Laser Safety Manual

UNIVERSITY OF FLORIDA

Business Affairs
Division of Environmental Health and Safety
Department of Radiation Safety and Radiological Services

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P.O. Box 118340
Gainesville, FL 32611
Phone: (352) 392-7359
Email: lso@ehs.ufl.edu
Website: http://www.ehs.ufl.edu/Rad/laser/

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FOREWARD

By authority delegated from the University President, the Vice President for Business Affairs is responsible for the safety of all University facilities. Under this authority, policies are developed to provide a safe teaching, research, service, housing and recreational environment.

The Environmental Health and Safety Division was established in 1974 and given the responsibility for the management of all safety practices and the effective administration of the program.

The mission of the Environmental Health and Safety (EH&S) Division is to support and advance the teaching, learning and research activities of the University through promotion of a safe and healthy campus environment by providing and coordinating programs and services that minimize safety, health, environmental and regulatory risks to the University of Florida community in a manner consistent with responsible fiscal and environmental stewardship.

The University adopts all applicable federal and state safety laws, rules and regulations in order to carry out its duties and responsibilities. In addition EH&S will reference standards or codes related to safety, which have been adopted and promulgated by nationally recognized standards-setting organizations. The interpretation of safety codes and standards is the responsibility of the Environmental Health and Safety Division.

In order to assure an effective Environmental Health and Safety program for the University of Florida, it is imperative that all individuals associated with the University comply fully with the policies and procedures set forth in this manual.

Curtis Reynolds

Vice President
Business Affairs

POLICY STATEMENT

It is the policy of the University of Florida to provide a safe working environment. The primary responsibility for insuring safe conduct and conditions in the laboratory resides with the principal investigator.

Radiation Control and Radiological Services is responsible for providing up-to-date information and training to the research community concerning the safe conduct of laser use in accordance with all pertinent local, state and federal regulations, guidelines and laws. To that end, we provide this manual as a resource to be used in conjunction with other safety manuals and resource materials available from Environmental Health and Safety.

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1. Introduction

1.1 Purpose

This manual defines the Laser Safety Program for the University of Florida. This program has been developed to provide guidance to faculty, staff, students and visitors for the safe use of lasers and laser systems. This manual also provides essential reference information on non-ionizing optical radiation.

The primary purpose of the University of Florida Laser Safety Program is to ensure that no laser radiation in excess of the maximum permissible exposure (MPE) limit reaches the human eye or skin. In addition, the program is designed to ensure adequate protection against non-beam (collateral) hazards that can be associated with lasers. Non-beam hazards include the risk of electrical shock, explosion, fire, and personal exposure to harmful chemical or biological hazards. In order to control these hazards, the UF Laser Safety Program follows the safety guidelines established by the American National Standards Institute (ANSI) standard Z136.1 – 2007, *American National Standard for the Safe Use of Lasers* and standard Z136.5 – 2009, *American National Standard for the Safe Use of Lasers in Educational Institutions.*

This manual is intended to serve as a quick reference guide through which all University personnel may familiarize themselves with the policies and safety precautions necessary for the safe use of lasers. It is by no means a complete or all-encompassing source of laser safety. Other references on laser safety may be obtained through the Radiation Control and Radiological Services Department (phone number 392-1589).

1.2 Objectives

The objectives of the Laser Safety Program are to:

- Identify potential hazards to health and safety associated with lasers, laser systems and laser operations and to prescribe suitable means for the evaluation and control of these hazards.
- Investigate all laser accidents and institute immediate corrective action to prevent reoccurrence.
- Provide guidance for compliance with Federal and State regulations.
- Make specific reference to Federal and State regulations where appropriate.

1.3 Scope

This manual states the organizational responsibilities and procedural safety requirements of the UF Laser Safety Program. The appendices contain principles of laser radiation safety and other sources of useful information and reference materials.

1.4 Applicability

The recommendations and policies contained in this manual apply to all facilities involved in the use of lasers and laser systems under the jurisdiction of the University of Florida.

2. Applicable Regulations and Standards

The purpose of the Laser Safety Program is to comply with the regulations and standards for the safe use of lasers.

2.1 ANSI Standards

The principal laser safety guidelines in the United States are the consensus standards drafted by the American National Standards Institute (ANSI), Committee Z-136. These include the primary standard entitled, *ANSI Z-136.1, Safe User of Lasers*. This standard outlines the maximum permissible exposure (MPE) limits for laser users, defines laser hazard categories, and provides detailed information for determining the appropriate safety precautions for each laser hazard category. This standard also provides the basis for international regulation.

2.2 Federal Laser Performance Standard

The basic hazard classification concept was incorporated into federal government regulation issued by the Food and Drug Administration. This standard is found in the *Code of Federal Regulations, Title 21, Part 1040.10*. This regulation applies to manufacturers of laser products and requires them to minimize hazardous exposure by incorporating certain safety features into all laser products.

2.3 Florida Department of Health

The State of Florida has also incorporated laser safety regulations into the Florida Administrative Code (FAC). These regulations are found in FAC, Chapter 64E-4, *Control of Non-ionizing Radiation Hazards*. The State of Florida Laser Safety Program is administered through the Florida Department of Health (FL DOH). UF is subject to inspection and review by FL DOH personnel. If a FL DOH inspection demonstrates that UF is not in compliance with state regulations, the University may be fined, or in the case of a serious infraction, laser use will be suspend or revoked. In order to ensure compliance with state regulations for the control of laser radiation it is essential that all personnel who use lasers understand and follow the requirements of this manual. The Florida Administrative Code, Chapter 64E-4 can be found at the following website: http://www9.myflorida.com/Environment/radiation/regs/64e-4.pdf

3. Program Organization and Responsibilities

The effectiveness of the UF Laser Safety Program depends on the complete cooperation and commitment of all parties involved. Although the PI is ultimately responsible for laser safety, each party in the Laser Safety Program must assume individual responsibility for conducting procedures in the proper manner and according to established protocols.

3.1 Laser Safety Committee (LSC)

The LSC is responsible for laser protection oversight at UF. This is done through establishing policies, procedures and guidance for the control of laser hazards. The LSC is appointed by and is a subcommittee of the Radiation Control Committee. The LSC is responsible for the following:

3.1.1 Policy and Procedures
The LSC reviews internal policies and procedures to ensure compliance with applicable regulations and standards.

3.1.2 Laser Safety Issues
The LSC resolves conflicts and issues identified by the LSO, laser users or other parties.

3.1.3 Authority
The LSC and the LSO have the authority to suspend, restrict or terminate the operation of a laser or laser system that presents an imminent danger or excessive hazard.

3.2 Laser Safety Officer (LSO)
The LSO is designated by the LSC and has the authority to monitor and enforce the control of laser hazards at UF. The LSO is responsible for the day-to-day operation of the Laser Safety Program and for effective compliance with the State of Florida regulations. The LSO functions as a liaison between the LSC and the laser users, ensuring the safety standards of each laser laboratory are adequate. Duties of the LSO include, but are not limited to, the following:

3.2.1 Laser Hazard Evaluation
The LSO is responsible for hazard evaluation of laser work areas, including the establishment of Nominal Hazard Zones (NHZ).

3.2.2 Laser Classification
The LSO will classify lasers that have been modified or manufactured on campus. Lasers purchased commercially may retain their classification given by the manufacturer in compliance with the requirements of the Federal Laser Product Performance Standard provided that modifications that could alter the laser classification have not been made.

3.2.3 Control Measures
The LSO is responsible for assuring that the prescribed control measures are in effect and will recommend or approve control measures when primary measures are not practical or feasible. The LSO will periodically audit the functionality of the control measures in use.

3.2.4 Signs and Labels
The LSO will approve laser area warning signs, sign wording, and equipment labels.

3.2.5 Protective Equipment
The LSO will recommend or approve protective equipment such as eyewear, clothing, barriers and screens used for personnel safety. The LSO will ensure that protective equipment is periodically audited to ensure proper working order.

