Radiation Safety Manual
For Lasers

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I. INTRODUCTION

This manual has been prepared by the Environmental Health & Safety Department (EHS) at Florida Atlantic University (FAU) to address the safety policies, responsibilities, and procedures for the safe use of lasers on all FAU campuses. It is intended as a guide for faculty, staff, and students to promote compliance with all State and Federal laws and guidelines relating to safe laser use. These standards may change from time to time and where a provision in this manual is in conflict with a standard or could be interpreted to conflict with an applicable standard, the manual should be interpreted so as to comply with all current applicable laws and regulations. These regulations include **the Florida Administrative Code (FAC) Chapter 64E-4**, the **Code of Federal Regulations (CFR) Title 21 Part 1040.10**, and the **American National Standard for the Safe Use of Lasers (ANSI Z136.1)**.

Although Principal Investigators bear the ultimate responsibility for the safe conditions and procedures for laser use in their research areas, each member of a group of laser operators is responsible for complying with the standards set forth in this manual. Since laser activities are diverse, this manual should not be considered a comprehensive review of all potential hazards. Individuals with additional questions should contact the Laser Safety Officer (LSO) at 7-2385.

II. OBJECTIVES

The objectives of the laser safety program include the following:

- Assure that all laser activities adhere to the applicable regulations and employ the proper safety precautions.
- Provide basic laser safety training to all University employees involved in laser activities. Basic laser safety training will cover fundamentals, general theory, and user safety applications. This course will be offered through EH&S on-line.
- Assure that all employees working with laser systems, receive the appropriate training from the manufacturer, where applicable. Manufacturer training will deal with specific applications related to the unique operation of a laser from a particular company. These courses will be given by the instrument manufacturer or distributor and the records of training will be maintained by the respective departments. Copies of these records must also be provided to the LSO.
- Ensure that <u>all</u> Class IIIB and Class IV lasers are registered with the FL State Department of Health within the necessary time frame (within 30 days of receipt).

III. RESPONSIBILITIES

The effectiveness of the University's Laser Safety Program depends on the complete cooperation and commitment of all parties involved. These parties include EH&S, the Principal Investigator (PI), Purchasing, and the laser operators themselves. Although the PI is ultimately responsible for laser safety in the research area, each party in the laser safety program must assume individual responsibility for conducting procedures in the proper manner and according to established protocols.

A. Laser Safety Officer (LSO)

The LSO has the responsibility for the administration of the laser safety program. These responsibilities will focus primarily on monitoring facilities and overseeing training. The LSO will also be responsible for the following:

- Review of purchases and acquisitions of lasers, and the maintenance of updated laser inventories throughout the University.
- Registration of Class 3B and 4 lasers with the State of Florida Department of Health (DOH). All records of registration, training, and other documentation will also be maintained by the LSO.
- Regulatory compliance with state and federal regulations, ANSI standards, and University policies.
- Safety inspections of lasers and laser systems both before operations begin and periodically afterwards, to assure compliance with the requirements outlined in this manual.
- Approval of the standard operating procedures (SOP) for use of Class 3B and 4 lasers which must be completed by the PI and approved by the LSO before research begins.

B. Principal Investigators (PI's)

PI's have the primary responsibility for safety in the research area. They must ensure that all operators under their direction complete the necessary safety requirements (training, use of personal protective equipment, etc.) before allowing laser operation. The PI's responsibilities also include:

- Notifying the LSO of the purchase, acquisition and location of lasers and providing the LSO with the information necessary to register the laser with the State DOH.
- Preparing the research area to meet applicable safety requirements *before* the arrival of a laser.
- Maintaining the records of medical surveillance for laser operators as necessary.
- Ensuring that all operators complete the required safety training and, when necessary, hands-on training provided by the laser manufacturer.
- Preparing a detailed standard operating procedure (SOP) outlining the methods and requirements for the use of a laser before operations begin. This SOP must be approved by the LSO.

C. Purchasing Office

The purchasing office will ensure that during acquisition of a laser, the LSO has been notified before an order is placed with the vendor. The LSO will also receive a copy of the purchase order, which will detail the laser specifications, safety equipment, and other relevant information included with the laser. The LSO will review this information and maintain a record of laser acquisition. The LSO will also register any new Class 3B or 4 lasers with the state.

