FIU Environmental Health & Safety

FLORIDA INTERNATIONAL UNIVERSITY

LASER SAFETY MANUAL

Document Number:

EHS-DOC700.01

EH&S PROGRAM AND PROCEDURE		
Program Number: EHS700	**Program Title:** **LASER SAFETY MANUAL**	
Effective Date: *7/1/2019*	**Revision Number:** 2	**Superseded Date:** 6/17/2017
REQUIRED SIGNATURES		
Program Owner: **David Roelant**	**Signature:**	**Date:**
Approved By: **Tamece Knowles, Director**	**Signature:**	**Date:**
Approved By: Click here to enter text.	**Signature:**	**Date:**
REFERENCE AND MATERIALS		
Cross References: (Program Drivers, Training Modules, Other referenced documents) N/A		
Reference(s): N/A	**Training Module Title(s):** *Laser Safety (Course ID: FIUEHS700-OT)*	
TRAINING REQUIREMENTS		
Is Training Required For This Revision? ☐ **Yes** ☐ **Program** ☐ **Training Module** **Specific Jobs Requiring Training:** N/A. ☐ **No (If No, Please Explain)** Researchers using Classes 3 and 4 lasers are required to take the FIU Laser Safety online training. This revision does not require updated training.	**Departments Impacted By This Program:** FIU academic Departments, Centers and Institutes with research and teaching labs using Class 3 or Class 4 laser systems. Also, Facilities and others at FIU using Class 3 and 4 laser systems.	

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1.0 Introduction

The word laser is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. Lasers are used by many organizations at Florida International University for purposes such as research, teaching, facilities maintenance, construction and much more. Lasers are used in enclosed systems such as optical drives in computer systems or other instrumentation. These systems prevent beams for damaging eyes during normal operations. There are also open beam lasers which go from presentation pointers to power bench-top systems that can do serious damage to the skin or eyes of humans.

Laser devices are classified into different classes- Class 1, 1M, 2, 2M, 3R, 3B and 4 based on the potential for the direct beam or beam viewed with an optical aid or reflected beam to cause biological damage to the eyes and/or skin. The laser classification in this manual is based on the guidelines recommended by American National Standard for the Safe Use of Lasers, ANSI Z136.1 – 2014.

With this 2019 revision to the Laser Safety Manual, similar types of information have been grouped together and a new Section 5 entitled, "Guide to Everything You Need to Know about Lasers at FIU" has been added. The goal of this section, in combination with sections 1 -4, is to succinctly (in 10 pages) answer many questions and provide a roadmap to where further details can be found in the 70+ pages of information in the appendices. All those using laser systems need to read and understand this manual in its entirety.

2.0 Purpose of this Manual and Statement of Compliance

Purpose: The purpose of this Manual is to ensure the safe use of lasers at Florida International University by identifying hazards, providing laser safety training, and implementing the necessary engineering and administrative controls. To achieve this goal, the University has adopted the guidelines recommended by American National Standard for the Safe Use of Lasers, ANSI Z136.1-2014. The laser safety manual is available on the EH&S website (https://ehs.fiu.edu/safety-programs/laser/index.html).

Access to EH&S website with a link to the FIU Laser Safety Manual printed and taped to the computer monitor must be available in each lab using Class 3B or Class 4 lasers or a hardcopy of the manual can substitute for the online access.

Statement of Compliance: All Users of Laser devices at FIU shall comply with the following:

- All applicable federal, state and local safety laws, rules and regulations relating in any way to the purchase, handling, use, storage, transfer and disposal of these devices;
- The terms and restrictions set forth in the University's license, permit or registration relating to the purchase, handling, use, storage, transfer and disposal of these devices, as applicable;
- Applicable university policies and procedures; and
- The procedures described in the laser safety manual, that assure responsibility, accountability and physical safeguards with regards to these devices.

PIs and ALL researchers shall be held responsible and accountable for all aspects of compliance!

3.0 Scope, Authority and Administration of this Manual and Laser Safety at FIU

Scope: The Laser Safety Manual provides the necessary structure, management and operating procedures to assure the safe use of laser devices in teaching and research laboratories operating under the direction of any FIU employee, officer or agent.

Authority: The safety standards contained herein are based on the American National Standards Institute, Inc., "American National Standard for the Safe Use of Lasers" (ANSI Z136.1-2014). This manual represents the generally accepted best practice standards and University's Special Hazard Materials' Policy for the safe use of lasers within the fields of industry, education, research, and medicine.

Administration: Responsibility for the administration of the safety standards contained herein rests with the Director of Environmental Health & Safety who may delegate the management and oversight of this program to a Certified Laser Safety Officer.

4.0 Responsibilities for Laser Safety at FIU

4.1 Laser Safety Committee

The Laser Safety Committee (LSC), a Standing Committee at Florida International University ("University"), is the governing body for all aspects of laser protection at FIU, including all affiliated research, clinical, instructional and service units that use laser devices in work or research facilities owned or controlled by the University. The LSC in its capacity as a governing body shall ensure that all possession, use and disposition of laser devices by University personnel at Florida International University comply with pertinent federal, state and University regulations.

The LSC approves policies, rules and procedures for the safe use of laser devices. The LSC has the authority to grant, deny, or withdraw permission for the use of laser devices by an authorized user within the University. The LSC is responsible for the following:

- Approving University procedures, safety manuals, and criteria for training (and refresher training) and testing of each category of workers involved with the use of laser devices, including support staff, to ensure that the laser safety program is properly implemented according to accepted safety practices.
- Ensuring that only qualified individuals are permitted to use laser devices or to supervise such use by others.
- Reviewing annual reports from the LSO summarizing lab inspections, including compliance with safety related engineering and administrative controls and use of personal protective equipment, occupational exposure for all personnel to laser radiation and other conventional hazards, and compliance with Federal/State of Florida regulations.
- Enforcing compliance with the program, including imposition of sanctions for non-compliances.
- Providing advice to research groups, departments and investigators via the LSO.
- Tracking corrective action of items of concern brought to the Committee.
- Endorsing recommendations and university policies to be submitted to FIU Operations Committee for approval

4.2 Laser Safety Officer

The Laser Safety Officer is responsible for the day to day administration and implementation of the procedures that support safety and compliance in the laser safety program. To be qualified to execute the function a Laser Safety Officer shall complete bachelor's degree or higher in relevant field of study and have one full year of experience working with laser devices or managing safety of laser devices. Certification by Board of Laser Safety (www.lia.org) as Laser Safety Officer (CLSO) is preferred. The LSO specific responsibilities are as follows:

- The LSO shall review all request for purchase of laser devices and approve prior to purchase.
- The LSO shall classify, or verify classifications, of lasers and laser systems used under the LSO's jurisdiction.
- The LSO shall be responsible for hazard evaluation of laser work areas, including the establishment of Nominal Hazard Zones (NHZ).
- The LSO shall be responsible for assuring that the prescribed control measures are implemented and maintained. This includes avoiding unnecessary and duplicate controls and recommending or approving substitute or alternate control measures when the primary ones are not feasible or practical.
- The LSO shall approve Class 3B and Class 4 standard operating procedures and other procedures that may be part of the requirements for administrative and procedural controls.
- The LSO shall recommend or approve protective equipment, i.e., eyewear, clothing, barriers, screens, etc., as may be required to assure personnel safety. The LSO shall assure that protective equipment is evaluated periodically to ensure proper working order.
- The LSO shall approve the wording on area signs and equipment labels.
- The LSO shall review and approve Class 3B and Class 4 laser installation facilities and laser equipment prior to use. This also applies to modification of existing facilities or equipment.
- The LSO shall assure that the safety features of the laser installation facilities and laser equipment are audited periodically to assure proper operation.
- The LSO shall assure that adequate safety education and training, including refresher training is provided to laser area personnel.
- The LSO shall identify the personnel categories for medical surveillance.
- The LSO shall assure that the necessary records (required by applicable government regulations, medical examinations, maintenance of safety programs, SOPs, audits, etc.) are maintained.
- The LSO shall maintain a plan to respond to notifications of incidents of actual or suspected exposure to potentially harmful laser radiation and prepare reports.
- Approval of a Class 3B or Class 4 laser or laser system for operation will be given only if the LSO is satisfied that the laser hazard control measures are adequate. These include Standard Operating Procedures (SOPs) for maintenance and service operations within enclosed systems, and operation procedures for class 3B and 4 systems. The procedures should include adequate consideration to assure safety from non-beam hazards.
- All purchases of laser equipment will be through the LSO. A purchase requisition/request shall be submitted to the LSO for approval prior to forwarding it to the Purchasing Department.

4.3 Principal Investigators Supervisors (of students & staff using lasers)

The supervisors shall be knowledgeable of the requirements of laser safety, the potential hazards and associated control measures for all classes of lasers and laser systems; education; and all policies, practices and procedures pertaining to laser safety at locations under their authority. Their responsibilities are as follows:

- The supervisor **shall** be responsible for the issuance of appropriate instructions and training on laser hazards and their control, including On-The-Job training to all personnel who may work with lasers that are operated within the supervisor's jurisdiction.
- The supervisor **shall not** permit the operation of a laser unless there is adequate control of laser hazards to employees, visitors, and the general public.
- The supervisor **shall** submit the names of the individuals scheduled to work with lasers to the LSO and shall submit information as requested by the LSO for medical surveillance scheduling and training completion.
- The supervisor shall budget for safety devices and eye examination of the individuals using laser devices. See Section 11.3 - Procedure for Eye Examination.
- The supervisor shall verify that the students using laser devices have medical insurance.
- When the supervisor knows of, or suspects, an accident resulting from a laser operated under his authority, the supervisor **shall** immediately implement the institution's accident responsible plan and ensure it includes notification of the LSO.
- If necessary, the supervisor **shall** assist in obtaining appropriate medical attention for any employee involved in a laser accident.
- The supervisor **shall not** permit the operation of a new or modified Class 3B or Class 4 laser under his or her authority without the approval of the LSO.
- The supervisor **shall** submit plans for Class 3B and Class 4 laser installations or modifications of installations to the LSO for review.
- For Class 3B and Class 4 lasers and laser systems, the supervisor **shall** develop SOPs for laser operation and beam alignment for review and approval by the LSO and ensure that they are provided to users of such lasers.
- The supervisor shall provide, implement, and enforce the safety recommendation and requirements prescribed in this Manual. The supervisor shall complete the Laser Registration Form(s) (see Section 13.4) and submit them to the LSO within 7 days of receipt of the laser devices.
- The supervisor shall themselves participate in laser safety training

4.4 Individual Users (Employees and Students)

The individual users working with lasers or laser systems shall have the following responsibilities:

- Shall read and comply with FIU Laser Safety Manual;
- Shall complete laser safety training prior to starting work with lasers;
- Shall not energize or work with or near a laser unless authorized to do so by the owner of that laser;
- Shall comply with safety rules and procedures prescribed by the supervisor and the LSO. The employee shall be familiar with all operating procedures.
- Shall restrict access by ancillary services personnel into a room or area where a Class 3B or Class 4 laser is operating.
- Shall report all accidents or injuries to the Principal Investigator, Public Safety and EH&S immediately.
- Shall consult with the Principal Investigator before taking any steps beyond the scope of the SOP.

5.0 Guide to Everything You Need to Know about Lasers at FIU

Why and Who for Laser Safety Program: Sections 1-3 establish federal, state and local regulations governing laser safety at FIU. This manual and the FIU Laser Safety Program contained in it are legal requirements from these regulations. FIU established the Policy on Security in Laboratories with Special Hazards (Appendix M) to address some aspects of these requirements. Section 4 establishes the responsibilities of the Laser Safety Committee, the LSO, PIs authorized to user lasers, Supervisors of staff or students using lasers, and for all other researchers and FIU personnel using laser systems.

What Lasers are Regulated: Laser systems sold in USA are sold as Classes 1, 1M, 2, 2M, 3R, 3B, and 4. There are thousands of lasers at FIU and Class 1 and 1M systems are very common and not tracked by the LSO. That said, researchers need to be aware that embedded lasers can be given a lower rating for standard operations. It is critical that the actual Class of the embedded laser is determined. Some laser printers have the most dangerous and regulated Class 4 lasers inside and yet can have a Class 1 rating listed for the embedded system. Class 2, 2M and 3R are tracked and have some requirements described below but are quite safe and easier to work with. Class 3B and Class 4 lasers require registration with the State of Florida and have many more safety requirements.

<u>FIU regulates all but Classes 1 and 1M lasers but this must be the actual laser classification not be the lowered classification of the instrument with the laser embedded in it!</u>

When – Processes for Researchers Approvals for Safe Use of Lasers

<u>Authorized Laser User (ALU) Approval Process</u>: Any researcher that wishes to use lasers at FIU must: (1) successfully complete the required laser safety and other safety training requirements; (2) ensure all those that will work with the laser complete similar training; and (3) submit an application to LSO to forward to the LSC for approval for being recognized as an Authorized Laser User, ALU (application to contain: bio, description of R&D, description of laser system(s); and lab(s) where laser work will be performed).

<u>ALU authorization to begin working with a laser:</u>

Authorized Laser Users cannot obtain or use any lasers until each system is reviewed and approved by the LSO. Multiple systems can be approved simultaneous once requirements are met. The LSO reviews each laser system proposed and matches it to required training, possible registration by State of Florida, required door signage, required work area signage, signage for placement on the laser system itself; and various required engineering and administrative controls. Requirements to approve lasers for safe usage vary with individual characteristics of lasers (e.g., Class, power, CW vs pulsed, wavelength) as well as how they are used and beam equipment (lenses)

For this reason, there is no simple prescription for describing all requirements. That said, this manual contains details required for a ALU to obtain approvals.

For example, a Class 4 laser set up would required the following prior to approval: registration with State of Florida; written SOPs or protocols approved by the LSC for normal operation and possible maintenance of the systems, an authorized eye examination by Ophthalmologist, and engineering controls that should include appropriate eyewear Personal Protection Equipment (PPE); a lighted sign or beacon when laser is activated, possible interlock on lab doors to prevent entry when beam is active, signs, labels and more. The entire process is described in Section 11.

The researcher in charge of the laser must be approved as an Authorized Laser User.

The LSO or ESH are required to approve laser purchases. Section 13.2 describes this. This ensures that those buying the lasers are properly trained in laser safety and for the legally required registration of Classes 3B and 4 lasers with the State of Florida. Lasers can be purchased for research, operations, maintenance, printing, etc. For researchers wishing to secure funding to buy lasers, Section 18 contains an ORED Proposal Review Form alerting the LSO and ESH of the possible purchase and research with lasers.

Prior to using Classes 2, 2M, 3R, 3B or 4 lasers, the proper signage, labeling, and engineering controls and administrative controls must be in place. These scale with the potential danger of the higher class systems. For example, Classes 2 and 2M lasers may only require labeling and signage and proper training of the users while Class 4 systems often require safety interlocks, lights on when the beam is on, registration with the State of Florida, and written protocols for how the laser is to be operated in normal conditions and how it is to be maintained (if FIU would be doing this maintenance).

Section 8 describes in great detail the numerous **hazards of laser systems** which extend beyond eye safety to electrical shock, fire or explosion ignition, skin burns, generation of hazardous gases and respirable particles and more!

Section 9 describes required **laser hazard warning signs and labels** and the meanings of warnings: Caution, Danger, and Notice. Failure to have proper labels and signage on instrument, vicinity of the laser, and on the door of the lab containing the laser can result in the stoppage of the research and with a repeat violation, loss of the privilege of working with lasers at FIU.

Section 10 describes Engineering, Administrative, Equipment control measures. Class 4 lasers can cause eye damage when reflecting of a smooth surface such as some painted walls. This means that engineering controls just for line of sight for the laser are not enough. All researchers with Classes 3B and 4 lasers are required to have written Standard Operating Procedures (SOPs) for normal operation and for maintenance (if it applies). These are approved by the FIU Laser Safety Committee comprised of researchers at FIU actively using laser systems.
Eye exams are mandatory for those using Classes 3B and 4 lasers.

6.0 APPENDICES A - N

7.0 Appendix A: Laser Theory, Types, Classes and Safe Operation

A laser generates a beam of very intense light. The major difference between laser light and light generated by white light sources (such as a light bulb) is that laser light is monochromatic, directional and coherent.

Monochromatic means that all of the light produced by the laser is of a single wavelength. White light is a combination of all visible wavelengths (400 – 700 nm).

Directional means that the beam of light has very low divergence. Light from a conventional source, such as a light bulb, diverges, spreading in all directions. The intensity may be large at the source, but it decreases rapidly as an observer moves away from the source, falling as an inverse square of the distance from a point source. In contrast, the output of a laser has a very small divergence and can maintain high beam intensities over long ranges. Thus, relatively low power lasers are able to project more energy at a single wavelength within a narrow beam than that can be obtained from much more conventional light sources.

Coherent means that the waves of light are in phase with each other and they are of the same wavelength. A light bulb produces many wavelengths, and they are not in phase with each other.

The laser is a device, which produces a very intense and very narrow (collimated) beam of electromagnetic radiation in the wavelength range 180 nm to 1 mm. Important properties of lasers are: monochromaticity (narrow wavelength range), directionality (high collimation) and coherence (propagation in same phase). Because laser light is not an ionizing type of radiation, interaction with the body is generally at the surface. The eye and the skin are critical organs for laser radiation exposure, and the resultant effects vary depending on the type of laser (frequency or wavelength of the radiation) and beam energy output. Laser radiation of the proper wavelength and energy may be focused by the lens of the eye onto the retina causing severe damage. If laser radiation is of high enough energy, skin burns may also result if extremities or other body parts are placed in the laser beam.

7.1 Components of a Laser

The basic components of a laser are the lasing medium, energy pump and optical cavity.

The lasing medium is a substance that can be excited to a metastable state through addition of energy that is "pumped" into the lasing medium. The lasing medium can be a solid, liquid, gas or semiconductor.

The source of energy needed to excite the atoms of the lasing medium may be:

- An intense source of light that emits a wide range of photon energies and necessarily includes photons of the exactly the right energy to excite the lasing atoms,
- A radio frequency voltage, or
- A power source

The optical cavity contains mirrors at each end. One end is completely mirrored and the other end is partially mirrored. In the optical cavity the intensity of the photons is increased because they are reflected back into the cavity by mirrors. By pumping large amounts of light into the lasing medium, the atoms of the lasing medium are excited into metastable state and a "population inversion" is attained in which most of the atoms are in an excited state.

After a population inversion is achieved, the spontaneous decay of few electrons from the metastable state to lower energy level starts a chain reaction. The photons emitted spontaneously will hit (without being absorbed) other atoms and stimulate their electrons to make transition from the metastable energy level to lower energy levels, emitting photons of precisely the same wavelength, phase and direction.

To produce a laser this reaction must take place in the optical cavity. When the photons reach the end of laser material they are reflected by the end-mirror back into the material where the chain reaction continues and the number of photons is increased. When the photons arrive at a partially-reflecting mirror, only a portion will be reflected back into the cavity and the rest will emerge as laser beam.

The laser output may be pulsed or steady, as in continuous wave (CW) lasers. A Q-switch in the optical path is a method of providing laser pulses of extremely short time duration. The Q-switch may use a rotating prism, or a shutter device to create the pulse. Q-switched lasers may produce a high-peak-power laser pulse of a few nanoseconds duration.