3.2.6 Records
The LSO will review and approve purchases of Class IIIb and IV lasers and will maintain a current inventory. Laser safety inspections, instrument calibrations and incident/accident reports will be maintained for a minimum of five years in accordance with FAC 64E-4.012.

3.2.7 Accidents and Injuries

Upon notification of a known or suspected laser-related accident, injury or near miss, the LSO will investigate the situation and will take appropriate action. The LSO shall perform a hazard evaluation of the laser facility to determine the cause of the accident, interview individuals involved in the accident and make certain that necessary controls have been implemented before laser operations resume.

3.2.8 Inspections

The LSO will establish a program to periodically audit the safety features of laser facilities and laser equipment to verify proper operation.

3.3 Department Chairperson

The Department Chairperson has overall responsibility for the implementation of the Laser Safety Program within his/her department. In the event that a PI has not been formally identified for a particular laser, the Departmental Chairperson may designate a PI, and inform the LSO of the designation. The LSO will coordinate efforts with the Department Chairperson and PIs to ensure that adequate safety measures are taken to meet the specific needs of their department.

3.4 Principal Investigator (PI)

The PI has overall responsibility for laser safety within his/her laboratory. In addition to laser safety, the PI is directly responsible for the acquisition, use, and maintenance for all lasers under their authority. PIs are responsible for the following:

3.4.1 Registration and Notification

A PI shall not permit operation of a new, modified or manufactured Class IIIb or IV laser under their authority without prior approval from the LSO. The PI must notify the LSO of any changes in operational status, such as location changes or modifications, to any laser equipment that may alter the laser classification. The PI is responsible for submitting the online Laser System Registration form http://webfiles.ehs.ufl.edu/lasersysreg.pdf to the LSO for all class IIIb and IV lasers within 10 days of receipt and prior to operation of the laser equipment. The LSO will in turn register the laser with the FL DOH within 30 days in accordance with FAC 64E-4.001.

3.4.2 Training

The PI shall ensure that all laser users (LUs) under his/her control, as well as incidental personnel, are properly trained with respect to the safe operation of lasers and are made aware of the associated hazards before they are authorized to operate any Class IIIb or IV laser or laser system http://webfiles.ehs.ufl.edu/laserstatetrain.pdf . PIs shall establish and maintain a list of current LUs that are approved to operate specific types of Class IIIb and IV lasers under their supervision and provide a copy of the list to the LSO.

3.4.3 Standard Operating Procedures (SOPs)

The PI is responsible for developing, maintaining, and updating SOPs for all Class IIIb and IV laser activities. The SOP must be posted within sight of the laser system and outline all operating, alignment and emergency procedures for that particular laser project. Refer to Appendix D for guidelines on creating SOPs.

3.4.4 Accidents and Injuries

The PI shall notify the LSO and the Department Chairperson of all known or suspected laser-related accidents and injuries. If necessary, the PI will assist in obtaining appropriate medical attention for any employee or student involved in a laser accident. The PI shall cooperate with the LSO and the Laser Safety Committee during the course of their investigation and implement recommendations to prevent recurrence. The PI shall submit a written incident report to the LSO within 10 business days.

3.4.5 Personal Protective Equipment

The PI will ensure that personal protective equipment (eye wear and protective clothing) is available, properly maintained and is worn when necessary. Refer to Section 7 for more information on personal protective equipment.

3.5 Laser User (LU)

Personnel who are authorized and trained to operate a Class IIIb or IV laser are classified as LUs http://webfiles.ehs.ufl.edu/laserstatetrain.pdf. All LUs must follow the general laser safety requirements outlined in this Manual and the SOP for the specific laser activity they are to perform. LUs are responsible for the following:

3.5.1 Authorization and Training

LUs shall not operate a Class IIIb or IV laser before they are given general laser safety training, including system specific training from the authorized PI. LUs must also submit a Statement of Training and Experience Form http://webfiles.ehs.ufl.edu/laserstatetrain.pdf.

3.5.2 Compliance

LUs shall ensure they are in compliance with all established safety rules, SOPs and other procedural requirements prescribed by the Department Chair, PI and LSO.

3.5.3 Accident Reporting

LUs must inform the PI and the LSO of any apparent safety problems associated with the use of the laser. All injuries and accidents involving lasers shall be reported to the PI and medical treatment, if needed, should be sought immediately. The LSO should be informed of the accident as soon as possible after the PI has been informed and medical treatment provided. Refer to Appendix H for more information on emergency procedures.

4. Hazard Classification

Laser hazard classification was developed to aid laser users in assessing the potential hazards of a laser system. ANSI Z-136.1-2007 outlines a simplified method that is used throughout the world. Lasers are divided into classes depending upon the power or energy of the beam, the wavelength of the emitted radiation and the exposure duration. Laser classification is based on the laser's potential for causing biological damage to the eye or skin and the potential for causing fires, either from direct exposure to the beam or from diffuse or specular reflections. Corresponding labels are affixed to the laser to positively identify the laser class. Laser users can then follow the necessary safety precautions that are specific to that class. Understanding the laser classification is a fundamental prerequisite for any discussion of laser safety.

Commercial lasers and laser systems manufactured after August 1976 are classified in accordance with the *Federal Laser Product Performance Standard* (*21 CFR Part 1040)*, and are appropriately labeled by the manufacturer. However, the classification may change whenever the laser or laser system is modified to accomplish a given task. If a laser is modified and alters the hazard class of the laser system, a new registration form http://webfiles.ehs.ufl.edu/lasersysreg.pdf is required.

Classification of lasers or laser systems shall be based on the maximum output available for the intended use. The classification of lasers or laser systems that are capable of emitting numerous wavelengths shall be based on the most hazardous possible operation. The evaluation of repetitively pulsed lasers or exposures, requires the use of certain correction factors. (For an explanation of these correction factors, refer to ANSI Z136.1-2007, Section 8.)

Any completely enclosed laser is classified as a Class I laser if emissions from the enclosure do not exceed the MPE values under any conditions inherent in the laser design. During service procedures, however, the appropriate control measures are temporarily required for the class of laser contained within the enclosure.

4.1 Class I

Class I lasers are considered to be incapable of producing damaging radiation during intended use and are therefore exempt from any special administrative and training requirements. This exemption applies only to emitted laser radiation hazards and not to other potential non-beam hazards. As a matter of good practice, unnecessary exposure to Class I laser light should be avoided.

4.2 Class II

Class II lasers can be used without restriction in the manner intended by the manufacturer and without special training or qualifications. Class II lasers emit accessible laser light in the visible region and are capable of creating eye damage through long term exposure. The human eye will blink within 0.25 seconds when exposed to Class II laser light. This natural blink reflex provides adequate protection. Class II lasers have power levels less than 1 milliwatt (mW), and are commonly used in alignment procedures.

4.3 Class IIIa

Class IIIa lasers normally would not produce injury if viewed only momentarily with the unaided eye, but can cause severe eye hazards when viewed through optical instruments such as telescopes, microscopes and binoculars. Class IIIa lasers are either visible or invisible and have power levels from 1 to 5 mW.

4.4 Class IIIb

Class IIIb lasers can cause injury upon direct viewing of the beam and specular reflections. The power output of Class IIIb lasers ranges from 5 to 500 mW for continuous wave (CW) lasers and less than 0.03 Joule (J) for pulsed lasers that have a pulse width of less than 0.25 seconds.

4.5 Class IV

Class IV lasers are always eye hazards. All beam types (direct beams, specular reflection, and diffuse reflections) can cause serious injury. In addition to eyes, Class IV lasers are capable of damaging skin and are a fire hazard. Class IV lasers operate at power levels greater than 500 mW (CW) or greater than 0.03 J (pulsed), and can be either visible or invisible. All requirements and control measures explained in this Manual apply to Class IV lasers and laser systems.

5. Control Measures

Control measures for Class IIIb and IV lasers are designed to reduce the possibility of eye and skin exposure to hazardous levels of radiation and to other hazards associated with laser systems.