D. Laser Operators

All laser users must be familiar with the characteristics of the laser(s) in their research areas. Their responsibilities also include:

- Completion of the required Basic Laser Safety Training course and, when necessary, completion of the hands-on training provided by the laser manufacturer.
- Adherence to the SOP designed by the PI and approved by the LSO for the safe operation of the laser, including the use of goggles and other personal protective equipment appropriate to individual lasers.
- Knowledge of emergency response procedures (what to do in case of an accident) and medical surveillance requirements.
- Operation of only those lasers for which they have been trained.

IV. LASER SAFETY STANDARDS

The purpose of the Laser Safety Program is to comply with the regulations and standards for the safe use of lasers. These regulations and standards vary in their scope and design, list exposure limits, define potentially hazardous conditions, and detail control measures to limit occupational exposures.

A. ANSI Standards

The principal laser safety guidelines in the United States are the consensus standards drafted by the American National Standards Institute (ANSI) Committee Z-136. These include the primary standard entitled **"ANSI Z-136.1, Safe Use of Lasers,"** and the medical application entitled, **"ANSI Z-136.5, Safe Use of Lasers in Educational Institutions"**. These standards outline the maximum exposure limits for laser users, define laser hazard categories, and provide detailed information for determining the appropriate safety precautions for each laser hazard category. The standards also provide the basis for international regulation.

B. Federal Laser Performance Standard

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

C. State of Florida Laser Regulation

The State of Florida has also incorporated laser safety regulations into the **Florida Administrative Code (FAC) Chapter 64E-4**, **Control of Non-ionizing Radiation**

Hazards. The laser safety program is administered through the Department of Health, Bureau of Radiation Control (BRC). The details of laser registration, the requirements for personnel protection, the safe operation of lasers, and the requirements for laser light shows are included in the regulations.

V. FUNDAMENTAL CONCEPTS

Lasers are described as sources of electromagnetic radiation which emit beams of energy that include wavelengths from the ultraviolet portion of the optical spectrum to the far-red. The term *laser light* classically refers to visible wavelengths of light produced through laser activity. With the development of devices generating wavelengths outside the visible region, the term *laser radiation* is now used to more accurately describe laser energy in both the visible and non-visible regions of the optical spectrum. These terms can be used interchangeably.

Although lasers produce electromagnetic radiation, they are considered *non-ionizing* radiation sources because of the effects laser energy has on atoms and biological tissue. Ionizing radiation can strip atoms of electrons and create radicals which can change the nature of molecules and damage tissue. Non-ionizing radiation does not remove electrons from atoms but instead causes an increase in electron energy which typically results in heating or secondary light emission called fluorescence.

A. Laser Components

The word LASER is an acronym briefly describing the process which creates laser light: Light Amplification by Stimulated Emission of Radiation. This is a process in which photons produced by atoms and molecules are amplified and emitted. All lasers have three basic physical components: an *active medium*, an *energy source*, and *a resonant cavity*. Each of these components is responsible for a different part of the laser process. The active medium provides the source of light and radiation, the energy source provides the stimulation, and the resonant cavity enables amplification and emission.

Active Medium

Laser light is generated in an active medium, which can be a solid, liquid, or gas. Only certain types of media have the necessary optical, mechanical, atomic, and/or molecular characteristics to make laser activity possible. For laser action to occur, the majority of the molecules in the active medium have to be brought to a higher energy (excited) state simultaneously.

The excitation of the active medium can be done with a variety of energy sources. These power sources elevate the molecules in the active medium to an energetic or excited state and create a condition known as population inversion. This condition occurs when energy is poured into the active medium so rapidly that most of its molecules absorb excess energy. Once this excited state is reached, the molecules are primed to have this energy amplified and released.

Energy Source

The energy source provides the excitation mechanism for priming and focusing the molecules in an active medium. These energy sources can include electrical discharges, chemical reactions, and high-powered light sources (flash lamps). The type of active medium will determine the nature of the needed excitation device. In general, electrical discharges are needed for gas media (helium-neon, argon, krypton, etc.), chemical energy mechanisms for liquid media, and powerful light sources for crystalline and solid-state media.

