operation of the particular lasers in use. No person may work unescorted in an NHZ prior to completing this laser safety training.

5.3.9 Each Class 3B or 4 laser shall provide visual or audible indication during the emission of accessible laser radiation (i.e. flashing 'Laser In Use' signage). The indication shall occur prior to emission of radiation with sufficient time to allow appropriate action to avoid exposure. Any visual indication shall be visible through protective eyewear for the wavelength of the laser. Exemptions from this requirement shall be approved by the LSO.

5.3.10 The regulations recognize that in situations where an engineering control may be inappropriate the University LSO shall specify alternate controls to obtain equivalent laser safety protection. Alternate controls shall be submitted in writing to the LSO and, if accepted, will be documented in the SOP.

5.4 Eyewear

5.4.1 Each Permittee shall provide protective eyewear that meets the requirements of 25 TAC 289.301(t)(1) and ANSI Z136.1.

5.4.2 The eyewear shall be located where persons who operate the laser have unrestricted access to the eyewear.

5.4.3 The eyewear shall be worn for alignment and general operation where the laser beam is not enclosed.

5.4.4 No person shall operate a Class 3B or 4 lasers without protective eyewear specific for the laser and the appropriate training for the specific eyewear.

5.4.5 Protective eyewear shall meet the following requirements:

5.4.5.A Provide a comfortable and appropriate fit all around the area of the eye

5.4.5.B Be in proper condition to ensure the optical filter(s) and holder provide the optical density or greater at the specific wavelength of the laser, and retain all protective properties during its use

5.4.5.C Be of optical density adequate for the laser energy involved

5.4.5.D Have the optical density or densities and associated wavelengths permanently and prominently labeled on the filters or eyewear

5.4.5.E Be examined at intervals not to exceed 12 months, to ensure the reliability of the protective filters and integrity of the holders. Unreliable eyewear shall be discarded and replaced immediately.

5.4.5.F The Optical Density of the protective eyewear shall be appropriate for the specific frequency and pulse length of the laser beam, and shall provide reduction of the incident energy to less than the MPE of the laser.

5.5 Caution Signs, Labels, and Postings

5.5.1 The laser controlled area shall be conspicuously posted with a sign or signs as specified TAC 289.301(dd)(2) and ANSI Z136.1.

5.5.2 Labeling lasers and posting laser facilities. All signs and labels associated with Class 2, 3a, 3b, and 4 lasers shall contain the following wording.

5.5.2.A The signal word “Caution” shall be used with all signs and labels associated with Class 2 and 2M lasers and laser systems that do not exceed the applicable MPE for irradiance.

5.5.2.B The signal word "Warning” shall be used on laser area warning signs associated with lasers and laser systems whose output exceeds the applicable MPE for irradiance, including all Class 3B and most Class 4 laser and laser systems.

5.5.2.C The signal word “Danger” indicates that death or serious injury will occur if necessary control measures are not implemented to mitigate the hazards in the laser controlled area. This signal word shall be restricted to those Class 4 lasers with high (e.g. multi-kilowatt) output power or pulse energies with exposed beams.

5.5.2.C The sign shall contain the wording described below or similar wording, as applicable:

- for all Class 2 lasers, the words "LASER RADIATION – DO NOT STARE INTO BEAM";
- for Class 3R lasers that do not exceed the appropriate MPE, as designated in ANSI Z136.1-2000, Safe Use of Lasers, the words "LASER RADIATION – DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS";
- for all other Class 3R lasers, the words "LASER RADIATION - AVOID DIRECT EYE EXPOSURE";
- for all Class 3B lasers, the words "LASER RADIATION -

AVOID DIRECT EYE EXPOSURE"; or

- for Class 4 lasers, the words "LASER RADIATION – AVOID EYE or SKIN EXPOSURE to DIRECT or SCATTERED RADIATION".

