



Laser Safety Plan

Florida Institute of Technology (Florida Tech)

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Introduction

Florida Tech is committed to providing a safe and healthful environment for all employees, students, and visitors.

The purpose of the Florida Tech Laser Safety Plan is to ensure that there are no laser radiation exposures beyond the maximum permissible exposure (MPE) limits (to the human eye or skin) and to protect against non-beam hazards that can be associated with lasers including but not limited to electrical shock, explosion, fire, collateral radiation, and exposure to harmful chemical or biological hazards.

The Florida Tech Laser Safety Plan has been developed in accordance with the safety guidelines established by the American National Standards Institute (ANSI Z136.1-2014) as well as state ([Florida Administrative Code 64E-4, Control of Non-Ionizing Radiation Hazards](#)) and federal regulations ([FDA 21 CFR 1040, Standards for Light- Emitting Products](#)).

1.0 Responsibilities

1.1 Laser Safety Officer (LSO)

The LSO is designated by Environmental Health and Safety (EHS) at Florida Tech. The LSO functions as a liaison between the EHS and laser users and ensures laser laboratory safety standards are adequate and in compliance with state and federal regulations as well as established safety standards. Duties of the LSO include but are not limited to the following:

- Development, implementation, and revisions of the Laser Safety Plan.
- Evaluation of laser hazards and establishment of Nominal Hazard Zones.
- Classifying lasers that have been modified or manufactured on campus. Lasers purchased commercially retain their manufacturer given classification provided no modifications are made.
- Assuring control methods are in effect, evaluating and periodically auditing control methods, and recommending and approving control measures.
- Accessing and approving SOPs for laser operations.
- Approving and assessing approved warning signs and labels.
- Approving, recommending, and periodically auditing PPE such as eyewear, clothing, barriers, and screens.
- Review and approve purchases of Class 3B and 4 lasers, maintain current inventory of Class 3B and 4 lasers (including embedded lasers), and maintain current inventory of all lasers Class 2 or higher.
- Inspect and periodically audit the safety features and engineering controls of laser facilities and equipment.
- Investigate incidents and perform hazard evaluations to determine cause and implement controls before allowing laser operations to resume after incidents.
- Maintain records of safety inspections, instrument calibrations, and incident reports for a minimum of five years in accordance with [64E-4.001 F.A.C.](#)

1.2 Department Leads/Supervisors

The Department Leads/Supervisors have overall responsibility for the implementation of the Laser Safety Plan within their department. The Supervisor designates a Principal Investigator (PI) and informs the LSO of the designation (a supervisor may designate themselves if they are a trained laser user). The LSO will coordinate efforts with the Supervisor and PIs to ensure that adequate safety measures are taken to meet the specific needs of their department.

1.3 Principal Investigator (PI)

The PI has overall responsibility for laser safety within their laboratory. In addition to laser safety, the PI is directly responsible for the acquisition, use, and maintenance for all lasers under their authority. Responsibilities of the PI include the following:

- Obtaining approval from the LSO before permitting operation of new, modified, or manufactured Class 3B or 4 lasers and registering lasers within 30 days with the [Florida Department of Health](#).
- Ensure all laser users under PI's authority are properly trained in the safe operation of lasers and the hazards of operating lasers before they are authorized to operate Class 3B or 4 lasers.
- Keep a list of current laser users and provide the LSO with a copy of the list.
- Ensure availability, proper maintenance, and use of PPE for laser operations.
- Developing, maintaining, and updating SOPs for all Class 3B and 4 laser activities.
- Notify LSO and Supervisor of incidents, accidents, injuries, and near misses related to the operation of a laser and help personnel injured by lasers in obtaining appropriate medical attention (if needed).
- Work with the LSO during investigations of incidents and implement the LSO's recommendations.
- Contact the LSO before transfer or disposal of Class 3B and 4 lasers and laser systems.

1.4 Laser Users

Laser users are employees and students who are authorized and trained to operate lasers and laser systems requiring control methods (such as Class 3B and Class 4 lasers). Laser users must follow safety procedures as outlined in Florida Tech's Laser Safety Plan and the SOPs associated with specific laser operations. Laser users are responsible for the following:

- Ensure they have completed approved laser safety training before operating Class 3B and 4 lasers.
- Be compliant in the rules of the Laser Safety Plan and procedural rules under the authority of the LSO, Supervisor, and PI.
- Inform their PI and the LSO of any possible safety issues concerning the operation of the laser.
- Immediately report any incident, accidents or injuries to the PI and seek medical treatment immediately if needed.