Resonant Cavity

The resonant cavity is the area in the laser where the primary laser activity occurs. The main housing in a laser consists of a short cylinder with mirrors placed on either end. The space between these two mirrors is filled with the excited molecules from the active medium. This space is called the resonant cavity because photons produced by the energized medium bounce back and forth between the mirrors becoming more amplified.

One of the mirrors is only partially silvered to allow some light to leave the cavity and escape as a focused beam. The degree to which this mirror allows light to exit depends upon the type of medium being used, the power input from the energy source, and the wavelength of the photons in the cavity. The laser is designed so that enough light is reflected back into the cavity to allow the lasing action to continue.

B. Characteristics of Laser Light

Although lasers vary in size and intensity, all laser light has fundamental characteristics, which distinguishes it from natural light. Laser produced light is *monochromatic*, *directional*, and *coherent*. Each of these properties is important for the many scientific, medical, and industrial applications of lasers.

Monochromaticity

Natural light is composed of a combination of all visible and some non-visible wavelengths (colors). Laser light is described as a monochromatic light source because it consists of only one uniform color found on an extremely narrow band in the optical spectrum.

Directionality

This is one of the most unusual properties of laser light. A laser beam does not expand or disperse as easily as natural light. The angle of divergence (the rate at which light spreads as it moves away from a source) is small. This makes the laser beam more hazardous than conventional light sources because it maintains its intensity over much longer distances.

Coherence

The light waves in a laser beam leave the resonant cavity in phase with each other. This uniform spatial relationship between the waves (coherence) amplifies the duration and energy of the beam.

VI. CLASSIFICATION

Laser hazard classification was developed to aid the user in assessing the potential hazards of a laser system. **ANSI Z-136.1** outlines a simplified method, which is being used throughout the world. **Title 21 CFR Part 1040** applies this same method to manufacturers and their labeling requirements.

The basis of the hazard classification is a set of accessible emission limits (AELs) that are dependent on the exposure limits for occupational occurrences, with certain assumptions made as to reasonable exposure duration that might be anticipated when using the laser. AEL refers to the maximum acceptable emission level or power output allowed for a laser class and is one of the most important tools used in classification. It is derived from a combination of the maximum permissible exposure (MPE) limit and the area of the limiting aperture through which the beam travels from a laser. This limiting aperture is usually compared with 7mm which corresponds to the diameter of the pupil (pupillary aperture) in the human eye.

Hazard classification also includes the following parameters:

- The wavelength (λ) of the laser.
- The average power output of a laser and duration of exposure within an eight-hour working day to beam emissions.
- The total energy per pulse (for pulsed lasers), pulse duration, pulse repetition frequency, and pulse energy emissions.

ANSI-Z136.1 categorizes lasers into four safety classes. Each class has specific procedures, required training, and record keeping necessary for compliance with that particular class.

A. Class 1 Lasers

A Class 1 laser is a laser that is incapable of emitting laser radiation in excess of 0.4 microwatts. This applies to very low power devices such as those in some semi-conductor diode lasers. Most Class 1 lasers are in this category because they are housed in an enclosure that limits the laser radiation exposure to the Class 1 level. Some of these include laser videodisc players, laser printers, and optical fiber communication systems.

Lasers that are more powerful than Class 1, but have limited emissions due to protective enclosures are called embedded lasers. Any removable portion of the protective housing of such lasers has to be secured or interlocked to limit user access to the beam.

B. Class 2- Low Power Lasers

Class 2 lasers are not normally considered hazardous unless an individual was to force himself to stare directly into the beam. These lasers have limited energy emissions in the visible region (400 nm to 710 nm) of the optical spectrum. They are low risk because the human aversion response (blinking reflex, 0.25 seconds) to bright light enables a user to limit exposure before damage can be done.

In industrial settings, Class 2 lasers are typically used for alignment or to mark the path of more powerful invisible lasers. This application is readily used in the medical setting as well. The AEL for a Class 2 laser is 1.0 milliwatts (mW). If the retina of the eye were exposed to this level of laser energy for a prolonged period of time, some damage could occur. Such exposures, however, are not very likely (primarily because of the blinking reflex). Class 2 lasers are therefore considered to pose a *theoretical* hazard but not a *realistic* hazard in most situations.

