TITLE:

SAF-367, LASER SAFETY PROGRAM

1. PURPOSE

The purpose of this document is to provide guidelines for protection from workplace hazards associated with the use of Class 3B and/or Class 4 lasers. This purpose is to be accomplished through the implementation of administrative and engineering controls and the use of personal protective equipment (PPE) as prescribed in the American National Standards Institute's American National Standard for the Safe Use of Lasers – ANSI Z136.1 – 2007. While some departments or entities within Emory University may have additional and/or stricter guidelines for the safe use of Class 3B and Class 4 lasers, the guidelines outlined in this document shall serve as the minimum requirements for all of Emory University.

2. SCOPE

The Laser Safety Program applies to all Emory University employees, students, and to employees of Emory Healthcare who operate laser equipment classified as Class 3B and/or Class 4, or who work in areas where these classes of lasers are used. It also applies to any other individuals who may visit or have access to these areas at any time.

3. POLICY

Emory University is committed to the minimization of accidents and/or injuries caused by the use of Class 3B and/or Class 4 lasers. The main goal is to ensure that all exposures to laser radiation (both to the eyes and skin) are kept below the applicable maximum permissible exposure (MPE) limit. This will be accomplished through training and education of personnel on laser safety and the use of administrative controls, engineering controls, and PPE. For determination of its effectiveness and for any necessary amendments, this Laser Safety Program will be re-evaluated periodically.

While this program addresses hazards associated with the use of Class 3B lasers, Class 4 lasers, and any non-beam hazards associated with the laser work environment, any hazardous conditions encountered that are not addressed by this document should be reported to the Environmental Health and Safety Office for investigation.

4. REFERENCES

4.1. ANSI Z136.1 – 2007; American National Standard for Safe Use of Lasers

4.2. State of Georgia Rules and Regulations

5. LASER SAFETY IN MEDICAL FACILITIES

The ANSI Z136.1 Standard provides guidance for the safe use of laser devices and laser systems. The American National Standards Institute also offers standards that are more specific to laser use in healthcare facilities, the Z136.3 Standard for Use of Lasers in Healthcare Facilities. Although the Z136.3 standard is specific to healthcare facilities, it is intended to be followed in addition to the Z136.1 standard.

Emory Healthcare has a Laser Safety Policy that provides additional guidance for laser use in a healthcare setting. For additional guidelines on laser safety that cover Emory University Hospitals and Emory Clinics, access the Emory Healthcare intranet at www.eushc.org. If you have questions or need assistance, call (404) 712–7299.

6. RESPONSIBILITIES

6.1. Environmental Health and Safety Office (EHSO)

As the administrative department for the Laser Safety Program, EHSO is responsible for:

6.1.1. Appointment of a Laser Safety Officer (LSO), as prescribed by section 1.3.2 of ANSI Z136.1-2007.

6.1.2. Review and approval of the Laser Safety Program and any amendments made by the LSO.

6.1.3. Enforcement of the Laser Safety Program.

6.1.4. Retention of all training and inspection records in accordance with ANSI Z136.1-American National Standard for Safe Use of Lasers.

6.2. Laser Safety Officer (LSO)

The LSO represents EHSO as the program administrator for laser safety and is responsible for:

6.2.1. Development of the written Laser Safety Program and all necessary amendments.

6.2.2. Compiling and maintaining (as needed) a laser system/device inventory for all Class 3B and Class 4 lasers on site.

6.2.3. Ensuring that all Class 3B and Class 4 lasers are marked with the appropriate designation from the manufacturer, including warning label, power, and wavelength. If this is not the case, the LSO must provide the appropriate designation.

6.2.4. Assessment of hazardous conditions or potential hazards in work areas where lasers are used.

6.2.5. Establishing a nominal hazard zone (NHZ), when necessary, to determine the boundary between the hazardous areas and non-hazardous areas of the work environment.

6.2.6. Recommending and/or implementing control measures to remedy hazardous conditions in the areas where lasers are used.

6.2.7. Investigating all accidents and/or injuries that occur as a result of laser operation.

6.2.8. Examining and approving all forms eye personal protective equipment used in the laser work environment. The LSO shall make these examinations periodically to ensure that all PPE is adequate, in satisfactory condition, and to determine whether replacements are necessary.

6.2.9. Ensuring that all labs or work areas where lasers are used have signage on the exterior door(s) indicating the presence of laser equipment (refer to www.ehso.emory.edu for the most current Laboratory Signage Requirements Form).

6.2.10. Administration of initial laser safety training to laser operators prior to use of lasers; refresher training will be provided as needed – either for remediation or changing regulation.

6.2.11. The LSO will coordinate with the PI regarding instrument orientation, training, standard operating procedures, and control measures to ensure that the equipment is operated according to the ANSI Z136.1 standard.

6.2.12. Performing periodic inspections to ensure that implemented control measures are being followed, all procedures are conducted in a safe manner, and all PPE is in working condition. During each inspection, the laser inventory will be compared against which devices are actually present in the laser work area (to ensure that all lasers are accounted for; new equipment will be added, and surplus laser equipment will be removed from the inventory).

6.3. Laser Safety Committee

A laser safety committee may be created when the number of lasers, types of hazards, and complex applications are substantial. Laser Safety Committees can consist of professionals from multiple fields of expertise, and are responsible for:

6.3.1 Providing guidance and/or feedback on laser safety issues.
6.3.2 Evaluating all content revisions to laser safety guidelines, training, and proposed control measures.
6.3.3 Informing the LSO of any recognized laser safety issues in their area of expertise.