2.0 Laser Classes

Per ANSI Z-136.1-2014, lasers are classified by their potential hazards to eyes and skin and their ability to start fires whether from direct beam exposure or diffuse and specular reflections. All lasers should be labeled to identify their class, and safety precautions should be followed that are specific to laser class.

Post August 1976 manufacturers of commercial lasers and systems classify and label lasers in accordance with [21 CFR Part 1040](#). However, if a laser or laser system is modified or altered, it will need to be reclassified and registered anew. Lasers and laser systems are classified on the

maximum output available for intended use. Lasers that emit multiple wavelengths will be classified by their most hazardous operation. Pulse lasers require correction factors for classification (see ANSI Z136.1-2014 for information).

2.1 Class 1 Lasers

These are incapable of producing damaging radiation levels and are considered non-hazardous. Class 1 applies to any laser or laser system appropriately designed to assure that accessible laser radiation levels do **not** exceed the *accessible emission limit* (AEL) for a Class 1 laser (Table 1 in [21 CFR 1040](#)).

Examples include *embedded higher-class lasers* configured to prevent laser radiation hazards, laser printers, CD players, and DVD players. Completely enclosed lasers are Class I except during service procedures, and control measures will be required temporarily in accordance with the class of the laser within the enclosure.

2.1.1 Class 1M Lasers

Class 1M lasers may exceed Class 1 AEL if magnifying optics, such as binoculars, are used. Contact the LSO before using or installing optical aids in a laser lab. An example of a Class 1M laser would be a fiber optic communication system.

2.2 Class 2 Lasers

Class 2 lasers are low power (less than 1 milliwatt) and emit wavelengths in the visible spectrum (400 to 700 nanometers). Class 2 laser AELs exceed those of Class 1 lasers, but the beam hazards are mitigated by the aversion response of the eye (0.25 seconds). AELs are specified in [21 CFR 1040](#). An example of a Class 2 laser would be a supermarket barcode scanner and some diode powered lasers.

2.2.1 Class 2M

The Class 2M designation is the same hazard level as Class 2, but these lasers are potentially hazardous when viewed with optical aids. Contact the LSO before using or installing optical aids in a laser lab. Examples would include levelling instruments and some construction industry lasers.

2.3 Class 3 Lasers

Class 3 lasers are lasers with AELs above the levels for Class 1 and Class 2 lasers. Class 3 lasers are divided per ANSI Z136.1-2014 into two classes: Class 3R and Class 3B.

Note: Older Class 3 lasers were divided into Class 3A and Class 3B. Class 3R lasers are typically identical to Class 3A lasers provided the beam diameter is less than 7 millimeters. Some older Class 3B lasers may also qualify as Class 3R provided it emits lower than 5 milliwatts. Contact the LSO for assistance if you have an older Class 3 laser.

2.3.1 Class 3R

Class 3R lasers have outputs between 1 to 5 times Class I AELs for wavelengths below 400 nanometers and above 700 nanometers or less than 5 times the Class 2 AELs for the visible spectrum (400 to 700 nanometers): output powers range from 1 milliwatts to 5 milliwatts.

The laser beam is unlikely to be hazardous except when the viewer overcomes their aversion response or views the beam with optical aids. Do **not** view a Class 3R beam directly and do **not** point a Class 3R beam into another person's eyes. Some laser pointers are an example of a Class 3R laser.

2.3.2 Class 3B

Class 3B lasers include:

- Lasers and laser systems with wavelengths below 400 nanometers and greater than 1400 nanometers that emit accessible radiant power above Class 3R AELs but cannot emit an average accessible power of 0.5 Watts for greater than 0.25 seconds or pulse energies greater than 0.125 Joules for durations less than 0.25 seconds, or
- Lasers and laser systems in the visible spectrum (400 to 700 nanometers) and near infrared (700 to 1400 nanometers) that emit in excess of the AEL for Class 3R but cannot emit an average accessible power of 0.5 Watts for greater than a duration greater than 0.06 times the correction factor C_A seconds or pulse energies greater than 0.03 times C_A Joules for durations less than 0.06 times C_A seconds with a maximum pulse energy of 0.125 Joules.

Class 3B lasers pose hazards to the eye via the beam and specular reflections. Class 3B lasers are normally not a diffuse reflection hazard, fire hazard, nor a laser generated air contaminant (LGAC) production hazard.

2.4 Class 4

Class 4 lasers are lasers with power greater than 500 milliwatts and with AELs greater than those for all the other classes.

The hazards to the eye posed by Class 4 lasers include injuries to the eye through the beam, specular reflections, and diffuse reflections as well as injuries to the skin through. Direct exposure to Class 4 laser beams may cause serious skin injuries. Class 4 lasers also pose fire hazards.