A continuous wave laser has a steady power output, measured in watts (W). For pulsed lasers, the output generally refers to energy, rather than power. The radiant energy is a function of time and is measured in joules (J).

Two terms are often used when measuring or calculating exposure to laser radiation. Radiant Exposure is the radiant energy divided by the area of the surface that receives the laser energy. It is expressed in J/cm^2. Irradiance is the radiant power incident per unit area upon the surface. It is expressed in W/cm^2. For repetitively pulsed lasers, the pulse repetition factor (prf) and pulse width are important in evaluating biological effects.

7.2 Types of Lasers

There are many types of lasers available for research, medical, industrial, and commercial uses. Lasers are often described by the kind of lasing medium they use - solid state, gas, excimer, dye, or semiconductor, etc.

Solid state lasers employ a lasing material distributed in a solid matrix. One example is the Neodymium-YAG laser. The term: YAG is an abbreviation for the crystal: Yttrium Aluminum Garnet which serves as the host for the Neodymium ions. This laser emits an infrared beam at the wavelength of 1064 nanometers. Accessory devices that may be internal or external to the cavity may be used to convert the output to visible or ultraviolet wavelength. Solid state lasing media are typically optically pumped, using either a flash lamp or arc lamp, or by laser diodes. Diode-pumped solid-state lasers tend to be much more efficient, and have become much more common as the cost of high power semiconductor lasers has decreased.

Solid-state lasers where the light is guided due to the total internal reflection in a waveguide are called fiber lasers. Because of huge ratio of the length to the transversal size the active element of such a laser looks as a fiber. Guiding of light allows extremely long gain regions providing good cooling conditions; fibers have high surface area to volume ratio allows efficient cooling. In addition, the fiber's wave guiding properties tend to reduce thermal distortion of the beam.

Gas lasers use a gas or a mixture of gases within a tube in the laser cavity. A voltage (the external pump source) is applied to the tube to excite the atoms in the gas to a population inversion. The most common gas laser uses a mixture of helium and neon (He-Ne), with a primary output of 632.8

nanometers which is a visible red color. All gas lasers are quite similar in construction and behavior. For example, the CO_2 gas laser radiates at 10,600 nm in the far-infrared spectrum. Argon and krypton gas lasers operate with multiple frequency emissions principally in the visible spectra. The main emission wavelengths of an argon laser are 488 and 514 nm. The light emitted from this type of laser is normally continuous wave (CW).

A chemical laser is a laser that obtains its energy from a chemical reaction. Chemical lasers can achieve continuous wave output with power reaching to megawatt levels. They are used in industry for cutting and drilling, and in military as directed-energy weapons. Common examples of chemical lasers are the chemical oxygen iodine laser (COIL), all gas-phase iodine laser (AGIL), and the hydrogen fluoride laser and deuterium fluoride laser, both operating in the mid-infrared region. There is also a DF-CO_2 laser (deuterium fluoride-carbon dioxide), which, like COIL, is a "transfer laser." The hydrogen fluoride and deuterium fluoride lasers are unusual in that there are several molecular energy transitions with sufficient energy to be above the threshold required for lasing. Since the molecules do not collide frequently enough to re-distribute the energy, several of these laser modes will operate either simultaneously, or in extremely rapid succession so that an HF or DF laser appears to be operating simultaneously on several wavelengths unless a wavelength selection device is incorporated into the resonator.

Dye lasers use a laser medium that is usually a complex organic dye in liquid solution or suspension. The most striking feature of these lasers is that they are highly tunable, or produce very short-duration pulses (on the order of a few femtoseconds). Proper choice of the dye and its concentration allows the production of laser light over a broad range of wavelengths in or near the visible spectrum. Dye lasers commonly employ optical pumping although some types have used chemical reaction pumping. The most commonly used dye is Rhodamine 6G which provides tunability over 200 nm in the red portion (620 nm) of the spectrum.

Excimer lasers (the name is derived from the terms excited and dimers) use reactive gases such as chlorine and fluorine mixed with inert gases such as argon, krypton, or xenon. When electrically stimulated, a pseudomolecule or dimer is produced and when lased, produces light in the ultraviolet range. They are used in semiconductor photolithography and in LASIK eye surgery. Examples of excimers lasers are: ArF (193 nm), KrCl (222 nm), KrF (248 nm), XeCl (308 nm), and XeF (351 nm).

Metal vapor lasers produce laser light in the infrared, visible, or ultraviolet. They must operate at high temperatures to keep the metals vaporized; they are excited by electrical discharges in mixtures of metal vapor and noble gases. Copper vapor lasers produce green and yellow light from a mixture of copper vapor with helium or neon. They are excellent sources of short, high-intensity laser pulses at very high pulse-repetition rates. Copper vapor lasers are used in some machining and laser cutting applications. They can also be used to separate isotopes of uranium using selective ionization of hyperfine transitions.

Semiconductor lasers (sometimes referred to as diode lasers) are not to be confused with solid state lasers. These are the most widely used lasers today and emit visible or infrared light when an electric current passes through them. The emission occurs at the interface (p-n junction) between two regions doped with different materials. The p-n junction can act as a laser medium, generating stimulated emission and providing lasing action if it is inside a suitable cavity. These lasers are generally very small physically, and individually of only modest power. However, they may be built into larger arrays. The most common diode laser is the Gallium Arsenide diode laser with a central emission of 840 nm. The source pump for these lasers is electric current.

A free electron laser, or FEL, is a laser that shares the same optical properties as conventional lasers such as emitting a beam consisting of coherent electromagnetic radiation which can reach high power, but which uses some very different operating principles to form the beam. Unlike gas, liquid, or solid-state lasers such as diode lasers, in which electrons are excited in bound atomic or molecular states, FELs use a relativistic electron beam as the lasing medium which move freely through a magnetic structure, hence the term free electron. The free electron laser has the widest frequency range of any laser type, and can be widely tunable, currently ranging in wavelength from microwaves, through terahertz radiation and infrared, to the visible spectrum, to ultraviolet, to soft X-rays. FELs find applications in medicine and anti-missile directed weapons.

7.3 Laser Classification

The objective of this manual is to provide a reasonable and adequate guidance for the safe use of lasers and laser systems. A practical means for accomplishing this is first to (1) classify lasers and laser systems according to their relative hazards and then to (2) specify appropriate controls for each classification. Laser devices are classified into 7 different classes- Class 1, 1M, 2, 2M, 3R, 3B and 4 based on the ability of the laser beam to cause biological damage to the eye or skin during use. Examples:

A Class 1 laser system is:

- Considered to be incapable of producing damaging radiation levels during operation, and
- Exempt from any controls or other forms of surveillance with the exception of requirements for embedded lasers.

Any laser, or laser system containing a higher Class laser, that cannot emit accessible radiation levels during operation in excess of the applicable Class 1 accessible emission level (AEL) for any duration within the maximum duration (30,000 s except for infrared system where 100 s shall be used) inherent in the design or intended use of the laser or laser system.

Products which have previously have been classified as Class IIa (emitting visible radiation less than 0.4 mW) under Federal Laser Product Performance Standard (FLPPS) should be treated as Class 1.

A Class 1M laser system is:

- Considered to be incapable of producing hazardous exposure conditions during operation unless the beam is viewed with an optical instrument such as an eye-loupe (diverging beam) or a telescope (collimated beam), and
- Exempt from any controls measures other than to prevent potentially hazardous optically aided viewing; and is exempt from other forms of surveillance.

Any laser, or laser system containing a laser that cannot emit during operation, accessible radiation levels in excess of the applicable Class 1 AEL under the conditions of measurement for the unaided eye, but exceeds the Class 1 AEL for telescopic viewing and does not exceed the Class 3B AEL, for any emission duration within the maximum duration (30,000 s) inherent in the design or intended use of the laser or laser system.

A Class 2 laser system:

- Emits in the visible portion of the spectrum (0.4 to 0.7 µm), and
- Eye protection is normally afforded by the aversion response.

A Class 2M laser system:

- Emits in the visible portion of the spectrum (0.4 to 0.7 µm), and
- Eye protection is normally afforded by the aversion response for unaided viewing.
- However, Class 2M is potentially hazardous if viewed with optical aids.

Class 2 and 2M lasers and laser systems are visible CW and repetitive-pulse lasers systems which can emit accessible radiation energy exceeding the appropriate Class 1 AEL for the maximum duration inherent in the design or intended use of the system, but not exceeding the Class 1 AEL for any applicable pulse emission duration < 0.25 s and not exceeding average radiation power of 1 mW. Class 2M lasers and laser systems pose the same ocular hazards to the unaided eye as Class 2, but are potentially hazardous when viewed with optical aids.

Any laser, or laser system that cannot emit during operation accessible radiation levels in excess of the applicable Class 2 AEL under the conditions of measurement for the unaided eye, but exceeds the Class 2 AEL for telescopic viewing and does not exceed the Class 3B AEL, for any emission duration within the maximum duration (0.25 s) inherent in the design or intended use of the laser or laser system is a Class 2M laser, or laser system.

A Class 3R laser system is:

- Potentially hazardous under some direct and specular reflection viewing condition if the eye is appropriately focused and stable, but the probability of an actual injury is small. This laser will not pose either a fire hazard or diffuse-reflection hazard.

Class R lasers and laser systems include lasers and laser systems which have an accessible output between 1 and 5 times the Class 1 AEL for wavelengths shorter than 0.4 µm or longer than 0.7 µm, or less than 5 times the Class 2 AEL for wavelengths between 0.4 and 0.7 µm.

Note – Lasers can be classified as Class 1M and Class 2M even if their output exceeds Class R.

A Class 3B laser system:

- May be hazardous under direct and specular reflection viewing conditions, but is normally not a diffuse-reflection or fire hazard.

Class 3B lasers and laser systems include:

a) Lasers and laser systems operating outside the retinal hazard region (< 400 nm or > 1400 nm) that can emit accessible radiation power in excess of Class 3R AEL during any emission duration within the maximum duration inherent in the design of laser and laser system, but which (a) cannot emit accessible average radiation power in excess of 0.5 W for $T \geq 0.25$ s or (b) cannot produce accessible radiation energy greater than 0.125 J within an exposure duration $T \geq 0.25$.
b) Visible (400 nm to 400 nm) and near infrared (700 nm to1400 nm) lasers and laser systems that can emit in excess of the AEL of Class R but which (a) cannot emit accessible average radiation power in excess of 0.5 W for $T \geq 0.06\ C_A$ s and (b) cannot emit accessible radiation energy greater than 0.0.03 C_A J per pulse for $t < 0.06\ C_A$ s when 0.5 W peak power is exceeded. In addition per pulse accessible radiation energy shall not exceed 0.125 J. For this limit pulses separated by less than t_{min} are to be considered one pulse

T – Total exposure duration for a train of laser pulses

T – Duration of a single pulse or exposure (s)

T_{min} - duration (> 1 ns) for which there is no significant flow of heat from the volume of tissue in which the energy was absorbed, and therefore of the absorbing tissue during the exposure.

Class 3B lasers require labeling and physical controls to prevent viewing of direct and specularly reflected beam.

A Class 4 laser system (high power):

- Is a hazard to eye or skin from the direct beam, and
- May pose a diffuse-reflection or fire hazard
- May also produce laser generated air contaminants (LGAC) and hazardous plasma radiation.

AEL for Class 4 lasers and laser systems is greater than that for class 3B lasers.

Laser and laser systems designated for a specific class by a manufacturer in accordance with the Federal Laser Product Performance Standard (FLPPS) (or latest version thereof) or International Electrotechnical Commission (IEC) 60825-1 (or latest version thereof) may be considered as fulfilling all classification requirements of the ANSI standards. In cases where the Laser and laser system classification is not provided, or where the class level may change because of addition or deletion of engineering controls, the Laser and laser system classification shall be classified by the Laser Safety Officer (LSO).

Changes in classification in the new standard:

- All former Class 1 are now Classes 1 and 1M.
- Most former Class 2 are now Class 2 (or 2M if a highly diverging beam, e.g., a diode laser)
- All former products labeled as ANSI Class 3a (IEC 3B) with a “Danger” logo, such as most laser pointers are renamed Class 3R.
- Class 3a expanded-beam lasers are now Class 1M and 2M.

Embedded systems:

Class 2, 3 or 4 lasers or laser systems contained in a protective housing and operated in a lower classification mode may be classified at a lower classification. Specific control measures may be required to maintain the lower classification. For embedded systems that are non-commercial design and construction, the University LSO shall determine the classification.

For the purposes of laser safety, a direct beam, which has been reflected from a mirror or polished surface, is considered to be as intense as the direct beam. Laser beams, which hit flat or non-mirror like surfaces are considered to be diffused and the diffusely reflected beam is not as intense or as well defined as the direct beam.

7.4 Examples of Typical Lasers

The primary wavelengths for commonly used lasers include the ultraviolet, visible and infrared regions of the spectrum. Ultraviolet radiation for lasers consists of wavelengths between 180 and 400 nanometers (nm). The visible region consists of radiation with wavelengths between 400 and 700 nm. The infrared region of the spectrum consists of radiation with wavelengths between 700 nm and 1 mm.

The color or wavelength of light being emitted depends on the type of lasing material being used. For example, if a Neodymium: Yttrium Aluminum Garnet (Nd:YAG) is used as lasing material, light with a wavelength of 1064 nm will be emitted. Table 6.1 below, Typical Laser Systems, illustrates various types of lasers, the lasing material used, and the wavelength emitted by that type of laser. Note that certain material and gases are capable of emitting more than one wavelength. The wavelength of the light emitted in this case is dependent on the optical configuration of the laser.

Table 7.1 Typical Laser Systems and Associated Wavelengths

LASER TYPE MEDIA	SPECTRUM	WAVELENGTH (nanometers)
Excimer Gas Lasers		
Argon Fluoride	UV	193
Krypton Chloride	UV	222
Krypton Fluoride	UV	248
Xenon Chloride	UV	308
Xenon Fluoride	UV	351
Gas Lasers		
Nitrogen	UV	337
Helium Cadmium	UV	325
	Violet	441
Argon	UV	275, 351, 363
	Blue	457, 476, 488
	Green	514
Krypton	UV	351, 356, 416
	Green	530
	Yellow	568
	Red	647, 676, 799
Xenon	White	Multiple
Helium Neon	Green	543
	Yellow	594
	Orange	612
	Red	633
	NIR	1152
	FIR	3390
Hydrogen Fluoride	FIR	2700

LASER TYPE MEDIA	SPECTRUM	WAVELENGTH (nanometers)
Carbon Dioxide	FIR	10600
Carbon Monoxide	FIR	5000-5500
Metal Vapor Lasers		
Copper Vapor	Green	510
	Yellow	570
Gold Vapor	Red	627
Solid State Lasers		
Quadrupled Nd: YAG	UV	266
Doubled Nd: YAG	Green	532
Neodymium: YAG	NIR	1064
Erbium: Glass	MIR	1540
Erbium: YAG	MIR	2940
Holmium: YLF	MIR	2100
Chromium Sapphire (Ruby)	Red	694
Titanium Sapphire	NIR	700-1000
Alexandrite	NIR	720-800
Dye Lasers		
Rhodamine 6G	VIS	500-700
Coumarin C30	Green	504
Semiconductor Lasers		
Gallium Arsenide (GaAs)	NIR	840
Gallium Aluminum Arsenide	VIS/NIR	670-830

8.0 Appendix B: Laser Hazards

The hazards of lasers may be separated into two general categories: beam-related hazards to eyes and skin and non-beam hazards, such as electrical and chemical hazards.

8.1 Beam-Related Hazards

Improperly used laser devices are potentially dangerous. Effects can range from mild skin burns to irreversible injury to the skin and eyes. The biological damage caused by lasers is produced through thermal, acoustical and photochemical processes.

Thermal effects are caused by a rise in temperature following absorption of laser energy. The severity of the damage is dependent upon several factors, including exposure duration, wavelength of the beam, energy of the beam, and the area and type exposed to the beam.

Acoustical effects result from a mechanical shockwave, propagated through tissue, ultimately damaging the tissue. This happens when the laser beam causes localized vaporization of tissue, causing the shockwave, analogous to ripples in water from throwing a rock into a pond.

Beam exposure may also cause photochemical effects when photons interact with tissue cells. A change in cell chemistry may result in damage or change to tissue. Photochemical effects depend greatly on wavelength. Table No. 2, Summary of Laser Biological Effects, summarizes the probable biological effects of exposure of eyes and skin to different wavelengths.

8.2 Types of Beam Exposure

Exposure to the laser beam is not limited to direct beam exposure. Particularly for high-powered lasers, exposure to beam reflections may be just as damaging as exposure to the primary beam.

Intrabeam exposure means that the eye or skin is exposed directly to all or part of the laser beam. The eye or skin is exposed to the full irradiance exposure or radiant exposure possible.

Specular reflections from mirrored surfaces can be as harmful as exposure to the direct beam, particularly if the surface is flat. Curved mirror-like surfaces will widen the beam such that while the exposed eye or skin does not absorb the full impact of the beam, there is a larger area for possible exposure.

A diffuse surface is a surface that will reflect the laser beam in many directions. Surfaces that are not completely flat, such as jewelry or metal tools, may cause diffuse reflections of the beam. These reflections do not carry the full power or energy of the primary beam, but may still be harmful, particularly for high-powered lasers. Diffuse reflections from Class 4 lasers are capable of initiating fires.

Eye

The major danger of laser light is hazards from beams entering the eye. The eye is the organ most sensitive to light. Just as a magnifying glass can be used to focus the sun and burn wood, the lens in the human eye focuses the laser beam into a tiny spot that can burn the retina. A laser beam with low divergence entering the eye can be focused down to a 10 to 20 micro-meter diameter spot at the retina, thereby increasing the irradiance of the beam at the retina by 100,000 to 200,000 times of the beam entering the eye.

8.3 Safe Use of Laser Pointer Devices

The light energy emitted from laser pointers into the eye can be more damaging than staring directly into the sun.

Laser devices are ranked by class according to their energy or power, and hence, their potential to cause injury. Laser pointers are typically Class 2 or Class 3R devices. They are usually hand held and emit a low-divergence visible beam of less than 5 milliwatts. Laser pointers are usually limited to a class 3R (5 mW) output or less; however, there are more powerful laser pointers available and these devices present a **significant** potential for an **eye injury** if viewed directly.

Laser pointers are typically used in lecture presentation to identify objects or images. Their accuracy and precision is also used in aiming firearms or other visual targeting practice.

The scope of potential for injury with laser pointers has not been fully determined even though numerous exposure incidents have been recorded. It has been shown that a momentary exposure to a laser pointer, such as might occur from an inadvertent sweep of the beam across a person's eye usually causes a **temporary impairment** and does not usually result in a retinal burn. However, in addition to the hazards created by exposure to a direct beam, other exposure concerns include ocular effects such as **flash blindness**, afterimage, and glare. Ocular exposure to the beam from a pointer could lead to temporary vision dysfunction and present possible physical dangers if the individual is engaged in a vision-critical activity such as driving or operating machinery during the exposure.

Federal law requires a warning on the product label about the potential hazard to the eyes caused by the pointer. Users of laser pointers must be alert to the potential hazards and follow the recommended safety procedures.

