THE UNIVERSITY of NEW ORLEANS
OFFICE OF RESEARCH

Laser Safety Guidelines

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Purpose

The purpose of this document is to provide guidelines for protection from workplace hazards associated with the use of Class IIIB and Class IV 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 within the University of New Orleans (UNO) may have additional and/or more strict guidelines for the safe use of Class IIIB and Class IV lasers, the guidelines outlined in this document shall serve as the minimum requirements for UNO.

These guidelines apply to all UNO faculty, staff, and students who operate laser equipment classified as Class IIIB and Class IV lasers or who work in areas where these classes of lasers are used. They also apply to any other individuals who may visit or have access to these areas at any time.

1. Definitions

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 – the UNO 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 – any condition that has the capacity to cause injury or adverse effects to the exposed individual(s)

Laboratory 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

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

Maximum permissible exposure (MPE) – the level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eyes or skin

Nominal hazard zone (NHZ) – 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 = log10 (Hp/MPE) = -log10 τλ where transmittance = τλ. 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

2. Responsibilities

Laboratory Safety Officer/Laser Safety Officer

The laboratory safety officer is the authority over the Laser Safety Guidelines. The laboratory safety officer is responsible for:

- Development of the written Laser Safety Guidelines and all necessary amendments.
- Review and approval of the Laser Safety Guidelines and any amendments made by the LSO.
- Enforcement of the Laser Safety Guidelines.
- Retention of all training and inspection records in accordance with ANSI Z136.1-American National Standard for Safe Use of Lasers.
- Compiling and maintaining (as needed) a laser system/device inventory for all Class IIIB and Class IV lasers on site.
- Ensuring that all Class IIIB and Class IV 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.
- Assessment of hazardous conditions or potential hazards in work areas where lasers are used.

- Establishing a nominal hazard zone (NHZ), when necessary, to determine the boundary between the hazardous areas and non-hazardous areas of the work environment.
- Recommending and/or implementing control measures to remedy hazardous conditions in the areas where lasers are used.
- Investigating all accidents and/or injuries that occur as a result of laser operation.
- Examining and approving all forms of eye personal protective equipment (PPE) 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.
- 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 the Laboratory Signage Requirements Form found at https://www.uno.edu/research/funding/compliance under Lab Signage).
- 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.
- 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).

EHSO

EHSO will support the LSO in all aspects listed above.

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:

- Providing written Standard Operating Procedures (SOPs) for work practices using Class IIIB and Class IV 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.
- Administration of initial laser safety training to laser operations prior to use of lasers and refresher training as needed. Training must include hands-on operation instructions unique to each specific laser that will be operated.
- Implementing control measures that minimize potential hazards associated with laser use.
- Maintaining an up-to-date inventory of all Class IIIB and Class IV lasers that fall under their authority.
- Providing all laser operators with adequate personal protective equipment for use with lasers, particularly adequate eye protection.
- Notifying the LSO of any potential hazards associated with laser use not covered in this document.

- Notifying the LSO of any new purchases of Class IIIB or Class IV lasers, or any such equipment that requires transfer and/or decommissioning.
- 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.
- Reporting any accidents, injuries, or suspected injuries, associated with the use of lasers to the LSO.
- Contacting the LSO for any questions regarding laser safety.

Employees and Students

Employees and students are responsible for:

- Complying with all rules set forth in this document.
- Attending all required laser safety training.
- Reporting all accidents, injuries, or suspected injuries to their PI, supervisor, director, or lab manager and to the LSO. This includes completing an accident report found on SharePoint.
- Notifying their PI, supervisor, director, or lab manager and the LSO of any unsafe conditions in the work area.
- Contacting their PI, supervisor, director, or lab manager and the LSO when questions arise regarding the safe use of lasers in the work area.
- Reporting any obvious or suspected problems to their PI, supervisor, director, or lab manager regarding PPE/eye protection.

3. Training Requirements

The PI or lab manager is responsible for ensuring that laser safety training is provided to those who operate Class IIIB and Class IV lasers. Training must include the following, at a minimum:

- Basic concepts about laser devices
- Biological effects of laser radiation on the eyes and skin
- The significance of specular and diffuse reflections of laser radiation as they relate to eye injuries
- Classification rationale for laser devices and laser systems
- Hazards associated with the use of Class IIIB and Class IV lasers that are not directly related to the laser beam
- Implementation of control measures as methods of injury prevention
- Selection, use, and appropriate care of personal protective equipment.

Refresher training is up to the PI and lab manager but should be given if there are any issues or concerns regarding the safe operation of Class IIIB or Class IV lasers in the lab by employees or students. Refresher training is required when ANSI standards regarding Class IIIB and Class IV lasers are updated.