Much greater controls are required to ensure the safe operations Class 4 lasers.

3.0 Laser Hazards

Laser hazards included those from the beam itself as well as non-beam hazards. All possible hazards for specific lasers and laser systems should be addressed in the SOPs.

3.1 Beam Hazards

Class 3B, Class 4, and optically modified lasers may be hazardous to eyes and skin depending on the factors listed below.

3.1.1 Eyes:

Damage to the eye from exposure to the laser beam is the most prominent safety hazard. The type of damage and threshold at which damage occurs is dependent upon the wavelength, power, and duration of the laser. Damage can come from acute and chronic laser exposures. The important areas of the eye most affected by laser hazards are the retina, cornea, and lens. Never look directly into a laser beam!

3.1.1.1 Retina

Injury to the retina of the eye can occur instantaneously with Class 3B and 4 lasers. The wavelengths that focus on the retina are visible (400 – 700 nm) and near infrared (700 – 1400 nm). Possible injuries to the retina include scotomas (blind spots), thermal burns, acoustic damage, and photochemical damage.

3.1.1.2 Cornea

The cornea can be damaged at UV-B and UV-C (100 - 315 nm) and far infrared (>1400 nm) wavelengths. Possible injuries to the cornea include photokeratitis (a painful cornea burn also called “flash burn” or “welder’s flash”) and thermal burns.

3.1.1.3 Lens

The lens of the eye can be damaged at UV-A (315 – 400 nm) and IR-A and IR-B (760 – 3000 nm) wavelengths. Possible injuries to the lens include cataracts.

3.1.2 Skin:

Class 4 lasers can potentially damage the skin. The higher the energy of the beam, the greater the possibility of injury. The wavelength of the laser beam determines the type of damage to the skin and depth in the skin. Infrared wavelengths can cause severe thermal burns, and UV wavelengths can cause erythema (sunburn) and an increased risk for skin cancer.

3.2 Non-Beam Hazards

Lasers can pose hazards unrelated to the beam itself.

3.2.1 Electrical Hazards

Electrical hazards pose the greatest risk for injury and fatalities due to the high voltage components of a laser. Always follow the [Control of Hazardous Energy Lockout/Tagout Plan](#) when servicing or maintaining a laser’s high voltage components.

3.2.2 Chemical Hazards

Chemical hazards are a result of the media used in laser radiation such as dyes and excimers. These chemicals may be toxic, corrosive, flammable, or otherwise hazardous. A Safety Data Sheet (SDS) must be available and accessible for every chemical handled in the laboratory.

Consult the SDS for hazard, handling, storage, and PPE requirements. The [Chemical Hygiene Plan](#) should also be consulted whenever chemicals are handled or stored at Florida Tech.

3.2.3 Compressed Gas and Cryogenic Hazards

Compressed gas and cryogenic fluids may be used in some laser applications. SOPs should contain references to the safe handling of compressed gases, hazardous gases, and cryogenic fluids. Please consult the [Compressed Gas Safety Plan](#) for information and reference.

3.2.4 Fire Hazards

Fire is a hazard associated with Class 4 lasers. Barriers and enclosures for these lasers should be made from non-flammable materials. Flammable and combustible materials must be kept outside the Nominal Hazard Zone (NHZ).

3.2.5 Explosion Hazards

Explosion hazards include high-pressure arc lamps, filament lamps, and capacitor banks. All possible explosion hazards should be enclosed in housing that can withstand high pressure from explosive forces.

3.2.6 LGACs

Laser Generated Air Contaminants (LGACs) refers to contaminants in the air associated with the use of Class 3B and 4 lasers. The type of air contaminant is determined by the target material, cover gas, and beam irradiance. Ensure that laser operations are conducted under adequate ventilation to keep contaminant levels below worker permissible exposure limits.

3.2.7 Collateral Radiation

Collateral radiation refers to ionizing and non-ionizing radiation hazards of a laser system other than the beam itself. Lasers with power supplies over 15 kilovolts may produce ionizing X-rays due to either the high voltage vacuum tubes of laser power supplies or from electric discharge lasers. UV and Visible radiation at hazardous levels may be generated by laser discharge tubes and pump lamps. Consult the LSO or the Radiation Safety Officer (RSO) for assistance with mitigating these hazards.

3.2.8 Plasma Radiation

Plasma radiation may be produced when target materials are hit with very high-power laser beams. This radiation typically contains “blue light” and UV emissions that can cause conjunctivitis, photochemical damage, and erythema to the skin. Screens and shielding should be used to attenuate this radiation.