Use laser pointers with caution and only for their intended purpose. Comply with the manufacturer's safety recommendations:

- **Never** point a laser pointer at anyone, and never look directly into the beam.
- Never aim a laser pointer at surfaces that would reflect the light back, such as mirrors or mirrored surfaces.
- Purchase only those laser pointer devices with a clear warning on the label about the potential to cause eye damage. Read the instructions carefully, and follow them.
- Choose a laser pointer that stays "ON" **only** when you apply pressure with your fingers. That way you can never leave the beam "ON" by accident.
- Choose laser pointers with power that is appropriate to serve the intended purpose.

Skin

Lasers can harm the skin via photochemical or thermal burns. Depending on the wavelength, the beam may penetrate both the epidermis and the dermis. The epidermis is the outermost living layer of skin. Far and mid-ultraviolet (the actinic UV) are absorbed by the epidermis. Sunburn (reddening and blistering) may result from short-term exposure to the beam. UV exposure is also associated with an increased risk of developing skin cancer and premature aging (wrinkles, etc.) of the skin.

Thermal burns to the skin are rare. They usually require exposure to high-energy beams for an extended period of time. Carbon dioxide and other infrared lasers are most commonly associated with thermal burns, since this wavelength range penetrates deeply into skin tissue. The resulting burn may be first degree (reddening), second degree (blistering) or third degree (charring).

Some individuals are photosensitive or may be taking prescription drugs that induce photosensitivity. Particular attention must be given to the effect of these (prescribed) drugs, including some antibiotics and fungicides, on the individual taking the medication and working with or around lasers.

Table No. 3, Summary of Bioeffects of Commonly Used Lasers, summarizes the biological effects of commonly used lasers on the skin as well as on the cornea, lens and retina.

8.4 Non-Beam Hazards (electrical shock, heating, fire, explosion, bio, nanoparticle, chemical)

In addition to direct hazards to the skin and eyes associated with exposure to the laser beam, it is also important to address other hazards not related to exposure of the eye and skin to the laser beam. Non-beam hazards are a class of hazards that do not result from direct human exposure to a laser beam.

Non-beam hazards include physical, chemical, and biological agents. Non-beam hazards may occur when a material is exposed to laser beam (e.g., fire or airborne contaminants); when materials used to generate the beam (e.g., flow-through gases, dyes and solvents) are released into the atmosphere, or when individuals contact system components (e.g., shock or electrocution).

Because of the diversity of these potential hazards, the LSO may employ safety and/or industrial hygiene personnel to effect the hazard evaluations for special considerations.

PHYSICAL AGENTS

Electrical Hazards: Electrical equipment in general presents three potential hazards: shock, resistive heating, and ignition of flammable materials.

Shock: The use of lasers or laser systems can present an electric shock hazard. This may occur from contact with exposed utility power utilization, device control, and power supply conductors operating at potentials of 50 volts and above. These exposures can occur during laser setup or installation, maintenance and service, where equipment protective covers are often removed to allow access to active components as required for those activities. Those exposed can be equipment installers, users, technicians, and uninformed members of the public, such as passers by.

The effect upon those who accidentally come into contact with energized conductors at or above 50 volts can range from a minor “tingle”, to startle reaction, to serious personal injury, or death. Because the pathways of current are all pervasive, such as ground, it is not possible to characterize all the parameters in any situation to predict the occurrence or outcome of an electric shock accident. Electric shock is a very serious opportunistic hazard, and deaths associated with laser systems have occurred.

Protection against accidental contact with energized conductors by means of a barrier system is the primary method of preventing electric shock accidents with laser equipment. Hazard warnings and safety instructions extend the safety system to embody exposures caused by conditions of use, maintenance, and service, and provide protection against the hazards of possible equipment misuse. It is recommended that electrical surge protection be provided to minimize transients, spikes, harmonics, outages, and electromagnetic interference.

Grounding should be provided by providing a reliable, continuous metallic connection between the part or pats to be grounded and the grounding conductor of the power wiring system. Where required “Emergency Power Off” shall be installed to allow the elimination of electrical hazards during emergencies.

Resistive Heating: Heating of a conductor due to electric current flow increases with the conductor’s resistance. Unchecked and increasing resistive heating can produce excessive heat buildup and potentially damage/corrode system components. While laser system designers generally provide sufficient cooling for routine operations, it is important that this equipment be regularly checked for excessive resistive heating symptoms such as component warping, discoloration, or corrosion, and repaired as needed.

Electrical Spark Ignition of Flammable Materials: Equipment malfunction can lead to electrical fires. In addition, electrical sparks can serve as an ignition source in the presence of flammable vapor.

Using recognized independent testing organizations that verify the efficacy of equipment safety systems, with respect to the requirements of consensus safety standards, is important for the protection of the equipment user.

Electrical Hazard Control Regulations: Additional electrical safety requirements are imposed upon laser devices, systems, and those who work with them, by the United States Department of Labor, Occupational Safety and Health Administration (OSHA) (https://www.osha.gov/pls/oshaweb/owastand.display_standard_group?p_toc_level=1&p_part_number=1910) , the National Electrical Code (NFPA 70), and related state and local laws and regulations. These requirements govern equipment connection to the electrical utilization system, electrical protection parameters, and specific safety training.

OSHA [e.g., 29 CFR 1910.303(g)(2)(1)] requires additional control measures for those circuits operating t more than 50 volts. Where applicable, the user shall comply with provisions of OSHA Standards for Electrical Safety-Related Work Practices (29 CFR 1910 Subpart S) and the Control of Hazardous Energy (lockout/tagout; 29 CFR 1910.147).

These requirements must be observed with all laser installations. In addition, it is recommended that fire extinguishers designed for electrical fires should be used with laser systems. A panic button can also serve to eliminate or minimize electrical hazards in an emergency if the button cuts power to the system. The following are potential electrical safety related problems:

- Uncovered and improperly insulated electrical terminals.
- Hidden "power-up" warning lights.
- Lack of personnel trained in current cardiopulmonary resuscitation (CPR) practices, or lack of refresher training. EH&S provides CPR training. This training is recommended for the individuals using high voltage/current equipment. Please contact EH&S training coordinator at ehstrain@fiu.edu for additional information.
- Failure to properly discharge and ground capacitors.
  Note- High voltage electrical storage capacitors may spontaneously partially recharge after discharge unless they are shortened.
- Non earth-grounded or improperly grounded equipment. **If stored electrical energy exists (e.g., capacitors), discharge or remove the stored energy and apply grounds to the normally energized conductors.**
- Non-adherence to the OSHA lockout standard (29 CFR 1910.147).
- Excessive wires and cables on floor that create fall or slip hazards.

Non-Laser Radiation (NLR): The operation of laser systems and application of laser energy onto materials can produce a variety of radiation sources in addition to the laser radiation that the device was designed to produce**.** Sources of NLR include collateral radiation and LTIR.

Collateral radiation is any electromagnetic radiation, except laser radiation, emitted by laser or laser system (e.g., excitation frequency emissions, flash lamp light leakages, X-rays emitted by laser components). In very high powered pulsed laser systems it may present hazards that warrant additional control measures.

LTIR is emitted by a material as a result of being exposed to laser beam. LTIR emission depends primarily on the laser irradiance at the target and composition of the target material. Example - plasma radiation is generated when an energetic laser beam interacts with matter, typically metals. When high power pulsed laser beams (peak irradiance of the order of 10^{12} W.cm^{-2}) are focused on a target. Plasma is form of matter that has been heated to a completely or partially ionized state.

Ionizing Radiation: X-ray radiation may be generated by electronic components of the laser systems (e.g., high–voltage vacuum tubes- usually > 15 kV) and from pulsed laser beams with a peak irradiances of the order of 10^{16} W.cm^{-2}, or higher, that are focused on a target. Plasma radiation produced by extremely high powered laser beams (> 10^{18} W.cm^{-2}) incident on specially-designed targets may also accelerate ions to produce ionizing radiation, particularly neutrons, which may in turn lead to activation in materials surrounding the target.

Optical Radiation: Collateral ultraviolet (UV) radiation emitted from the discharge tubes and pump lamps, as well as plasma emissions created during laser-material interaction processes, may contain sufficient UV and blue light (180 nm to 550 nm) to pose a long terms ocular viewing hazard unless appropriate eye protection is worn. UV radiation may also cause photodermatitis or photokerititis. Studies have shown that the integrated blue-light irradiance levels are much higher for CO_2 than Nd:YAG laser/target interactions. Also welding events yield higher plasma radiation levels than cutting events. Photosensitizing agents from industrial chemicals or medications can make an individual more susceptible to those effects. Laser-related UV sources shall be suitably shielded so that personnel exposures are maintained with exposure limits specified by the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit values for Chemical Substances and Physical Agents and Biological Exposure indices. High levels of shorter wavelength UV radiation can produce significant amounts of ozone, which will need to be exhausted if concentrations approach recognized exposure limits. Visible and infrared radiation exposures from non-laser sources should be controlled to within the limits specified in the appropriate guidance documents [e.g., the ANSI/IESNA RP-27 series of Recommended Practices (Photobiological Safety for Lamps)]. Much of the optical radiation band may be shielded by plastics such as polycarbonate and poly(methyl methacrylate)-type plastics, although additives (dyes) may be necessary for visible and some IR wavelengths.

The control measures include distance, shielding and personal protective equipment.

Fire Hazards: Class 4 laser beams represent a fire hazard. Enclosure of Class 4 laser beams can result in potential fire hazard if the enclosure materials are likely to be exposed to irradiances exceeding 10 W.cm^{2} or beam powers exceeding 0.5 W. Under some conditions where flammable compounds and substances exist, it is possible that fires can be initiated by Class 3B lasers

Note - The NFPA standard 115 states that for CW lasers, 0.Wcm^{-2} is a possible ignition hazard.

Opaque laser barriers, e.g., curtains can be used to block the laser beam from exiting the work area during certain operations. While these barriers can be designed to offer a range of protection, they normally cannot withstand high irradiance levels for more than few seconds without some damage, e.g., production of smoke, open fires or penetrations. Users of commercially available barriers should obtain appropriate fire prevention information from the manufacturer.

Operators of Class 4 lasers should be aware of the ability of unprotected wire insulation and plastic tubing to catch fire from intense reflected or scattered beams, particularly from lasers operating at invisible wavelengths. The risk of fire is greater in oxygen-rich atmospheres when oxygen or nitrous oxide is being used such as in electrical setting.

The three components required for a fire to start are: a combustible material, an oxidizing agent and a source of ignition. Therefore, to reduce the risk of fire in laser applications, great care should be taken to keep these components separated from each other.

Explosion Hazards: High-pressure arc lamps and capacitor banks in laser equipment shall be enclosed in housing which can withstand the maximum explosive pressure resulting from component disintegration. The laser target and elements of the optical train which may shatter during laser operation shall also be enclosed or equally protected to prevent injury to operators and observers. Explosive reactions of chemical laser reactants or other laser gases may be of concern in some cases.

There have been several reports of explosions caused by the ignition of dust that has collected in ventilation systems serving laser processes. The potential for such can be minimized by good maintenance practice.

Mechanical Hazards: In many industrial applications lasers are employed in conjunction with robots. Robots can punch holes in protective housing, damage the delivery system, and cause a laser beam to be aimed at operators or enclosures. In addition to such hazards, the mechanical safety of the robots installation must be considered to prevent accidents, e.g., a worker being pinned between a robot and a confining object.

Noise Hazard: Certain lasers (e.g., pulsed lasers) and associated electrical devices can generate painful and unpleasant noises at high frequency or repetitive rate which are harmful to the ears. Sources of this noise originate from 1) the laser system itself, 2) the fume extraction device and 3) the laser procedures.

Recommended preventative measures are:

- Implement administrative controls to restrict individual exposure time.
- Eliminate excessive noise by installing the noise absorbing material, if possible.
- Maintain smoke evacuation system regularly or replace with a low noise level system
- Employ visual warning (flashing lights) instead of audible alarms.
- Wear ear protectors where noise exceeds the recommended limits.
- Evaluate the noise hazard and post a hearing protection warning sign.

Fiber Optic Fragment Hazard: Small lengths or particles of optical fiber material can pose risk of irritation, infection, or injury, particularly when cleaving fibers during slicing operations. Use of protective finger guards, gloves, or shields should be considered when performing cleaving operations. Adhesive tape can be used to pick up loose particles or slices during operations. A good work practices is to collect discarded fibers in a container to avoid subsequent embedding in clothing, skin, eye, or under the finger nails.

Nanoparticles: Interaction of high energy femtosecond lasers with solid material can cause material blow off (ablation) of fast ions and atoms, as well as clusters and nanoaggregates of target material. The quality and quantity of that energy will determine the amount of ablated material as well as the average particle size.

Processes that produce laser-generated nanoparticles shall be engineered so as to avoid the entry of particles into the body via inhalation, ingestion or absorption processes.

Chemical Agents: These include laser generated airborne contaminants, compressed gases, dyes and solvents, and assist gases.

Laser Generated Air Contaminants (LGAC): Air contaminants may be generated when certain Class 3B and Class 4 laser beams interact with matter. The quantity, composition, and chemical complexity of the LGAC depend greatly upon target material, cover gas and the beam irradiance. The LSO shall ensure that industrial hygiene aspects of exposure to LGAC are addressed and that appropriate control measures are recommended and documented.

While it is difficult to predict what LGAC may be released in any given interaction situation, it is known that contaminants, including a wide variety of new compounds, can be produced with many types of lasers. When the target irradiance reaches a given threshold, approximately 10^7 W.cm^{-2}, target materials including plastics, composites, metals, and tissues, may liberate carcinogenic, toxic and noxious airborne contaminants.

The amount of the LGAC may be greater for lasers that have most of their energy absorbed at the surface of the material. Such compounds may be gaseous or particulate and can, under certain conditions, pose occupational concern. LGAC include metallic fumes, chemical and gaseous vapors, and biological fragments from human and animal tissues (bio-aerosols, dead and live cellular material, bacteria, fungi, and viruses). Some of the compounds from materials include: polycyclic aromatic hydrocarbons from mode burns on poly-methyl methacrylate-type polymers; hydrogen cyanide and benzene from cutting of aromatic polyamide fibers; fused silica from cutting quartz; mutagenic agents from laser surgery; heavy metals from etching; benzene from cutting polyvinyl chloride; plus cyanide, formaldehyde and synthetic and natural fibers associated with other processes.

The LSO shall ensure that appropriate industrial hygiene characterizations of exposure to LGAC are effected in accordance with applicable federal, state and local requirements.

Compressed Gases: Many hazardous gases are used in lasers and laser applications including chlorine, fluorine, hydrogen chloride, and hydrogen fluoride. All compressed gases having a hazardous material information system (HMIS) health, flammability or reactivity rating of 3 or 4 shall be contained in an approved and appropriately exhausted gas cabinet that is alarmed with sensors to indicate potential leakage conditions. Standard operating procedures should be developed for safely handling compressed gases. Typical safety problems that often arise when using compressed gases are: Working with free-standing cylinders not isolated from personnel.

- Inability to protect open cylinders (regulator disconnected) from atmosphere and contaminants.
- No remote shutoff valve or provisions for pumping gas before disconnect or reconnect.
- Labeled hazardous gas cylinders not maintained in appropriate exhaust enclosures.
- Gases of different categories (toxic, corrosives flammable, oxidizer, inert, high pressure, and cryogenic) not stored separately in accordance with OSHA and Compressed Gas Association requirements.

Cryogenic Liquids/ Gases: Cryogenics can cause burns of the skin and eye and can pose an asphyxiation hazard by replacing oxygen in small enclosed spaces. Personal protective equipment, such as lab coats, insulated gloves and eye protection should always be worn when handing such materials.

Laser Dyes: Laser dyes are complex fluorescent organic compounds, which, when in solution with certain solvents, form a lasing medium for dye lasers. Certain dyes are highly toxic or carcinogenic. Since these dyes frequently need to be changed, special care must be taken when handling, preparing solutions for, and operating dye lasers. A Material Safety Data Sheet (MSDS) for dye compounds shall be available to all appropriate workers.

The use of dimethylsulfoxide (DMSO) as a solvent for cyanine dyes in dye lasers should be discontinued if possible. DMSO aids in the transport of dyes into the skin. If another solvent cannot be found, low permeability gloves should be worn by personnel any time a situation arises where contact with the solvent may occur.

Dye lasers containing at least 100 milliliters of flammable liquid shall conform to the provisions of the NFPA (NFPA 30, 45 and 99) and the NEC (Article 500). Laser dyes shall be prepared in a laboratory fume hood. Dye pumps and reservoirs should be placed in secondary containment vessels to minimize leakage and spills in conformance with NFPA 115.

Assist Gases: These gases may be used to produce an inert atmosphere, to remove materials from the beam-interaction site, and to minimize deposition on components (e.g., mirrors and lenses).

Control Measures for LGAC: In general, there are three major control measures available to reduce the concentration of LGAC to acceptable levels. They are exhaust ventilation, respiratory protection, and isolation of the process. The priority of control requires that engineering controls be used as the primary control measure, with respiratory protection and other forms of PPE) used as supplementary controls.

Exhaust Ventilation: Wherever possible, recirculation of LGAC should be avoided. Exhaust ventilation ensures that all personnel exposures to hazardous concentrations of LGAC are maintained at or below the allowable levels specified by OSHA, NIOSH, or the ACGIH. Enclosing hoods should be used to control LGAC. Enclosing hoods afford better control than exterior hoods, are less susceptible to drafts, and may provide protection from reflected and scattered radiation.

Respiratory Protection: Respiratory protection may be used to control brief exposures, or as an interim control measure until other engineering or administrative controls are implemented. If respiratory protection is utilized, the program shall comply with the provisions specified by the US Department of Labor, Occupational Safety and Health Administration (29CFR 1910.134) (or latest version thereof). This standard requires medical evaluation and a respirator fit test prior to use of a respirator.

Process Isolation: The laser process may be isolated by physical barriers, master-slave manipulators, or remote control apparatuses. Process isolation should be used with laser welding or cutting of targets such as plastics, biological material, coated metals, and composite substrates. In addition, during biomedical application, the work area and personal protective equipment shall be disinfected or sterilized immediately after use. See Table 10.1, "Control Measures for the Four Laser Classes," for engineering, administrative and procedural controls.

Control Measures for Chemical Hazards

- Consult the MSDS for the chemical in use.
- Wear personal protective equipment such as lab coats, gloves and goggles when handling the chemical.
- Store the chemical in proper place.
- Provide adequate ventilation.
- Follow the clean-up and waste disposal procedures for any chemical spills.

Biological Agents: These include LGAC and infectious materials. LGAC may be generated when high power laser beams interact with tissue. Infectious materials, such as bacterial and viral organisms, may survive beam irradiation and become airborne.

Use a portable local evacuation system of suitable air flow capacity that can be installed close to the source and that is equipped with high efficiency easily maintainable filtration system and that produces low noise. The working area should also have general ventilation to reduce concentration of the contaminants below the threshold limiting values.

Nanoparticle Exposure: Airborne nanoparticles are generated in nanoparticle generation processes such as laser ablation to produce carbon nanotubes. Some of LGAC generated in surgical and other processes may also be in the nano size range. Nanoparticles may penetrate into the skin and possibly beyond into the blood stream. Exposure to nanoparticles can be controlled by use of local and general ventilation, process isolation, filtration and personnel protective equipment including respiratory protection.