5.5.2.D Adequate space shall be provided to allow for the inclusion of pertinent information such as:

- Laser Eye Protection Required
- Invisible Laser Radiation
- Knock Before Entering
- Do Not Enter When Light is Illuminated
- Restricted Area, Authorized Personnel Only

The signs shall contain the following information, as applicable from subsections (dd)(1) and (2) of TAC 289.301

- The type of laser or the emitted wavelength, pulse duration (if appropriate), or maximum output.
- The class of laser and the optical density of required eyewear.

5.5.3 Lasers, except lasers used in the practice of medicine, shall have:

5.5.3.A The word "invisible" shall immediately precede the word "radiation" on labels and signs required by this subparagraph for wavelengths of laser and collateral radiation that are outside of the range of 400 to 700 nm.

5.5.3.B The words "visible and invisible" shall immediately precede the word "radiation" on labels and signs required by this subparagraph for wavelengths of laser and collateral radiation that are both within and outside the range of 400 to 700 nm.

5.6 Standard Operating Procedures

5.6.1 Each Class 3B and 4 laser shall have a Standard Operating Procedure (SOP) written for its operation. An SOP in this use is the same as a laboratory/laser/research specific protocol that specifies safe use and procedures for the laser system.

5.6.2 The SOP is to be documented on EHS-LAS-F-001 Laser SOP Template and attached to the equipment listing in UT HERD for approval by the LSO.

5.6.3 If alignments are performed by the lab, the SOP shall include instructions for the lab specific alignment protocol.

5.6.4 The SOP shall include at a minimum, operating instructions, safety eyewear parameters and instructions for proper use, interlock instructions, and checklist for

operation.

5.6.5 The SOP shall include clear warnings to avoid possible exposure to laser radiation in excess of the MPE.

5.6.6 The SOP shall be present or readily available at the operating console or control panel of the laser.

5.6.7 The SOP shall be updated and resubmitted for approval if any changes arise that require deviation from the original approved procedure.

5.7 Nominal Hazard Zone

5.7.1 For all open beam Class 3B and 4 lasers the MPE will be assumed to be exceeded and appropriate precautions taken. The NHZ (nominal hazard zone) will therefore comprise the enclosure (room or area the beam is restricted to by virtue of walls, curtains or other barriers) in which the laser(s) is operating.

5.7.2 The LSS may call for specific conditions in determining the NHZ by using information supplied by the laser manufacturer, by measurement, or by using the appropriate laser range equation or other equivalent assessment. Permittees shall not allow persons to be exposed to levels of laser radiation exceeding the MPE.

5.7.3 Each laser shall, as part of the NHZ and MPE determination, have an evaluation made of non-radiation hazards which may be present as part of the laser's construction or operation.

5.7.4 This evaluation shall include electrocution, chemical, cutting edge, compressed gases, noise, confined spaces, fire, explosives, ventilation, and physical safety hazards.

5.7.5 The evaluation shall be placed with the laser's documentation and be available for review.

5.8 Inspections & Surveys

5.8.1 Each laboratory containing Class 3B or 4 lasers shall be surveyed (inspected) at intervals not to exceed 12 months.

5.8.2 The survey shall include a determination that all warning devices are functioning within their design specifications.

5.8.3 The survey shall include a determination that the controlled area is properly controlled and posted with accurate warning signs.

5.8.4 The survey shall include an evaluation of potential hazards from surfaces that may be associated with beam paths.

5.8.5 Additional surveys may be required to evaluate the primary and collateral radiation hazard incident to the use of lasers

5.8.6 Survey records shall be retained for inspection by the Laser Safety Officer.

5.8.7 The survey, inspection, or evaluation is to be documented within UT Herd.

5.8.8 Corrective actions shall be implemented within a timely manner respective to the

risk they pose to personnel or the operation.