4.0 Control Measures

Hazard control measures include engineering controls, administrative controls, and personal protection equipment (PPE). When feasible, engineering controls are always the preferred method to provide for safety in a laser laboratory followed by administrative controls: PPE

should be the last control method considered. Control measures are established in the ANSI Z136.1-2014 standard, [21 CFR 1040](#), and [64E-4 F.A.C.](#)

4.1 Engineering Controls

Engineering controls place barriers between the laser user and the laser hazards. The following are engineering controls for Class 3B and 4 lasers:

4.1.1 Beam Enclosures

Use beam enclosures whenever practical. These are the most effective engineering controls for lasers and laser systems.

4.1.2 Laser-Controlled Area

Nominal Hazard Zones (NHZ) shall be established for all open beam paths. The NHZ is a laser-controlled area, and appropriate control methods must be established in this area.

4.1.3 Protective Housing

Protective housing shall be available for each laser system.

4.1.4 Safety Interlocks

Protective housing shall be interlocked so that removal of the protective housing prevents laser beam exposure greater than the MPE. Remote interlock connectors should be available for Class 3B lasers and shall be available with Class 4 lasers. Interlocks shall not be defeated or overridden during normal operation of the laser.

- For pulsed lasers, interlocks shall prevent unintentional firing such as by dumping stored energy into a dummy load.
- For CW lasers, interlocks shall turn off the power supply or shutter the beam. Service access panels shall be interlocked with a special tool for removal and have warning labels.

4.1.5 Key Access

Class 3B lasers should and Class 4 shall have a key controlled master switch. The PI has authority for key access. The laser should be disabled by removing the key when not in use.

4.1.6 Activation Warning Systems

Class 3B laser and Class 4 laser-controlled areas shall have a visible area warning device (such as a lighted laser warning sign) that is visible at the entrance to the controlled area. Within controlled areas, Class 3B laser controlled-areas should and Class 4 laser controlled-areas shall have an emission indicator visible warning device. Audible warning systems may also be used: the distinctive and clearly identifiable sounds that arise from auxiliary equipment (such as a vacuum pump or fan) and that are uniquely associated with the emission of laser energy are also acceptable as audible warnings. Emission warnings shall activate in a manner to give a laser user adequate response time to act in avoiding exposure to laser radiation.

4.1.7 Viewing Optics

All viewing portals, display screens, and collecting optics shall be designed to prevent exposure to the laser beam above the applicable MPE for all conditions of operation and maintenance.

4.1.8 Barriers

All windows and doorways shall be either controlled or restricted in such a manner as to prevent escape of potentially hazardous laser radiation. Lasers with open beam configurations shall have laser safety curtains for doorways and windows.

4.1.9 Beam Stops

Class 3B lasers should and Class 4 lasers shall have permanent beam stops in place. While most lasers come with permanent beam stops in place that lower the MPE at the aperture from the protective housing, additional beam stops may be needed to keep beam hazards limited to the area of the experiment.

4.1.10 Remote Operations

Whenever possible, Class 4 lasers should be operated/fired from a remote location.

4.2 Administrative Controls

Administrative controls are methods that specify rules and practices that supplement or implement engineering controls. The following are administrative controls for Class 3B and Class 4 lasers.

4.2.1 Standard Operating Procedures (SOPs)

Written SOPs are required and must be available near each individual laser or laser system.

4.2.2 Education and Training

Laser users must have basic laser safety training. The course is available through [Florida Tech's Safety Training](#). Class 3B and Class 4 laser users shall also require training specific to individual laser operations under the authority of their PI. This specific training should be documented and retained in the PIs laser user records.

4.2.3 Output Emission Limitations

Laser operators shall use the minimum radiant laser energy or power level required for an application.

4.2.4 Authorized Personnel

Only authorized personnel may operate, maintain, and service lasers. PIs are responsible for authorizing laser users and must maintain a current list of laser users.

4.2.5 Beam Height

Keep the beam height at levels other than the eye when in normal standing and sitting positions.

4.2.6 Service Personnel

Whenever access to the beam is possible during service or maintenance of laser equipment, control methods must be in place to prevent exposures to laser radiation above the MPE. PIs must require service personnel to have training and education specific to the hazard class of laser embedded in the protective housing.

A temporary laser controlled-area shall be established by service personnel that provides the safety requirements for all personnel both within and outside of the area appropriate to the laser or laser system, and a notice sign shall be posted outside the temporary laser-controlled area to warn of the potential hazards.

4.2.7 Visitors

Visitors are not permitted in the laser-controlled areas unless specific protective measures are taken, hazards and protective measures are explained to visitors, and the LSO approves these protective methods.