9.0 Appendix C: Warning Signs and Labels

Sign dimensions, letter size and color, etc., shall be in accordance with American National Standard Specifications for Accident Prevention Sign ANSI Z535 series (or latest version thereof).

There are two possible Symbol designs that can be used:

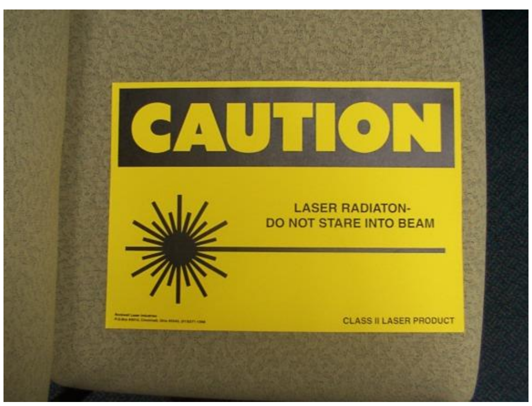
- **ANSI Z535 Design:** the laser hazard symbol shall be sunburst consisting of two sets of radial spokes of different lengths and one long spoke, radiating from a common center (see image below)
- **International Electrochemical Commission (IEC 60825-1) Design:** The laser symbol shall be composed of an equilateral triangle surrounding a sunburst pattern consisting of two sets of radial spokes of different lengths and one long spoke, radiating from a common center (see below).

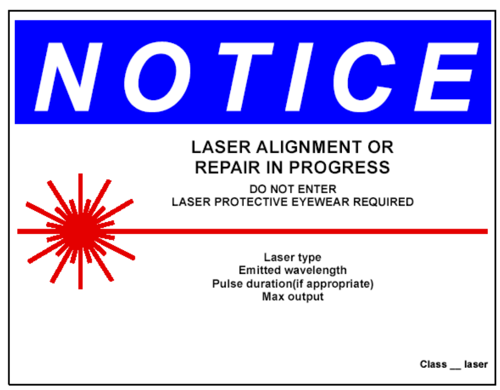
9.1 Meaning of Signal Words on Signs and Labels

The following signal words are used with the ANSI Z535 design laser sign and labels:

- Caution: The word "Caution" shall be used with all signs and labels associated with all Class 2 and 2M lasers and laser systems that do not exceed the appropriate MPE for irradiance (see below).
- Danger: The word "Danger" shall be used with all signs and labels associated all lasers and laser systems that exceed the applicable MPE for irradiance, including all Class 3R, Class 3B and Class 4 lasers and laser systems. The optical density (OD) of the protective eyewear and wavelength shall be shown on the sign for a location requiring the use of eyewear.
- Notice: The word "Notice" shall be used on signs posted outside a temporary laser controlled area, for example, during period of service. When a temporary laser controlled area is created, the area outside the temporary area remains Class 1, while the area within is either Class 3B or Class 4 and the appropriate danger warning is required within the temporary laser controlled area.

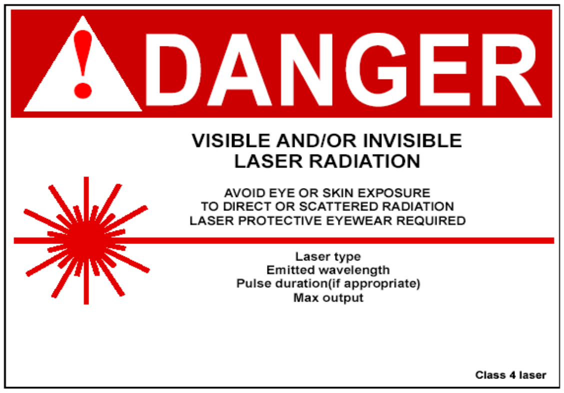
Caution Sign for Classes 2 and 2M Lasers (below left)





Warning Sign used outside a Temporary Laser Controlled Area during periods of Service (above right).

Warning Sign for Class 3R, Class 3B and Class 4 Laser Systems (below left).



IEC Warning Logo and Information Label (above right)

The rectangular box yellow area is for legend, e.g.,

LASER RADIATION, DO NOT STARE INTO THE BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS.

CLASS 2M, LASER PRODUCT, MAXIMUM OUTPUT of 10 mW, 630 nm

9.2 Pertinent Sign Information

a) For area signs, at position 1 (see images above) above the tail of the sunburst, place special precautionary instructions or protective action that may be applicable, for example:

- Laser Protective Eye Wear Required (state required OD for DANGER sign)
- Invisible Laser Radiation
- Knock Before Entering
- Do Not Enter When Light is On
- Restricted Area

b) At position 2 below the tail of the sunburst, state the type of laser or the emitted wavelength, pulse duration (if applicable), and maximum output.

c) At position 3, state the class of the laser or laser system.

d) All signs shall be conspicuously displayed in locations where they best serve to warn onlookers.

e) Equipment labels shall conform to the following specifications:

At position 1 above the tail of the sunburst, place special precautionary instructions actions required such as:

- For Class 2 lasers and laser systems, “Laser Radiation – Do Not Stare into Beam”
- For Class 2M and Class 3R lasers and laser systems where accessible irradiance does not exceed the applicable MPE based upon a 0.25 s exposure for wavelengths between 0.4 and 0.7 µm, “Laser Radiation – Do Not Stare into Beam or View Directly with Optical Instruments”
- For all other Class 3R lasers and laser systems, “Laser Radiation – Avoid Direct Eye Exposure”

- For Class 3B lasers and laser systems, “Laser Radiation – Avoid Direct Exposure to Beam”
- For Class 4 lasers and laser systems, “Laser Radiation – Avoid Eye or Skin Exposure to Direct or Scattered Radiation.

All warning labels shall be conspicuously displayed in locations on the equipment where they best serve to warn onlookers. Websites for some of the labels suppliers are:

Laser Vision: www.lasersafety.com; Fianium US Inc.: www.fianium.com; Kentek: www.kenteklaserstore.com; Rockwell Laser Industries: www.rli.com

9.3 Labeling of Protective Equipment (Class 3B and Class 4 Lasers)

All protective equipment shall be permanently labeled as specified below:

- All laser protective eyewear shall be labeled with the optical density and wavelength(s) for which protection is afforded. All laser protective window, sold other than as an integral part of a product, shall be labeled with the optical density and wavelength(s) for which protection is afforded. Such windows should also be labeled with the exposure time for which the limit applies and conditions under which protection is afforded.
- All permanently mounted collecting optics housing containing laser protective filters sold other than as integral part of the product shall be labeled with the optical density and wavelength(s) for which protection is afforded. All collecting optical filter housing should also be labeled with the threshold limit and exposure time for which the limit applies and conditions under which protection is afforded.
- All laser protective barriers sold other than as an integral part of a product shall be labeled with the barrier exposure time for which the limit applies and the beam exposure conditions under which protection is afforded.
- All laser protective viewports and films sold other than as an integral part of a product should be labeled with the optical density and the spectral region for which protection is afforded. This information shall be provided by the manufacturer.

10.0 Appendix D: Control Measures

10.1 Background

Control measures shall be devised to reduce the possibility of exposure of the eyes and skin to hazardous levels of laser radiation and other hazards associated with devices during operation and maintenance.

For all uses of lasers and laser systems, it is recommended that the minimum laser radiation required for the application be used. Also, it is recommended that the beam height be maintained at a level other than the normal position of the eye of a person in the standing or seated position. Review of reported accidents shows the major causes of accidental exposures are:

- Inadequate laser safety program: LSC committee, LSO, controls, internal oversight
- Inadequate training
- Unanticipated eye exposure during alignment
- Remote viewing methods for laser (TV camera or image converter) not used
- Misaligned optics and upwardly directed beams
- Available eye protection not used
- Equipment malfunction
- Eyewear worn not appropriate for laser in use
- Improper methods of handling high voltages
- Intentional exposure of unprotected personnel
- Operators unfamiliar with laser equipment
- Ignorance of potential hazards
- Lack of protection of non-beam hazards
- Improper restoration of equipment following service
- Unanticipated eye/skin exposure during laser usage
- Inhalation of LGAC and/or viewing laser generated plasmas
- Fires resulting from Ignition of materials
- Failure to follow SOPs

60% of laser accidents in the research setting happen during laser alignment/ beam manipulation, almost all without the user wearing laser protective eyewear.

Some famous quotes from the laser users who do not comply with the safety measures:

- "Don't insult my intelligence"
- "I'll get it the work done one way or the other"
- "That can't happen to me"
- "15 years working with lasers and I haven't had an accident yet"
- "Nothing bad will happen"
- "Hey, I have two eyes"
- "Trust me"

10.2 Accident Identification and Response

<u>The immediate response following an accident is to provide first aid/medical attention and to take actions to remove unsafe condition.</u>

Immediate Response

- Shut down the laser system
- Keep the individual who sustained injury as cool as possible
- Seek immediate medical attention (ambulance/Public Safety for transportation) to medical facility
- Contact the Laser Safety Officer (include after office contact numbers in procedures)
- Notify the supervisor
- Arrange for the examination of the individual by an ophthalmologist/ a doctor, as applicable
- Do not operate laser system further until the incident has been investigated and corrective actions have been taken

Reporting

- Prepare an initial concise report of the incident that covers the basics of 'who', 'what', 'where', and 'when' and submit to the LSO and supervisor immediately.

Investigation

- All incidents should be investigated to prevent recurrence, and reduce the possibility of severe trends.
- The investigation process should involve visiting the site, interviewing the individuals involved, taking pictures if they provide supporting information. The investigation team may involve the LSO, supervisors and other experts in the field.
- The depth of investigation depends on the severity of the accident. However, the investigation should be initiated quickly, should focus on the essential facts, be thorough and concluded within a reasonable time limit. The investigative process should avoid blaming. Results should be properly communicated and corrective action plans implemented as required.
- Lessons learned from the investigation should be clearly spelt out to prevent reoccurrence of the incidents.
- The Laser Safety Committee should analyze the reported incidents to monitor trends.

Remember: *Every incident is an opportunity to learn how to prevent similar events from occurring*

The following control measures should be used:

- Engineering
- Administrative and Procedural
- Protective Equipment

10.3 Engineering Controls

Commercial products manufactured in compliance with the Federal Laser Product Performance Standard (FLPPS) will be certified by the manufacturer and will incorporate those engineering controls required by the FLPPS or the IEC 60825-1 standard (or latest revision thereof).

The engineering applicable controls for a laser or laser system are:

- **Protective Housings (All Classes)**

A protective housing shall be provided for all classes of lasers or laser systems. Special safety procedures may be required when protective housings are removed. The use of appropriate eyewear is recommended at such times. If a user-created enclosure does not meet the requirements of a protective housing (e.g., a non-interlocked cover), it shall be considered as a barrier or curtain and other controls are required per section "operating a laser without protective housing."

- **Operative a Laser without Protective Housing (Class 3B and Class 4)**

In some circumstances, such as research and development and during the manufacture or servicing of lasers, operation of lasers or laser systems without a protective housing may become necessary. In such cases the LSO shall affect a hazard analysis and ensure that control measures are instituted appropriate to the class of maximum accessible emission level to assure safe operation. The control measures may include, but are not limited to: laser control area; eye protection; appropriate barriers, shrouds, beam stops, etc.; administrative and procedural controls; education and training.

- **Walk-in Protective Housing (Embedded Class 3B and Class 4)**

Class 1 lasers or laser systems which contain embedded Class 3B and Class 4 lasers with protective housings which are of sufficient size to allow personnel within the working space shall be provided with an area warning system which is activated upon entry by personnel into the protective housing. Only authorized personnel shall be provided means to override the sensors for alignment or testing procedures. If overridden, the appropriate warning (light, electronic tone, etc.) shall be activated.

- **Interlocks on Removable Protective Housings (All Classes)**

Fail-safe interlocks shall be provided for any portion of the protective housing which, by design, can be removed or displaced during operation and maintenance, and thereby allows access to Class 3B and Class 4 laser radiation.

- **Key Control (Class 3B or Class 4)**

A Class 3B or Class 4 laser or laser system should be provided with a master switch. This master switch shall effect beam termination and/or system shutoff and shall be operated by a key, or by a coded access (such as a computer code). The authority for access to the master switch shall be rested in the appropriate supervisory personnel.

As an alternative, the master switch can be designed to allow system activation using a momentary switch action (or alternative) that initiates system operation with the option that the key (or alternative) can be removed after operation commences. In this mode, if the system ceases to operate, the key switch (or alternative) must again be used to restart the laser or laser system.

- **Viewing Windows, Display Screens, and Collecting Optics**

In order to adequately address additional protection requirements, it is sometimes necessary to utilize a number of various protective devices such as viewing windows, display screens, and laser barriers.

All viewing windows and diffuse (reflective or transmitted) display screens included as integral part of a laser or laser system shall incorporate a suitable means (such as interlocks, filters, attenuators) to maintain the laser radiation at the viewing position at or below the applicable MPE as determined by the LSO.

All collecting optics (such as lenses, telescopes, microscopes, endoscopes, eye-loupe, etc.) that integrate use of a laser or laser system shall incorporate a suitable means (such as interlocks, filters, attenuators) to maintain the laser radiation through the collecting optics at or below the applicable MPE as determined by the LSO.

- **Beam Paths (Class 3B or Class 4)**

For Class 3B or Class 4 lasers or laser systems where a beam path is unenclosed or is partially enclosed, a laser hazard analysis shall be affected by the LSO.

In applications of lasers or laser systems where the entire beam path is enclosed, and the enclosure fulfills all requirements of a protective housing, requirements of Class 1 are fulfilled and no further controls are required. When the protective housing requirements are temporarily relaxed, such as during service, the LSO shall affect the appropriate controls (such as temporary control area and administrative and procedural controls).

- **Remote Interlock Connector (Class 3B or Class 4)**

A Class 3B laser or laser system should or a Class 4 laser or laser system shall be provided with a remote interlock connector. When the terminals of the connector are open circuited, accessible radiation shall not exceed the applicable MPE.

- **Beam Stop or Attenuator (Class 3B or Class 4)**

A Class 3B laser or laser system should or a Class 4 laser or laser system shall be provided with a permanently attached beam stop or attenuator. The beam stop or attenuator shall be capable of preventing access to laser radiation in excess of the applicable MPE when the laser or laser system output is not required, as in warm up procedures.

- **Laser Area Warning Signs and Activation Warnings (Class 3R, Class 3B, or Class 4)**

The purpose of a laser area warning sign is to convey a rapid visual-alerting message that:

(1) Warns the presence of a laser hazard in the area
(2) Indicates specific policy in effect relative to laser controls
(3) Indicates the severity of the hazard
(4) Instructs appropriate action(s) to take to reduce the hazard

Words “CAUTION,” “DANGER,” “NOTICE” are used in the warning. Class 3R areas should be and Class 3B and Class 4 areas shall be posted with the appropriate sign. The exterior boundary of the temporary laser controlled area shall be posted with a Notice sign.

Warning Signs for Non-beam Hazards: Warning signs for non-beam hazards shall be posted when the hazards are possible.

Activation Warning Systems (Class 3B and Class 4): An activation warning system should be used with Class 3B and shall be used with Class 4 lasers and laser systems during activation or startup.

Audible Warning Devices (Class 3B and Class 4): For single pulse lasers and laser systems, an audible system may commence operation when the laser power supply is charged for operation, for example, during the charging of capacitor banks. Distinctive and clearly identifiable sounds that arise from auxiliary equipment (such as vacuum pump or fan) and which are uniquely associated with the emission of laser energy are also acceptable as audible warnings.

Visible Warning Devices (Class 3B and Class 4): One form of visible warning is a single red light or lighted warning sign that flashes when the laser is operating and is readably visible through laser protective eyewear and also viewable within the area. The light can be electrically interfaced and controlled by the laser power supply so that the light is on and flashing only when the laser is operating.

Arrangement for installation of “Laser on” visible warning at the entrance to the laser lab (whether or not interlocked with the lasers) can be made with Facility Management by submitting Minor Project Request Form (***http://facilities.fiu.edu/Documents/Construction/00FIU_MinorProjectRequestForm_Rev2007_0604.xls***) and checking box for laser devices.

- **Laser Controlled Area (Class 3B or Class 4)**

A hazard analysis shall be performed by the LSO. If the analysis determines that the classification associated with the maximum level of accessible radiation is Class 3B or Class 4, a laser controlled area shall be established and adequate measures instituted.

- **Temporary Laser Controlled Area (All Classes)**

In those conditions where removal of panels or protective housing, overriding of protective housing interlocks, or entry into NHZ becomes necessary, and the accessible laser radiation exceeds the applicable MPE, a temporary laser controlled area shall be devised for the laser and the laser system. Such an area shall provide all safety requirements for all personnel, both within and outside the area.

- **Controlled Operation (Class 4)**

Whenever appropriate and possible, Class 4 lasers and laser systems should be controlled and monitored at a position as distant as possible from the emission portal of the laser or laser system.

- **Equipment Labels (All Classes)**

Warning Logotype Label for equipment (All Classes except Class 1): All lasers and laser systems (except Class 1) shall have appropriate warning labels with the laser sunburst logotype symbol and the appropriate cautionary statement.

Protective Housing Equipment Label (All Classes): An advisory protective housing label that indicates the relative hazard of laser contained within the housing shall be placed on all removable housings which have no safety interlock and which can be removed or displaced during operation, maintenance, or service, and thereby allow access to laser radiation in excess of applicable MPE. The laser sunburst logotype symbol is not required on such advisory labels.

Long Distance Beam Conduit Label (All Classes except Class 1): The LSO shall effect advisory protective housing labeling on long distance (>3 meters) beam conduits that contain beams operating above Class 1 levels. Such labeling shall be placed on the outside of the conduit at appropriate intervals (approximately 3 meters), to provide warning of the relative hazards of laser radiation contained within the conduit. The laser sunburst logotype symbol is not required on such advisory labels.