Class 2A

Some Class 2 lasers may be used in processes specifically designed to limit exposure to beam emissions. In these situations, the user is allowed an exposure duration less than or equal to 1000 seconds as long as the AEL for Class 1 is not exceeded. These lasers are designated as Class 2A.

C. Class 3- Medium Power Lasers

Class 3 lasers are potentially hazardous upon direct and instantaneous exposure of the eye. The beam, if viewed directly, could result in injury within less than the blinking reflex. The Class 3 category is divided into two subcategories: 3A and 3B.

Class 3A

These types of lasers are similar to the Class 2 devices. They emit energy within the visible spectrum but have power outputs between 1.0 and 5.0 mW. They also include some wavelengths in the ultraviolet and infrared regions as long as the power output is not more than five times the AEL of Class 1 or when using an expanded beam, the AEL is not exceeded if measured by the limiting aperture (determines the diameter of the beam) for that laser wavelength.

Class 3B

Class 3B lasers include any continuous-wave device with energy outputs above 5.0 mW and less than or equal to 500 mW. These lasers can cause damage with direct intra-beam exposure and from specular or diffuse reflections. Additional performance requirements and safety measures are required to provide protection from the energy emissions of these lasers. Some of these precautions include appropriate eye protection for the wavelength being used, beam controls (safety interlocks, enclosures, etc.), and clearly defined emergency procedures. Contact the LSO for more information on the proper methods and requirements for using Class 3B lasers.

D. Class 4-High Power Lasers

Class 4 lasers are those devices with power outputs exceeding 500 mW. These devices also include lasers that permit human access during operation to levels of laser radiation in excess of the AEL for Class 3B. The primary hazards to the skin and eyes come from direct beam exposure, and specular and diffuse energy reflections. Most research, medical, and surgical lasers are categorized as Class 4.

As with Class 3B lasers, additional performance requirements and safety measures must be taken to provide user protection. These requirements are specific to the type and wavelength of laser device being used. Some of these precautions include the creation of laser-controlled area, reduction of specular hazards, and a clearly defined standard operating procedure for the use of the device. Contact the LSO for more information on the requirements for using Class 4 lasers.

VII. REGISTRATION

Class 3 and 4 lasers used in University facilities must be registered with the Florida Department of Health (DH), Bureau of Radiation Control (BRC). This registration must be done within thirty days of the acquisition of the device.

When a laser is brought to the University from outside the State of Florida for temporary use, the BRC must be notified, in writing, at least twenty days before that device can be operated. To avoid delays, the LSO must be contacted at least 25 days in advance of the arrival of an outside laser device so that the necessary forms and documents can be prepared.

All notification and registration forms required by the BRC will be processed through the University's LSO in the EH&S department.

VIII. LABELING REQUIREMENTS

Class 2 and higher lasers must have labels which contain the appropriate warning tag words (CAUTION or DANGER), scripted with relevant safety instructions, and must have descriptive information about the device in question (class, type, wavelength, etc.). Class 1 lasers do not need hazard labels.

Class 2 and 2A lasers should use the warning logotype tag word "CAUTION" on the label as well as the phrase, "LASER RADIATION - DO NOT STARE INTO BEAM". "CLASS 2 (OR 2A) LASER PRODUCT" should also appear on the label.

Labels for Class 3A lasers must use the signal word "CAUTION" and one of the following accompanying phrases:

CAUTION
LASER RADIATION-DO NOT STARE INTO BEAM
OR VIEW DIRECTLY WITH OPTICAL
INSTRUMENTS
CLASS 3A LASER PRODUCT

CAUTION
LASER RADIATION-AVOID DIRECT
EYE EXPOSURE
CLASS 3A LASER PRODUCT

Labels for Class 3B and 4 lasers must include the following warning logotype wording:

DANGER
LASER RADIATION-AVOID DIRECT EXPOSURE TO BEAM
CLASS 3B LASER PRODUCT

DANGER
LASER RADIATION-AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION
CLASS 4 LASER PRODUCT

The above labels should also include descriptive information about the laser (type, class, wavelength, etc.). The area or room in which Class 3B and 4 lasers are located should have similar labels conspicuously posted for personnel unfamiliar with laser equipment.