4.3 Personal Protective Equipment

PPE is equipment worn to minimize exposure to laser hazards. The type of PPE required depends on the hazards. PIs are responsible for providing PPE for their laser users. Please consult the [Personal Protective Equipment Plan](#) for information and reference.

4.3.1 Laser Protective Eyewear

Laser protective eyewear must be available whenever there is a potential for laser radiation exposure above the MPE. Laser eyewear must be clearly labeled with the OD and wavelength at which it offers protection. Laser eyewear that doesn't match the OD and wavelength of the laser in use affords no protection. Protective eyewear should fit comfortably, provide adequate visibility, and be in good condition. Eyewear should be kept clean and stored in a case that protects it from contaminants and wear and tear. Inspect eyewear for cleanliness and damage before each use. Replace eyewear if it is cracked or otherwise damaged. Replace straps that are frayed or stretched.

Never look directly into a laser beam even when wearing laser protective eyewear. Do not expose laser eyewear to high-intensity beams, as this can damage the laser eyewear as to render it unusable for protection. Eyewear damaged by laser beams should be removed from use and replaced.

4.3.2 Clothing, Gloves, and Shields

Laser users should protect their skin with flame resistant clothing, gloves, and laser shields whenever the potential for laser radiation exposure greater than the MPE for skin exists.

4.3.3 Respiratory PPE

In circumstances where LGACs are generated and engineering controls cannot provide adequate protection, respirators are required. Please consult the [Respiratory Protection Plan](#) for information and reference.

4.4 Requirements for Control Measures

Control method requirements are determined by laser class.

4.4.1 Class 1 Lasers

Class 1 lasers and laser systems are exempt from requiring controls.

4.4.2 Class 1M Lasers

Class 1M lasers and laser systems are exempt from requiring controls unless optically aided direct viewing of the beam is expected or unattended operations where there is a potential for direct viewing by the direct public or personnel uninformed about laser hazards.

4.4.3 Class 2 Lasers

Class 2 lasers and laser systems are exempt from requiring controls except for intentional direct viewing of the laser beam.

4.4.4 Class 2M

Class 2M lasers and laser systems are exempt from requiring controls except for intentional direct viewing of the laser beam or potentially hazardous optically aided viewing.

4.4.5 Class 3R

Class 3R lasers and laser systems are exempt from requiring controls except for direct viewing of the beam, viewing the beams specular reflection, or unattended operations where there is a potential for direct viewing by the direct public or personnel uninformed about laser hazards.

4.4.6 Class 3B

Class 3B lasers and laser systems must have control measures. All control measures must be approved by the LSO.

4.4.7 Class 4

Class 4 lasers and laser systems must have control measures. All control measures must be approved by the LSO.

5.0 Laser Rules and General Procedures

5.1 Training and Records

The training course “Laser Safety” is available through [Florida Tech's Safety Training](#). The course is required for faculty, students, and staff who work in labs where lasers requiring control measures are in operation. The course provides an overview of laser fundamentals and associated hazards commonly found in the research environment and are designed to provide students with a basic understanding of lasers and laser safety. The class covers laser classification, signage, bio-effects, beam and non-beam hazards, controls, regulations and safety precautions.

All Laser Users as defined in this plan must also receive laser safety training specific to the individual lasers they use. It is the responsibility of their PI to implement a specific laser safety

training program for all staff and students working with or potentially exposed to the lasers or laser systems under their authority. The lesson plan should incorporate beam and non-beam hazards, specific hands on instruction in the use of laser systems, safety precautions associated with the laser, and the proper use of protective eyewear. This safety training must be documented and included in the PI's records. The LSO will evaluate this safety training during inspections and audits. Regular refresher training may be required by the LSO on a case by case basis.

5.2 Acquisition, Transfers, and Disposal of Lasers

PIs must notify the LSO if they plan to purchase, manufacture or otherwise acquire a Class 3B or Class 4 laser. The LSO will review with the PI the hazards of the proposed operation and make recommendations regarding the specific safety requirements that pertain to the proposed use of the laser system.

Contact the LSO before transferring Class 3B and Class 4 lasers or laser systems to another on-campus PI or off campus site. Transfer of lasers and laser systems to a person who does not have laser safety training, laser use training, and the appropriate PPE is prohibited.

Contact the LSO before disposing of Class 3B and Class 4 lasers or laser systems. Uncertified lasers that do not meet state or federal standards and lasers that have been manufactured on-campus shall be rendered inoperative before disposal. All lasers and laser systems should be evaluated for toxic or hazardous components by EHS prior to their disposal.