- High Severity: Shall be corrected and implement immediately before any further work is done. This would include findings such as open beam without proper eyewear, open beams in public occupied areas, unsecured operating room.
- Medium Severity: Shall be corrected and implemented within 7 days. This would include findings such as deficient training, out of date laser inventory, no Standard Operating Procedure.
- Low Severity: Shall be corrected and implemented within 30 days. This would include findings that do not pose an immediate threat to personnel or the operation.

5.8.9 Corrective Action or Information Requests made by EHS for laser safety require a timely response from the Principal Investigator and/or Lab contact who is the owner of the laser and the lab in which it is used. A written procedure is needed to address instances where responsible parties are unresponsive to requests for information or corrective actions. Collaboration between EHS and researchers is the preferred compliance model, and is mutually beneficial. For the rare times that this model does not work, the following process will be initiated:

1. Initial Request for information or action. An email message will be sent to the PI and Lab contact, requesting specific information or action as part of implementing laser safety.
2. If no response within 5 business days, a 2nd email can be sent.
3. If no response to both emails within 2 business days, a telephone call may made to the PI or Lab Contact.
4. If no positive response is shown from the emails and phone calls, a lab visit is performed.
5. If the lab visit reveals deficiencies related to the previous requests, an email is sent to the PI's Dept. Chair and Assoc. Dean regarding the request.

5.9 Infrared & UV Laser Systems

5.9.1 All lasers operating in invisible wavelengths shall have appropriate means of viewing both the beam and stray reflections.

5.9.2 End users shall check for reflections following alignment of an optic, and prior to releasing the beam for end use.

5.9.2 End users shall NOT lift or peak around eyewear to view any portion of the beam that may be in the visible spectrum.

5.9.3 An infrared laser beam shall be terminated in a fire-resistant material so that the laser beam is not inappropriately reflected.

5.9.3 Inspection of the terminating material shall occur at regular intervals no less than

monthly, and the inspection should be recorded.

5.10 Pulsed Laser Systems

5.10.1 All pulsed lasers shall have a documented hazard analysis showing the respective MPE, NOHD, NHZ, and eyewear OD to account for risks introduced by shortening the time domain of the pulse (i.e. mJ and μJ pulses can still be very hazardous and require significant eyewear OD).

5.10.2 All pulsed lasers shall have a documented hazard analysis that accounts for gain generated in any amplifier, or through compression.

5.10.3 End Users shall reduce power when interacting directly with the beam (i.e. alignment, sample placement).

5.10.4 Alignment of pulsed lasers should be conducted between pulses by blocking the beam while the adjustment is made.

5.11 Fiber Optic Cables

5.11.1 Optical cables used for transmission of laser radiation shall be considered part of the laser protective housing.

5.11.2 Disconnection of a fiber optic connector which results in access to radiation in excess of the MPE shall take place in a controlled area.

5.11.3 All connectors shall bear appropriate labels.

5.11.4 Optical cables shall be encased in an opaque sleeve to prevent leakage of laser radiation in case of breakage.

5.11.5 If the fiber is designed to emit light through the walls of the fiber, the LSS shall notify the LSO and include justification for lack of opaque cover in the SOP.

5.12 Magnification of Laser Beam

5.12.1 If at any time a laser beam is optically magnified or concentrated, special precautions shall be taken by the Permittee to prevent specular or diffuse reflection or other exposure greater than the MPE for the laser.

5.12.2 Lens information such as diameter and focal length shall be made available by the lab to EHS for inclusion in the hazard analysis.

5.12.2 Any special precautions shall be documented in the SOP for the laser.

5.13 Multiple Wavelengths

5.13.1 Personnel within the NHZ shall be provided adequate eyewear to reduce the ocular exposure below the MPE for all wavelengths present.

5.13.2 If adequate laser eyewear is not available to reduce ocular exposure to below the

MPE for all wavelengths, then an enclosure is required.

5.13.3 Eyewear shall be stored and labeled in a manner that readily identifies which eyewear applies to the laser or wavelength in use.