Laser control measures are designed to ensure that skin and eye exposures do not exceed the applicable maximum permissible exposure (MPE) limit. The MPE defines the maximum safe exposure without hazardous effects or adverse biological changes in the eye or skin. The MPE depends on the wavelength and exposure duration.

An important consideration when implementing control measures is to distinguish between operation, maintenance and service. Control measures are based on normal operation of the laser system. When either maintenance or service is performed, it is often necessary to implement additional control measures.

Control measures are classified into two groups; engineering control measures and administrative and procedural control measures. Engineering control measures are incorporated into the laser system and the laser laboratory. Administrative and procedural controls are methods or instructions that specify rules and work practices to supplement engineering controls. When feasible, engineering controls are always the preferred method to provide for safety in a laser laboratory.

5.1 Engineering Controls

Engineering controls for Class IIIb and IV lasers are listed below. Unless otherwise approved by the LSO, all Class IIIb and IV lasers at UF must have the following design features:

5.1.1 Beam Enclosures

Beam enclosures should be used whenever practical. Use of enclosures will significantly reduce the need for other engineering or administrative controls.

5.1.2 Protective Housings

A protective housing shall be provided for each laser system.

5.1.3 Safety Interlocks

The protective housing shall be interlocked such that removal of the protective housing will prevent exposure to laser radiation greater than the MPE. Interlocks shall not be defeated or overridden during normal operation of the laser. For pulsed lasers, interlocks shall be designed to prevent unintentional firing of the laser. An example of this would be by dumping the stored energy into a dummy load. For continuous wave (CW) lasers, the interlocks shall turn off the power supply or interrupt the beam (for example, by means of shutters). Service access panels that allow access to the beam during normal operation shall either be interlocked or require a special tool for removal and have an appropriate warning label. All commercially manufactured lasers come equipped with such interlocks and labels.

Class IIIb lasers should be provided with a remote interlock connector. Class IV lasers shall have a remote interlock connector. The remote interlock connector will decrease the laser beam power to a safe level when activated.

5.1.4 Controlled Access

A Class IIIb laser should have a key controlled master switch. A Class IV laser must have a key controlled master switch. The authority for key access is vested in the PI. All lasers shall be disabled by removing the key when it is not in use.

5.1.5 Activation Warning Systems

Inside the laser control area, an alarm (for example, an audible sound), a warning light (visible through protective eyewear), or a verbal "countdown" command must be used with Class IIIb and IV lasers or laser systems during activation or startup. Distinctive and clearly identifiable sounds that arise from auxiliary equipment (such as a vacuum pump or fan) that are uniquely associated with the emission of laser radiation are acceptable as an audible warning. A warning light outside the control area must be used with Class IIIb and IV lasers.

5.1.6 Emission Delay

For operation of Class IIIb or IV lasers, the warning system must be activated at a sufficient time prior to emission of laser radiation to allow appropriate action to be taken to avoid exposure to the laser.

5.1.7 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.

5.1.8 Window and Door Barriers

All windows and doorways must be either controlled or restricted in such a manner as to prevent escape of potentially hazardous laser radiation. Typically, laser safety curtains at doorways and window coverings are required for Class IIIb and IV lasers that have open beam configurations.

5.1.9 Controlled Areas

A controlled area shall be designated for all open beam paths. The controlled area is defined as the area where laser radiation is in excess of the MPE. Appropriate control measures must be implemented in laser controlled areas.

5.1.10 Beam Stops

Class IIIb lasers should have a permanent beam stop in place. Class IV lasers shall have a permanent beam stop in place. Most laser heads come equipped with a permanently attached beam stop or attenuator that will lower the beam power to MPE at the aperture from the housing. Additional beam stops may be needed in the beam path to keep the useful beam confined to the experimental area.

5.1.11 Remote Operations

Whenever possible, Class IV lasers should be operated and fired from a remote location.

5.2 Administrative and Procedural Controls

Administrative and procedural controls are methods that specify rules and work practices that implement or supplement engineering controls. The specified engineering control measures for Class IIIb and IV laser systems may be replaced by procedural, administrative or other alternate engineering controls that will provide equivalent protection.

5.2.1 Standard Operating Procedures (SOPs)

A written SOP is required for each Class IIIb or IV laser system, so that all LUs and service personnel can reference it. The written SOP shall be maintained in a visible location near the laser system. Refer to Appendix D for guidelines on creating SOPs.

5.2.2 Output Emission Limitations

The minimum laser radiant energy or laser power level required for the application shall be used.

5.2.3 Education and Training

All LUs that operate Class IIIb or IV lasers shall have the appropriate training in laser safety that is commensurate with the level of potential hazard. Refer to Section 9 for the laser safety training requirements. http://webfiles.ehs.ufl.edu/laserstatetrain.pdf

5.2.4 Authorized Personnel

Class IIIb and IV lasers shall be operated, maintained and serviced only by authorized personnel. The PI of the laser system is responsible for authorizing LU's and maintaining a listing of current LU's.

5.2.5 Alignment Procedures

Alignment of laser optical systems must be performed in such a manner that the primary beam, or a specular or diffuse reflection of a beam, does not expose the eye to dangerous levels of laser radiation. The alignment procedures shall be outlined in the SOP. The use of low power visible lasers (Class I or II) for path simulation of higher power visible or invisible lasers is recommended. Refer to Appendix G for beam alignment safety guidelines.

5.2.6 Personal Protective Equipment

Personal protective equipment (such as eyewear, barriers, clothing and gloves) may be required to eliminate potential exposure in excess of the applicable MPE when other control measures are inadequate. Refer to Section 10 for more information on personal protective equipment.

5.2.7 Service Personnel

During periods of service or maintenance, control measures appropriate to the class of the embedded laser shall be implemented when the beam enclosures are removed and access to the beam is possible. The PI shall require that service personnel shall have the education and training commensurate with the class of the laser or laser system contained within 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. A notice sign shall be posted outside the temporary laser controlled area to warn of the potential hazards.

5.2.8 Visitors and Spectators

Visitors and spectators shall not be permitted within a laser controlled area during operation of a Class IIIb or IV laser or laser system unless:

A. Specific protective measures for visitors and spectators have been approved by the LSO.
B. The degree of hazard and avoidance procedure has been explained to the spectators.
C. Appropriate protective measures have been taken.

5.3 Converting to a Class I Laser

Any laser or laser system can be converted to a Class I enclosed laser by incorporating all of the following controls (5.3.1 to 5.3.5) in the laser system design. These controls will effectively enclose the laser, thus preventing personnel from contact with any laser radiation while permitting unrestricted access into the area.

5.3.1 Protective Housing

A. House the laser system within a protective enclosure to prevent escape of laser radiation above the MPE.
B. The protective housing must prevent personnel access to the laser system during normal operations.
C. Personnel entering the enclosure to perform maintenance or adjustment tasks must be made aware of the higher risks and comply with the control measures for the higher risk laser class.

5.3.2 Safety Interlocks

A. Install safety interlocks wherever the protective enclosure can be opened, removed or displaced.
B. When activated, these interlocks must prevent a beam with a radiant energy above the MPE from leaving the laser or laser system.
C. Service adjustments or maintenance work performed on the laser system must not render the interlocks inoperative or cause exposure levels outside the enclosure to exceed the MPE, unless the work is performed in a laser controlled area with limited access and appropriate safeguards, supervision and control.

5.3.3 Fail-Safe Design

The protective enclosure and the laser system must be designed and fabricated so that if a failure occurs, the system will continue to meet the requirements for an enclosed laser.

5.3.4 Attenuated Viewing Windows

Use viewing windows containing a suitable filter material that will attenuate the transmitted laser radiation to levels below the MPE under all conditions of operation.

5.3.5 Warning Signs and Labels

A. Label the enclosure with “Caution- Enclosed Laser” signs.
B. Attach a label directly to the laser that will display the laser classification in the absence of the enclosure. Make sure that the warning label is immediately visible before enclosure is opened.