4. Recordkeeping

Training and inspection records are retained and available in the Lab Safety Binder.

5. Program Evaluation

The LSO is responsible for the evaluation of the Laser Safety Guidelines to ensure that all of its components work effectively in the protection of Class IIIB and Class IV lasers operators.

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

- Inspect all laser work areas for imminent beam and non-beam hazards.
- Consult PIs, lab managers, and laser operators for their comments and/or concerns regarding laser safety.
- Investigate and document any incidents, accidents, and/or injuries associated with laser use that have been recorded by the PI, lab manager, supervisor, employee, or student.
- Inspect all laser eye protection for appropriate storage, chips, cracks, and deterioration.
- Compare laser inventory to that of the PI to capture any new laser devices not registered with the LSO and any laser equipment removed from service.

6. Policy

UNO is committed to the minimization of accidents and/or injuries caused by the use of Class IIIB and/or Class IV 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, these Laser Safety Guidelines will be re-evaluated periodically.

While this program addresses hazards associated with the use of Class IIIB lasers, Class IV 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 LSO.

7. Laser Classification

Class I Lasers

Lasers or laser systems that are incapable of producing laser radiation levels in excess of the Class I accessible emission limit (AEL) values for any period of time during normal operation is considered a Class I 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. The output capacity during normal operation is what determines the laser class. Class I lasers can be divided into two subclasses:

- Class I 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 Guidelines. In circumstances where the protective housing of the laser may need to be opened, the requirements for embedded lasers apply.

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

Class II Lasers

Class II 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 I 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:

- Class II lasers are those that are not intended to be viewed directly while in normal operation. Class II 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 Guidelines.
- Class IIM lasers are not capable of emitting accessible laser radiation that exceeds the Class II AEL under normal operating conditions. However, they exceed the Class II AEL for telescopic viewing, but do not exceed the Class IIIB AEL. Class IIM lasers are exempt from all control measures other than those that protect against potentially hazardous optically aided viewing (appropriate protective viewing filters).

Class III Lasers

Laser or laser systems in Class III are divided into two subclasses as well.

- Class IIIR lasers and laser systems are those that have accessible output energy between one and five times the Class I AEL values on either side of the visible portion of the electromagnetic spectrum or less than five times the Class III AEL values within the visible portion of the spectrum.
    - Class IIIR lasers are considered hazardous if the beam is viewed by an unaided, focused eye.
    - Injury cannot occur unless the beam of the Class IIIR laser is viewed for a time longer than the normal aversion time of 0.25 seconds. Diffuse reflections of Class IIIR lasers are not hazardous. There is no fire hazard associated with Class IIIR lasers.
    - Class IIIR lasers are exempt from the Laser Safety Guidelines with the exception of when viewed through collecting optics.
    - Ensure all appropriate protective viewing filters are in place.
- Class IIIB 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 IIIR lasers during any period of time, and can emit power of less than 500 milliwatts (mW).

- Class IIIB 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).
- Class IIIB 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 IIIB laser radiation and because diffuse reflections of Class IIIB laser radiation is considered hazardous, the lasers of Class IIIB will be covered under the Laser Safety Guidelines.

Class IV Lasers

Class IV lasers and laser systems are those that emit laser radiation levels that exceed the AEL values of Class IIIB.

Class IV 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).

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

Class IV 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 and skin and can cause fires.

Class IV lasers are covered under the Laser Safety Guidelines.

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

All PIs must inform the LSO of any existing lasers and new purchases of laser devices or laser equipment of Class IIIB and Class IV by registering them using the Laser Registration Form available found at https://www.uno.edu/research/funding/compliance under Laser Safety.

9. 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 IIIB and Class IV 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.

Class IIIB Lasers

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

- Individuals who operate Class IIIB lasers shall be trained in general laser safety aspects and must be authorized by the PI to operate the equipment.
- The path of the laser beam shall be enclosed as much as feasible.
- 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.
- No individual shall point the laser beam of a Class IIIB (or any) laser at or in the direction of the eyes of another person.
- No individual using lasers shall position his or her unprotected eyes near or within the path of the laser beam.
- No individual shall knowingly allow another person to position his or her unprotected eyes near or within the path of the laser beam.
- Any individual who operates a Class IIIB 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.
- 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.
- Protective housings must be secure on the laser device.
- In the event that the protective housing must be removed, the laser must have a safety interlock system that can be activated.
- Service access panels (removed only when servicing the laser) must be interlocked, must require a tool for removal and have an appropriate warning label.
- Aiming lasers in the direction of windows, doorways, or the windows of doors shall be prohibited.
- No individual shall operate the laser prior to specific control measures (for the laser work area) being implemented.