6.0 Ancillary Hazards

6.1 Chemical

Fumes produced when laser radiation vaporizes or burns a target material, whether metallic, organic, or biological may be hazardous. Adequate ventilation must be provided. Many dyes and solvents used with lasers are toxic; some may be carcinogenic. Potential exposures to dyes and solvents are most likely to occur during preparation. Failure of the dye laser's pressure system can also expose personnel, and can cause fires.

- During solution preparation, dye and solvent mixing should be done inside a chemistry fume hood.
- Gloves, lab coats, and eye protection should be worn. Avoid skin contact.
- During dye laser disassembly, use proper personal protective equipment and be alert to contaminated parts, e.g., dye filters. Be sure to cap off dye solution lines.
- Don't smoke, eat, or drink in chemical use areas.
- Dye pumps and tubing/pipe connections should be designed to minimize leakage. Pumps and reservoirs (notorious for leaking) should be set inside spill pans. Tubing/pipes systems should be pressure-tested prior to using dye solutions and periodically thereafter. Dye solutions can be corrosive. Stainless steel heat exchangers are recommended.
- For waste disposal and spills, emphasis should be placed upon solvent characteristics since dye concentrations are low.
- Keep all containers of solvent, solutions, and dyes tightly closed, clearly labeled, and stored in a cool, dry place. Keep oxidizers away.

6.2 Fire

The beam path and operating area of the laser must be kept free of flammable materials. Class 4 lasers have the potential for igniting combustible materials. Keep a fire extinguisher of the proper class readily accessible in the area. Solvents, cleaning agents, and other flammable chemicals shall be stored in their appropriate flammable cabinet while lasers are in operation.

6.3 Electrical

Most laser systems involve high potential, high current electrical supplies. The most serious accidents with lasers have been electrocutions. There have been several fatalities related to lasers nationwide. Make sure electrical systems are off and locked out and that high-energy capacitors are fully discharged prior to working on a system. The system

should be shorted during repair or maintenance procedures to prevent accidental charging and discharge. The discharge of large capacitors requires proper equipment and procedures because significant levels of stored energy can be released as heat or mechanical energy.

- Class 3B and 4 lasers should have a separate circuit and local disconnect switch for the circuit.
- Label and post electrical hazards. Clearly identify the main switches to cut-off power. Before working on the laser, de-energize the machine. Positively disconnect it. If there is more than one source of power, disconnect them all. Lock out and tag the disconnect switches so that power is not reconnected while you are working on the laser.
- It is good practice to have at least two persons in an area while working on high energy power systems.
- Keep cooling water connections away from main power and high voltage outlets and contacts. Use double hose clamps on cooling water hoses. Inspect cooling water hoses and connections, and power cables and connectors periodically as part of a regular equipment inspection.
- In labs where laser power supplies are opened or serviced by lab personnel, staff should be trained in cardiopulmonary resuscitation.

6.4 Compressed Gases

Compressed gases present significant hazards if proper handling, use, and storage precautions are not followed. Some gases may also require special ventilation. Gas cylinders must be properly secured to prevent falling. Such tanks can become high velocity projectiles and can cause significant property damage and injuries.

6.5 Cryogenic Materials

Wear appropriate protective clothing and face shields when handling liquid nitrogen (LN2) or other cryogenic materials. Exposure to the liquid or the cold gas can cause severe frostbite. Liquid nitrogen can condense oxygen from the air and cause enhanced fire or explosion hazards. LN2 and inert gases can displace air in a room or confined area and cause asphyxiation. Good ventilation is required in areas where these gases and cryogenic liquids are used.

6.6 X-ray Radiation

Some of the high voltage systems with potentials greater than 15 kV may generate x-rays at significant dose rates. Plasma systems and ion sources operated at high voltages should also be checked for x-rays. High power electron pump excimer lasers can generate significant x-ray levels. These devices need to be checked by Radiation Safety upon installation to ensure adequate shielding is included. Free electron lasers are driven by powerful devices which are regulated radiation-producing machines. All users of these devices are required to have training addressing the ionizing radiation hazards and the

protection systems and procedures associated with these devices.