Table 10.1 Control Measures For The Seven Laser Classes

Engineering Control Measures	**Classification**						
	1	1M	2	2M	3R	3B	4
Protective Housing	X	X	X	X	X	X	X
Without Protective Housing	LSO shall establish Alternate Controls						
Interlocks on Removable Protective Housing	∇	∇	∇	∇	∇	X	X
Service Access Panel	∇	∇	∇	∇	∇	X	X
Key Control	-	-	-	-	-	•	•
Viewing Windows, Display Screens and Collecting Optics	Assure viewing limited < MPE						
Collecting Optics	X	X	X	X	X	X	X
Fully Open Beam Path	-	-	-	-	-	X NHZ	X NHZ
Limited Open Beam Path	-	-	-	-	-	X NHZ	X NHZ
Enclosed Beam Path	None, if required controls for Protective Housing and Interlocks on Removable Protective Housings are fulfilled						
Area Warning Device	-	-	-	-	-	•	X
Laser Radiation Emission Warning	-	-	-	-	-	•	X
Class 4 Laser Control Area	-	-	-	-	-	-	X
Entryway Controls	-	-	-	-	-	-	X
Protective Barriers and Curtains	-	-	-	-	-	•	•

Administrative and Procedural Controls	**Classification**						
	1	1M	2	2M	3R	3B	4
Standard Operating Procedures	-	-	-	-	-	•	X
Output Emissions Limitations	-	-	-	-	LSO Determination		
Education and Training	-	•	•	•	•	X	X
Authorized Personnel	-	-	-	-	-	X	X
Indoor Laser Controlled Area	-	+	-	+	-	X	X
Class 4 Laser Controlled Area	-	-	-	-	-	-	X
Temporary Laser Controlled Area	∇ MPE	∇ MPE	∇ MPE	∇ MPE	∇ MPE	-	-
Controlled Operation	-	-	-	-	-	-	•
Outdoor Controlled Measures	X	+ NHZ	X NHZ	+ NHZ	X NHZ	X NHZ	X NHZ
Laser in Navigable Airspace	•	•	•	•	•	•	•
Alignment Procedures	∇	X	X	X	X	X	X
Spectators	-	+	-	+	-	•	X
Service Personnel	LSO Determination						

Personal Protective Equipment	**Classification**						
	1	1M	2	2M	3R	3B	4
Laser Eye Protection	-	-	-	-	-	X	X
Skin Protection	-	-	-	-	-	•	•
Protective Clothing	-	-	-	-	-	•	•

Control Measures: Special Considerations and Warning Signs	**Classification**						
	1	1M	2	2M	3R	3B	4
Laser Optical Fiber Transmission Systems	MPE	MPE	MPE	MPE	MPE	X	X
Laser Robotic Automatic Installations	-	-	-	-	-	X NHZ	X NHZ
Laser Controlled Area Warning Signs	-	-	-	-	-	X	X

Legend

X Shall

• Should

\- No requirements

∇ Shall if enclosed Class 3B and Class 4

MPE Shall if MPE is exceeded

NHZ Nominal Hazard Zone analysis required

+ May apply with use of optical aids

[#] Temporary laser controlled area shall be devised for lasers or laser systems, where removal of panels or protective housing or entry into the NHZ become necessary, and the laser radiation exceeds applicable MPE.

10.4 Administrative and Procedural Controls (Class 3B and Class 4 Lasers)

Administrative and procedural controls are methods or instructions that specify rules, or work practices, or both, which implement or supplement engineering controls and which may specify the use of personal protective equipment. Unless otherwise specified, administrative and procedural controls shall apply only to Class 3B and Class 4 lasers or laser systems. Important administrative and procedural controls are listed below:

- Standard Operating Procedures (Class 3B or Class 4)
- Output Emission Limitations (Class 3R, Class 3B, or Class 4)
- Education and Training (All except Class 1)
- Authorized Personnel (Class 3B or 4 or Embedded Class 3B or 4) – Class 3B or Class 4 lasers or laser systems shall be operated, maintained, or serviced only by authorized personnel. Lasers or laser systems with enclosed Class 3B or Class 4 lasers shall be maintained or serviced only by authorized personnel if such procedures would permit access to levels which exceed 3R AEL.
  Alignment Procedures (All except Class 1) – Alignment of Class 2, 3R, 3B, or Class 4 laser optical systems (mirrors, lenses, beam deflectors, etc.) shall 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 a level above the applicable MPE. Written standard operating procedures (SOPs) outlining alignment methods should be approved for Class 3B and shall be approved for Class 4 lasers or laser systems. SOPs shall also be applicable for all classes of lasers or laser systems which contain embedded Class 3B or Class 4 lasers under conditions which would allow access during alignment procedures. The use of lower power (Class 1, Class 2 or Class 3R) visible lasers for path simulation of higher power lasers is recommended for alignment of higher power Class 3B or Class 4 visible or invisible lasers or laser systems.

- Alignment Procedures for Class 3B and Class 4 Lasers. Alignment should be done only by those who have received laser safety training. In addition, the following actions should be taken:
  (1) Exclude unnecessary personnel from the laser area during beam alignment.
  (2) Whenever possible use low-power visible lasers for path simulation of high-power visible or invisible lasers.
  (3) Wear protective eyewear and clothing to the extent practicable.
  (4) When aligning invisible (and in some cases visible) laser beams, use beam display devices such as image converter viewers or phosphor cards to locate beams.
  (5) Perform alignment tasks that use high-power beams at the lowest power level.
  (6) Use a shutter or beam block to block high-power beams at their source except when actually needed during the alignment process.
  (7) Use a laser rated block to terminate high-power beams down range of the optics being aligned.
  (8) Use beam blocks and/or laser protective barriers in conditions where alignment beams could stray into areas with uninvolved personnel.
  (9) Place beam blocks behind optics (e.g., turning mirrors) to terminate beams that might miss mirrors during alignment.
  (10) Locate and block all stray reflections before proceeding to the next optical component/section.
  (11) Be sure all beams and reflections are properly terminated before high-beam operation.
  (12) Post appropriate area warning signs during alignment procedures where lasers are normally Class 1 (enclosed).

- Spectators (Class 3B or Class 4) – Spectators should not be permitted within a laser-controlled area which contains a Class 3B laser or laser system and spectators shall not be permitted within a laser-controlled area which contains a Class 4 laser or laser system unless:
  (1) Appropriate approval from the supervisor has been obtained
  (2) The degree of hazard and avoidance procedure has been explained, and
  (3) Appropriate protective measures are taken.
- Service Personnel (All Classes) – Personnel who require access to Class 3B or Class 4 lasers or laser systems enclosed within a protective housing or protected enclosure shall comply with the appropriate control measures of the enclosed or embedded laser or laser system. The LSO shall confirm that service personnel have the education and safety training commensurate with the class of the laser and system contained within the housing.
- Federal, State, or Local Requirements: The laser operator or LSO responsible for producing the laser demonstration shall determine that applicable federal, state, or local requirements are satisfied.

10.5 Protective Equipment

Enclosure of the laser equipment or beam path is the preferred method of control, since the enclosure will isolate or minimize the hazard. When engineering controls do not provide adequate means to prevent access to direct or reflected beams at levels above the MPE, it may be necessary to use personal protective equipment. Note that the use of protective equipment may have serious limitations when used as the only control measure with higher power Class 4 lasers or laser systems. The protective equipment may not adequately reduce or eliminate the hazard and may be damaged by the incident laser radiation.

10.6 Protective Eyewear

Eye Protection (Class 3B or Class 4)

Eye protection devices which are specifically designed for protection against radiation from Class 3B lasers and laser systems should be administratively required within the NHZ and their use enforced when engineering or other procedural and administrative controls are inadequate to eliminate potential exposure in excess of the applicable MPE. Eye protection devices which are specifically designed for protection against radiation from Class 4 lasers and laser systems shall be administratively required and their use enforced when engineering or other procedural and administrative controls are inadequate to eliminate potential exposure in excess of the applicable MPE.

Laser protective eyewear is usually not required for Class 2 and Class 3R lasers and laser systems except in conditions where intentional long-term (> 0.25 s) direct viewing is required.

Laser protective eyewear may include goggles, face shields, spectacles or prescription eyewear using special filter materials or reflective coatings (or a combination of both) to reduce exposure to below the MPE. Eye protection may also be necessary to protect against physical or chemical hazards.

UV Laser Protection: Special care shall be given to the possibility of producing undesirable reactions in the presence of UV radiation, for example, formation of skin sensitizing agents, ozone, LGACs, etc. Personal protective equipment shall be used when working with open beam Class 3B or Class 4 UV lasers. This shall include both eye and skin protection.

The following factors shall be considered in selecting the appropriate laser protective eyewear to be used:

- Laser power and/or pulse energy.
- Wavelength(s) of laser output.

- Potential for multi-wavelength operation.
- Radiant exposure or irradiance levels for which protection (worst case) is required.
- Exposure time criteria.
- Maximum permissible exposure (MPE).
- Optical density requirement of eyewear filter at laser output wavelength.
- Angular dependence of protection afforded.
- Visible light transmission requirement and assessment of the effect of the eyewear on the ability to perform tasks while wearing it.
- Need for side-shield protection and maximum peripheral vision requirement.
- Radiant exposure or irradiance and the corresponding time factors at which laser safety eyewear damage (penetration) occurs, including transient bleaching.
- Need for prescription glasses.
- Comfort and fit.
- Degradation of filter media, such as photo bleaching.
- Strength of materials (resistance to mechanical trauma and shock).
- Capability of the front surface to produce a hazardous specular reflection.
- Requirement for antifogging design or coatings.

10.7 Laser Eye Protection Selection Process

- Determine the wavelength of the laser: Eye protection is wavelength-specific. Eyewear that provides protection for CO_2 lasers will not necessarily protect against Nd:YAG lasers.
- Determine the maximum anticipated viewing duration: Viewing duration will fall into one of three categories:
  - Unintentional, accidental exposure to visible lasers (400-700 nm), use 0.25 seconds.
  - Unintentional, accidental viewing of near infrared (700-1000 nm) beams, use 10 seconds.
  - For all other lasers, use laser on time or 600 seconds for visible Class 3B or
  - Class 4; diffused reflection or extended source viewing maximum viewing time during any given 8-hour period or 30,000 s for long-term exposure. Repeated exposures are additive over a 24-hour duration regardless of the
  - repetition rate for the wavelength range of 0.180 to 0.400 µm. Determine the maximum irradiance or radiant exposure to which the eye may be exposed.

  Consider the following:

  - If the emergent beam is not focused down to a smaller spot and is greater than 7 mm in diameter, the emergent beam radiant exposure/irradiance may be considered the maximum intensity that could enter the eye.
  - If the beam is focused after emerging from the laser or if the beam diameter is less than 7 mm, assume that all of the laser energy/power could enter the eye. In this case, use limiting beam aperture of 7 mm.
- Determine the optical density needed. The optical density is logarithm to the base 10 of the reciprocal of transmittance (ratio of transmitted power or energy to incident power or energy). Transmittance is also the ratio of MPE to irradiance or radiation exposure.
- Select the type of eye protection needed: Laser eye protection is available in the form of glasses and goggles. The lens may be made out of glass or crystalline filter material or plastic. Generally, glass or crystalline lenses are recommended for harsh environments, such as areas where solvents and corrosives are used.
- Test the eye protection. Always check the integrity of the lens before use. At very high beam

intensities, filter materials become bleached out or otherwise damaged. A continuous wave power exceeding 10 W can fracture glass and burn through plastics.

Identification of Eyewear

- All laser protective eyewear shall be clearly labeled with the optical density and wavelength for which protection is afforded. Color-coding or other distinctive identification of laser protective eyewear is recommended in multi-laser environments.

Cleaning and Inspection

Periodic cleaning and inspection shall be made of protective eyewear to ensure the maintenance of satisfactory condition. This shall include:

- Periodic cleaning of laser eyewear. Care should be observed when cleaning lenses of protective eyewear to avoid damage to the absorbing and reflecting surfaces. Consult eyewear manufacturers for instructions for proper cleaning methods.
- Inspection of the attenuation material for pitting, crazing, cracking, discoloration, etc.
- Inspection of the frame for mechanical integrity.
- Inspection for light leaks and coating damage that would permit hazardous intrabeam viewing.
- Eyewear in suspicious condition should be tested for acceptability or discarded.

Purchasing Information for Protective Eyewear

The following information should accompany each laser safety protective eyewear device purchased:

- Wavelength(s) and corresponding optical density for which protection is afforded.
- Pertinent data such as damage threshold for laser safety purposes.
- Manufacturer's recommendations on shelf life, storage conditions, and use.

10.8 Laser Protective Windows (Class 3B and Class 4 Lasers)

Facility windows (exterior or interior) that are located within the NHZ of a Class 3B or Class 4 laser or laser system shall be provided with an appropriate absorbing filter, scattering filter, blocking barrier, or screen that reduces any transmitted laser radiation to levels below the applicable MPE level.

Such laser windows shall be specifically selected to withstand direct and diffusely scattered beams. In this case, the window barrier shall exhibit a damage threshold for beam penetration for a specified exposure time commensurate with the total hazard evaluation for the facility and specific application.

Important in the selection of the window are the factors of flammability and decomposition products of the window material. It is essential that the window not support combustion or release toxic airborne contaminants following a laser exposure.

10.9 Laser Protective Barriers and Curtains (Class 3B and Class 4 Lasers)

A blocking barrier, or screen, or curtain which can block or filter the laser beam at the entryway should be used inside the controlled area to prevent the laser light from exiting the area at levels above the applicable MPE level.

Such laser barriers shall be specifically selected to withstand direct and diffusely scattered beams. In this case, the barrier shall exhibit a damage threshold for beam penetration for a specified exposure time commensurate with the total hazard evaluation for the facility and specified application

Important in the selection of the barrier are the factors of flammability and decomposition products of the barrier material. It is essential that the barrier not support combustion or release toxic fumes following a laser exposure.

Websites for some of the suppliers of laser safety curtains, windows, laser safety panels, laser barriers; laser dumps, laser shutters, entry control systems, interlocks, eyewear, etc. are:

Laser Vision: www.lasersafety.com;
Kentek: www.kenteklaserstore.com; www.laserbarriers.com;
Rockwell Laser Industries: www.rli.com;
Noir: www.lasershields.com;
Beamstop'r: www.Beamstopr.com;
Laser Safety Systems: https://www.lasersafetysystems.com/products.html

10.10 Skin Protection (Class 3B and Class 4 Lasers)

In some laser applications, such as use of excimer lasers operating in the ultraviolet, the use of a skin cover shall be employed if chronic (repeated) exposures are anticipated at exposure levels at or near the applicable MPE limits for the skin.

Skin protection can best be achieved through engineering controls. If the potential exists for a damaging skin exposure, particularly for ultraviolet lasers (295 - 400 nm), and/or laser cutting application, then skin covers and / or "sunscreen" creams are recommended. Most gloves will provide some protection against laser radiation. Tightly woven fabrics and opaque gloves provide the best protection against laser radiation. A laboratory jacket or coat can provide protection for the arms. For Class 4 lasers, consideration shall be given to flame-retardant materials. For wavelengths greater than 1400 nm, large-area exposures can cause heat loading – causing skin dryness and heat stress. These exposures shall be minimized.

10.11 Laser Safety Tips (Post this near Laser)

- Follow written standard operating procedures
- All laser users complete laser safety. They complete refresher training every 3 years
- Hands-on beam alignment training should be administered by the supervisors and documented
- Level of training provided by the supervisors should be commensurate with the hazard
- Activate a visual or audible indicator prior to emission of the beam
- Operate lasers in well lighted areas whenever possible to reduce pupil size and minimize possible eye damage
- Post the laser area with warning signs
- Use remote firing with video monitoring or other remote viewing techniques when feasible
- Remove reflective materials (watches, rings, etc.) from the beam path
- Locate and block all unwanted reflectors at each optical element
- Terminate laser beam with beam trap
- Block beam before adding optical elements
- Except as required for medical use, configure the laser beam path such that the exposed beam is above eye level of a person in standing position or below eye level of a person in seated position
- Avoid vertical or oblique beams
- Perform alignment at low power
- Use minimum power or energy, as practicable
- Use barriers to confine beam
- Perform final sweep to verify beam controls
- Use appropriate personal protective equipment to prevent eye injuries, skin/hair burns, and inhalation exposures
- Use frame for the eyewear with widest field of view as possible
- Frame should have at least the same damage threshold as the filter
- Provide eyewear to patients and visitors for access to areas where beam irradiance > Maximum Permissible Exposure
- Remember, ultra-short lasers degrade eyewear filters upon exposure
- Ask for documentation from the manufacturer for test on eyewear
- Claim by suppliers/manufacturers regarding eyewear optical density (OD) > 7 is questionable, if untested
- Clean and maintain eyewear, and discard them if there is a visible sign of damage
- Remember laser safety glasses are designed to protect your eyes against accidental direct hit of the laser beam, and NOT for long-term or intrabeam laser viewing
- Provide adequate protection from non-beam hazards (fire, electric shocks, plasma radiation, exposure to laser generated airborne contaminants, hazardous gases, etc.)
- Provide proper earth-grounding for laser and laser systems
- Keep combustible materials such as unprotected wire insulation, plastic, rubber, paper, human tissues, human hair, intestinal gases, and skin treated with acetone and alcohol-based preparation, away from the path of intense direct or reflected beams. They may catch fire
- Use suitable ventilation system to exhaust laser generated airborne chemical or biological contaminants
- Investigate all incidents to enhance quality of the environment, safety and health, and to prevent recurrence, and reduce the possibility of severe trends.

11.0 Appendix E: Medical Eye Examinations

The basic reasons for performing medical surveillance of personnel working in a laser environment are the same as for other potential hazards. Medical surveillance should be limited only to those who are clearly known to be at risk from particular kind of laser radiation. Medical surveillance is not recommended for personnel using Class 1, Class 2, Class 2M or Class R lasers or laser systems, and should be required for Class 3B and Class 4 lasers or laser systems.

11.1 Medical Examinations: Preassignment, Periodic, Termination, and After Suspected Injury

Preassignment Medical Examinations

The purpose of the medical examination is to establish a baseline against which damage (primarily ocular) can be measured in the event of an accidental injury. A second purpose is to identify certain workers who might be at special risk from chronic exposure to selected continuous-wave lasers. For incidental workers (e.g., custodians, military personnel on maneuvers, clerical and surgical and supervisory personnel not working directly with lasers) only visual acuity measurement is required. For laser workers' medical histories, visual acuity measurement, and selected examination protocols are required. The wavelength of laser radiation is the determinant of which specific protocols are required. Examination should be performed by, or under the supervision of ophthalmologist or optometrist or other qualified physician.

Periodic and Termination Medical Examinations

Neither periodic medical examinations nor termination medical examinations are required by ANSI Z136.1-2007. However, EH&S highly recommends for individual departments to require their employees to be examined at the termination of laser or laser system operation assignments for the purpose of legal protection against unwanted claims that might occur after an employee leaves a particular job.

Examinations Following a Suspected or Actual Laser-Induced Injury

Medical examinations shall be performed as soon as practical (usually with 48 hours) when a suspected injury or adverse effect from a laser exposure occurs. In addition to the acute symptoms, consideration shall be given to the exposure wavelength, emission characteristics and exposure situation to assure appropriate medical referral.

11.2 Examination Protocols

Ocular History: The past eye history and family history are reviewed. Enquiry should be made into the general health status with a special emphasis upon systemic diseases which might produce ocular problems. The current refraction prescription and the date of the most recent examination should be recorded.

Certain medical conditions may cause the laser workers to be at an increased risk for chronic exposure. Use of photosensitizing medications, such as phenothiazines and psoralens, lower the threshold for biological effects in the skin, cornea, lens and retina of experimental animals exposed to ultraviolet radiation. Aphakic individuals would be subject to additional retina exposure from blue light and near UV and UV radiation.

Visual Acuity: Visual acuity for far and near vision should be measured with some standardized and reproducible method. Refraction corrections should be made if required for both distant and near test targets.

Macular Function: An Amsler grid or similar pattern is used to test macular function for distortions and scotomas. The test should be administered in a fashion to minimize malingering and false negatives. If any distortions or missing portions of the grid are present, the test is not normal.

Color Vision: Color vision discrimination can be documented by Ishihara or similar vision tests.