6.4. Principal Investigators, Directors, Supervisors, and Managers

The Principal Investigators, directors, supervisors, and managers have primary responsibility for providing a safe work environment for their employees that work in areas where lasers are used and are responsible for:

6.4.1. Providing written Standard Operating Procedures for work practices using Class 3B and Class 4 lasers to laser operators and the LSO. SOPs should include items such as PI name, laser operators, description of laser(s) used, laser specifications, operating and safety procedures, and all PPE used during operation.

6.4.2. Implementing control measures that minimize potential hazards associated with laser use.

6.4.3. Maintaining an up-to-date inventory of all Class 3B and Class 4 lasers that fall under their authority.

6.4.4. Ensuring that all laser operators have completed general laser safety training through EHSO.

6.4.5. Providing all laser operators with hands-on training on the operation of the specific Class 3B and Class 4 lasers they will be operating.

6.4.6. Providing all laser operators with adequate personal protective equipment for use with lasers, particularly adequate eye protection.

6.4.7. Notifying the LSO of any potential hazards associated with laser use not covered in this document.

6.4.8. Notifying the LSO of all new personnel who will operate lasers for training purposes.

6.4.9. Notifying LSO of any new purchases of Class 3B and Class 4 lasers, or any such equipment that requires transfer and/or decommissioning.

6.4.10. Notifying the LSO of any alterations made to laser devices or laser equipment that may elevate their hazard class above that set by the manufacturer.

6.4.11. Reporting any accidents or injuries, or suspected injuries associated with the use of lasers to the LSO.

6.4.12. Contacting LSO for any questions regarding laser safety.

6.5. Employees

Employees are responsible for:

6.5.1. Complying with all rules set forth in this document.

6.5.2. Attending all required laser safety training.

6.5.3. Reporting all accidents, injuries, or suspected injuries to their PI, supervisor, director, or lab manager, and to the LSO. This includes completing an Employee Accident/Injury Report, using the University STARS system.

6.5.4. Notifying their PI, supervisor, director, or lab manager of any unsafe conditions in the work area.

6.5.5. Contacting their PI, supervisor, director or lab manager, or LSO when questions arise regarding the safe use of lasers in the work area.

6.5.6. Reporting any problems to their PI, supervisor, director, or lab manager regarding PPE/eye protection (obvious or suspected).

7. LASER CLASSIFICATION

7.1. Class 1 Lasers

7.1.1. Lasers or laser systems that are incapable of producing laser radiation levels in excess of the Class 1 accessible emission limit (AEL) values for any period of time during normal operation is considered a Class 1 laser (see section 3.2 of ANSI Z136.1 for AEL values). In many cases, there are lasers of higher classes that are responsible for the laser output of these lasers, but the beam may be enclosed in a protective housing that prevents the higher energy from escaping (see section 10.3). The output capacity during normal operation is what determines the laser class. They can be divided into two subclasses:

7.1.1.1. Class 1 lasers or laser systems are considered exempt from all control measures or any other types of safety measures by the ANSI Z136.1, and are therefore exempt from the Laser Safety Program. In circumstances where the protective housing of the laser may need to be opened, the requirements for embedded lasers apply (see requirements section 9.3).

7.1.1.2. Class 1M lasers or laser systems are not capable of emitting accessible laser radiation that exceeds the Class 1 AEL under normal operating conditions. However, they exceed the Class 1 AEL for telescopic viewing, but do not exceed the Class 3B AEL. Class 1M lasers are exempt from all control measures other than those that protect against potentially hazardous optically aided viewing (appropriate protective viewing filters).

7.2. Class 2 Lasers

7.2.1. Class 2 lasers or laser systems emit energy at wavelengths that cover the entire visible portion of the electromagnetic spectrum. These are lasers that can be continuous wave (CW) or repetitively pulsed, and can produce output energy

exceeding the Class 1 AEL value for the maximum duration intended in the design of the device. Lasers in this class are fairly low power lasers, considering the average power emitted within the class does not exceed 1 milliwatt (mW). They can be divided into two subclasses:

7.2.1.1. Class 2 lasers are those that are not intended to be viewed directly while in normal operation. Class 2 lasers would not pose a significant hazard during normal operation, but would prove hazardous if viewed directly for extended periods of time. The normal human aversion response time (0.25 seconds) would suffice in protecting the eyes. Because no other control measures are needed, Class 2 lasers are exempt from the Laser Safety Program.

7.2.1.2. Class 2M lasers are not capable of emitting accessible laser radiation that exceeds the Class 2 AEL under normal operating conditions. However, they exceed the Class 2 AEL for telescopic viewing, but do not exceed the Class 3B AEL. Class 2M lasers are exempt from all control measures other than those that protect against potentially hazardous optically aided viewing (appropriate protective viewing filters).

7.3. Class 3 Lasers

Lasers or laser systems in Class 3 are divided into two subclasses as well.

7.3.1. Class 3R lasers and laser systems are those that have accessible output energy between one and five times the Class 1 AEL values on either side of the visible portion of the electromagnetic spectrum or less than five times the Class 2 AEL values within the visible portion of the spectrum.

7.3.1.1. Class 3R lasers are considered hazardous if the beam is viewed by an unaided, focused eye.

7.3.1.2. Injury cannot occur unless the beam of the Class 3R laser is viewed for a time longer than the normal aversion time of 0.25 seconds. Diffuse reflections of Class 3R laser are not hazardous. There is no fire hazard associated with Class 3R lasers.