6.7 Plasma

Materials can be made incandescent when exposed to laser radiations. These incandescent spots are very bright and cause serious photochemical injuries to the eyes. The laser protective eyewear may not protect against such exposures. View such spots through suitable filters; use video cameras, etc., as may be appropriate.

7.0 Training

7.1 Personnel at The University of Texas at Austin who will be using Class 3B or 4 lasers or laser systems will be required to pass OH-304 - Laser Safety Training within the UT Learn system.

7.2 Personnel shall also attend a laboratory specific training provided by the owner for the specific laser in use. This training is to be documented within the SOP (EHS-LAS-F-001) for the specific laser.

8.0 Records

8.1 Records of Surveys, Training, NHZ and MPE calculations, and other Laboratory specific information shall be maintained in the laboratory, and shall be available for inspection/review by the LSO at any time.

8.2 Records shall be maintained for a period of not less than 5 years after the record date while the laser is in operation and for a period of 7 years after the laser is no longer in operation.

9.0 Emergency Response & Incident Reporting

9.1 Each Permittee shall immediately seek appropriate medical attention for an injured individual and notify the LSO by telephone within 24 hours of any exposure injury involving a laser possessed by The University.

9.2 The LSO shall be notified within 48 hours of any noninjury incident which involves potential exposure to laser radiation exceeding the MPE.

9.3 A written summary of an injury or noninjury incident shall be forwarded to the LSO not later than one week following the incident.

9.4 Records of the incident shall be maintained by the Laser Safety Officer.

9.5 A medical eye exam may be required immediately following a suspected hazardous exposure under the guidance of a medical professional.

Glossary

- **Absorption -** Radiation imparts some or all of its energy to any material through which it passes
- **Accessible Radiation -** Laser radiation that can expose human eye or skin in normal usage
- **Aperture** - The opening through which laser radiation can pass
- **Attenuation** - The decrease in radiant flux as it passes through an absorbing or scattering medium
- **Aversion Response** - Action, such as closing of the eye or movement of the head, to avoid exposure to laser light.
- **Beam** - A collection of rays which may be parallel, divergent, or convergent.
- **Beam Diameter** - The distance between diametrically opposed points in that cross section of a beam where the power per unit area is 1/e times that of the peak power per unit area
- **Beam Divergence** - The full angle of the beam spread between diametrically opposed 1/e irradiance points; usually measured in milliradians (1 milliradian = 3.4 minutes of arc)
- **Continuous Wave** - The output of a laser, operated in a continuous rather than pulsed mode.
- **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.
- **Cornea** - The transparent outer coat of the human eye which covers the iris and the crystalline lens. The cornea is the main refracting element of the eye.
- **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** - A laser enclosed in a laser system, having an assigned class number higher than the inherent capability of the laser system. The laser system's lower classification is appropriate because of the engineering features that limit accessible emission.
- **Enclosed laser** - A laser contained in a protective housing. Opening or removing the protective housing provides additional access to laser radiation above the applicable MPE. (An embedded laser is a type of enclosed laser.)
- **Energy (Q)** - The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers and is generally expressed in Joules (J).
- **Erythema -** The medical term for redness of the skin due to congestion of the capillaries.
- **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 to 1 mm.
- **Inoperable** – A laser or laser system that has been rendered incapable of producing laser light. For example, separation of the lasing medium from the power source or severing the power cable.
- **Intrabeam viewing** - The viewing condition whereby the eye is exposed to all or part of a laser beam
- **Iris -** The circular pigmented membrane that lies behind the cornea of the human eye.
- **Irradiance (E)** - Power per unit area, expressed in watts per square centimeter.
- **Joule (J)** - A unit of energy (1 joule = 1 watt-second).