Examination of the Ocular Fundus with an Ophthalmoscope or Appropriate Fundus Lens at a Slit Lamp: This portion of the examination is to be administered to individuals whose ocular function is not normal. The points to be covered are: the presence or absence of opacities in the media; the sharpness of outline of the optic disc; the depth of physiological cup, if present; the ratio of the size of retina veins to that of the arteries, the presence or absence of a well-defined macula and the presence or absence of a foveal reflex; and any retinal pathology that can be seen with an ophthalmoscope (hyper-pigmentation, depigmentation, retinal degeneration, exudate, as well as any induced pathology associated with changes in macular function). Even small deviations from normal should be described and carefully localized. Dilation of pupil is required.

Skin Examination

Pre-placement skin examination of workers is not required; however, it is suggested for employee with history of photosensitivity or working with UV lasers. **Chronically exposed individuals to UV radiation should receive annual skin cancer screening.**

Records and Record Retention

Complete and accurate records of all medical examinations (including specific test results) should be maintained for all personnel included in medical surveillance program. Records should be retained for at least 30 years.

11.3 Procedures For Eye Examination

Environmental Health & Safety has established an agreement with College Optical Express located at 11099 W 10th St., PG6, Miami, FL 33199 for eye examination in accordance with the requirements of ANSI Z 136.1-2014.

Eye examination is required for all FIU employees who work with Class 3B or Class 4 lasers or who may be exposed to laser radiation because they frequently access these areas as a part of their duties (ANSI Z136.1-2014 Section 6 and Appendix F). Such employees are eligible to receive employer provided eye examination and should be provided with the opportunity to have their eyes examined by an optometrist. For your convenience EH&S has a price schedule with:

College Optical Express located at 11099 W 10th St., PG6, Miami, FL 33199, O: (305) 348-8439 and F: (305) 348-8330. At present the EH&S engages the services of Board Certified Doctor of Optometry: Dr. Claire Lee.

The steps to obtain approval for eye examination under the agreement are as follows:

- The principal Investigator (PI) identifies operators in their group for eye exam and makes budget provision for eye exam.
- The negotiated cost per person for eye examination is $ 39.00.
- The PI sends notification to the Laser Safety Officer (by letter, e-mail: LSO@fiu.edu) as follows:

Notification Re: Occupationally Approved Laser Eye Examination

In accordance with the requirement of ANSI Z136.1-2014 the following individuals have been scheduled for eye examination which will be paid by the PI/department:

Name: ______________________________ Department: _________________

- The LSO sends e-mail acknowledgment to the authorized individual (cc PI) advising him/her to schedule an appointment at their convenience with medical service provider.
- Authorized individual schedules an appointment and PI pays the exam fee to medical service provider.
- Medical service provider conducts medical eye examination in accordance with ANSI Z 136.1-2014.
- Medical service provider sends report, per ANSI, to the Laser Safety Officer at AHC4 Suite 120, 11200 SW 8th St., Miami, FL 33199.
- Authorized individual receives e-mail confirmation of results from LSO. The individual receives the eye exam report from the LSO.
- All medical records are confidential and will be maintained by medical service provider for a period of 30 years after the last known exposure at FIU.
- Medical service provider is responsible to contact the individual to follow up, if necessary.
- Individuals may request that their records be furnished to their private physicians.

- An employee with suspected eye injury must be **immediately** referred to an ophthalmologist. Notification must be provided to FIU Workers Compensation Coordinator: (305) 348-7960 as soon as possible. For work related injury or claim or notice visit:

https://hr.fiu.edu/leadership/managing-at-fiu/#worker-comp-process

11.4 Sample Authorization Letter for an Eye Examination

MEMORANDUM

Date:

To: Name, ___________ Department

From: David Roelant, Laser Safety Officer, EH&S
Phone: (305) 348-6625; E-mail: LSO@fiu.edu

Re: Authorization to Schedule Eye Examination by Authorized Service Provider

---

The Department of Environmental Health & Safety has established an agreement with College Optical Express located at 11099 W 10th St., PG6, Miami, FL 33199 for eye examination in accordance with the requirements of ANSI Z 136.1-2014.

The negotiated cost per person for eye examination is $39.00. This letter is confirmation that the eye examination is required for compliance with the laser safety program. The examination will be conducted by a board certified optometrist and will comprise of: Medical Histories, Visual Acuity Measurement and Selected Examination Protocols described in ANSI Z 136.1-2014.

Please schedule an appointment with College Optical Express and make sure your PI/department has made arrangement to pay for the exam before it is completed.

Please complete the examination as soon as possible and inform me when the examination is completed. Please inform the doctor to send the eye examination report to Laser Safety Officer, LSO@fiu.edu or 11555 SW 17th Street, Campus Support Complex 164, Miami, FL 33199.

The working hours of optometrist are:

- Dr. Claire Lee------------- 9::30 AM to 4:30 PM------------
Phone: (305) 348-8439; Fax: (305) -348-8330

Should you have questions please feel free to contact me.

Cc Tamece Knowles, Director, Environmental Health & Safety

Principal Investigator, _______ Department

College Optical Express, CollegeOptical@fiu.edu

11.5 Sample Eye Examination Report

MEMORANDUM

Date:

To:

CC: Department Head/Principal Investigator/Laboratory Manager (without attachment)

From: David Roelant, Laser Safety Officer

Re: Eye Examination Report

I have reviewed the attached report submitted by Dr. ________________________, an independent Board Certified Optometry, regarding your eye examination conducted in accordance with the requirements of ANSI Z 136.1-2014.

Based on the report you are approved to work with laser devices. Please acknowledge below and return this memo by -------: No records or copies of your report have been maintained on file with FIU. This document is required as a substitute for the attached report.

Thank you.

Approved: YES ☐ NO ☐

Name______________________________

(Please Print)

Signature ___________________________ Date___________________________

12.0 Appendix F: Laser Safety Training

12.1 Requirements and Available Laser Safety Trainings

Laser safety training shall be provided to the LSO and users of Class 3B and 4 lasers. Laser safety training should be provided to users of Class 1M, Class 2, Class 2M or Class 3R lasers. The level of training shall be commensurate with the degree of potential laser hazards, both from the laser radiation and non-beam hazards. Laser safety training shall include warning against the misuse of lasers.

Users shall include operators, technicians, engineers, maintenance and service personnel, and any other persons working with or potentially exposed to laser radiation in excess of Class 1.

Topics for inclusion in a laser safety program may include, but are not limited to, the following:

- Fundamentals of laser operation (physical principles, construction, etc.)
- Bioeffects of laser radiation on the eyes and skin
- Significance of specular and diffuse reflections
- Non-beam hazards of lasers
- Laser and laser system classifications
- Control measures
- Overall responsibilities of management and employee
- Medical surveillance practices (if applicable)
- CPR for personnel servicing or working on lasers with exposed high voltages and/or the capability of producing potentially lethal electrical currents.

In addition to the above referred topics, the LSO and other individuals responsible for the laser safety program, hazards evaluations and implementation of control measures shall be trained in the following topics:

- Laser terminology
- Types of lasers, wavelengths, pulse shapes, power/energy
- Basic radiometric units and measurement devices
- MPEs
- Laser hazard evaluations and other calculations

The laser safety training at FIU is conducted in two phases. The first is a Web-Based course covering laser safety basics and regulations (http://ehs.fiu.edu/Pages/default.aspx). This is followed by hands-on laser alignment on-the-job-training taught by a laser laboratory supervisor. Laser operators learn how to align visible and invisible lasers safely using low power lasers, common optical elements, control measures, viewing aids, and appropriate eyewear. Before operating a laser independently the user shall acknowledge completion of training and eye examination requirements and obtain approval from the supervisor and the LSO (See form on the next page).

Refresher Training: The Laser Safety Committee shall address the needs for maintaining the appropriate level of laser safety proficiency through the use of periodic training. The FIU on-line safety training serves the purpose of refresher training which should be completed every 3 years.

12.2 Form for FIU ESH Certificate for Successful Completion of Laser User Safety Training and Eye Examination

Please Complete the Following and Return to the LSO at LSO@fiu.edu

Laser User Name (print)	Phone	Laser Supervisor	Department

1. Training Acknowledgment

I hereby certify that

- I have completed on-line safety training provided by FIU, EH&S.
- I have been instructed by my supervisor --------------------------------------- in the safe user of lasers and laser systems that I will be operating in the FIU laboratory/ laboratories.
- I will use appropriate protective eyewear before using any lasers
- I have read and understood the FIU Laser Safety Manual

Laser User Name (print)	Signature	Date

2. Baseline Eye Examination Report Acknowledgment

Dr. -------------------------------------- optometrist/ Ophthalmologist has completed my baseline eye examination on ………….. I have received the original eye examination report from the Laser Safety Officer for which no copies or records have been maintained on file with FIU EH&S.

Laser User Name (print)	Signature	Date

3. Approval by Laser Supervisor

I acknowledge that the above individual has met all requirements to use the following laser(s)

Laser Type/Classification	Comments/Restrictions	Date
Supervisor Name (print below)	Signature below	Date

4. Approval by the LSO

I certify that the above individual has met all requirements set forth by the Laser Safety Committee to become a laser operator.

Laser Safety Officer Name (print above)	Signature	Date

13.0 Appendix G: FIU Laser Safety Procedures

The following procedures have been established:

- Online Laser Safety Training Procedure
- Laser Purchasing Procedure
- Laser Registration with EH&S
- Laser Registration with the State
- Authorized User Change or Relocation of Lasers
- Laser Laboratory Inspection Procedure
- Eye Examination Procedure
- Eye Examination Authorization Procedure
- Eye Examination Report
- Laser Research Proposal Review Procedure
- Laser Disposal

13.1 Online Laser Safety Training Procedure

All laser operators (employees and students) must successfully complete on-line laser safety training. For this they should visit FIU EH&S website (http://ehs.fiu.edu/Pages/default.aspx), and register for laser training, attend the training and appear for examination. A certificate is printed for those who score a minimum of 80%.

13.2 Laser Purchasing Procedure

For the purchase of special hazard materials, such as laser devices, radioactive materials, etc. prior approval is required from the applicable safety officer. For example, approval must be obtained from the Laser Safety Officer before purchase order for a Class 3B or Class 4 laser device is placed. As commodity codes are completed, PantherSoft purchasing system will direct for approval of special hazard materials to the approving safety officer. Till that time the present procedure of e-mailing or faxing requisition or request for approval to the safety officer, obtaining approval and electronically attaching the approval to the PantherSoft purchase will continue. Given below is the procedure:

- The Principal Investigator identifies that he/she plans to purchase a laser device.
- He/she fills in details of the laser device – name, address and phone number of the company; model number, wavelength, maximum power/energy and class of the laser, location where laser will be installed.
- The LSO reviews the safety features, contacts the PI if necessary regarding safety issues, and approves the purchase.
- On receipt of the laser device the PI contacts the LSO.
- Within seven days of the receipt of the device the PI fills in the laser registration form and submits it to the LSO.
- PI installs the device in consultation with the LSO.

13.3 Laser Registration with FIU EH&S and State of Florida

All Class 3B and 4 lasers must be registered with EH&S by filling in LASER REGISTRATION WITH EH&S FORM (see next page). According to Florida Administrative Code (FAC) all Class 3B and 4 lasers must be registered with the State within 30 days after acquisition of the laser product

(http://www.myfloridaeh.com/radiation/nonion1.htm). The LSO or EHS fills in the required registration form and submits it to the State. The State evaluates the registration request, approves it and returns the form to FIU EH&S with a registration number.

13.4 Laser Registration With EH&S Form

Principal Investigator:	Phone:
Co-Principal Investigator:	Phone:
Departmental Laser Safety Officer:	Phone:

Laser Manufacturer:	
Model Number:	Serial Number:
FIU ID Number:	

Laser Location:

Building Name /No.	Room No.
Department:	

Laser Characteristics

Laser Name and Type (e.g., Nd:YAG):		
Classification		
Wavelength (nm):	Beam Diameter (mm):	Beam Divergence (mrad):

Mode

Continuous Wave	Avg. Power (watts):	
Pulsed	Joules/pulse	Repetition Freq:
Q-Switched	Pulse Width:	Joules/Pulse:

GENERAL	Yes	No
Have all users received training?		
Has the training been documented?		
Have laboratory Standard Operating Procedures (for operation, maintenance and beam alignment) and safety guidelines been developed for use of lasers?		

Are American National Standards Institute guidelines (ANSI Z136.1 2014) and Florida Administrative Code, Chapter 64E.4 being followed for the safe use of lasers?		
Has a baseline eye test been performed and recorded for all users?		
Has laboratory been inspected and approved by the University Laser Safety Officer? If yes, date of inspection:		
Purpose of use:		
Comments: Signature .... Date: (Principal Investigator)		

Standard Operating Procedures must be reviewed annually and updated when there are significant changes.

Details of laser systems and a list of all qualified laser users in your lab should be sent regularly to the Laser Safety Officer at EH&S Office: CSC 162; Phone: (305) 348-6625/2621; email: LSO@fiu.edu

13.5 Laser Laboratory Inspection Procedure

The LSO schedules an inspection with the PIs possessing Class 3B and Class 4 laser devices, uses the laser laboratory inspection checklist (see Appendix 9) and conducts the inspection and submits the inspection report to the PI. The PI complies with safety concerns raised by the LSO and responds to the LSO. The LSO performs final compliance inspection.

13.6 Eye Examination Procedure Authorization and Report

Section 11 contains the procedures for eye examinations and for authorizing an individual for an eye examination. The LSO receives a report of the eye examination of an individual and forwards the original report to the examinee along with an acknowledgment (see Section 11) of the receipt of the report. The individual retains the report for his/her records and returns the signed acknowledgment to the LSO.

13.7 Laser Research Proposal Review Procedure

All researchers whose research involves use of laser devices fill out the Office of Research and Economic Development Safety Clearance form (see Appendix 13) and submit to the ORED. ORED forwards the form to EH&S. The LSO evaluates the safety issues and submits the report to the ORED.

13.8 Authorized User Change or Relocation of Lasers (transfer, surplus, donate or disposal)

All class 3B and 4 laser devices are registered with the Bureau of Radiation Control in the name of an individual at a particular location. Whenever there is change in the user or a place of use it must be brought to the attention of the LSO who is responsible to update inventory and registration with the Bureau.

For Laboratory Relocation Guide visit the EH&S website: https://ehs.fiu.edu/Programs/Chemical-Safety/Pages/default.aspx.

Arrangement for transfer/pick up materials with special hazards such as lasers can be made by downloading property control form from https://finance.fiu.edu/controller/downloads/Transfer_Form.doc, checking box for lasers and submitting to the Property Control (see next section).

If an authorized user of laser devices separates from FIU, procedures for separation from FIU must be followed to account for laser devices, which otherwise, particularly laser diodes, may be misplaced/ lost.

Laser System Transfer to New Location, Surplus or Disposal

Transfer, Surplus or Disposal of all Classes 3 and 4 lasers and laser system shall be only through the LSO. There are 4 authorized methods to remove these lasers once they are no longer being used and **ALL must be coordinated with the LSO.**

The first method is to **transfer** the laser to another researcher at the University. Provide to the LSO details of the lasers you no longer need or want. The LSO will bring it to the attention of laser users in the University. If you know of a researcher who needs and is willing to take your laser coordinate the transfer through the LSO.

The second method is to **donate** the laser to an organization that can use it. Such organizations can be schools, industrial companies, hospitals, etc. The donor should assure that the equipment being given complies with all applicable product safety standards, such as FLLPS, and is provided with adequate safety instructions for operations and maintenance. The donor should ensure that the laser will be used by individuals who are trained in laser safety.

The third method is to **surplus** it. It can be return the laser to the manufacturer for credit on a new laser. Sometimes the manufacturer may agree to take it free and cover for all packing and shipping expenses. It can also be designated as surplus and sent to another organization outside FIU but this must be coordinated with LSO and Property Control. For Class 3 and Class 4 lasers, FIU must document that the organization receiving the system is properly training it is safe use. Such a laser can be transferred to the LSO and should not be mingled with the large volume of equipment regularly sent to surplus at FIU.

The fourth method is to move it to **dispose** of the laser in trash. This requires that the PI eliminate the possibility of activating the laser by removing all means by which it can be electrically activated and removing all hazardous materials found inside the laser components, such as mercury switches, oils, and other chemicals. Once this has happened the laser could then be disposed. This should be the option for only older, non-working lasers not needed or wanted by anyone.

Proper waste disposal of contaminated laser-related material such as flue and smoke filters, organic dyes, solvent solutions and hazardous chemicals shall be handled in conformance with appropriate federal, state, and local guidelines.

Below is the FIU Form for the Transfer of Instrumentation Containing Hazards (laser, radioactive material, biohazards, controlled substances or hazardous chemicals).

13.9 FIU Form for the Transfer of Instrumentation Containing Hazards (laser, radioactive material, biohazards, controlled substances or hazardous chemicals)

FIU Property Control: Phone: (305) 348-2167 ……………….Fax: (305) 348-2775

☐ Requests for Transfer of equipment to a new location

☐ Request for Transfer from one Department/Project number to another

In accordance with the Media Sanitation Policy and Data Stewardship Procedure, the University requires that all computer equipment that has storage devices be erased using a repeated overwrite operation, purged, degaussed, or destroyed prior to being surplus, donated, transferred or discarded.

☐ Check here if deemed not necessary for this transfer (there is no sensitive data on this computer)

Otherwise, indicate if this requirement will be performed by:

- ☐ **Department's ITA (security.fiu.edu)**
- ☐ **Department's Staff member (security.fiu.edu)**
- ☐ **UTS Call (305) 348-2284**
- ☐ **Property Control**
- ☐ **Non – Applicable (for furniture and non-electronic equipment)**

Name of person performing the cleansing ______________________________ Date______________
(Adhere a compliance "sticker" to the computer after the procedure is performed)
Originating Department / Project Name: ____

Department/Project ID: **From: __________________________ To: __________________________**

Contact Person: ____ Phone: _________________

Description	FIU Tag #	Originating Location	Destination

Prior approval from Risk Management & Environmental Health & Safety Department (EH&S) is required if the equipment contains any material which is regulated or that could be of health concern.

Please contact (305) 348-2621 for EH&S related questions. Please review the Laboratory Relocation Guide (http://www.fiu.edu/~ehs/bio_chemical_safety/Lab_Relocation_Procedure.pdf).

Please check the appropriate Yes or No box. Does the equipment contain any of the following*?

Radioactive materials ☐ Yes ☐ No

Laser devices (Class 3B or 4) ☐ Yes ☐ No

Hazardous chemicals ☐ Yes ☐ No

Biohazardous materials (all types) ☐ Yes ☐ No

Controlled substances ☐ Yes ☐ No

* If the answer is "Yes", please attach EH&S Clearance Form

AUTHORIZATION SIGNATURES

____

Originating Department / Project Name Contact Signature Date

____

Receiving Department/ Project Name Contact Signature Date

14.0 Appendix H: Records Retention Requirements

(1) FIU shall maintain current records, which shall be kept available to inspection by the Department of Health, showing:

(a) The results of all surveys (inspections performed by the LSO) required under Rule 64E-4.009, F.A.C.

(b) The results of all instrument calibrations under Rule 64E-4.010, F.A.C.

(c) The reports of incidents as described under Rule 64E-4, F.A.C.