7.3.1.3. Class 3R lasers are exempt from the Laser Safety Program with the exception of when viewed through collecting optics.

7.3.1.4. Ensure all appropriate protective viewing filters are in place.

7.3.2. Class 3B lasers include those that operate in the ultraviolet and infrared regions of the electromagnetic spectrum, and can emit laser energy in excess of the AEL values of Class 3R lasers during any period of time, and can emit power of less than 500 milliwatts (mW).

7.3.2.1. Class 3B also includes lasers in the visible and near infrared portions of the spectrum and can emit power from 5.0 – 500 milliwatts (mW) via continuous wave or greater than 0.03 joules (J) per pulse (for pulsed lasers).

7.3.2.2. Class 3B lasers are considered to be hazardous within normal aversion time (less than 0.25 seconds), and even diffuse reflections can be hazardous. Because the normal aversion time does not protect the eye from Class 3B laser radiation, and because diffuse reflections of Class 3B

laser radiation is considered hazardous, the lasers of Class 3B will be covered under the Laser Safety Program.

7.4. Class 4 Lasers

7.4.1. Lasers and laser systems in Class 4 are those that emit laser radiation levels that exceed the AEL values of Class 3B.

7.4.2. Class 4 lasers can produce hazards from direct viewing as well as diffuse reflections. They can emit power in excess of 500 milliwatts (mW), and direct viewing and diffuse reflections can cause eye injury within the normal aversion time (less than 0.25 seconds).

7.4.3. This class of lasers can also have the potential to cause skin hazards/injuries and fires.

7.4.4. Class 4 lasers can cause injury to the eyes by direct viewing and by diffuse reflections. The normal aversion time does not protect against the laser radiation. The laser radiation can cause injury to the eyes, skin, and can cause fires.

7.4.5. Lasers of Class 4 are covered under the Laser Safety Program.

7.5. Alternate Laser Classification

The classification scheme used in this section is prescribed by the ANSI Z136.1 standard. However, some laser devices on campus may be labeled using an alternate classification scheme. The International Electrotechnical Commission (IEC) and the Center for Devices and Radiological Health (CDRH) both have classification schemes for lasers that are similar to that of ANSI, but have minor differences (see Appendix A - Summary of Laser Classification Schemes for additional information regarding these schemes).

8. LASER REGISTRATION

8.1. All Principal Investigators must inform the LSO of any existing lasers and new purchases of laser devices or laser equipment of Class 3B and Class 4 by registering.

8.2. Each laser of these classes must be registered with EHSO using the Laser Registration Form, available on the EHSO website (www.ehso.emory.edu).

9. TRAINING

9.1. The LSO is responsible for ensuring that laser safety training is provided to those who operate Class 3B and/or Class 4 lasers. Training will be provided initially for all laser operators and will include the following:

9.1.1. Basic concepts about laser devices.

9.1.2. Biological effects of laser radiation on the eyes and the skin.

9.1.3. The significance of specular and diffuse reflections of laser radiation as they relate to eye injuries.

9.1.4. Classification rationale for laser devices and laser systems.

9.1.5. Hazards associated with the use of Class 3B and Class 4 lasers that are not directly related to the laser beam.

9.1.6. Implementation of control measures as methods of injury prevention.

9.1.7. Selection, use, and appropriate care of personal protective equipment.

9.2. Refresher training will be given to ~~each~~ laser operators at the discretion of the LSO to ensure that the most current information is being provided as updated ANSI standards are released and as new developments are made in the field.

10. CONTROL MEASURES FOR LASER OPERATION

Control measures must be implemented to ensure that all laser operators and any other at-risk individuals, such as spectators and service personnel, are protected from Class 3B and Class 4 laser radiation. These control measures have a broad range from simple administrative controls such as training, signage, and restricted access, to minimizing possible exposure to the beam, to eye protection to protect individuals from the beam. The goal is to ensure the work environment is as safe as feasible without disrupting the work process.

10.1. Class 3B Lasers

The following control measures must be implemented as prescribed by the ANSI Z136.1 standard to protect against Class 3B laser radiation:

10.1.1. Individuals who operate Class 3B lasers shall be trained in general laser safety aspects and must be authorized by the Principal Investigator to operate the equipment.

10.1.2. The path of the laser beam shall be enclosed as much as feasible.

10.1.3. When full output of the laser is not required, all shutters and filters on laser equipment shall be used to minimize hazardous levels of laser radiation.

10.1.4. No individual shall point the laser beam of a Class 3B (or any) laser at or in the direction of the eyes of another person.

10.1.5. No individual using lasers shall position his or her unprotected eyes near or within the path of the laser beam.

10.1.6. No individual shall knowingly allow another person to position his or her unprotected eyes near or within the path of the laser beam.

10.1.7. Any individual who operates a Class 3B laser or is a spectator during the operation of the laser shall wear adequate eye protection for the laser in use. For unique situations (such as multiple open beams in operation simultaneously), a hazard assessment may be needed.

10.1.8. The presence of reflective surfaces (hanging mirrors, jewelry, etc) shall be prohibited from the work environment while the laser is in operation in order to prevent unwanted reflections that may cause injury.

10.1.9. Protective housings must be secure on the laser device.

10.1.10. In the event that the protective housing must be removed, the laser must have a safety interlock system that can be activated.

10.1.11. Service access panels (removed only when servicing the laser) must be interlocked, must require a tool for removal, and have an appropriate warning label.