- **Laser** - A device that produces an intense, coherent, directional beam of light by stimulated electronic or molecular transitions to lower energy levels. Laser is an acronym for Light Amplification by Stimulated Emission of Radiation.
- **Laser Safety Officer** - Individual with the authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.
- **Laser System** - An assembly of electrical, mechanical and optical components that includes one or more lasers.
- **Macula** - The small, uniquely pigmented and specialized area of the retina.
- **Maximum Permissible Exposure (MPE)** - The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. MPE is expressed in terms of either radiant exposure (joules/cm2) or irradiance (watts/cm2).
- **Nominal Hazard Zone (NHZ)** - Describes the space within which the level of the direct, reflected, or scattered radiation during normal operation exceeds the MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level.
- **Optical Density (D)** - Logarithm to the base ten of the reciprocal of the transmittance: $D_\lambda = -\log(T)$ where T is transmittance.
- **Power** - The rate at which energy is emitted, transferred, or received, usually expressed in watts
- (joules per second). Also called radiant power.
- **PRR** - Abbreviation for pulse repetition rate. (See repetitively pulsed laser.)
- **Protective Housing** - An enclosure that surrounds a laser or laser system, preventing access to laser radiation above the applicable MPE level.
- **Pulse Duration** - Duration of a laser pulse, usually measured as the time interval between the half-power points on the leading and trailing edges of the pulse.
- **Pulsed Laser** - A laser that delivers its energy in the form of a single pulse or a train of pulses which are less than or equal to 0.25 s.
- **Q-switch** - Device that produces very short (~10-250 ns) intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium.
- **Q-switched laser** - Laser that emits short (~10-250 ns), high power pulses by means of a Q-switch.
- **Radiant Energy or Flux (D)** - Laser energy emitted, expressed in joules.
- **Radiant exposure (H)** - Surface density of the radiant energy received, expressed in joules per cm2
- **Radiant power** - Laser power emitted, expressed in watts
- **Reflection** - Deviation of radiation following incidence on a surface.
- **Repetitively pulsed laser** - A laser with multiple pulses of radiant energy occurring in sequence with a PRR of 1 Hz.
- **Retina** - The sensory membrane that receives the incident image formed by the cornea and lens of
the human eye. The retina lines the inside of the eye.
- **Specular reflection** - A mirror-like reflection.
- **Transmittance (T)** - The ratio of total transmitted radiant power to total incident radiant power.

- **Ultraviolet Radiation** - Electromagnetic radiation with wavelengths smaller than visible radiation.
- **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 of 0.4 to 0.7 □m.
- **Watt (W)** - Unit of power or radiant flux (1 watt = 1 joule per second).
- **Wavelength (γ)** - The distance between two successive points on a periodic wave that have the same phase.

10.0 APPENDICIES

Appendix A: Laser Classification

Lasers are divided into a number of classes depending upon the power or energy of the beam and the wavelength of the emitted radiation. Laser classification is based on the laser's potential for causing immediate injury to the eye or skin and/or potential for causing fires from direct exposure to the beam or from reflections from diffuse reflective surfaces. Since August 1, 1976, commercially produced lasers have been classified and identified by labels affixed to the laser. In cases where the laser has been fabricated in house or is otherwise not labeled, Radiation Safety should be consulted on the appropriate laser classification and labeling. Lasers are classified using physical parameters of the laser, power, wavelength, and exposure duration.