(2) FIU shall maintain such records required by Rule 64E-4.012, F.A.C., for 5 years.

15.0 Appendix I: Glossary

Absorption: Transformation of energy to a different form of energy by interaction with matter.

Accessible emission limit (AEL): The maximum accessible emission level permitted within a particular laser hazard class.

Accessible optical radiation: Optical radiation to which human eye or skin may be exposed for the condition (operation, maintenance or service) specified.

Administrative control measure: Control measures incorporating administrative means (e.g., training, safety approvals, LSO designation, and standard operating procedures (SOP)) to mitigate the potential hazards associated with laser use.

Alpha max: The angular limit subtense of an extended source beyond which additional subtense does not contribute to the hazard and need not be considered. This value is 100 mrad for retinal thermal effects and 110 mrad for retinal photochemical effects.

Alpha min: The angular subtense of a source below which the source can be effectively considered as a point source. The value of alpha min is 1.5 mrad.

Aperture: An opening, window or lens through which radiation can pass.

Apparent visual angle: The angular subtense of the source as calculated from the source size and the distance from the eye.

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

Authorized personnel: Individuals approved by management to operate, maintain, service, or install laser equipment.

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

Aversion response: Closure of the eyelid, eye movement, papillary constriction or movement of the head to avoid an exposure to a noxious or bright light stimulant. The aversion response to an exposure from a bright, visible, laser source is assumed to limit the exposure of a specific retinal area to 0.25 seconds or less.

Beam: A collection of light/photonic rays characterized by direction, diameter (or dimensions) and divergence (or convergence).

Beam diameter: The distance between diametrically opposed points in that cross-section of a beam where the power per unit area is l/e (0.368) times that of the peak power per unit area.

Blink reflex: The involuntary closure of the eyes as a result of stimulation by an external event such as irritation of the cornea or conjunctiva, a bright flash, the rapid approach of an object, an auditory stimulus or with facial movements. The ocular aversion response for a bright flash of light is assumed to limit the exposure of a specific retina to 0.25 s or less.

C_A: Correction factor which increases the MPE in the near infrared (IR-A) spectral band (0.7-1.4 um) based upon reduced absorption properties of melanin pigment granules found in the skin and in retinal pigment epithelium.

C_B: Correction factor which increases the MPE in the near infrared (IR-A) spectral band (0.45-0.69 um), because of greatly photochemical hazards.

C_C: Correction factor which increases the MPE for ocular exposure because of pre-retinal absorption of radiant energy in the spectral region between 1.15 and 1.40 um.

C_E: Correction factor used for calculating the extended source MPE for the eye from the point source MPE, when the laser source subtends a visual angle exceeding **Alpha min.**

C_P: Correction factor which reduces the MPE for repetitive-pulse exposure of the eye.

Carcinogen: An agent potentially capable of causing cancer.

Coherent: A beam of light characterized by a fixed phase relation (spatial coherence) or single wavelength, i.e., monochromatic (temporal coherence).

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

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

Collimated beam: Effectively, a "parallel" beam of light with very low divergence or convergence.

Condition 1: Pertains to determining hazard classification with the consideration for optically aided viewing of collimated beams through telescopes or binoculars.

Condition 2: Pertains to determining hazard classification with the consideration for optically aided viewing of sources with highly divergent beams through magnifiers or unaided viewing with or without strong accommodation.

Note- Condition 2 has slightly different measurement conditions in IEC 60825-1.

Conduit: A pipe or hollow cable through which laser energy passes.

Continuous wave (CW): A laser operated with or modeled as having a continuous output for a period $\geq$ 0.25 sec. is regarded as a CW laser.

Control measure: A means to mitigate potential hazards associated with the use of lasers. Control measures are divided into three groups> engineering, procedural (administrative) and personal protective equipment (PPE).

Controlled area: An area where the occupancy and activity of those within are subject to control and supervision.

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

Critical frequency or Crossover pulse-repetition frequency: The pulse repletion frequency above which the laser output is modeled as continuous wave. For example, for a short unintentional exposure (0.25 s) to nanosecond (or longer) pulse in the visible, the crossover pulse repletion frequency is 13,000 pulse/second (Table 1 in the standard).

Diffraction: Diffraction is the slight bending of light as it passes around the edge of an object. The amount of bending depends on the relative size of the wavelength of light to the size of the opening.

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

Divergence: The increase in the diameter of the laser beam with distance from the exit aperture, based on the full angle at the point where the irradiance (or radiant exposure for pulsed lasers) is 1/e times the maximum value. Symbol: Φ

Electromagnetic radiation: The flow of energy consisting of orthogonally vibrating electric and magnetic fields lying transverse to the direction of propagation. Gamma rays, X-rays, ultraviolet, visible, infrared, and radio waves occupy various portions of the electromagnetic spectrum and differ only in frequency, wavelength, or photon energy.

Embedded laser: An enclosed laser that has a higher classification than the laser system in which it is incorporated, where the system's lower classification is appropriate due to the engineering features limiting accessible emission.

Enclosed laser: A laser that is contained within a protective housing of itself or of the laser or laser system in which it is incorporated. Opening or removal of the protective housing provides additional access to laser radiation above the applicable MPE than possible with the protective housing in place.

Energy: The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers, and is generally expressed in joules (J). Symbol: Q

Engineering control measure: Control measures designed or incorporated into the laser or laser system (e.g., interlocks, shutters, watch-dog timer) or its application.

Epithelium (of the cornea): The layers of cells forming the outer surface of the cornea.

Erythema: Redness of the skin due to exposure from laser radiation.

Extended source: A source of optical radiation with an angular substance at the cornea larger than α_{min}.

Eye-safe laser: Class 1 laser product. Because of frequent misuse of the term *eye-safe* wavelength to mean retina-safe, (e.g., 1500 nm to 1800 nm) and *eye-safe* laser to refer to a laser emitting at wavelengths outside the retina hazard region, the term *eye-safe* can be a misnomer. Hence, use of *eye-safe* laser is discouraged.

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.

Federal Laser Product Performance Standard (FLPPS): The Center for Devices and Radiological Health (CDRH) is a regulatory bureau within the U.S. Federal Food and drug Administration (FDA) of the Department of Health and Human Services. CDRH has been chartered by Congress to standardize the performance safety of manufactured laser products. All laser products that have been manufactured and entered into commerce, after August 2, 1976, must comply with these regulations. The regulation is known as the Federal Laser Product Performance Standard (FLPPS), and is identified as 21CFR subchapter parts 1040.10 and 1040.11.
There are three Product Performance Schemes:

1. FLPPS/CDRH 21 CFR 1010 and 1040: For countries that recognize U.S. FLPPS. This should be considered if the laser product is only sold in the U.S.

2. IEC 60825 – 1: For countries that only recognize IEC. For example Europe normally only accepts this format.

3. FLPPS/CDRH + Laser Notice # 50: Recommended scheme for selling to an international market. For example selling both into Europe and the U.S. this option should be used. Laser Notice #50 provides guidance on the conditions under which laser product manufacturers may introduce into United States that comply with the IEC standards 60825-1 and IEC 60601-2-22.

Field of view: The full solid angle from which a detector's active area receives radiation.

Focal Length: The distance from the secondary nodal point of a lens to the secondary focal point. For a thin lens imagining a distant source, the focal length is the distance between the lens and the focal point.

Glaucoma: An ocular disease characterized by loss of visual field from damage to the optic nerve and retinal nerve fibers, generally associated with increased intraocular pressure.

Hertz (Hz): A unit expressing the frequency of a periodic oscillation in cycles per second.

Hot spot: Term applied to a laser beam to denote areas within the beam, not necessarily centered in the beam, that are above the average irradiance.

Illuminance: The luminous flux per unit area incident upon a surface. The basic units of illuminance is lumens•m^{-2} (lux). Some instruments that measure illuminance are calibrated in foot-candles (lumens•ft^{-2})

Infrared (IR): For purposes of this standard, the region of the electromagnetic spectrum between the long-wavelength extreme of the visible spectrum (700 nm) and the shortest microwaves (1000 µm).

Installation: Placement and connection of laser equipment to enable intended operation

Ionizing radiation: Electromagnetic radiation having sufficiently large photon energy to directly ionize atomic or molecular systems with a single quantum event.

Integrated radiance: The integral of the radiance over the exposure duration, expressed in joules-per-centimeter-squared-per-steradian (J•cm^{-2}•sr^{-1})

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

Iris: The annular pigmented structure that lies behind the cornea of the human eye. The central opening is the pupil.

Irradiance (at a point of a surface): Radiant power incident per unit area upon a surface. Unit: W.cm^{-2}.

Joule (J): A unit of energy. 1 Joule = 1 Watt-second.

Lambertian surface: An ideal diffuse surface whose emitted or reflected radiance is independent of the viewing angle.

Laser: A device that produces radiant energy predominantly by stimulated emission. Laser radiation may be highly coherent temporally, or spatially, or both. LASER is an acronym for Light Amplification by Stimulated Emission of Radiation.

Laser barrier: A device used to block or attenuate incident direct or diffuse laser radiation. Laser barriers are frequently used during times of service to the laser system when it is desirable to establish a boundary for a controlled laser area.

Laser classification: An indication of the beam hazard level of a laser or laser system during normal operation, or the determination thereof. The hazard level of a laser or laser system is represented by a number or a numbered capital letter. The laser classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B and Class 4.

Laser Controlled Area (LCA): A laser a use area where the occupancy and activity of those within is controlled and supervised. This area may be defined by walls, barriers, or other means. Within this area, potentially hazardous beam exposure is possible.

Laser diode: A laser employing a forward-based semiconductor junction as the active medium.

Laser personnel: Person who routinely work around hazardous laser beams.

Laser pointer: A laser or laser system designed or used to specify a discrete point or location, such as those lasers used in classroom lectures or for the aiming of firearms. These products are normally Class 1, Class 2 or Class 3R.

Laser safety officer (LSO): One who has authority and responsibility to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

Laser system: An assembly of electrical, mechanical, and optical components, which includes a laser.

Laser target interaction radiation: Non-laser radiation, including ionizing radiation, emitted by a material as a result of that material's exposure to laser radiation.

Lesion: An abnormal change in the structure of an organ or part due to injury or disease.

Limiting angular subtense: See: *Alpha min.*

Limiting aperture diameter: The diameter of a circle over which irradiance or radiant exposure is averaged for purposes of hazard evaluation and classification. Symbol: D_f

Limiting cone angle: The cone angle through which radiance or integrated radiance is averaged when photochemical effects are considered in hazard evaluation and classification. Symbol: γ

Limiting exposure duration: An exposure duration that is specifically limited by the design or intended use(s). Symbol: T_{max}

Macula: The small uniquely pigmented specialized area of the retina of the eye, which, in normal individuals, is predominantly employed for acute central vision (i.e., area of best visual acuity).

Magnified Viewing: Viewing an object through an optical system that increases the apparent object size. This type of optical system can make a diverging laser beam more hazardous, (e.g., using a magnifying optic to view the end of an energized optical fiber). See also: *Collecting optics*

Maintenance: Performance of those adjustments or procedures (specified in the user information provided by the manufacturer, and considered preventative, to maintain optimal performance of the laser system), which are to be carried out by the user to ensure the intended performance of the product. Maintenance does not include *operation* or *service* as defined in this section.

Maximum permissible exposure (MPE): The level of laser radiation to which an unprotected person may be exposed without adverse biological changes in the eye or skin.

Meter: A unit of length in the international system of units; currently defined as the length of a path traversed in vacuum by light during a period of 1/299792488 seconds. Typically, the meter is subdivided into the following units:

centimeter (cm) = 10^{-2} m

millimeter (mm) = 10^{-3} m

micrometer (μm) = 10^{-6} m

nanometer (nm) = 10^{-9} m

Minimum viewing distance: The minimum distance at which the eye can produce a focused image of a diffuse source, usually assumed to be 10 cm.

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

Non ocular hazard distance (NOHD): The distance along the axis of the unobstructed beam from a laser, fiber end, or connector to the human eye beyond which the irradiance or radiant exposure does not exceed to direct or scattered laser radiation.

Non-beam hazard (NBH): All hazards arising from the presence of a laser system, excluding direct human exposure to direct or scattered laser radiation.

Non-laser radiation (NLR): All radiation arising from the operation of a laser system, excluding laser radiation. This includes collateral radiation and laser target interaction radiation.

Ocular fundus: The interior posterior surface of the eye (the retina) as seen during ophthalmoscopy examination.

Operation: The performance of the laser or laser system over the full range of its intended functions (normal operation). Operation does not include *maintenance* or *service* as defined in this section.

Ophthalmoscope: An instrument for examining the interior of the eye.

Optically aided viewing: Viewing with a telescopic (binocular) or magnifying optic. Under certain circumstances, viewing with an optical aid can increase the hazard from a laser beam (*see telescopic viewing or magnified viewing*).

Optical density: Logarithm to the base ten of the reciprocal of the transmittance: $D_\lambda = \log_{10} (1/\tau_\lambda)$, where τ_λ is transmittance at the wavelength of interest.

Personal protective equipment (PPE): Personal safety protective devices used to mitigate hazards associated with laser use (e.g., laser eye protection (LEP), protective clothing, and gloves).

Photochemical effect: A biological effect produced by a chemical change in molecules resulting from the absorption of photons. The changed molecules fail to function as before.

Photopic luminous efficiency: A function that is the ratio of the radiance at λ_m to that at λ, which produces the same photopic luminous sensation as observed by the standard human eye for the specialized conditions defined by the International Commission on Illumination (CIE). For the standard photopic observer, λ_m = 555 nm and $V(\lambda_m)$ = V(555 nm) = 1.0. *Symbol:* $V(\lambda)$

Photosensitizers: Substances that increase the biological response of a person to exposure by optical radiation.

Plasma radiation: Laser target interaction radiation (LTIR) generated by a plasma.

Point source: For purposes of this standard, a source with an angular subtense at the cornea equal to or less than alpha-min (α_{min}), i.e., ≤ 1.5 mrad.

Power (Φ): The rate at which energy is emitted, transferred, or received. Unit: watts (joules per second).

Procedural control measure: *See:* **Administrative control measure**

Protective housing: An enclosure that surrounds the laser or laser system and prevents access to laser radiation above the applicable MPE. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing limits access to other associated radiant energy emissions and to electrical hazards associated with components and terminals, and may enclose associated optics and a workstation.

Pulse duration: The duration of a laser pulse; usually measured as the time interval between the half-power points on the leading and trailing ends of the pulse. *Symbol: t.* Typical units:

microsecond (µs)	=	10^{-6} s
nanosecond (ns)	=	10^{-9} s
picosecond (ps)	=	10^{-12} s
femtosecond (fs)	=	10^{-15} s

Pulse-repetition frequency (PRF): The number of pulses occurring per second, expressed in hertz. *Symbol: F*

Pulsed laser: A laser that delivers its energy in the form of a single pulse or a train of pulse. For purposes of this standard, the duration of a pulse is less than 0.25 s.

Pupil: The variable aperture in the iris through which light travels to the interior of the eye.

Q-switch: A device for producing very short (≈10 – 250 ns), intense laser pulses by enhancing the storage and dumping of electronic energy in and out of the lasing medium, respectively.

Q-switched laser: A laser that emits short (≈10 – 250 ns), high-power pulses by means of a Q-switch.

Radian (rad): A unit of angular measure equal to the angle subtended at the center of a circle by an arc whose length is equal to the radius of the circle. 1 radian ≈ 57.3 degrees, 2π radians = 360 degrees.

Radiance: Radiant flux or power output per unit solid angle per unit area. Unit: Watts per centimeter squared per steradian ($W. cm^{-2}. sr^{-1}$). Symbol: L

Radiant energy: Energy emitted, transferred, or received in the form of radiation. Unit: joule (J).

Radiant exposure: Surface density of the radiant energy received. Unit: joules per centimeter squared ($J. cm^{-2}$).

Radiant flux: Power emitted, transferred, or received in the form of radiation. Unit: watt (W). Also called radiant power. Symbol: Φ

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

Radiometry: For the purposes of this standard, the measure of infrared, visible, and ultraviolet radiation.

Reflectance: The ratio of the total reflected radiant power to the total incident power, also called "reflectivity."

Reflection: Deviation of radiation following incidence on a surface.

Refraction: The bending of a beam of light in transmission through an interface between two dissimilar media or in a medium whose refractive index is a continuous function of position (graded index medium).

Refractive Index (of a medium): The ratio of the velocity of light in a vacuum to the velocity of light in the medium. Symbol: *n*

Repetitive pulsed laser: A laser with multiple pulses of radiant energy occurring in sequence with a pulse repetition frequency (prf) $\geq$ 1 Hz.

Retina: The sensory membrane, which receives the incident image formed by the cornea and lens of the human eye. The retina lines the inside of the eye.

Safety latch: A mechanical device designed to require a conscious decision to override the latch to gain entry to a controlled area.

Saturable absorption: The property of laser eye protection and other optical materials where the absorption of light decreases (OD decreases) with increasing irradiance. This has been shown to occur with certain laser eye protection materials with high-energy nanosecond and shorter duration pulses.

Scanning laser: A laser having a time-varying direction, origin, or pattern of propagation with respect to a stationary frame of reference.

Secured enclosure: An enclosure to which casual access is impeded by an appropriate means (e.g., a door secured by a magnetically or electrically operated lock or latch, or by fasteners that need a tool to remove)

Service: The performance of procedures, typically defined as repair, to bring the laser or laser system or laser product back to full and normal operational status. Service does not include *operation* or *maintenance* as defined in this section.

Shall: The word *shall* is to be understood as mandatory.

Should: the word *should* is to be understood as advisory.

Solid angle: The three-dimensional angular spread at the vertex of a cone measured by the area intercepted by the cone on a unit sphere whose center is the vertex of the cone. *Unit:* steradians (sr).

Source: A laser or a laser-illuminated reflecting surface.

Spectator: An individual who wishes to observe or watch a laser or laser system in operation and who may lack the appropriate laser safety training.

Specular reflection: A mirror-like reflection.

Steradian (sr): The unit of measure for a solid angle. There are 4π steradians about any point is space.

T_1: The exposure duration (time) beyond which the MPEs based upon photochemical injury are lower (more restrictive) than the MPEs based upon thermal injury, for exposure to point sources.

T_2: The exposure duration (time) beyond which extended source MPEs based upon thermal injury are expressed as a constant irradiance.

Telescopic viewing: Viewing an object from a long distance with the aid of an optical system that increases the size of the image. The system (e.g., binoculars) generally collects light through larger aperture thus magnifying hazards from large-beam, collimated lasers.

Thermal effect: For purposes of this standard, an effect brought about by the temperature elevation of a substance due to absorption of laser energy.

Threshold limit (TL): The term is applied to laser protective eyewear filters, protective windows, and barriers. The TL is an expression of the "resistance factor" for beam penetration of a laser protective device. This is generally related by the Threshold Limit (TL) of protective device, expressed in $W\bullet cm^{-2}$ or $J\bullet cm^{-2}$. It is the maximum average irradiance or radiant exposure at a given beam diameter for which a laser protective device provides adequate beam resistance. Thus, laser exposures delivered on the protective device at or below the TL will limit beam penetration to levels at or below applicable MPE.

T_{max}: The total expected or anticipated exposure duration, which may differ depending upon its use.