5.3 Signage and Labeling

Locations and labs with unenclosed Class 3B and Class 4 must have posted warning signs at all entrances. Laser-controlled areas must also be labeled with appropriate warning signs. Wording on the sign must correspond to the highest-class laser contained in the area/location. Signage and labels shall be provided by the LSO by request.

Danger indicates the most serious level of hazard. Death and serious injury will occur if the necessary control measures are not taken within the controlled area. This signal word shall be restricted to Class 4 lasers with high output power or pulse energies with exposed beams.

Warning shall be used for lasers and laser systems with outputs that exceed the MPE, which includes all Class 3B lasers and most Class 4 lasers.

Caution may be used if Class 1 and Class 2 lasers locations are posted (this is optional) and for lasers that do not exceed the MPE.

Notice may be used for practices not related to personal injury and must not include the safety alert symbol.



Figure 1. Sample ANSI Z535.2 Compliant Warning Sign (Class 3B and Class 4 LCAs)



Figure 2. Sample ANSI Z535.2 Compliant Danger Sign (Class 4 LCAs)

A **Notice** sign must also be posted for temporary laser control areas where acceptable MPEs are exceeded (such as during laser system servicing that requires removal of protective enclosures or disabling of safety interlocks).



Figure 3. Sample Notice Signal Word

Class 2 or higher lasers and laser systems require appropriate labels. Manufactured lasers must not have their labels removed. Modified and constructed lasers must be provided with labels that are visible during operation and affixed to the housing or control panel (or both if these are separated more than 2 meters).

Class 2 lasers: "Laser Radiation – Do Not Stare into Beam"

Class 2M lasers: “Laser Radiation – Do Not Stare into Beam or View Directly with Optical Instruments”

Class 3R and 3B lasers: “Laser Radiation—Avoid Eye Exposure to Beam”

Class 4: “Laser Radiation—Avoid Eye Exposure to Direct or Scattered Radiation; Avoid Skin Exposure to Direct Radiation”

5.4 Alignment Procedures

Most laser beam incidents in research occur during alignment procedures. Alignment of laser optical systems shall be performed in such a manner that the primary beam, a specular reflection of the beam, or a diffuse reflection of a beam does not expose the eye to levels above the MPE.

Written SOPs of alignment procedures shall be approved by the LSO for Class 3B lasers and Class 4 lasers. When embedded lasers of Class 3B or Class 4 hazard must be exposed for alignment procedures, an SOP shall be available as well.

Use lower hazard class or reduced power visible lasers for path simulation when performing alignment procedures on Class 3B or Class 4 lasers.

Only personnel trained in laser safety should perform alignments. Laser controlled areas for Class 3B and Class 4 lasers shall be established. The following actions should also be taken:

- Exclude unnecessary personnel from the laser-controlled area during alignment.
- Use lower hazard class visible lasers for path simulation of invisible lasers and high-powered lasers whenever possible.
- Use beam display devices (such as phosphor cards or image converter viewers) when aligning invisible beams.
- Use the lowest possible power level when performing alignments.
- Wear PPE to the extent practical.
- Use shutters, beam blocks, and barriers to block or terminate high power beams at their source when not needed, down range of optics being aligned, behind turning mirrors, and wherever beams could stray into an uncontrolled area.

5.5 Audit Requirements and Inspections

Regulatory agencies such as the Florida Department of Health and OSHA may periodically inspect Florida Tech for compliance with regulations. To ensure compliance with regulations and to avoid penalties for lack of compliance, lasers, laser systems, and labs that house Class 3B and Class 4 lasers shall be periodically audited.

All PIs at Florida Tech should inspect their labs for laser hazards at least annually. PIs may use the self-audit checklist in Appendix B.

The LSO will annually audit active Class 3B and Class 4 laser labs (in association with the PI) to ensure compliance with the standards and regulations. A report for PIs will be available when the audit is complete. Any corrective action requested by the LSO shall be completed in a timely manner.

5.6 Recordkeeping and Documents

PIs shall keep current inventories of their lasers, their authorized laser users, and training records for authorized users. Records for lasers removed from inventory should be kept for at least five years, including information regarding the method of removal. PIs should also keep records of self-audits.

PIs shall keep SOPs for all lasers and laser systems and written procedures for alignments and maintenance procedures. SOPs and written procedures shall be kept for all lasers in service and at least five years after the removal of the any lasers or laser systems.

6.0 Incidents and Emergencies

For life-threatening emergencies and fires call 911. Report all actual or suspected exposures to laser hazards and all laser incidents and emergencies to the LSO as soon as possible (ext. 8889).