6. Controlled Areas

If the beam of a Class IIIb or IV laser is completely enclosed, the laser will meet the standard of a Class I laser (all areas below MPE), and no further restrictions will be required. If the beam path is not fully enclosed, then a Nominal Hazard Zone (NHZ) needs to be accessed and a controlled area established.

6.1 Class IIIb Controlled Areas

Class IIIb lasers with an open beam configuration may only be operated in designated laser controlled areas. The purpose of a laser controlled area is to confine laser hazards to well-defined spaces that are under the control of the LU. This is an attempt to prevent injury to those visiting and working near the laser controlled area. All personnel who require entry into a Class IIIb laser controlled area shall be appropriately trained. They are required to follow all applicable administrative and operational controls. The area designated as a laser controlled area for Class IIIb lasers shall have the following adequate control measures:

6.1.1 Posting

The area must be posted with appropriate warning signs that indicate the nature of the hazard and conform to the ANSI Z136.1 guidelines. Such signs must be posted at all entrances to the laser controlled area during the time a procedure utilizing the active beam is in progress, and shall be removed when the procedure is completed.

6.1.2 Authorization

Only personnel who have been authorized by the responsible PI may operate the laser. Personnel may be authorized upon compliance with the requirements identified in Section 9 (Training). The PI may stipulate additional authorization requirements.

6.1.3 Beam Stops

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

6.1.4 Eye Protection

Lasers should be mounted so that the beam path is not at eye level for standing or seated personnel. Laser protective eyewear of adequate optical density and threshold limit for the beams under manipulation must be provided and worn at any point where laser exposure could exceed the MPE. Procedures and practices must ensure that optical systems and power levels are not adjusted upstream during critical open beam operations (during beam alignment). It is the responsibility of the PI to obtain and provide appropriate laser protective eyewear. Refer to Section 7.1 (Protective Eyewear) for more information.

6.1.5 Laser Light Containment

Laser light levels in excess of the MPE must not pass the boundaries of a laser controlled area. All windows, doorways, open portals, and other openings through which light might escape from a laser controlled area must be covered or shielded in such a manner as to preclude the transmission of laser light.

6.2 Class IV Controlled Areas

Only appropriately trained personnel may enter a Class IV laser controlled area during the time a procedure utilizing the active beam is in progress. All personnel within the laser controlled area must be provided with appropriate protective equipment and are required to follow all applicable administrative controls. <u>The area designated as a laser controlled area for Class IV lasers shall meet the requirements of a Class IIIb control area (Section 6.1) and the following additional control measures:</u>

6.2.1 Rapid Egress and Emergency Access

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

6.2.2 Laser Activation Warning Systems

Procedural area or entryway controls must be in place to prevent inadvertent entry into a laser controlled area, or inadvertent exposure to the active laser beam. These measures shall include a visible sign and/or audible warning sign or signal at the entrance to the laser controlled area to indicate when the laser is energized and operating.

6.2.3 Limited Access

Class IV lasers must have a master switch that is controlled by a key or code. Access to the key or code must only be provided to authorized and trained LUs.

6.2.4 Deactivation Switch

For emergency conditions, a control disconnect switch, panic button or equivalent device must be available for deactivating the laser. The switch shall be clearly marked and readily accessible to all laser personnel. When activated, this button will power down the laser or will reduce the output power of the laser to levels below MPE. The following are acceptable examples of "panic buttons".

- Key switch to deactivate the laser
- Master switch on power source to turn off power
- Red mushroom-type button on control panel or other readily accessible location within the area

6.2.5 Entryway Controls

Never direct a beam toward an entryway. Locking entryway doors as a means of access control is not acceptable because it is contrary to the principle of permitting rapid egress or emergency access, as mentioned in Section 6.2.1. Entry to rooms containing Class IV lasers and laser systems must be interlocked with the laser to prevent unexpected entry of personnel while the laser is in operation. The PI shall implement one of the following three mechanisms to protect personnel:

A. Non-defeatable entryway.
   Non-defeatable entryway controls (safety latches and entryway or area interlocks such as electrical switches, pressure sensitive floor mats, or motion detectors) shall be used to deactivate the laser or reduce the output levels to less than MPE should unauthorized entry into the laser area occur.

B. Defeatable entryway

Defeatable entryway controls (safety latches and entryway or area interlocks) shall be used if the controls in the previous paragraph adversely affect the intended use of the laser or laser system. If there is no laser light hazard at the entry point, the interlock may be bypassed to allow access to authorized personnel provided they have been adequately trained and provided with adequate personal protective equipment.

C. Procedural entryway safety controls

Where the above entryway safety controls are not practical or are inappropriate, the following shall apply:

- All authorized personnel shall be trained and proper personal protective equipment shall be available upon entry.
- A secondary barrier (laser curtain, wall or partition) shall be used to block the laser radiation at the entryway. This secondary barrier will intercept a beam or scatter so that a person entering the room cannot be exposed above MPE limits.
- At the entryway there should be a visible or audible indication that the laser is in operation. Existing installed laser-warning signs or flashing lights may satisfy this requirement.

6.3 Temporary Controlled Areas

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

7. Personal Protective Equipment (PPE)

Enclosure of the laser equipment or beam path is the preferred method of control. However, it may be necessary to use PPE when other control measures do not provide adequate means to prevent access to direct or reflected beams at levels above the MPE.

7.1 Protective Eyewear

Even if you are wearing protective eyewear, never look directly into any laser beam. Always use engineering controls (example, enclosing the entire beam path) whenever possible to eliminate the need for laser protective eyewear. Wear approved laser protective eyewear specifically designed for the type of laser to be used whenever working in a class IIIb or IV laser controlled area. Even when the accessible radiation levels are considered safe, it is good practice for LUs to wear eye protection at all times when operating lasers.

Laser eyewear should not be subjected to high-intensity beams. High average intensity and high peak intensity beams can physically damage the lenses, resulting in loss of eye protection.

Protective eyewear devices shall meet the following requirements:

A. Provide a comfortable fit all around the area of the eye
B. Provide adequate visibility (luminous transmission)
C. Be in proper condition to ensure the optical filters and holder provide the required optical density (OD) or greater at the desired wavelengths and retain all protective properties during its use
D. All protective eyewear must be clearly labeled with the OD and wavelength for which the protection is afforded

7.1.1 Care and Maintenance

The proper care and maintenance is essential to ensure that the equipment remains in good condition. Eyewear can represent a significant investment and will last longer and give better service if it is kept clean and properly stored. Eyewear should be stored in a clean and sanitary condition in an area away from dust, dirt and other contaminants. If the eyewear needs to be cleaned, follow the recommendations of the manufacturer. Generally, a mild soap solution is fine for polycarbonate eyewear. Special care may be needed for coated or laminated eyewear.

7.1.2 Inspection

Eyewear inspections shall be conducted periodically. Inspect the filter material for pitting or cracking and inspect the goggle frame for mechanical integrity and light leaks. Straps should be inspected as well and replaced if they have been stretched or are frayed.

7.2 Skin Protection

When there is a possibility of exposure to laser radiation greater than the MPE for skin, LUs are required to use protective gloves, clothing, and shields.

7.3 Other Personal Protective Equipment

As a temporary control measure, respirators and other PPE shall be required whenever engineering controls are unable to provide protection from laser generated air contaminants (LGAC) and other hazards.

8. Warning Signs and Labels

Areas where Class IIIb and IV lasers are used must be secured against persons accidentally being exposed to beams and be must provide a proper warning indication. It is the responsibility of the laboratory to purchase and maintain the proper signage.