IX. EVALUATION OF HAZARDS

The operation of lasers and laser systems can lead to potentially hazardous situations. These situations can be minimized or eliminated through the proper identification of hazards, engineering control measures, good research practices, and the use of personal protective equipment. Safety hazards for laser users arise from the following areas: hazards inherent to the laser itself, hazards from operator work procedures, and hazards associated with laser use.

A. Inherent Hazards

These hazards are derived from direct or reflected beam exposure. Most of these hazards are identified by power output, wavelength, and exposure duration. The consequential health effects range from minor skin burns to irreversible eye injury including blindness. Evaluation of these hazards is based upon the maximum permissible exposure limit (MPE) and must address the following areas: personal protective equipment, the nominal hazard zone, and the laser control area.

<u>Personal Protective Equipment (PPE)</u>
Each laser operator must have the necessary PPE (goggles, clothing, etc.) to safely use a laser. Eye and skin protection must be suitable for the wavelength of the laser involved. Safety eyewear must have the wavelength and optical density inscribed on it as required by **ANSI Z-136.1**. Additional information on the use of protective eyewear can be found in the section of this manual on "Eye Protection".

<u>Nominal Hazard Zone (NHZ)</u>
This is the area within which the level of direct, reflected, or scattered laser radiation exposure exceeds allowable limits. Although several factors contribute to the

determination of the NHZ, MPE, power output, and wavelength are the most important. Laser users must be trained to work outside the NHZ whenever possible.

Laser Controlled Area

For Class 3B and 4 lasers, this is a room or section of a research area designed specifically to house these devices. The controls, safety features, and additional safety measures, as determined by the LSO, must be implemented before the laser occupies the area. This area must include appropriate signage, have access restricted to only authorized personnel, and have limited specular surfaces (these may produce reflections). Examples of engineering control measures for various classes of lasers can be found in Appendix B, Table I. For additional information on the creation of a laser-controlled area, contact the LSO.

B. Operator Work Procedures

The primary hazards for laser users and workers near laser areas derive from improper training and the lack of familiarity with procedures. The Principal Investigator (PI) is responsible for ensuring the level of training as well as providing clear descriptions of procedures for all potentially exposed individuals. Access to the laser must also be limited where necessary, and warnings must be visibly displayed when appropriate. Examples of administrative and procedural control measures for various classes of lasers can be found in Appendix B, Table II.

Training

All laser users (including PIs) must complete Basic Laser Safety training on-line before beginning operations. This training will cover laser characteristics, general theory, and safety policies and procedures. Each participant will be certified upon completion of course work and demonstration of satisfactory understanding of the training information. Verification of training will be reviewed for each operator during annual facility inspections.

Laser manufacturers also offer training for laser systems. PIs using these systems must have training material reviewed by the LSO. The records of training must be available to the LSO upon request.

Standard Operating Procedure

The PI must prepare a Standard Operating Procedure (SOP) detailing the methods, responsible individuals, and materials being used with the laser and have this approved by the LSO before beginning research.

This SOP should also include, but not be limited to, the following:

- The location of the laser by campus, building, and room.
- A description of the laser including the class and the beam characteristics listed on the manufacturer's label.
- The intended use of the device and the type of research.
- An analysis of the potential hazards and the establishment of safety parameters.
- The use of the appropriate PPE (especially eye protective equipment) suitable to limit laser beam exposure.

- A complete step by step listing of the operating procedures including target preparation, shut down procedures, and emission delay techniques as necessary.
- A description of the emergency procedures and contingency plan necessary to deal with accidents and injuries.

The SOP must also be relevant to all classes and wavelengths of lasers in a research area, if multiple devices are in use. Contact the LSO for additional information on the development of the SOP.

C. Hazards Associated with Laser Use

The diversity of uses for lasers in industrial, research, and medical applications has produced a host of potential hazards ancillary to direct laser operations. In fact, most laser accidents result from these types of hazards. Some of these include hazards associated with general industrial hygiene, problems dealing with laser generated air contaminants, and exposure to non-laser energy sources. These associated hazards must be properly identified so that they can be minimized or eliminated.