Class IV Lasers

The following control measures must be implemented as prescribed by the ANSI Z136.1 standard for Class IV lasers **in addition to** those control measures outlined for Class IIIB lasers:

- During operation, the path of a Class IV laser beam shall be completely enclosed where feasible to reduce hazards.
- In cases where beam enclosure is not feasible, remove operation should be utilized where possible.
- Any individual who operates a Class IV 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 (ex. Remote operation, closed circuit television, etc.) are strongly recommended.
- Class IV lasers shall have an operational key switch to prevent unauthorized use.
- For laser devices that have key switches to prevent unauthorized use, the key must be removed from the device when unattended.
- To diminish fire hazards, attenuators and fire-resistant, absorbent target material and beam stops shall be used.
- Countdown devices or verbal countdowns should be used to inform laser operators of exactly when the laser beam will be emitted.
- The laser equipment should be equipped with remote interlock connectors.

Embedded Lasers

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.

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 IIIB or Class IV laser radiation.

Therefore, when being serviced, all embedded lasers will be included in the Laser Safety Guidelines 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 IIIB or Class IV.

Multiple Wavelength Lasers

Some lasers have the capability to operate at multiple wavelengths of the electromagnetic spectrum, which 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 IIIB or Class IV lasers.

Ultraviolet Lasers

For lasers that are used in the ultraviolet region of the electromagnetic spectrum (180nm – 400nm), additional caution should be taken when in operation. Whether the hazard class of the laser is Class IIIB or Class IV, the following precautions should be taken **in addition to** those of its respective hazard class:

- Minimization of UV radiation by use of beam shields.
- Minimization of UV radiation by wearing clothing that attenuates radiation levels to below the applicable MPE for specific wavelengths (ex. Lab coats).

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 lasers 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 IIIB and Class IV) IR and UV lasers.

10. Control Measures for the Work Environment

Control measures must also be implemented with regard to the laser work area in 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.

Nominal Hazard Zone (NHZ)

For work environments where Class IIIB or Class IV lasers are used, a nominal hazards zone (NHZ) must be established when necessary. The purpose for the establishment of the NHZ is to determine where the hazards associated with exposure to the Class IIIB or Class IV laser 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.

Positioning of Laser Equipment

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

- 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.
- All laser equipment shall be securely mounted on a sturdy surface to prevent unintended distribution of the laser beam.
- 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.
- No laser equipment shall be moved and operated away from the currently established NHZ.
- When operating laser equipment, take all necessary precautions when working near surfaces that are wet.

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 IIIB or Class IV lasers, the following precautions should be taken:

- Allow only necessary personnel to be present in the work area during the procedure.
- When feasible, use lower power, visible lasers to simulate alignment for higher power lasers.
- Wear adequate eye protection and protective clothing to the extent feasible.

- 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.
- When aligning high power lasers, do so at the lowest possible power level.
- Use shutters or beam blocks to block high power beams at the source, except when needed during the alignment process.
- Use a laser-rated beam block to terminate high power beams down range of the optics being aligned.
- Use beam blocks in conditions where stray beams could expose uninvolved personnel.
- Place beam blocks behind optics (ex. Turning mirrors) to terminate beams that may miss mirrors during alignment.
- Locate and block all stray reflections before proceeding to the next optical component or section.
- Before operating high power beams, ensure all beams and reflections are properly terminated.
- Post appropriate warning signs during alignment procedures (when lasers are normally Class 1 – in the case of embedded lasers).

Postings

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

- The sign must display the word "DANGER" in large letters (see Figure 1, Class IIIB and Class IV Laser Signage and Figure 2, Temporary Signage for Figure 1).
- Laser type, with regard to the active medium.
- The wavelength(s) emitted.
- Maximum energy output.
- 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)."

11. Additional Control Measures

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

- 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.
- Lighted/flashing or hanging warning signs should be used outside the work area to indicate that a laser is in use.
- 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.
- Laser operators should not operate laser equipment while working alone. Another laser operator or qualified individual should be present in case of an accident.
- 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.
- 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.
- In the event of a fire, an operational fire extinguisher (or appropriate fire method for extinguishing fires) should be available.
- Emergency contact numbers must be posted in the work area in the event of an injury or other hazardous condition.

12. 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 (PPE) must be used as the primary means of protection. Since the hazards associated with the use of Class IIIB and Class IV lasers are primarily to the eyes, it is imperative for all employees operating these lasers to wear laser eye protection.

Eye Protection

The careful selection of eye protection is very important in protecting the eyes against Class IIIB and Class IV 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 IIIB and Class IV laser radiation:

- Wavelength of the laser or the spectral range for which protection is needed.
- The optical density at the specific wavelength.
- The Maximum Permissible Exposure (MPE) at the specific wavelength.
- The damage threshold, which is the maximum irradiance or beam power for which the PPE provides protection for a time frame of 10 seconds.
- Laser power or pulse energy (where applicable).