8.1 Laser Warning Signs

A warning sign must be posted near the entrance to any area or laboratory that contains a Class IIIb or IV laser or laser system. The sign and the wording must be commensurate with the highest-class laser contained within the area or laboratory. Laser controlled areas must be indicated with the appropriate warning signs. The term “proper warning indication” generally means that an illuminated warning sign is outside of the area.
The light should be flashing and lit only when the laser is on. When a Class IIIb or IV laser is left on and all personnel leave the room, the door shall always be locked. Lights

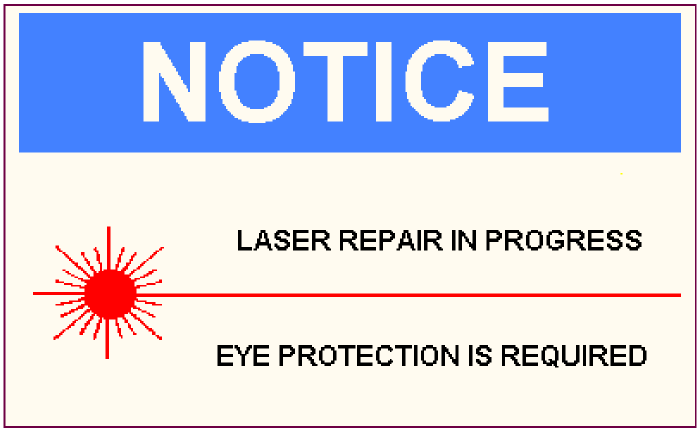
alone do not suffice as adequate warning unless the light is clearly posted as to its meaning. A well-designed warning light should have redundancy (two lights), a "safe" light when the laser is off, and two lamps, wired in parallel, in the "laser on" signal. Non-English speaking personnel who may need to enter areas where lasers are used must be given appropriate instruction as to the meaning of the warning signs and labels.

In accordance with ANSI Z136.1-2007, an area which contains a Class IIIa laser or laser system shall be posted with an appropriate caution sign. (See example below)

In accordance with ANSI Z136.1-2007, an area which contains a Class IIIb or IV laser or laser system shall be posted with an appropriate caution sign. (See example below)

8.2 Temporary Laser Control Area Signs

Post a notice sign outside any area or laboratory designated as a temporary laser control area. Temporary laser control areas are required when accessible laser radiation exceeds the acceptable MPE. Use wording that describes the required precautionary procedures. (See example below)



8.3 Equipment Labels

All lasers, except Class I, are required to contain warning labels in accordance with the Federal Laser Product Performance Standard. Labels shall contain the laser sunburst logo and the appropriate cautionary statement. Manufacturers place these labels on laser equipment and it is important that they are not removed. Modified or constructed laser systems at UF shall be provided with labels that are clearly visible during operation and be affixed to the laser housing or control panel. Labels must be placed on both the laser housing and the control panel when they are separated by more than two meters. Ancillary hazards shall also be appropriately labeled.

9. Training http://webfiles.ehs.ufl.edu/laserstatetrain.pdf

Laser users who operate a Class IIIb or IV laser or laser system must:

A. Read this UF Laser Safety Manual
B. Read all relevant SOP's
C. Read all manufacturer supplied safety instructions for relevant laser systems
D. Receive PI training on the specific laser equipment to be used
E. View the Fundamentals of Laser Safety presentation online

The Fundamentals of Laser Safety presentation includes the following:

- Fundamentals of laser operation
- Bio effects of laser radiation on the eye and skin
- Relations of specular and diffuse reflections
- Non-beam hazards
- Laser and laser system classifications

- Control measures
- Protective equipment
- How to handle and report accidents
- Overall management and employee responsibilities

Because of the hazard of electrocution, it is recommended that laser lab personnel take courses in cardiopulmonary resuscitation (CPR) and in the proper rescue techniques to follow in the event of electrocution. This type of training is especially important where lab-built lasers and power supplies are in use, or where lab personnel modify, repair or maintain laser systems. All laser service personnel, research personnel and their assistants working with high voltages should be trained in CPR.

10. Eye and Skin Hazards

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

10.1 Retina

Retinal injuries can occur instantaneously with Class IIIb and IV lasers and the damage may be irreparable. Laser light in the visible (400 nm - 700 nm) and near infrared (700 nm - 1400 nm) regions that enters the eye is focused on the retina. This can result in the following types of retinal damage:

10.1.1 Thermal Burn

Normal focusing by the eye results in an irradiance amplification of approximately 100,000. Therefore, a 1 mW/cm^2 beam entering the eye will result in a 100 W/cm^2 exposure at the retina. The most likely effect of intercepting a laser beam of sufficient irradiance with the eye is a thermal burn that destroys the retinal tissue. For added protection, the MPE values are set well below the threshold level for thermal burns.

10.1.2 Acoustic Damage

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

10.1.3 Photochemical Damage

Laser light with wavelengths less than 400 nm does not focus on the retina. The light can be laser output, ultraviolet (UV) from the pump light, or blue light from a target interaction. The effect is cumulative over a period of days. The ANSI standard is designed to account only for exposure to the laser light. If UV light from a pump light or blue light from a target interaction is emitted, additional precautions must be taken.

10.2 Cornea

The Cornea and the conjunctiva tissue surrounding the eye can also be damaged by exposure to laser light. Damage to the cornea and conjunctiva tissue usually occurs at greater power levels. Therefore, these issues only become a concern for those wavelengths that do not penetrate through to the retina, such as UV (< 315 nm) and far infrared (> 1,400 nm) laser light. This includes UV with wavelengths from 200 to 215 nm and infrared with wavelengths greater than 1400 nm. When UV or far infrared laser light enters the eye, much of the light is absorbed at the cornea and in the lens. Depending on the level of exposure, this may cause immediate thermal burns or the development of cataracts over a period of years.

10.3 Skin

Since the skin is the largest organ of the body, it has the greatest risk of coming into contact with a laser beam. We almost always speak in terms of arms, hands, or head when discussing skin hazards. These three body parts are most likely to accidentally move into the beam during alignment or other operations requiring close proximity to the beam. If the beam is of sufficient energy, the skin can experience thermal burns, acoustic lesions, and photochemical changes from laser exposure. These effects are almost entirely independent of the coherent nature of the laser light but are aggravated by the high power density of lasers. Also, the wavelength of the beam determines the layer of the skin that will be affected. Personnel should observe common-sense safety practices when working with lasers that have the potential to cause burning of the skin, such as wearing long-sleeved shirts and gloves of fire-resistant or fire-proof material.

Summary of Basic Biological Effects of Light

Spectral Domain	Eye Effects	Skin Effects
Far UV C (100 - 280 nm)	Photokeratitis	Erythyma (sunburn), skin cancer
Mid UV B (280 - 315 nm)	Photokeratitis	Accelerated skin aging, increased pigmentation
Near UV A (315 - 400 nm)	Photochemical UV cataract	Pigment darkening
Visible (400 - 700 nm)	Photochemical and thermal retinal injury	Photosensitive reactions
Near IR A (780 – 1,400 nm)	Cataract, retinal burns	Skin burn
Mid IR B (1,400 - 3,000 nm)	Corneal burn, aqueous flare, IR Cataract	None
Far IR C (3,000 nm – 1 mm)	Corneal burn only	None

11. Non-Beam Hazards

While beam hazards are the most prominent laser hazards, other hazards pose equal or possibly greater risk of injury or death. These hazards must be addressed in the SOP where applicable.

11.1 Electrical

Accidental electrocution while working with high voltage sections of laser systems can be lethal. Electrical hazards are not normally present during laser operation, but great care should always be exercised during installation, maintenance, or service. Laser users must ensure that high voltage electrodes are not exposed and that capacitors are correctly discharged. Some laser systems incorporate the use of a water-cooling system. The combination of water and electrical hazards greatly increases the risk of serious injury. Systems that permit access to components at lethal levels must be interlocked. Even though a system may be interlocked, electrical components often become exposed or accessible during maintenance and alignment procedures. This has caused numerous serious and some fatal shocks.