<u>Industrial Hygiene Hazards</u>
Industrial hygiene laser hazards arise from problems associated with the components of lasers and laser systems. Examples include toxic chemical active media (some dyes used in laser active media can also be carcinogenic), compressed gas cylinders, cryogenic substances, etc. Each laser operator must use the appropriate control measures to deal with these potential hazards. (M)SDS information should also be available where necessary. The PI must contact the LSO, before beginning research, for additional guidance on dealing with these potential hazards.

<u>Laser Generated Air Contaminants (LGACs)</u>
LGACs are byproducts of the interaction of high-powered lasers (Class 3B or 4) with targeted matter. These contaminants are usually found in the vapors generated by the interaction between the beam and the target (also called the plume). The degree to which these substances can be hazardous will depend upon the type of matter being used and the power of the laser beam. Adequate ventilation must be installed to avoid the accumulation of potentially toxic or hazardous fumes and vapors.

Although the chemical composition of the LGAC depends upon the target, the exact type of contaminants that will be released is difficult to predict. Some studies suggest that the general composition of the LGACs vary from toxic chemical byproducts (polycyclic aromatic hydrocarbons, hydrogen cyanide, benzene, etc.) to mutagenic agents. Lasers used for surgery or on biological systems have even been shown to produce airborne infectious substances. PIs must coordinate activities with the LSO so that the proper engineering controls and PPE can be used to limit exposure to LGACs.

<u>Non-Laser Energy Exposure Hazards</u>
Hazardous exposures to energy not directly associated with laser radiation can occur in both low and high-powered lasers. Non-laser energy exposure may result from two primary sources: 1) deficiencies in the laser electrical systems and 2) incidental radiation generated from the laser operation.

Electrical system problems account for most accidents in laser related activities in research areas. The problems include deficiencies in supplies and parts, non-insulated terminals, poorly functioning switches, and defective outlet receptacles. In addition, power fluctuations and power supply problems can create shock hazards dangerous to laser users. All laser equipment applications require specific electrical installation and connection to the appropriate power supplies and surge protections. This equipment must be installed in accordance with the National Electric Code (NFPA 70) to limit unnecessary electrical energy exposure.

Incidental radiation, also known as collateral radiation, can result from the interaction of the components of a laser system such as the active media, target matter, photofilament, etc. and may include hazardous optical radiation. In fact, ultraviolet radiation that can be emitted from some laser discharge tubes, pumping lamps, and welding plasmas, must be suitably shielded to reduce exposure to safe levels. Contact the LSO for additional information on the limitations of exposure to collateral radiation.

X. EYE PROTECTION

The human eye is the organ of the body most sensitive to damage from laser light. This is because it is living tissue exposed to the environment and as the organ of vision; light is collected and concentrated on the retina. There are no protective membranes or cell layers to insulate this sensitive area from excessive light exposure (or other hazardous exposures to the outside environment). There are two main sources of natural eye protection: the tearing mechanism and the eyelids. Most lasers are powerful enough to overcome these natural protections. This is the reason for the importance of the proper selection and use of protective laser eyewear.

A. Natural Eye Protection

Reflexes stimulate the optical protective mechanisms of the eye. The *tearing reflex* helps to wash noxious materials and foreign bodies from the surface of the eye. This helps to remove debris, which could potentially obstruct the visual input areas.

The *blinking reflex* (0.25 seconds) enables the eyelids to limit exposure to most intense wavelengths of light. Blinking can also be triggered by temperature elevation. High-power lasers, however, can cause irreversible damage before the blinking reflex protects the eye. For this reason, additional external eye protection is required when using these types of lasers (generally Class 3B and 4 lasers).

B. Biological Effects of Laser Light

The biological effects of laser light on the eye depend predominantly upon wavelength and power output. Laser energy cannot damage a tissue unless it can both reach and be absorbed by that tissue. For this reason, light rays in the visible and near infrared bands of the spectrum will be transmitted through the clear media of the eye and strike the retina. This energy can be amplified as much as 100,000 times causing significant damage to the areas of the retina responsible for acute vision. The high-resolution area of the retina, called the macula, has a center, the fovea, which is the size of only fractions of a square millimeter. If either of these small areas is damaged as a result of hazardous energy exposure, significant vision loss will occur.