Written emergency procedures shall be included for each laser SOP. The section on emergency procedures shall include shut-down procedures, first-aid, and assistance to personnel requiring medical assistance.

6.1 Medical Examinations

Eye exams shall be performed after any actual or suspected laser-induced eye injury. Evaluation by a medical professional should occur as soon as possible after the exposure. Referrals for medical examinations shall be consistent with the medical symptoms and the anticipated biological effect based upon the laser system in use at the time of the incident. For laser-induced injury to the retina, the medical examination shall be performed by an ophthalmologist. Employees with skin injuries should be seen by a physician.

Appendix

Appendix A – Definitions

Appendix B – Self Audit Checklist

Appendix A – Definitions

Accessible emission: in normal operation, laser radiation to which it is possible for the human eye or skin to be exposed.

Accessible Emission Limit (AEL): the maximum accessible emission level permitted within a particular class as set forth in 21 C.F.R. Part 1040.

ANSI: ANSI Z136.1-2014, “American National Standard for Safe Use of Lasers.”

Aperture: any opening in a protective housing through which radiation is emitted, thereby allowing human access to such radiation.

Attenuation: the decrease in the radiant flux of any optical beam as it passes through an absorbing or scattering medium.

Aversion response: closure of the eyelid, or movement of the head to avoid exposure to a bright light. The average response to an exposure from a bright laser source is assumed to occur within 0.25s.

Beam: a collection of rays characterized by direction, diameter, and angle.

C_A: a correction factor used to determine MPEs in the near infrared region based up reduced absorption properties in the retinal epithelium.

Collateral radiation: any electronic product radiation, except laser radiation, emitted by a laser because of the operation of the laser or any component of the laser product that is physically necessary for the operation of the laser. The accessible emission and maximum permissible exposure limits for collateral radiation are specified in 64E-4.016 and ANSI.

Continuous wave (CW): constant, steady-state delivery of laser power.

Controlled area: any area where the occupancy and activity of those within is subject to control and supervision for protection from radiation hazards.

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

Demonstration laser: any laser manufactured, designed, intended, or used for purposes of demonstration, entertainment, advertising display, or artistic composition.

Diffuse reflection: the 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 with an assigned class number higher than the inherent capability of the laser system in which it is incorporated, where the system's lower classification is appropriate to the engineering features limiting accessible emission.

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

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), the product of power (watts) and duration (seconds). One watt second = one Joule.

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

Fail-safe Interlock: an interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into (or remain in) a safe mode.

Human access: access to laser or collateral radiation by any part of the human body.

Incident: an event or occurrence that results in a real or suspected accidental exposure to laser radiation which caused or is likely to cause biological damage.

Infrared radiation (IR): invisible electromagnetic radiation with wavelengths that lie within the range of 700 nm to 1 mm. These wavelengths are often broken up into regions: IR-A (700 nm – 1400 nm), IR-B (1400 nm – 3000 nm) and IR-C (3000 nm – 1 mm).

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

Irradiance (E): the radiant power incident on an element of a surface divided by the area of that element, expressed in watts per square centimeter ($W\text{ cm}^{-2}$).

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

Laser Safety Officer (LSO): any individual, qualified by training and experience in the evaluation and control of laser hazards, which is designated by the registrant and has the authority and responsibility to establish and administer the laser protection plan for a facility.

Laser system: an assembly of electrical, mechanical, and optical components that includes a laser.

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

Maintenance: the performance of those adjustments or procedures by the user to keep equipment in its intended operating condition. Maintenance does not include operation or service as defined in these rules.

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. Exposure levels should be maintained as far below the MPE values as practicable.

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 tasks required for the equipment to perform its intended functions. It does not include maintenance or service tasks as defined in these rules.

Optical Density (OD): a logarithmic expression of the optical attenuation afforded by a material.
OD =
 $\log_{10} (\text{incident power}/\text{transmitted power})$.

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

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

Protective housing: any panel, partition, dividing wall, or similar device which prevents human access to laser or collateral radiation more than the prescribed accessible emission limit.

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

Pulse duration: the “on” time of a pulsed laser, it may be measured in terms of milliseconds, microseconds, nanoseconds, picoseconds and femtoseconds as defined by half-peak-power points on the leading and trailing edges of the pulse.

Pulse interval: the time duration between identical points on two successive pulses.

Radiance: radiant power per unit area of a radiating surface per unit solid angle of emission, expressed in watts per square centimeter per steradian ($\text{W cm}^{-2} \text{sr}^{-1}$).

Radiant energy: energy emitted, transferred or received in the form of radiation, expressed in joules (J).