11.1.1 Electrical Safety Guidelines

- No one should work on lasers or power supplies unless qualified and approved to perform the specific tasks
- Do not wear rings, watches or other metallic apparel when working with electrical equipment
- Do not handle electrical equipment when hands or feet are wet or when standing on a wet surface
- When working with high voltages, regard all floors as conductive and grounded
- Be familiar with electrocution rescue procedures and emergency first aid
- Prior to working with electrical equipment, de-energize the power source and "lock-out tag-out" the disconnect switch
- Check that each capacitor is discharged, shorted and grounded prior to working in the area of the capacitors
- When possible, use shock preventing shields, power supply enclosures and shielded leads in all experimental or temporary high voltage circuits

11.1.2 Common Electrical Hazards

- Uncovered electrical terminals
- Improperly insulated electrical terminals
- Hidden power-up warning lights
- Lack of personnel training in CPR
- Buddy system not being practiced during maintenance and alignment work
- Improperly grounded laser equipment
- Excessive wires and cables on the floor that create trip hazards

11.2 Chemical

In some laser systems, dyes are used as the optically active medium. Laser dyes are often toxic, carcinogenic, and/or corrosive chemicals that are dissolved in flammable solvents.

This creates the potential for personal chemical exposures, fires and hazardous spills. Frequently, the most hazardous aspect of a laser operation is the mixing of chemicals that make up the laser dye. A material safety data sheet (MSDS) should accompany any chemical handled in the laser laboratory. The MSDS will supply appropriate information pertaining to the toxicity, personal protective equipment needed and storage requirements of hazardous chemicals.

11.3 Ionizing Radiation

X-rays may be produced from two main sources: high voltage vacuum tubes of laser power supplies, such as rectifiers and thyratrons, and electric discharge lasers. Any power supply that requires more than 15 kilovolts may produce enough x-rays to be a health concern.

11.4 UV and Visible Radiation

Laser discharge tubes and pump lamps may generate ultraviolet and visible radiation. The levels produced may exceed safe limits thus causing skin and eye damage.

11.5 Fire

Class IV lasers represent a fire hazard. Depending on the construction materials used, beam enclosures, barriers, beam stops and wiring are all potentially flammable if exposed to high beam irradiance for more than a few seconds.

11.6 Explosion

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

11.7 Compressed and Toxic Gases

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

11.8 Cryogenic Fluids

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

11.9 Laser Generated Air Contaminants (LGAC)

Air contaminants may be generated when certain Class IIIb and Class IV laser beams interact with matter. When the target irradiance reaches a given threshold of approximately 10^7 W/cm^2, target materials (including plastics, composites, metals and tissues) may liberate toxic and noxious airborne contaminants. Hazardous fumes or vapors need to be captured or exhausted.

11.10 Plasma Radiation

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

12. Special Requirements for IR, UV and Optical Fibers

12.1 Infrared Lasers

Since infrared (IR) and ultraviolet (UV) wavelengths are normally invisible to human eyes, they possess a higher hazard potential than visible light lasers. Therefore, the use of laser eyewear that will protect against the worst-case exposure is required at all times. The collimated beam from an IR laser should be terminated by a highly absorbent backstop wherever practicable. Many surfaces which appear dull visually can act as reflectors of IR.

12.2 Ultraviolet Lasers

Exposure to UV should be minimized by using shield material that attenuates the radiation to levels below the appropriate MPE for the specific wavelength. UV radiation causes photochemical reaction in the eyes and the skin, as well as in materials that are found in laboratories. The use of long-sleeved coats, gloves, and face protectors is recommended.

12.3 Optical Fibers

Laser transmission systems that employ optical cables shall be considered enclosed systems with the optical cable forming part of the protective housing. Disconnection of a connector resulting in access to laser radiation in excess of the MPE shall take place in a laser controlled area. A special tool shall be required to disconnect a connector for service and maintenance when the connector is not within a secured enclosure. All connectors shall bear an appropriate warning label or tag. Fibers used to deliver high-powered laser light have the potential of burning through standard fiber sheathing if the fiber is broken.

13. Laser Acquisitions, Transfers and Disposal

13.1 Acquisitions

PIs are required to notify the LSO of any decision to purchase, fabricate or otherwise acquire a Class IIIb or IV 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.

13.2 On-Campus Transfers

The on-campus transfer of a Class IIIb or IV laser to a person who does not have appropriate training, does not understand the associated hazards of the laser or does not have proper protective equipment could result in injuries and is prohibited. The transferor and transferee shall both contact the LSO to initiate the transfer.

13.3 Off-Campus Transfers or Disposal

Contact the LSO before transferring or disposing of Class IIIb and IV lasers. Sales or disposal of lasers off-campus requires that certain safety steps be taken. The bill of sale shall warn persons that the device may emit hazardous laser light, which could cause injuries, and that the University neither offers nor implies any warranty as to the safety of its use. The bill of sale shall bear the buyer's signed acknowledgement and include a "hold-harmless" clause. 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 EH&S prior to their disposal.

14. Laser Accidents and Incidents

No matter how minimal, all laser accidents at UF require an incident report.
http://webfiles.ehs.ufl.edu/IIIRpt.pdf

14.1 Emergency Procedures

If individuals suspect they have received a laser exposure, they shall seek immediate medical attention. Every incident involving an alleged or suspected laser radiation overexposure will be investigated and documented. Refer to Appendix H (emergency procedures) for more information.

14.2 Emergency & Radiation Control Services

Radiation Control provides 24 hour-a-day, 365 days-per-year response to laser incidents at UF. Reports shall be received through phone number (352) 392-7359 during normal business hours (8:00 AM to 5:00 PM M-F, excluding UF holidays). If a laser incident occurs at any other time, the reporter should contact the University Police Department at (352) 392-1111 to inform them that a laser accident has occurred. UF authorities will then notify the LSO or other EH&S personnel who will respond to the situation.

14.3 Major Causes of Laser Accidents

- Eye exposure during alignment
- Misaligned optics and upwardly directed beams
- Available eye protection not used
- Equipment malfunction
- Improper methods of handling high-voltage circuits
- Intentional exposure of unprotected personnel
- Operators unfamiliar with laser equipment
- Lack of protection from ancillary hazards
- Improper restoration of equipment following service
- Eyewear worn not appropriate for laser in use
- Failure to follow SOPs

15. References

American Conference of Governmental Industrial Hygienists, ACGIH-1990, *A Guide for Control of Laser Hazards*

American National Standards Institute, Standard Z136.1 – 2007, *American National Standard for the Safe Use of Lasers*

American National Standards Institute, Standard Z136.5 – 2009, *American National Standard for the Safe Use of Lasers in Educational Institutions*

Federal Laser Products Performance Standard (FDA), 21 CFR 1040, *Standards for Light-Emitting Products*

State of Florida Department of Health, Florida Administrative Code 64E-4, *Control of Non-Ionizing Radiation Hazards*

Appendix A: Glossary of Terms

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

American National Standards Institute (ANSI). (ANSI Z136.1-2007) National standards for safe use of lasers.

aperture. Any opening in a protective housing through which radiation is emitted, thereby allowing human access to such radiation.

argon. A gas used as a laser medium. It emits a blue-green light, primarily in 448 and 515 nm.

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 that may be parallel, divergent, or convergent.

beam diameter. The distance between diametrically opposed points in the cross sections of a circular beam where the intensity is reduced by a factor or e^{-1} (0.368) of the peak level (for safety standards). The value is normally chosen at e^{-2} (0.135) of the peak level for manufacturing specifications.

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

blink reflex. See aversion response.

collateral radiation. Any electronic product radiation, except laser radiation, emitted by a laser as a result 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. (ANSI Z136.1-2007)

controlled area. Any area where the occupancy and activity of those within is subject to control and supervision for the purpose of 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.

continuous wave (CW). Constant, steady-state delivery of laser power.

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

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.

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

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

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

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).

integrated radiance. Radiant energy per unit area of a radiating surface per unit solid angle of emission, expressed in joules per square centimeter per steradian ($J\ cm^{-2}\ sr^{-1}$).

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

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

joule (J). A unit of energy: 1 Joule = 1 watt second.