10.1.12. Aiming lasers in the direction of windows, doorways, or the windows of doors shall be prohibited.

10.1.13. No individual shall operate the laser prior to specific control measures (for the laser work area) being implemented (see section 11.0 for control measures).

10.2. Class 4 Lasers

The following control measures must be implemented as prescribed by the ANSI Z136.1 standard for Class 4 lasers **IN ADDITION TO** those control measures outlined for Class 3B lasers:

10.2.1. During operation, the path of a Class 4 laser beam shall be completely enclosed where feasible to reduce hazards.

10.2.2. In cases where beam enclosure is not feasible, remote operation should be utilized where possible.

10.2.3. Any individual who operates a Class 4 laser or is a spectator during the operation of the laser shall wear adequate eye protection for the laser in use. For unique situations (such as multiple open beams in operation simultaneously), alternate control measures (i.e. remote operation, closed circuit television, etc.) are strongly recommended.

10.2.4. Class 4 lasers shall have an operational key switch to prevent unauthorized use.

10.2.5. For laser devices that have key switches to prevent unauthorized use, the key must be removed from the device when unattended.

10.2.6. To diminish fire hazards, fire resistant, absorbent target material and beam stops, and attenuators shall be used.

10.2.7. Countdown devices or verbal countdowns should be used to inform laser operators of exactly when the laser beam will be emitted.

10.2.8. The laser equipment should be equipped with remote interlock connectors.

10.3. Embedded Lasers

10.3.1. Embedded lasers, under normal operational circumstances, are exempt from control measures as they usually carry the Class 1 designation. This is due to a protective housing and safety interlocks that are generally installed by the manufacturer.

10.3.2. However, when being serviced, the protective housing of the laser may need to be opened. Most of these protective housings require safety interlocks to be in place which further limit the exposure to the laser beam. In the event that these safety interlocks are malfunctioning or are defeated, the laser equipment has the potential to cause injury to the eyes through exposure to Class 3B or Class 4 laser radiation.

10.3.3. Therefore, when being serviced, all embedded lasers will be included in the Laser Safety Program, and temporary control measures must be implemented. The control measures to be followed by service personnel must be appropriate for the accessible radiation hazard, whether Class 3B or Class 4.

10.4. Multiple Wavelength Lasers

Some lasers have the capability to operate at multiple wavelengths of the electromagnetic spectrum, which also enables them to produce a broad spectrum of hazards depending on their operational wavelengths. Multiple wavelength lasers must be classified according to the highest potential for hazard.

The appropriate control measures outlined in this document will be implemented for multiple wavelength lasers when they are operational as Class 3B or Class 4 lasers.

10.5. Ultraviolet Lasers

10.5.1. For lasers that are used in the ultraviolet region of the electromagnetic spectrum (180 nm – 400 nm), additional caution should be taken when in operation. Whether the hazard class of the laser is Class 3B or Class 4, the following precautions should be taken IN ADDITION TO those of its respective hazard class:

10.5.1.1. Minimization of UV radiation by use of beam shields.

10.5.1.2. Minimization of UV radiation by wearing clothing that attenuate radiation levels to below the applicable MPE for specific wavelengths (example – lab coats).

10.6. Lasers With Invisible Beams

Lasers that operate in the IR and UV wavelengths of the electromagnetic spectrum are invisible to the human eye. Because these laser beams cannot be seen, the potential for accidents and injuries is greater. It is strongly recommended that adequate eye protection be worn at all times when operating (Class 3B and Class 4) IR and UV lasers.

11. CONTROL MEASURES FOR THE WORK ENVIRONMENT

Control measures must also be implemented with regard to the laser work area and its physical orientation to ensure that the work environment is safe for all personnel. The following control measures must be implemented as prescribed by the ANSI Z136.1 standard with regard to the laser work area.

11.1. Nominal Hazard Zone (NHZ)

For work environments where Class 3B or Class 4 lasers are used, a nominal hazard zone, or NHZ must be established when necessary. The purpose for the establishment of the NHZ is to determine where the hazards associated with exposure to Class 3B or Class 4 lasers end and the safe, laser hazard-free areas begin within the work environment. The establishment of the NHZ is the responsibility of the LSO. In certain situations, it may be practical to designate an entire laser work area as the NHZ.

11.2. Positioning of Laser Equipment

Laser equipment should be positioned in the work environment using the following methods where feasible:

11.2.1. The laser or laser system shall be positioned at a level above or below eye level where feasible to prevent direct exposure to the beam, reflections, or scattered laser radiation.

11.2.2. All laser equipment shall be securely mounted on a sturdy surface to prevent unintended distribution of the laser beam.

11.2.3. All areas of traffic within the work area shall be free of all electrical cords extending from laser equipment to prevent tripping or possible unintended exposure to laser radiation.

11.2.4. No laser equipment shall be moved and operated away from the currently established NHZ.

11.2.5. When operating laser equipment, take all necessary precautions when working near surfaces that are wet.

11.3. Alignment Procedures

The possibility for eye hazards/injuries is increased during alignment procedures due to the proximity of the laser operator's eye(s) to the beam. Alignment procedures should not be performed by individuals who have not received training in Laser Safety. During alignment procedures for Class 3B or Class 4 lasers, the following precautions should be taken:

11.3.1. Allow only necessary personnel to be present in the work area during the procedure.

11.3.2. When feasible, use lower power, visible lasers to simulate alignment for higher power lasers.

11.3.3. Wear adequate eye protection and protective clothing to the extent feasible.

11.3.4. When available, use beam display devices such as image converter viewers or phosphor cards to locate beams when aligning invisible (and in some cases visible) beams.