More powerful lasers (Classes 3B and 4) can cause damage to tissues in the anterior portion of the eye without reaching the retina. These ocular structures (cornea and lens) may absorb this energy and cause significant damage. Examples of bioeffects from different wavelengths of light and selected lasers can found in Appendix B, Table III and Table IV.

C. Selection and Use of Protective Eyewear

The intensity of the beam and the ability of structures in the eye to either absorb laser energy or amplify beam power underscore the importance of using the appropriate eye protection. *All* Class 3B and 4 laser users must use eye protection designed for that specific wavelength (λ) and optical density (D_λ). The manufacturer, in compliance with **ANSI Z-136.1,** must also print this information (λ and $D\lambda$) on the eyewear.

Although many lasers are similar in power and design, their wavelengths may differ. For this reason, laser operators must not use protective eyewear interchangeably among different lasers. Other factors that are important in the selection of eye protection are proper fit, comfort, and visual performance. Eyewear that is not comfortable or is difficult to see through is not likely to be used and therefore increases the risk of exposure. Contact the LSO for additional information about the proper selection and use of laser eyewear.

XI. MEDICAL SURVEILLANCE PROGRAM

A **baseline medical examination** is no longer required. Eye exams are only required:

(a) Immediately after a suspected abnormal exposure or
(b) for specific eye complaints possibly related to laser usage.

Records of medical examinations and exposure incidents must be filed with the LSO and the Occupational Medicine Program administered by Environmental Health and Safety.

APPENDIX A
Forms

FLORIDA ATLANTIC UNIVERSITY
LASER OPERATOR PROGRAM

Laser Operator Record

Name ____________________________________ Phone ____________________

Department ____

Laboratory Location

Campus ____________________ Building/Room ____________________________

Laser Operation Beginning Date ____

Training

A. Basic Laser Information ____

B. Laser Operation Training ____

C. Laser Safety Training ____

____

LSO's Signature Date

FLORIDA ATLANTIC UNIVERSITY
LASER INVENTORY FORM

Laser Device Description:

Manufacturer:____

Manufacturer Model Name/Number:_____________________________________

Serial Number:____

Laser Medium (Solid State, Ar, CO2, etc.)______________________________

Wavelength(s) in nm:____

Max Output:_________________________________ W or J (please specify)

Pulsed_____ or Continuous Wave_____

Laser Class: IIIB____ IV____ Other____

Intended Use: Research____ Education ____ Other (please specify)______________

Laser Device Location:

Campus/Building/Room: ____

Principle Investigator: ____

Operator(s) Name(s): ____

SOP submitted to LSO? Yes____ No____
Operation of Laser cannot begin until SOP is approved by LSO.

Comments:

____

____

Principle Investigator Date LSO Date

APPENDIX B
Tables

TABLE I Engineering Control Measures for Lasers[1]

CONTROL MEASURES Engineering Controls	CLASSIFICATION[2] I	IIA	II	IIIA	IIIB	IV
Protective Housing (4.3.1)[3]	X	X	X	X	X	X
Without Protective Housing (4.3.1.1)	LSO shall establish alternate control					
Interlocks on Protective Housing (4.3.2)	∇	∇	∇	∇	X	X
Service Access Panel (4.3.3)	∇	∇	∇	∇	X	X
Key Control (4.3.4)	—	—	—	—	•	X
Viewing Portals (4.3.5.1)	—	—	MPE	MPE	MPE	MPE
Collecting Optics (4.3.5.2)	MPE	—	MPE	MPE	MPE	MPE
Totally Open Beam Path (4.3.6.1)	—	—	—	—	X/NHZ	X/NHZ
Limited Open Beam Path (4.3.6.2)	—	—	—	—	X/NHZ	X/NHZ
Enclosed Beam Path (4.3.6.3)	None is required if 4.3.1. and 4.3.2. fulfilled					
Remote Interlock Connector (4.3.7)	—	—	—	—	•	X
Beam Stop or Attenuator (4.3.8)	—	—	—	—	•	X
Activation Warning Systems (4.3.9)	—	—	—	—	•	X
Emission Delay (4.3.9.1)	—	—	—	—	—	X
Indoor Laser Controlled Area (4.3.10)	—	—	—	—	X/NHZ	X/NHZ
Class IIIB Laser Controlled. Area (4.3.10.1)	—	—	—	—	X	-
Class IV Laser Controlled. Area	—	—	—	—	—	X
Laser Outdoor Controls (4.3.11)	—	—	—	—	X	X
Laser in Navigable Airspace (4.3.11.2)	—	—	—	•	•	•
Temp. Laser Controlled Area (4.3.12)	∇	∇	∇	∇	—	—
Remote Firing and Monitoring (4.3.13)	—	—	—	—	—	•
Labels (4.3.14 and 4.7)	—	X	X	X	X	X
Area Posting (4.3.15)	—	—	•	•	X/NHZ	X/NHZ