- **Class 1 Lasers -** Class 1 lasers are considered to be incapable of producing damaging radiation levels, and are therefore, exempt from most control measures or other forms of surveillance. Example: Laser printers and CD players.
- **Class 2 Lasers -** Class 2 lasers emit radiation in the visible portion of the spectrum, and protection is normally afforded by normal human aversion response (blink reflex) to bright radiant sources. In general, the human eye will blink within 0.25 seconds when exposed to Class 2 laser light. This blink reflex provides adequate protection. However, Class 2 lasers emit laser light in the visible range and are capable of creating eye damage through chronic exposure. Examples: Laser pointers, surveying lasers.
- **Class 2a Lasers -** Class 2a lasers are visible special-purpose lasers not intended for viewing. Their power output is less than 1 mW. This class of lasers causes injury only when viewed directly for more than 1,000 seconds. The 1,000 seconds is spread over an 8-hour day, not continuous exposure. Example: Many bar-code readers fall into this category.
- **Class 3R Lasers -** Class 3R laser are those that normally would not produce injury if viewed only momentarily with the unaided eye. They may present a hazard if viewed using collecting optics, e.g., telescopes, microscopes, or binoculars. Example: HeNe laser above 1 milliwatt but not exceeding 5 milliwatts radiant power, or some pocket laser pointers.

- **Class 3B Lasers -** Class 3B laser light will cause injury upon direct viewing of the beam and specular reflections. Example: Visible HeNe laser above 5 milliwatts but not exceeding 500 milliwatts radiant power.
- **Class 4 Lasers -** Class 4 lasers include all lasers with power levels greater than 500 mW radiant power. They pose eye hazards, skin hazards, and fire hazards. Viewing of the beam and of specular reflections or exposure to diffuse reflections can cause eye and skin injuries. All of the control measures explained in this manual must be implemented. Example: Most Nd:YAG Lasers.

Appendix B: Beam Alignment Precautions

The following guidance document is to serve as a general procedure for beam alignments when working with Class 3B or 4 Lasers. It includes both general practices as well as a short procedural example of an alignment. This alignment procedure is for guidance only and does not replace the alignment SOP provided by the laboratory.

General Beam Alignment Practices

- Properly wear the appropriate laser protective eyewear as prescribed by the laboratory.
- Secure the Controlled Area from unauthorized entry.
- Turn on, or place laser warning signs to entrances to Controlled Area.
- Notify all personnel in the Controlled Area that an alignment is being performed.
- Clear work area of any obstruction or reflective, combustible, or unused materials.
- Ensure all optics are securely mounted to the table
- Use the lowest possible beam intensity (irradiance) for alignment. For non-variable output lasers, a neutral density (ND) filter may be used to reduce the irradiance emitted. For pulsed lasers, the Q-Switch may need to be turned off to reduce the power. For high powered lasers, where the irradiance is not below the MPE, an alignment (HeNe, diode) laser should be used. The owner of the equipment should standardize the means of power reduction in the laser specific SOP.
- Use remote viewing tools such as cameras and IR viewers whenever possible rather than viewing the beam directly.
- Align the beam path one segment at a time ensuring the beam is terminated at the end of the segment before powering the laser on.

Laser Alignment Procedure

1. Clear the lab of non-essential personnel and anyone not equipped with proper safety gear.
2. Place the "LASER CURRENTLY IN USE – DO NOT ENTER WITHOUT PROPER EYEWEAR – KNOCK LOUDLY IF ENTRY IS REQUIRED" sign over the entry door keypad. Verify cypher lock is on.
3. Check that the eyewear in use has proper OD for laser wavelength. Keep the eyewear on at all times.
4. Use appropriate gloves and skin protection if needed.
5. Remove laser protective barriers from optics table.

6. Before adjusting optics, check laser indicator lights to ensure lasing has ceased, and if possible, verify with phosphor cards to ensure that the laser is off.
7. Once the optics are adjusted, ensure that all possible beam termination sites have a beam block behind them.
8. Review beam path as a final check before powering on the laser
9. Verify eyewear in use by all present.
10. Set laser power to lowest setting necessary for alignment
11. Give verbal warning in lab that laser is ready to be fired. The laser will now be emitting hazardous laser radiation.
12. If optics need to be readjusted, turn the laser off with the controller and repeat step 6 to make sure all lasing activity has ceased.
13. Repeat steps 6-12, until alignment is complete.
14. Shut down laser
15. Remove laser controller and store separately, if laser work is complete
16. Replace protective laser barriers before starting normal work.