11.3.5. When aligning high power lasers, do so at the lowest possible power level.

11.3.6. Use shutters or beam blocks to block high power beams at the source, except when needed during the alignment process.

11.3.7. Use a laser rated beam block to terminate high power beams down range of the optics being aligned.

11.3.8. Use beam blocks in conditions where stray beams could expose uninvolved personnel.

11.3.9. Place beam blocks behind optics (example – turning mirrors) to terminate beams that may miss mirrors during alignment.

11.3.10. Locate and block all stray reflections before proceeding to the next optical component or section.

11.3.11. Before operating high power beams, ensure all beams and reflections are properly terminated.

11.3.12. Post appropriate warning signs during alignment procedures (when lasers are normally Class1 – in the case of embedded lasers).

11.4. Postings

According to the ANSI Z136.1 standard, work areas where Class 3B and Class 4 lasers are located must be labeled as follows (please note: specifications listed below are suggested by ANSI):

11.4.1. The sign must display the word "DANGER" in large letters (see Figure 1**,** Class 3B and Class 4 Laser Signage Figure 2, Temporary Signage for Figure 1).

11.4.2. Laser type, with regard to the active medium.

11.4.3. The wavelength(s) emitted.

11.4.4. Maximum energy output, and

11.4.5. Pulse duration, where applicable.

Figure 1, **Class 3B and Class 4 Laser Signage**

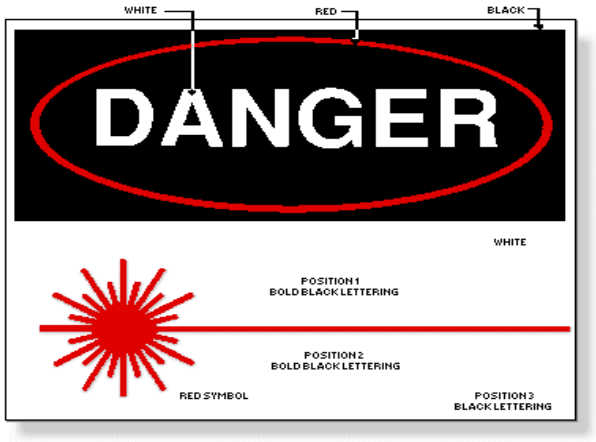
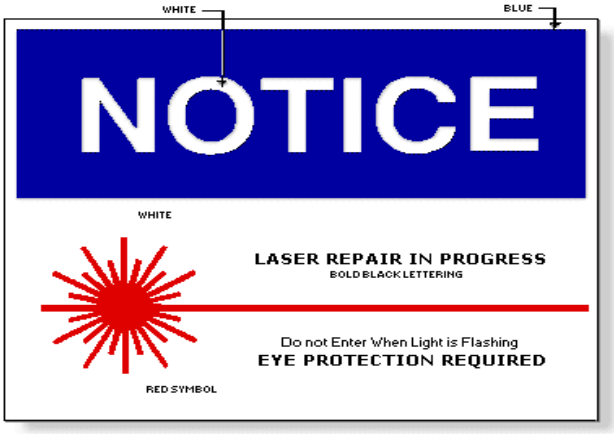


Figure 2, Temporary Signage for Maintenance of Embedded Lasers



NOTE: With respect to embedded lasers, the word "DANGER" is replaced with the word "NOTICE," and the sign will read, "Do Not Enter; Laser repair in progress; eye protection required (see Figure 2)."

12. ADDITIONAL CONTROL MEASURES

The following additional control measures are prescribed by ANSI Z136.1 for work areas containing Class 3B and Class 4 lasers:

12.1. All doors in work areas containing laser equipment should be locked (when no procedures are ongoing), giving only authorized personnel access to the area. This is to prevent unauthorized access and to prevent inadvertent entry by laypersons during operation.

12.2. Lighted/flashing or hanging warning signs should be used outside the work area to indicate that a laser is in use.

12.3. All windows and windows built into doors of the work area should be covered with dark, non penetrable material to confine all laser radiation to the work area.

12.4. Laser operators should not operate laser equipment while working alone. Another laser operator or qualified individual should be present in case of an accident.

12.5. The use of checklists to outline all operational and safety procedures while the laser equipment is in use would ensure that every possible measure is taken to prevent injury.

12.6. It is recommended that individuals working in the laser environment be trained in CPR in the event that there is an injury involving high voltage or respiratory arrest.

12.7. In the event of a fire, an operational fire extinguisher (or appropriate fire method for extinguishing fires) should be available.

12.8. Emergency contact numbers must be posted in the work area in the event of an injury or other hazardous condition.

13. PERSONAL PROTECTIVE EQUIPMENT

When working with lasers, the ultimate goal for employee protection is to minimize the hazard as much as feasible to prevent exposure to the radiation. However, when it is not feasible to minimize exposure, personal protective equipment, or PPE must be used as the primary means of protection. **Since the hazards associated with the use of Class 3B and Class 4 lasers are primarily to the eyes, it is imperative for all employees operating these lasers to wear laser eye protection.**

13.1. Eye Protection

The careful selection of eye protection is very important in protecting the eyes against Class 3B and Class 4 laser radiation. There are several factors that must be considered when selecting eye protection. Failure to adhere to such factors could lead to the inadvertent selection of inadequate protection. The following factors must be considered when selecting adequate eye protection from Class 3B and Class 4 laser radiation:

13.1.1. Wavelength of the laser or the spectral range for which protection is needed.

13.1.2. The optical density at the specific wavelength.

13.1.3. The Maximum Permissible Exposure (MPE) at the specific wavelength.

13.1.4. The damage threshold, which is the maximum irradiance or beam power for which the PPE provides protection for a time frame of 10 seconds.