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

laser controlled area. See controlled area.

laser medium. Material used to emit the laser light and for which the laser is named.

laser protective device. Any device used to reduce or prevent exposure of personnel to laser radiation. Such devices may include protective eyewear, garments, engineering controls, and operational controls.

laser radiation. All electromagnetic radiation emitted by a laser product of frequencies between 3 x 1011 and 1.67 x 1015 hertz or wavelengths in air between 10-3 and 1.8 x 10-7 meter within the spectral range specified in the definition of "laser" in 64E-4.002 that is produced as a result of controlled stimulated emission or that is detectable with radiation so produced through the aperture stop having a diameter, a solid angle of acceptance, and collimating optics as specified in 64E-4.010 of these rules.

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 radiation protection program for a particular 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 = log10.

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 in excess of 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.

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

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

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 that element, expressed in joules per square centimeter (J cm-2).

radiant power. 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 in excess of 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.

specular reflections. A mirror-like reflection.

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.

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

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

watt (W). The unit of power or radiant flux; 1 watt = 1 joule per second (J sec-1).

Appendix B: Guidelines for Creating SOPs

These guidelines are intended to assist laser users in preparing standard operating procedures (SOPs) for laser laboratories. The information should be used as a guide to allow you to develop a SOP that is specific to your laser system. Try to keep the SOP brief to increase the probability of use.

A. INTRODUCTION

Describe the laser location, laser type, manufacturer, model, serial number, classification, and technical specifications (wavelength, power/energy, pulse length, repetition rate, beam diameter and divergence, etc.) Briefly describe the purpose of the operation.

B. HAZARDS

Identify and analyze the specific hazards associated with this laser operation; include beam hazards as well as any non-beam hazards (electrical, hazardous chemicals, high pressure, laser generated air contaminates, etc.).

C. HAZARD CONTROLS

Describe the means used to mitigate each of the hazards listed above in the HAZARDS section.

D. TRAINING REQUIRMENTS

Describe the training requirements for the laser users and incidental personnel. LUs shall have training in general laser safety as well as hands-on training with the specific laser system. Incidental personnel shall be made aware of the specific hazards associated with the laser operation in their area.
http://webfiles.ehs.ufl.edu/laserstatetrain.pdf

E. OPERATING PROCEDURES

List the sequential events that describe the complete operation, including when to implement the hazard control measures. The procedures shall be written for the benefit of the laser user who must read and understand them to perform the operation safely.

F. ALIGNMENT PROCEDURES

List the steps used to perform beam alignment on the laser or laser system. Special attention should be given to control measures that can reduce the potential for exposure. Examples for control measures are shutting down the main laser and using an alignment laser, reducing the power/energy of the laser, use of beam dumps for the primary beam, etc.

NOTE: Most laser accidents from the beam occur during the alignment operation.

G. EMERGENCY PROCEDURES

Describe your planned actions in case of an accident, injury, fire, or other emergency. Include names and phone numbers of those that must be contacted in case of an emergency. (Your PI, UF LSO 392-7359, and UPD at 392-1111)

H. RESPONSIBILITY AND REGISTRATION

State the name, title, office location and phone number of the principal investigator responsible for ensuring that the operation is carried out in accordance with the SOP.

All laser systems must be registered with the LSO using the online registration form.

Appendix C: General Laser Safety Precautions by Class

Class I lasers

- No laser-specific safety precautions are necessary

Class II lasers

- Do not allow anyone to stare continuously into the beam
- Do not point the laser into an individual's eyes

Class III lasers

- Do not aim the laser at an individual's eyes
- Permit only properly trained and authorized personnel to operate the laser
- Enclose as much of the beam path as possible
- Place beam stops at the end of the useful beam path
- Restrict the access of unauthorized personnel and control spectators
- Operate the laser only in a controlled area, unless the beam path is totally enclosed
- Employ a warning light or buzzer to indicate when the laser is in operation
- Locate the plane of the laser beam and associated optical devices well above or below the eye level of observers sitting or standing positions
- Firmly mount the laser to ensure the beam does not stray from the intended path
- Use proper eye protection if eye exposure to the direct beam or a specular reflection is possible
- Do not view the beam or its specular reflection with collecting optics without sufficient eye protection.
- Remove all unnecessary reflective surfaces from the area of the beam path

Class IV lasers (in addition to Class III precautions)

- Operate within a laser controlled area or secured enclosure only; do not allow access to any unauthorized personnel
- Permit only properly trained and authorized personnel to operate the laser
- Enclose the entire beam path if possible
- Provide and ensure use of proper eye protection for everyone within the laser controlled area
- Use appropriate shielding between personnel and any beam having sufficient irradiance to pose a skin or fire hazard
- Use remote viewing methods where feasible (video monitoring) to accomplish any necessary viewing of the beam
- Construct beam stops of fire resistant material that create a diffuse reflection

Appendix D: Table of Control Measures

This summary is taken from the ANSI Z.136.1-2007. Reference numbers in parentheses refer to sections in the standard.

Control Measures						
Classification	I	IIa	II	IIIa	IIIb	IV
Engineering Controls						
Protective Housing (4.3.1)	X	X	X	X	X	X
Without Protective Housing (4.3.1.1)	LSO shall establish alternate controls					
Interlocks on Protective Housing (4.3.2)	%	%	%	%	X	X
Service Access Panel (4.3.3)	%	%	%	%	X	X
Key Control (4.3.4)	--	--	--	--	*	X
Viewing Portals (4.3.5.1)	--	--	MPE	MPE	MPE	MPE
Collecting Optics (4.3.5.2)	MPE	--	MPE	MPE	MPE	MPE
Totally Open Beam Path (4.3.6.1)	--	--	--	--	X,NHZ	X,NHZ
Limited Open Beam Path (4.3.6.2)	--	--	--	--	X,NHZ	X,NHZ
Enclosed Beam Path (4.3.6.3)	None is required if 4.3.1 and 4.3.2 are fulfilled					
Remote Interlock Connector (4.3.7)	--	--	--	--	*	X
Beam Stop or Attenuator (4.3.8)	--	--	--	--	*	X
Activation Warning Systems (4.3.9)	--	--	--	--	*	X
Emission Delay (4.3.9)	--	--	--	--	--	X
Indoor Laser Controlled Area (4.3.10)	--	--	--	--	X,NHZ	X,NHZ
Class 3b Laser Controlled Area (4.3.10.1)	--	--	--	--	X	--
Class 4 Laser Controlled Area (4.3.10.2)	--	--	--	--	--	X
Laser Outdoor Controls (4.3.11.1)	--	--	--	--	X,NHZ	X,NHZ
Laser in Navigable Airspace (4.3.11.2)	--	--	--	*	*	*
Temporary Laser Controlled Area (4.3.12)	%,MPE	%,MPE	%,MPE	%,MPE	--	--
Remote Firing & Monitoring (4.3.13)	--	--	--	--	--	--
Labels (4.3.14 and 4.7)	X	X	X	X	X	X
Area Posting (4.3.15)	--	--	--	*	X,NHZ	X,NHZ

Administrative & Procedure Controls						
SOPs (4.4.1)	--	--	--	--	*	X
Output Emission Limitations (4.4.2)	--	--	--	LSO determination		
Education and Training (4.4.3)	--	--	*	*	X	X
Authorized Personnel (4.4.4)	--	--	--	--	X	X
Alignment Procedures (4.4.5)	--	--	X	X	X	X
Protective Equipment (4.4.6)	--	--	--	--	*	X
Spectator (4.4.7)	--	--	--	--	*	X
Service Personnel (4.4.8)	%,MPE	%,MPE	%,MPE	%,MPE	X	X
Demonstration with General Public (4.5.1)	MPE,+	--	X	X	X	X
Laser Optical Fiber Systems (4.5.2)	MPE	MPE	MPE	MPE	X	X
Laser Robotic Installations (4.5.3)	--	--	--	--	X,NHZ	X,NHZ
Eye Protection (4.6.2)	--	--	--	--	*,MPE	X,MPE
Protective Windows (4.6.3)	--	--	--	--	X,NHZ	X,NHZ
Protective Barriers and Curtains (4.6.4)	--	--	--	--	*	*
Skin Protection (4.6.5)	--	--	--	--	X,MPE	X,MPE
Other Protective Equipment (4.6.5)	Use may be required					
Warning Signs and Labels (4.7)	--	--	*	*	X,NHZ	X,NHZ
Service and Repairs (4.8)	LSO determination					
Modification of Laser Systems	LSO determination					

LEGEND		
	X	Shall
	*	Should
	--	No requirements
	%	Shall if enclosed Class IIIb or Class IV
	MPE	Shall if MPE is exceeded
	NHZ	Nominal Hazard Zone analysis required
	+	Applicable only to UV and IR lasers
	LSO	Laser Safety Officer

Appendix E: Safety Guidelines for Beam Alignment

Over sixty percent of laser accidents in research settings occur during the alignment process. If an alignment procedure is recommended or required, use the following as a guide for items that may need to be considered in your particular application.