[1]The information in this table is taken from ANSI Z136.1.
[2]Legend: "X" - Shall; "●" - Should; "Ä" - No requirement; "∇" - Shall if enclosed Class IIIB or Class IV; "MPE" - Shall if "MPE" is exceeded; "NHZ" - Nominal Hazard Zone analysis required.
[3]Numbers in parentheses refer to location of topic in the ANSI standard.

Table II Administrative and Procedural Laser Control Measures[1]

CONTROL MEASURES	CLASSIFICATION[2]					
Administrative and Procedural Controls	**I**	**IIA**	**II**	**IIIA**	**IIIB**	**IV**
Standard Operating Procedures	—	—	—	—	•	X
Output Emission Limitations	—	—	—	LSO determination		
Education and Training	—	—	•	•	X	X
Authorized Personnel	—	—	—	—	X	X
Alignment Procedures	—	—	X	X	X	X
Protective Equipment	—	—	—	•	X	X
Spectator	—	—	—	—	•	X
Service Personnel	∇/MPE	∇/MPE	∇/MPE	∇/MPE	X	X
Demonstration with General Public	MPE	—	X	X	X	X
Laser Optical Fiber Systems	MPE	MPE	MPE	MPE	X	X
Laser Robotics Installations	—	—	—	—	X/NHZ	X/NHZ
Eye Protection	—	—	—	—	•/MPE	X/MPE
Protective Windows	—	—	—	—	X/NHZ	X/NHZ
Protective Barriers and Curtains	—	—	—	—	•	•
Skin Protection	—	—	—	—	X/MPE	X/MPE
Other protective Equipment	—	—	—	—	X/NHZ	X/NHZ
Warning Signs and Labels	—	—	•	•	X	X
Service and Repairs	LSO Determination					
Modification of Laser Systems	LSO Determination					

[1]The information in this table is reprinted by permission from the ANSI Standards Committee Z136.

[2]Legend: "X" - Shall; "●" - Should; "Ä" - No requirements; "∇" - Shall if enclosed class IIIB or Class IV; "MPE" - Shall if MPE is exceeded; "NHZ" - Nominal Hazard Zone analysis required; "_" - Applicable only to UV or infrared lasers.

Table III Selected Laser Device Bioeffects[1]

LASER TYPE	WAVELENGTH (µm)	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[2]	1.33	Thermal	X	X	X	X
Nd-YAG	1.06	Thermal	X			X
Gas (diode)	0.78-0.840	Thermal				X
He-Ne	0.633	Thermal				X
Ar	0.488-0.514	Thermal/Photochem	X			X[3]
XeFl	0.351	Photochemical	X	X		X
XeCl	0.308	Photochemical	X	X		

[1]The information in this table is taken from the Laser Institute of America
[2]Wavelength @ 1.33 µm more common in some Nd-YAG lasers has demonstrated simultaneous cornea/lens/retina effects in biological research studies.
[3]Photochemical effects dominate for long-term exposures to retina (greater than 10 seconds).

Table IV Examples of Bioeffects for Selected Wavelengths of Light[1]

Photobiological/Spectral Domain	EYE	SKIN
Ultraviolet C (200 nm- 280nm)	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 & Thermal retinal injury	Pigment darkening; Photosensitive reactions; Skin Burn
Infrared A (780 nm - 1400 nm)	Cataract & 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

[1]The information in this table was taken from the Laser Institute of America