13.1.5. Laser power or pulse energy (where applicable).

13.1.6. Visible light transmission (lasers in visible region), which should be as high as possible to ensure visibility of the laser while wearing the eye protection.

13.1.7. The visual transmittance for daylight and night, due to the variation in eye sensitivity to different forms of light at these times.

13.1.8. Field of view provided by design.

13.1.9. Curvature of the lens.

13.1.10. Anti-fogging designs.

13.1.11. Availability of prescription lenses, or sufficient size for prescription lenses to be worn inside.

13.1.12. Angular dependence of protection afforded.

13.1.13. Effect on color vision.

13.1.14. Need for side shield protection and maximum peripheral vision requirement.

13.1.15. Exposure time criteria.

13.1.16. Degradation of filter media, such as photobleaching.

13.1.17. Strength of materials.

13.1.18. The capability of the front surface to produce a hazardous specular reflection.

13.1.19. Comfort and fit.

13.2. Calculation of Eye Protection Parameters

The following steps are critical to ensure that the appropriate eye protection is chosen:

13.2.1. Determination of the operational wavelength of the laser and the maximum viewing time period for which the eye protection will be used. This will help determine the applicable MPE of the eye for those parameters (refer to ANSI Z 136.1 tables 2-7).

13.2.2. Determine the optical density using the MPE, worst case exposure (Hp), and the transmittance of the filter at the specific wavelength ($\tau\lambda$). These values can be used in the following equation to find optical density: $OD = \log_{10} (H_p/MPE) = -\log_{10} \tau\lambda$.

13.2.3. With respect to the factors of time, MPE limits, and worst case exposure, the following must also be considered when selecting appropriate eye protection for Class 3B and Class 4 lasers:

13.2.4. For visible Class 3B or Class 4 lasers: when long term exposure to visible lasers is not intended, the applicable MPE used to establish the OD requirement for eye protection should be based on an exposure time of 0.25 second, which is based on the normal aversion response to bright light. This becomes the initial defense for unexpected exposures.

13.2.4.1. In cases where exposure to a laser beam must exceed 0.25 seconds, such as alignment procedures (when viewing a diffusely reflected target), the applicable MPE used to establish the OD requirement for eye protection may be based on a 600 second exposure, which represents the worst case time exposure for these tasks.

13.2.5. For near-infrared Class 3B or Class 4 lasers: when long term exposure to near infrared lasers is not intended, the applicable MPE used to establish the OD requirement for eye protection should be based on an exposure time of 10 seconds. This represents a realistic worst case time exposure based on normal eye motions.

13.2.6. For diffuse viewing (Class 3B or Class 4 lasers): when viewing an extended source of the diffuse reflection of a beam from a Class 3B or Class 4 laser where intermediate viewing time is intended, the applicable MPE should be based on the maximum viewing time that would be required during any eight hour period.

13.2.7. These conditions are highlighted due to the wavelengths falling within the retinal hazard region, where the most profound injuries to the eyes can occur. If the inappropriate optical density is selected for an exposure condition, the laser radiation will not be decreased below the MPE limit, and the resulting energy penetrating the eye protection will cause injury.

13.3. Maintenance of Eye Protection

13.3.1. Eye protection designed to protect against laser radiation should be maintained to ensure effectiveness. The following measures must be taken to ensure that laser eye protection remain effective in protection against laser radiation:

13.3.1.1. Each pair of eye protection must be labeled with the appropriate optical density and electromagnetic wavelength (should be labeled from the manufacturer).

13.3.1.2. Each pair of eye protection must be inspected periodically for cracks, scratches, and breaks that could allow the penetration of laser radiation.

13.3.1.3. Each pair of eye protection should be stored in its own protective casing.

13.3.1.4. Each pair should be cleaned regularly with mild soap and water as opposed to harsh chemicals to prevent the thinning of the protective coating.

13.3.1.5. Eye protection that is suspected to be damaged or not working properly should be examined for functionality or disposed of if dysfunctional.

13.4. Skin Protection

13.4.1. Although protection of the eyes is the primary concern regarding hazards/injuries when operating lasers, the skin should also be protected in particular instances.

13.4.2. Engineering controls such as beam shields are the best way to protect the skin. However, alternative methods must sometimes be used. For protection from UV radiation (180 nm – 400 nm), the following control measures are recommended:

13.4.2.1. Wearing of skin covers

13.4.2.2. Wearing opaque gloves

13.4.2.3. Wearing tightly woven fabrics and/or lab coats

13.4.2.4. Flame retardant clothing is recommended for certain uses of Class 4 lasers

13.4.3. When the wavelength of the laser exceeds1400 nm, overexposure can cause heat loading which can lead to heat stress and skin dryness. In these cases, the recommendation is reduced personnel exposure.

14. NON-BEAM HAZARDS & CONTROL MEASURES

Injuries caused by exposure to laser radiation of Class 3B and Class 4 lasers are the primary focus of the Laser Safety Program. However, there are other hazards that are associated with the use of lasers that also require control measures. These hazards will also be evaluated by the LSO and the appropriate control measures will be implemented accordingly.