Radiant exposure: the radiant energy incident on an element of a surface divided by the area of the element expressed in joules per square centimeter (J cm^{-2}).

Radiant power: means power emitted, transferred or received in the form of radiation, expressed in watts (W).

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

Safety interlock: a device associated with the protective housing of a laser product, system or facility which prevents human access to laser or collateral radiation more than the prescribed accessible emission limit.

Secured enclosure: an enclosure to which casual access is impeded by some means, such as a door secured by lock, by latch, or by screws.

Service: the performance of adjustments, repairs, or procedures required to return equipment to its intended state. These adjustments and procedures usually require specialized training or tools. Service does not include operation or maintenance as defined in these rules.

Shall: Indicates a measure that is mandatory.

Should: Indicates a measure that is advisory.

Specular reflections: mirror-like reflections.

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

Uncontrolled area: any area to which access is not controlled by the registrant for purposes of protection from radiation hazards.

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

Appendix B – Self-Audit Checklist

Laser Safety
Self-Audit Checklist

Building _____ Room _____ Principal Investigator _____

Audit Performed by _____ Date _____

| A. Administrative | | | | |
|--|----------|----------|-----------|-----------------|
| | Y | N | NA | COMMENTS |
| 1. Lasers are classified appropriately (2, 3R, 3B, 4) | | | | |
| 2. Standard operating procedures are available | | | | |
| 3. Alignment procedures are available | | | | |
| 4. Viewing cards are used for alignment | | | | |
| 5. Laser users attended appropriate training | | | | |
| 6. Lasers are included in inventory & registered | | | | |
| B. Labeling and Posting | | | | |
| | Y | N | NA | COMMENTS |
| 1. Certification label present | | | | |
| 2. Class designation and appropriate warning label present | | | | |
| 3. Radiation output information on label | | | | |
| 4. Aperture label present | | | | |
| 5. Appropriate warning/danger sign at entrance to laser area | | | | |
| 6. Warning posted for invisible radiation | | | | |

| C. Control Measures | | | | |
|---|----------|----------|-----------|-----------------|
| | Y | N | NA | COMMENTS |
| 1. Protective housing present and in good condition | | | | |
| 2. Beam attenuator present | | | | |
| 3. Laser table not at eye level when seated or standing | | | | |
| 4. Beam is enclosed as much as possible | | | | |
| 5. Beam not directed toward doors or windows | | | | |
| 6. Beams are terminated with fire-resistant beam stops | | | | |
| 7. Surfaces minimize specular reflections | | | | |
| 8. Controls are located so that the operator is not exposed to beam hazards | | | | |
| D. Personal Protective Equipment | | | | |
| | Y | N | NA | COMMENTS |
| 1. Eye protection is appropriate for wavelength | | | | |
| 2. Eye protection has adequate OD | | | | |
| 3. Warning/indicator lights can be seen through protective filters | | | | |
| E. Class 3B and 4 Lasers | | | | |
| | Y | N | NA | COMMENTS |
| 1. Interlocks on protective housing | | | | |
| 2. Service access panel present | | | | |
| 3. Limited access to spectators | | | | |
| 4. Nominal hazard zone determined | | | | |
| 5. Operators do not wear watches or reflective jewelry while laser is operating | | | | |
| 6. Viewing portals present where MPE is exceeded | | | | |

| F. Class 4 Lasers | | | | |
|--|----------|----------|-----------|-----------------|
| | Y | N | NA | COMMENTS |
| 1. Failsafe interlocks at entry to controlled area | | | | |
| 2. Area restricted to authorized personnel | | | | |
| 3. Laser fires remotely? | | | | |
| 4. If present, curtains are fire-resistant | | | | |
| 5. Area designed to allow rapid emergency egress | | | | |
| 6. Pulsed - interlocks designed to prevent firing of the laser by dumping the stored energy into a dummy load | | | | |
| 7. CW - interlocks designed to turn off power supply or interrupt the beam by means of shutters | | | | |
| 8. Operators know not to wear ties around the laser | | | | |
| 9. Panic button (nonlockable disconnect switch) installed on Class 4 lasers to allow rapid deactivation of the laser | | | | |
| G. Non-Beam Hazards | | | | |
| | Y | N | NA | COMMENTS |
| 1. High voltage equipment appropriately grounded | | | | |
| 2. High voltage equipment located away from wet surfaces or water sources | | | | |
| 3. High voltage warning label in place | | | | |
| 4. Compressed gases secured | | | | |
| 5. Respiratory PPE evaluated? | | | | |
| 6. Respirator PPE in good condition? | | | | |

Laser Safety - Self-Audit Checklist (Page 3 of 3)