T_{min}: The shortest exposure duration greater than 1 ns for which the MPE, expressed as radiant exposure ($J\ cm^{-2}$), decreases as the exposure duration decreases, reflecting a thermal damage mechanism. t_{min} is an analogue for the "thermal confinement time" for biological effects, a duration for which there is no significant flow of heat from the volume of tissue in which the energy was absorbed, and therefore no cooling of the absorbing tissue during the exposure.

Transmission: Passage of radiation through a medium.

Transmittance: The ratio of transmitted power (energy) to incident power (energy).

Troland: The measure of retinal illuminance or the "effective brightness" of a source and has the units of lumens-per-steradian incident upon the retina. The troland is not corrected for the transmission of the outer ocular media. In typical practice, the retinal illuminance in trolands is determined by multiplying the source luminance in $candelas\bullet m^{-2}$ by the pupillary area in mm^2.

Ultraviolet radiation: Electromagnetic radiation with wavelengths between 0.18 to 0.4 μm (shorter than those of visible radiation).

Uncontrolled area: An area where the occupancy and activity of those within is not subject to control and supervision for the purpose of protection from radiation hazards.

Viewing window: A visually transparent part of an enclosure that contains a laser process. It may be possible to observe the laser processes through the viewing windows.

Visible luminous transmission (VLT): The amount of visible light passing through a filter, weighted for the response of the human eye, expressed as a percentage.

Visible radiation (light): The term is used to describe electromagnetic radiation that can be detected by the human eye. For purposes of this standard, this term is used to describe wavelengths that lie in the range 400 nm to 700 nm. Derivative standards may legitimately use 380 nm to 780 nm for the visible radiation range.

Visual interference effects: Those effects associated with viewing of bright visible lights. These may include glare, flashblindness, and after-images.

Watt: The unit of power or radiant flux. 1 Watt = 1 Joule-per-second.

Wavelength: The distance in the line of advance of a sinusoidal wave from one point to the next point of corresponding phase (e.g., distance from one peak to the next).

Work practices: Procedures used to accomplish a task.

16.0 Appendix J: Laser Biological Effects vs Wavelength and for Common Types

Table 16.1 Laser Biological Effects vs Wavelength

Photobiological Spectral Domain	Eye	Skin
Ultraviolet C (200 nm – 280 nm)	Photokeratitis	▪ Erythema (sunburn) ▪ Skin Cancer ▪ Accelerated skin aging
Ultraviolet B (280 nm – 315 nm)	Photokeratitis	Increased pigmentation
Ultraviolet A (315 nm – 400 nm)	Photochemical cataract	▪ Pigment darkening ▪ Skin burn
Visible (400 nm – 780 nm)	Photochemical and thermal retinal injury	▪ Pigment darkening ▪ Photosensitive reactions ▪ Skin burn
Infrared A (780 nm – 1400 nm)	Cataract and retinal burn	Skin burn
Infrared B (1.4 µm – 3.0 µm)	Corneal burn, aqueous flare, cataract	Skin burn
Infrared C (3.0 µm – 1000 µm)	Corneal burn only	Skin burn

Table 16.2 Bioeffects of Commonly Used Lasers

LASER TYPE	WAVELENGTH (μ m)	BIOEFFECT Process	TISSUE AFFECTED			
			Skin	Cornea	Lens	Retina
CO_2	10.6	Thermal	X	X		
HFl	2.7	Thermal	X	X		
Erbium-YAG	1.54	Thermal	X	X		
Nd-YAG [a]	1.33	Thermal	X	X	X	X
Nd-YAG	1.06	Thermal	X			X
Gas (diode)	0.78-0.84	Thermal	[b]			X
He-Ne	0.633	Thermal	[b]			X
Ar	0.488-0.514	Thermal/ Photochemical	X			X[c]
XeFl	0.351	Photochemical	X	X		X
XeCl	0.308	Photochemical	X	X		

[a] Wavelength at 1.33 μm or more common in some Nd-YAG lasers has demonstrated simultaneous cornea/lens/retina effects in biological research studies

[b] Power levels not normally sufficient to be considered a significant skin hazard

[c] Photochemical effects dominate for long-term exposures to retina (exposure times more than 10 seconds)

17.0 Appendix K: Laboratory Laser Safety Inspection Checklist

☐ **Semi-Annual Inspection** ☐ **Follow-up Inspection**

A. Laboratory Specifications:

Department____Bldg./Room_____________________

Principal Investigator or Lab Manager: ____________________________________Phone__________

Persons present for inspection ____

B. Equipment and Laser Characteristics:

MEDIUM (Argon, CO2, Nd:YAG, etc.)	CLASS (IIIB or IV)	TYPE (CW or Pulsed)	WAVE LENGTH(s) (nm)	MAX. OUTPUT (Watts or Joules)	MANUFACTURER	MODEL	SERIAL NO.	PURPOSE OF USE

Attention PI/Authorized user:

Has the laser generation system/output been modified? Y or N (circle one). If the answer is yes, you assume responsibility of the manufacturer and are required to classify the laser. Please sign that you will provide classification for the laser.

Name: Signature: ………………………………… Date:

C. Laser Posting, Labeling and Security Measures:

	Yes	No	NA	
1.	☐	☐	☐	Entrance door is labeled with the name and phone numbers of the PI/Lab Manager & Alternate
2.	☐	☐	☐	Entrance door is labeled with Laser Class label
3.	☐	☐	☐	Entrance door is labeled with Laser Hazard label
4.	☐	☐	☐	Entrance door is labeled with Laboratory Hazard Identification Chart
5.	☐	☐	☐	Warning “LASER IN USE” lighted or audible alarm is activated when laser is turned on?
6.	☐	☐	☐	Laboratory security is adequate
7.	☐	☐	☐	Door interlock system is installed and working
8.	☐	☐	☐	Keyed Access to laser lab is only to the authorized personnel

D. Laser Unit Safety Controls:

	Yes	No	NA	
1.	☐	☐	☐	Protective housing is in place
2.	☐	☐	☐	Fail-safe interlock is installed on removable protective housing
3.	☐	☐	☐	Interlock on housing is functioning
4.	☐	☐	☐	Beam shutter is present
5.	☐	☐	☐	Beam shutter is functioning
6.	☐	☐	☐	Laser activation is indicated on console
7.	☐	☐	☐	Beam power meter is available
8.	☐	☐	☐	Emergency shutoff is available, If yes, where: ☐ near the laser or ☐ at a remote console or ☐ at both places

E. Engineering Safety Controls

	Yes	No	NA	
1.	☐	☐	☐	Laser is secured to table
2.	☐	☐	☐	Laser optics are secured to prevent stray beams
3.	☐	☐	☐	Optical table is properly grounded
4.	☐	☐	☐	Laser beam is not at eye level in the standing or seated position
5.	☐	☐	☐	Beam is enclosed
6.	☐	☐	☐	Beam barrier(s) is (are) in place
7.	☐	☐	☐	Beam stops are in place
8.	☐	☐	☐	Beam is viewed remotely
9.	☐	☐	☐	Reflective materials are kept out of beam path
10.	☐	☐	☐	Beam alignment procedures are adequate
11.	☐	☐	☐	Stray beams are not seen
12.	☐	☐	☐	Windows in room are covered
13.	☐	☐	☐	There are no Class 4 diffused beams in the operating (occupied) area

F. Administrative Safety Controls:

	Yes	No	NA	
1.	☐	☐	☐	All users have received training within the last 3 years
2.	☐	☐	☐	Training has been documented (certificates available)
3.	☐	☐	☐	Refresher training is attended, within the last 3 years
4.	☐	☐	☐	Authorized users only are working with lasers
5.	☐	☐	☐	Laboratory Standard Operating Procedures (for operation, maintenance and beam alignment) and safety guidelines are developed for use of lasers
6.	☐	☐	☐	Laboratory SOPs have been posted
7.	☐	☐	☐	Laser safety guidelines are posted
8.	☐	☐	☐	Laser safety policy manual is available
9.	☐	☐	☐	Emergency contact list is posted
10.	☐	☐	☐	Baseline eye test has been performed and recorded for all users
11.	☐	☐	☐	Laser is operated under the direct supervision or control of an experienced, trained operator
12.	☐	☐	☐	Protective equipment- eyewear, clothing, barriers, screens, skin protection- are available?
13.	☐	☐	☐	Protective equipment is in good condition
14.	☐	☐	☐	Eyewear is suitable for the wavelength and power/energy of laser

G. Non-Beam Hazards:

If potential for hazards from any of the following exists, describe how these are mitigated (e.g., use of fume hood):

	Yes	No	NA	
1.	☐	☐	☐	Toxic materials
2.	☐	☐	☐	Cryogens
3.	☐	☐	☐	Compressed gases
4.	☐	☐	☐	High voltage power
5.	☐	☐	☐	Collateral radiation
6.	☐	☐	☐	Explosion
7.	☐	☐	☐	Fire
8.	☐	☐	☐	LGAC production
9.	☐	☐	☐	Excessive noise

H. Survey meters:

a) Manufacturer: ___________________________ Model/Serial No.: ____________________

Suitable for radiant energy/power and wavelength: ______________________________________

Calibration performed by: ______________________________________Date: _____________

b) Manufacturer: ____________________________ Model/Serial No.: ____________________

Suitable for radiant energy/power and wavelength: ______________________________________

Calibration performed by: ______________________________________Date: ______________

Comments:

____

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Inspected By: __________________Signature: ___________________ Date: _________

18.0 Appendix L: FIU ORED Proposal Review Form

Proposal Title:	Date Received for Evaluation:
Name of Principal Investigator:	

Objectives:

CRITERIA	*RECOMMENDATIONS/COMMENTS
LOCATION(S)	
SECURITY CONTROLS	
HAZARDS	
ENGINEERING CONTROLS	
PROTECTIVE EQUIPMENT	
WASTE DISPOSAL	
SPILLS	
UNATTENDED RESEARCH	
TRAINING	
APPROVAL	

Comments:
Reviewed by:____ Date:

19.0 Appendix M: FIU Policy on Security in Laboratories with Special Hazards

All authorized users of materials with special hazards (radioactive materials, laser devices, controlled substance, select agents, infectious materials, carcinogenic materials, explosive materials) must be familiar with FIU "Security in Laboratories with Special Hazards" Policy. The policy has 3 important aspects namely responsibility, accountability and physical safeguards regarding materials with special hazards and the authorized users must comply with the policy. The policy is copied below.

University Community (faculty, staff and students)

SUBJECT (R*)	EFFECTIVE DATE (R)	POLICY NUMBER (O*)
SECURITY IN LABORATORIES WITH SPECIAL HAZARDS	August 30, 2007	125.405

POLICY STATEMENT (R)

All Users of Special Hazards Materials shall follow University processes in order to become an "Authorized User" as soon as possible and must abide by:

- All applicable federal, state and local safety laws, rules and regulations relating in any way to the purchase, handling, use, storage, transfer and disposal of these materials;
- The terms and restrictions set forth in the University's license, permit or registration relating to the purchase, handling, use, storage, transfer and disposal of the Special Hazards Material, as applicable; and
- The procedures described in the applicable program safety manuals, that assure responsibility, accountability and physical safeguards with regards to Special Hazards Materials.

REASON FOR POLICY (O*)

Florida International University's institutional ability to use Special Hazard Materials is contingent upon the compliance with all applicable laws, rules, regulations, terms and conditions relating in any way to the purchase, handling, use, storage, transfer and disposal of these materials.

RELATED INFORMATION (O)

10 CFR Parts 1-199, Nuclear Regulatory Commission

21 CFR Parts 1-1299, Food and Drug Administration, Department of Health and Human Services

21 CFR Parts 1300-1399, Drug Enforcement Administration, Department of Justice

29 CFR Parts 1900-2006, Occupational Safety and Health Administration, Department of Labor

40 CFR Environmental Protection Agency

49 CFR Transportation

Florida Department of Health, Florida Administrative Code Chapters 64E-5, 64E-16 and 64E-62

Miami-Date County Code Chapter 24 Environmental Protection

University Safety Policy

FIU Chemical Hygiene/Lab Safety Manual

FIU Radiation Safety Manual

FIU Bloodborne Pathogen Exposure Control Manual

FIU BioSafety Manual

FIU Control Substances Safety Manual

FIU Laser Safety Manual

FIU Laboratory Relocation Guide

CONTACTS (R)

Administrative Office's Address	Telephone Number	Fax Number
Roger Riddlemoser, Director, Environmental Health & Safety, 11200 S.W. Eighth Street, CSC 163, Miami, Florida 33199	(305) 348-2621	(305) 348-3574

DEFINITION (R)

Authorized User: A User (see below) who has authorization from the University to purchase, handle, store, transfer or dispose of Special Hazards Materials.

Carcinogenic Material: A substance or physical agent that causes cancer in humans, or on the basis of animal experiments, is suspected of being able to cause cancer in humans.

DEA Controlled Substances: Drugs and certain other chemicals, both narcotic and non-narcotic, which come under the jurisdiction of federal and state laws regulating their manufacture, sale, distribution, use and disposal.

Explosive Material: a substance, mixture, or compound capable of entering into a rapid and violent reaction that produces a sudden local, dramatic increase in pressure or shock wave.

Infectious Materials: Pathogen microorganism capable of causing communicable infection.

Laser: Light Amplification by Stimulated Emission of Radiation- A device that produces an intense, coherent, directional beam of light.

Radioactive Material: Any solid, liquid, or gaseous substance which emits radiation spontaneously.

Select Agent: Microorganism (virus, bacterium, fungus, rickettsia) or toxin listed by the Centers for Disease Control or the U.S. Department of Agriculture. It includes genetically modified microorganisms or genetic elements.

Special Hazards Materials: These materials include, but are not limited to, radioactive materials, Drug Enforcement Administration (DEA) controlled substances, select agents, carcinogenic and explosive materials, infectious materials, and laser devices, and any other hazardous materials, the purchase, handling, storage or transfer and disposal of which is regulated by federal, state, or local laws.

User: Consumer, registrant, permit holder, principal investigator, laboratory manager or laboratory worker designated control of a laboratory space, device, agent, material or specimen.

RESPONSIBILITIES (O)

ALL USERS:

All Users who have access to Special Hazards Materials are required to handle these materials in a safe manner and must take the necessary steps to assure:

Responsibility

- Take the necessary affirmative steps to become an Authorized User by following the appropriate University process as soon as possible.
- Obtain and maintain any and all necessary licenses, permits or registrations relating to the purchase, handling, use, storage, transfer and disposal of Special Hazards Materials.
- If relying upon the University's licenses, permits, or registrations, become familiar with the terms and conditions upon which the University is authorized to use the materials.
- Comply with all federal and state safety laws, rules and regulations, as well as any terms and conditions that apply to the purchase, handling, use, storage, transfer and disposal of Special Hazards Materials.
- Complete any training required by the appropriate safety program within the time specified.
- Secure Special Hazards Materials in their custody against unauthorized access or removal.
- Ask any questions, or raise concerns, regarding the Special Hazards Materials to the designated University official (e.g., Laser Safety Officer, Biosafety Officer, etc.)

Accountability

- Maintain current and accurate records of their inventory of Special Hazard Materials (ordered, received, stored, used, transferred and disposed) for three (3) years or more, as designated by the applicable safety program requirements.
- Make records relating to the inventory of Special Hazard Materials available at any time to EH&S.

Note: Accountability is a condition of a regulatory directive, or a license or permit from a regulatory agency, issued to FIU.

Physical Safeguards

- Provide a minimum of two (2) independent physical controls, which form tangible barriers that secure Special Hazard Materials from unauthorized removal, whenever the materials are not in use, or under constant surveillance. For example, a radioactive material stock solution in a laboratory that is not staffed during the evening must be in a locked cabinet/refrigerator. All points of entry to the laboratory must also be locked.
- Controlled substances require additional physical controls. Controlled substances must be in a locked safe. The safe must also be secured at all times by bolting it to the floor, so that it cannot be removed.

ENVIRONMENTAL HEALTH & SAFETY:

On a periodic basis, Environmental Health & Safety will inspect and audit laboratories, equipment and materials, and the physical safeguards that are in place for the proper use, transfer and disposal of Special Hazards Materials. Environmental Health & Safety will also conduct inventories, where appropriate.

FORMS/ONLINE PROCESSES (O)

***R = Required** ***O = Optional**

20.0 Appendix N: Mandatory and Timely Notifications and Reports of Incidents

Each authorized user shall report to the LSO any incident (that results in damage to the eye(s), skin or any part of the body with lasers devices involving any individual in his/her jurisdiction. The Director, EH&S / LSO shall report to the Florida Department of Health (DOH) per FAC 64E-4.011: **Notification and Reports of Incidents** any incident involving laser devices registered by FIU with the Department. The details of the types of exposures and duration within which the supervisor must notify the LSO or the Director of EH&S. In response, the LSO or Director of EH&S must notify the Florida Department of Health (FL DOH), and submit a written report. Details are given below in Table 20.1.

Each report required by Rule 64E-4.011(3), F.A.C., shall describe the extent of exposure of individuals to laser or collateral radiation, including estimates of each individual's exposure; levels of laser or collateral radiation involved; the cause of the exposure; and corrective steps taken or planned to be taken to assure against a recurrence.

Any report filed with the Department of Health pursuant to Rule 64E-4.011(3), F.A.C., above, shall include the full name of each individual exposed, an estimate of each individual's exposure and a description of any injuries. The report shall be prepared so that this information is stated in a separate part of the report.

Table 20.1 Notification of Incidents Involving Any Source of Laser or Collateral Radiation

Incident Type	Notification: PI/Supervisor to LSO	Notification: LSO to FL DOH
	Notification Window	
(a) An exposure to an individual of greater than 100 times the MPE or 21 C.F.R. 1040 limits of laser or collateral radiation; or (b) An exposure to an individual which involves the partial or total loss of sight in either eye; or (c) An exposure to an individual which involves perforation of the skin or other serious injury exclusive of eye injury.	By Telephone: Within 15 minutes of incident LSO: C:786-200-6220, O: X7-6625; EHS X7-2621 Written report shall be submitted within 2 days EH&S, CSC 162	By Telephone: Within 30 minutes of receiving report. Written report shall be submitted within 15 days Bureau of Radiation Control 4052 Bald Cypress Way, Bin #C21 Tallahassee, FL 32399-1741 Phone: (850) 245-4266 Fax: (850) 487-0435
(a) An exposure to an individual of greater than five times the MPE or 21 C.F.R. 1040 limits of laser or collateral radiation; or (b) An exposure to an individual with second- or third-degree burns to the skin or potential injury and partial loss of sight.	By Telephone: Within 60 minutes of incident LSO: C:786-200-6220, O: X7-6625; EHS X7-2621 Written report shall be submitted within 4 days	By Telephone: Within 2 hours of receiving report Written report shall be submitted within 15 days
(a) Each exposure of an individual to laser and collateral radiation in excess of the MPE limits or 21 C.F.R. 1040, (b) Any incident for which notification is required by Rule 64E-4.011(1) or (2), F.A.C., above	By Telephone: Within 3 hours of incident LSO: C:786-200-6220, O: X7-6625; EHS X7-2621 Written report shall be submitted within 5 working days	Written report shall be submitted within 15 days of receiving report