14.1. Laser Generated Air Contaminants

14.1.1. LGACs can be produced as a result of beam contact with metals, fabric, plastics, and human skin. The plumes of smoke or vapors generated can cause respiratory adverse effects when inhaled, and can produce biological effects if bacteria or viruses become airborne due to contact with the eyes or skin.

14.1.2. Local exhaust ventilation is strongly recommended in addition to the negative pressure design in the laser work area to minimize exposure to LGAC.

14.1.3. The area must have negative pressure to the corridor to contain any releases.

14.2. Electrical Hazards

Electrical hazards can result from the use of lasers. These hazards can occur during installation of the equipment, during the servicing of the equipment, or because the equipment is not properly grounded. Depending upon the voltage required to operate the equipment, injuries can vary from a minor shock to electrocution. To prevent serious injury or death from electrical hazards, the following precautions must be taken:

14.2.1. Extreme caution must be used whenever servicing laser power supplies.

14.2.2. Additional controls and training when working on live circuits operating at more than 50 volts, as prescribed by OSHA 29 CFR 1910 S.

14.2.3. Maintain the integrity of all electrical cords and terminals.

14.2.4. Ensure that the equipment is grounded well.

14.2.5. A clearly visible, power-on indicator should be present.

14.3. Laser Dyes

14.3.1. Various dyes and solvents are sometimes used (depending on the type of laser) as a lasing medium. Some of these substances are toxic and carcinogenic if absorbed through the skin or swallowed.

14.3.2. For each dye used with lasers, ensure that material safety data sheets (MSDS) are available.

14.3.3. For additional information, visit the EHSO website and search under Databases where the online MSDS database can be accessed.

14.4. Cryogenic Agents and Compressed Gasses

14.4.1. Cryogenic agents are used in conjunction with lasers or laser systems. These substances can cause explosions in the laser work area. Any container or vessel containing cryogenic liquids, which are extremely cold materials, have the potential to explode due to rapid expansion inside the vessel.

14.4.2. Liquid oxygen is highly flammable, as it contains more oxygen by volume than normal air, and should be kept away from all possible sources of ignition. Cryogenic liquids can also cause severe burns and frostbite if handled improperly.

14.4.3. Compressed gasses are often used in the laser work area and can also constitute an explosion hazard. Over pressurization of the container by heating can cause the gasses to expand, resulting in an explosion.

14.4.4. See the EHSO website and access the MSDS database for more information on these substances.

14.5. Explosion Hazards

Inside the protective housing of some lasers or laser systems are arc lamps, filament lamps or other glass structures that are under high pressure. These structures have the possibility to explode during normal operation of the laser and must remain enclosed inside the protective housing.

15. MEDICAL SURVEILLANCE

The control measures outlined in this document serve as guidelines for minimizing the exposure of personnel to Class 3B and Class 4 laser radiation in excess of the MPE limits. However, when this purpose has not been fulfilled, a method to assess the degree of injury must be in place. The rationale behind medical surveillance is to establish this method. The following measures must be in place for medical surveillance as prescribed by ANSI 136.1.

15.1. Pre-assignment Medical Examinations

Under the ANSI Z136.1 standard, it is recommended that all laser personnel (individuals who directly work with lasers) and all incidental personnel (exposure is possible, but unlikely) have a medical examination prior to beginning work with lasers or in an area where lasers are operated.

These exams are given for the purpose of establishing a baseline to make comparisons in the event of an injury to the eyes. They also may identify personnel who may have added risk due to chronic exposure to certain continuous wave lasers. All exams should be given by a qualified physician such as an ophthalmologist or optometrist.

The type of medical exams required depends on the personnel:

15.1.1. Laser personnel:

15.1.1.1. Review of ocular history – past eye history and family history are reviewed. Any current concerns are documented.

15.1.1.2. Visual Acuity – test for far and near vision.

15.1.1.3. Macular Function - Amsler grid (or similar test) given to test macular function for irregularities.

15.1.1.4. Color vision test.

Any individual whose test results are abnormal will need to undergo further testing for ocular function.

15.1.2. Incidental personnel should only be tested for visual acuity.

15.2. Post-Exposure Examinations

In the event of an injury, suspected injury, or exposure above the applicable MPE, personnel should seek medical examination as soon as possible (preferably within 48 hours). Information such as symptoms, the wavelength of the laser device, and the type of beam output (pulsed, continuous wave, or Q-switched) should be provided to the examiner. The tests performed after an injury should include at least those performed in the baseline exam.

15.3. Periodic Medical Examinations

Periodic medical examinations are not required by the ANSI Z136.1 standard.

16. ACCIDENT/INJURY REPORTING

In the event an accident or injury occurs during the operation of laser equipment (and/or when the injury is not related to the operation of the laser), refer to the Emergency tab of the EHSO website (www.ehso.emory.edu).

16.1. Notify EHSO (404-727-5922) of the injury as soon as possible.

16.2. Complete a STARS Incident Report Form, which can be found at www.ehso.emory.edu.

16.3. A post exposure medical exam for eye function should be performed within 48 hours (if the injury is laser related).

17. PROGRAM EVALUATION

17.1. The LSO is responsible for the evaluation of the Laser Safety Program to ensure that all of its components work effectively in the protection of Class 3B and Class 4 laser operators.