Access. To avoid injuries and embarrassing incidents, make sure that unauthorized people are not present and are not able to enter the lab at any time an alignment is being conducted.

Buddy System. When working with Class IV lasers, be sure to use the buddy system.

Preparation. To reduce accidental reflections, watches and reflective jewelry should be taken off before alignment activities begin. To make alignment as quick and easy as possible, locate all equipment and materials needed prior to beginning the alignment. Put surplus materials on a table away from the laser system to minimize the risk of stray specular reflections and non-beam hazards.

Reduced Beam Power. During alignments, use a Class II or IIIa coaxial alignment laser or run the laser at the lowest useful power. Avoid going to full power as much as possible during alignments.

Personal Protective Equipment (PPE). Identify the PPE to be used. For visible light, use laser protective eyewear with the maximum optical density (OD) that still allows the wearer to view necessary diffuse reflections. For chronic exposures, cover the skin with a lab coat, gloves, and if necessary, a UV face shield to protect from scattered UV light.

Beam Control. The individual who moves or places an optical component on an optical table is responsible for identifying and terminating each and every stray beam coming from that component. Close the laser shutter while conducting crude adjustments of optics or when entering the beam path. Make sure that the optics and beam blocks are secure prior to opening the shutter. Clearly mark beams that leave the horizontal plane. A solid stray beam shield should be securely mounted above the area to prevent accidental exposure to the laser beam. Have beam paths at a safe height, below eye level when standing or sitting and not at a level that temps one to bend down and look at the beam. If necessary, place a step platform around the optical table.

Invisible Beams. Use viewing aids (IR cards and viewers) or fluorescent materials (colored pieces of paper or Polaroid sheets). Note that IR cards and Polaroid sheets may be specular reflectors. Avoid alignment using invisible beams as much as possible by using a visible coaxial laser.

Pulsed Lasers. Align by firing pulses one at a time, if practical.

Intrabeam Viewing. Avoid intrabeam viewing. If intrabeam viewing is required, use a remote viewing camera.

Restoring Normal Controls. When alignment is complete, make sure that all beam blocks, barriers, interlocks, and enclosures are replaced and working.

Appendix F: Laser Accident Emergency Procedure

In the event of a laser accident, immediately perform the following:

1. Shut down the laser system.

2. Provide for the safety of personnel (examples, first aid and evacuations) as needed.

   NOTE: If a laser eye injury is suspected, have the injured person keep their head upright and still to restrict any bleeding in the eye. A physician should evaluate laser eye injuries as soon as possible.

3. Obtain medical assistance for anyone who may be injured.

UF Student Health Care Center	**392-1161**
Eye Center Shands at UF	**265-0860**
Shands at UF Emergency Department	**265-0050**
Ambulance (Urgent medical care)	**911**

4. If there is a fire, leave the area, pull the fire alarm, and contact the fire department by calling 911. Do not fight the fire unless it is very small and you have been trained in firefighting techniques.

5. Inform the Laser Safety Officer or the Radiation Control Officer as soon as possible.

Laser Safety Officer	**392-7359**
Radiation Safety Officer	**392-7359**

   After normal working hours, call **392-1111** to contact the University Police Department. UPD will utilize the EH&S emergency call list.

6. Inform the Principal Investigator as soon as possible. If there is an injury, the PI must submit a report of injury to Risk Management and the LSO as soon as possible.

7. Following laser accidents, do not resume use of the laser system until the Laser Safety Officer and the Laser Safety Committee have reviewed the incident.

Appendix G: Guidelines for Laser Pointers

Applicability:
These guidelines cover the use of all Class II or IIIa laser pointers used for seminar or classroom presentations. The use of any other Class laser pointer will need the prior approval from the LSO.

Rationale:
The use of laser pointers as an instructional aid continues to increase in popularity. Laser pointers fall into two laser hazard classifications. One is Class II, for which the human blink reflex is sufficient to provide protection (power output less than 1 mW). The other is Class IIIa, which can be safe for momentary viewing, but is a recognized eye hazard if viewed through optics. Class IIIa power output is between 1 to 5 mW. Most of the laser pointers available are Class IIIa and fall within the 630-680 nm range.

Labeling of Pointers:
Potential users should be aware that some of these devices might lack the appropriate warning labels. Federal law, 21 CFR Part 1040 requires the laser pointer manufacturer to have a laser-warning label on the pointer. ***The label needs to show the laser hazard symbol, laser classification, laser wavelength, and maximum power output.*** The laser pointer shall not be used if it is missing this label.

Green Pointers:
A new group of laser pointers now on the market are frequency doubled ND:YAG lasers that have an output that may be either continuous or pulsed. The output beam is 532 nm, with a blocked infrared beam at 1064 nm. These pointers are exceptionally bright to the human eye. For safety, it is critical that the invisible 1064 nm beam-blocking filter be in place.

Laser Pointer Safety Guidelines:
When used as intended, these devices do not present a hazard to the user or members of the audience. The following guidelines are provided to maximize safety:

- Never intentionally stare into the beam
- Only use pointers that are labeled as Class II or IIIa
- Never intentionally aim the pointer beam at oneself or another person, particularly in the facial area
- The beam should always be directed away from the audience
- The beam should be turned off when not in immediate use
- Mirror like surfaces (such as glass, metal and other highly reflective materials) should be avoided when directing the laser beam

Emergencies:
The potential for injury from a laser pointer is very slight. If an eye injury is suspected, obtain medical attention and notify your supervisor and the LSO at 392-7359 as soon as possible.

APPENDIX H: COMMON LASER TYPES AND WAVELENGTHS

Ultraviolet (180 nm - 400 nm)

Laser Type	Wavelength (nm)
Argon Fluoride	193
Krypton Fluoride	248
Neodymium: YAG (4th harmonic)	266
Argon	275, 351, 363
Xenon Chloride	308
Helium Cadmium	325
Nitrogen	337
Xenon Fluoride	351
Neodymium: YAG (3rd harmonic)	355

Visible (400 nm - 700 nm)

Laser Type	Wavelength (nm)
Helium Cadmium	442
Rhodamine 6G	450, 650
Argon	457, 476, 488, 514
Copper vapor	510, 578
Krypton	530
Neodymium: YAG (2nd harmonic)	532
Helium Neon	543, 632
Indium Gallium aluminum phosphide	670
Ruby	694

Near-infrared (700 nm - 1,400 nm)

Laser Type	Wavelength (nm)
Ti-Sapphire	700 - 1,000
Alexandrite	720 - 800
Gallium aluminum arsenide	780, 850
Gallium Arsenide	905
Neodymium: YAG	1,064
Helium Neon	1,180, 1,152
Indium Gallium Arsenic Phosphide	1,310

Mid-infrared (1,400 nm - 3,000 nm)

Laser Type	Wavelength (nm)
Erbium: Glass	1,540
Holmium	2,100
Hydrogen fluoride	2,600 - 3,000
Erbium	2,940

Far-infrared (3,000 nm - 1mm)

Laser Type	Wavelength (μm)
Helium Neon	3,390
Carbon Monoxide	5,000 - 5,500
Carbon Dioxide	10,600