17.2. As part of the evaluation process, the Laser Safety Officer will conduct periodic safety inspections. During the inspection process, the LSO will complete the following tasks:

17.2.1. Inspect all laser work areas for imminent beam and non-beam hazards.

17.2.2. Consult Principal Investigators and laser operators for their comments and/or concerns regarding laser safety.

17.2.3. Investigate and document any incidents, accidents, and/or injuries associated with laser use that have been recorded by the Principal Investigator, lab manager, supervisor, or employees.

17.2.4. Inspect all laser eye protection for appropriate storage, chips, cracks, and deterioration.

17.2.5. Compare laser inventory of LSO to that of the Principal Investigator to capture any new laser devices not registered with EHSO and any laser equipment removed from service.

18. RECORD KEEPING

Training and inspection records are retained and available through EHSO in accordance with the ANSI Z136.1 - Standard for the Safe Use of Lasers.

GLOSSARY OF TERMS

Accessible emission limit	The maximum accessible emission level allowed within a particular class of lasers.
Aversion response	Movement of the head or blinking of the eyelids in response to a stimulant such as a bright light. Normal aversion response is assumed to occur within 0.25 seconds of exposure to the stimulant.
Continuous wave	The output characteristic of any laser system that operates in a continuous mode, or as referred to in ANSI Z136.1, having a continuous output for greater than 0.25 seconds.
Diffuse reflection	Change in the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or medium.
EHSO	Environmental, Health and Safety Office
Embedded laser	An enclosed laser that has a higher class than that of the laser system in which it is enclosed; the lower classification of the system is appropriate due to engineering controls of the laser system and the limitation of its emission
Hazard	And condition that has the capacity to cause injury or adverse effects to the exposed individual(s).
Laser or LASER	A device that produces radiant energy by stimulated emission; also an acronym for Light Amplification by Stimulated Emission of Radiation.
Laser generated air contaminants	Respirable materials that have the potential to cause adverse effects to those exposed, and are produced as a result of the heating of target materials by lasers.
Laser equipment	An assembly of electrical, mechanical, and optical components which includes a laser.
Laser Safety Officer	An individual who has the authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.
Maximum permissible exposure	The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eyes or skin.
Nominal hazard zone	The space within which the level of direct, reflected, or scattered radiation during normal operation of a laser exceeds the applicable MPE.

Optical density	Logarithm to the base ten of the reciprocal of the transmittance. That is, OD = $\log_{10}$ (H_p/MPE) = -$\log_{10}$ $\tau\lambda$ where transmittance= $\tau\lambda$. Optical density is a critical factor in the selection of appropriate eye protection in the protection from exposure to laser radiation.
Power	The rate at which energy is emitted, transferred, or received.
Protective housing	The encasement of a laser that prevents exposure to laser radiation in excess of the applicable MPE level.
Pulsed laser	A laser that emits radiation in a pulse or series of pulses.
Safety interlock	An interlock where the failure of a mechanical or electrical component of the interlock will cause the system to go into safe mode.
Specular reflection	A mirror like reflection.
Wavelength	The distance between two successive points on a periodic wave having the same pulse.

APPENDIX A - SUMMARY OF LASER CLASSIFICATION SCHEMES

FDA/CDRH (21 CFR 1040.10)	ANSI Z136.1	IEC/EN 80625
Class I Levels of laser radiation are not considered hazardous.	**Class 1** No hazard; exempt from all control measures.	**Class 1** No risk, even with viewing instruments
N/A	**Class 1M** Not capable of producing hazards during normal operation unless beam is viewed with an optical instrument (e.g. eye loupe or telescope); exempt from control measures other than to prevent potentially hazardous optically aided viewing.	**Class 1M** No risk; possible risk to eyes when viewed through viewing instruments (eye loupes or binoculars.
Class II Levels of (visible only) laser radiation considered a chronic viewing hazard.	**Class 2** Visible (0.4-0.7 µm) lasers not considered hazardous for momentary viewing (<0.25 seconds), but for which the class 1 accessible emission limit may be exceeded for longer exposure durations; avoid prolonged staring.	**Class 2** No eye risk for short term exposures, even with viewing instruments; no risk to skin (applies to visible lasers only).
Class IIa Levels of laser radiation (applies to visible only) are not considered hazardous if viewed ≤ 1000 seconds but are considered a chronic viewing hazard for any period of time >1000 seconds.	**Class 2M** Emits in the visible region of the spectrum (0.4-0.7 µm); the aversion response is normally adequate protection during unaided viewing. Potentially hazardous if viewed with certain optical aids.	**Class 2M** No eye risk for short term exposures; possible with viewing instruments; no risk to skin (visible only)
Class IIIa Levels of laser radiation are considered, depending upon the irradiance, either an acute beam viewing hazard or chronic viewing hazard, and an acute viewing hazard if viewed directly with optical instruments.	**Class 3R** Potentially hazardous under some direct and specular reflection viewing conditions if the eye is focused and stable; probability of actual injury is small. Not a fire hazard; diffuse reflections not hazardous.	**Class 3R** Low risk to eyes, low risk to skin.
Class IIIb Levels of laser radiation are considered to be an acute hazard to the skin and eyes from direct radiation.	**Class 3B** Emit greater than Class 3a limits and pose an acute eye hazard; more rigourous controls are required to prevent exposure of the unprotected eye.	**Class 3B** Medium risk to eyes, low risk to skin.
Class IV Levels of laser radiation are considered an acute hazard to the skin and eyes from direct and scattered radiation.	**Class 4** Acute eye and skin hazard, plus ignition source (fire) and laser-generated airborne contaminants hazard; strict control measures required.	**Class 4** High risk to eyes and skin.