- 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.
- The visual transmittance for daylight and night, due to the variation in eye sensitivity to different forms of light at these times.
- Field of view provided by design.
- Curvature of the lens.
- Anti-fogging designs.
- Availability of prescription lenses, or sufficient size for prescription lenses to be worn inside.
- Angular dependence of protection afforded.
- Effect on color vision.
- Need to side shield protection and maximum peripheral vision requirement.
- Exposure time criteria.
- Degradation of filter media, such as photobleaching.
- Strength of materials.
- The capability of the front surface to produce a hazardous specular reflection.
- Comfort and fit.

Calculation of Eye Protection Parameters

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

- 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 Z136.1 Tables 2-7).
- Determine the optical density using the MPE, worst case exposure (Hp), and the transmittance of the filter at the specific wavelength (τλ). These values can be used in the following equation to find optical density: $OD = \log10(Hp/MPE) = -\log10\tau\lambda$.
- 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 IIIB and Class IV lasers:
    - For visible Class IIIB or Class IV 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 seconds, which is based on the normal aversion response to bright light. This becomes the initial defense for unexpected exposures. 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.
    - For near-infrared Class IIIB or Class IV 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.

- For diffuse viewing (Class IIIB or Class IV lasers): when viewing an extended source of the diffuse reflection of a beam from a Class IIIB or Class IV 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.
- 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.

Maintenance of Eye Protection

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 remains effective in protection against laser radiation:

- Each pair of eye protection must be labeled with the appropriate optical density and electromagnetic wavelength (should be labeled from the manufacturer).
- Each pair of eye protection must be inspected periodically for cracks, scratches, and breaks that could allow the penetration of laser radiation.
- Each pair of eye protection should be stored in its own protective casing.
- Each pair of eye protection should be cleaned regularly with mild soap and water as opposed to harsh chemicals to prevent thinning of the protective coating.
- Eye protection that is suspected to be damaged or not working properly should be examined for functionality or disposed of if dysfunctional.

Skin Protection

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

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 (180nm – 400nm), the following control measures are recommended:

- Wearing of skin colors.
- Wearing opaque gloves.
- Wearing tightly woven fabrics and/or lab coats.
- Flame retardant clothing is recommended for certain uses of Class IV lasers.

When the wavelength of the laser exceeds 1400nm, overexposure can cause heat loading which can lead to heat stress and skin dryness. In these cases, the recommendation is reduced personnel exposure.

13. Non-Beam Hazards and Control Measures

Injuries caused by exposure to laser radiation of Class IIIB and Class IV lasers are the primary focus of the Laser Safety Guidelines. 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.

Laser Generated Air Contaminants (LGACs)

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.

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

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

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:

- Extreme caution must be used whenever servicing laser power supplies.
- Additional controls and training when working on live circuits operating at more than 50 volts, as prescribed by OSHA CFR 1910 S.
- Maintain the integrity of all electrical cords and terminals.
- Ensure that the equipment is grounded well.
- A clearly visible, power-on indicator should be present.

Laser Dyes

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.

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

Cryogenic Agents and Compressed Gases

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.

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.

Compressed gases 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 gases to expand, resulting in an explosion.

Always consult the safety data sheets (SDSs) for more information.

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.

14. Medical Surveillance

The control measures outlined in this document serve as guidelines for minimizing the exposure of faculty, staff, and students to Class IIIB and Class IV 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.

Pre-assigned 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:

- Laser personnel:
    - Review of ocular history – past eye history and family history are reviewed. Any current concerns are documented.
    - Visual acuity – test for far and near vision.
    - Macular function – Amsler grid (or similar test) given to test macular function for irregularities.
- Color vision test – any individual whose test results are abnormal will need to undergo further testing for ocular function.
- Incidental personnel should only be tested for visual acuity.

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.

Periodic Medical Examinations

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

15. Accident/Injury Reporting

In the event of an accident or injury during the operation of laser equipment (and/or when the injury is not related to the operation of the laser), complete the following steps:

- Conduct immediate care
  - Eyewash station or safety shower, as applicable
  - Rinse or wash for 15 minutes
- Contact UNO Police at 504-280-6371 and 911
- Tell your supervisor
- Fill out an Accident or Injury Report located on SharePoint
- Follow-up as needed according to your supervisor and physician(s)
  - A post exposure medical exam for eye function should be performed within 48 hours, if the injury is laser-related

16. References

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

State of Louisiana Rules and Regulations

17. List of Associated Documents

Laser Registration Form

Laser Standard Operating Procedure (SOP) Template

Store these in the Lab Safety Binder.

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 1M** 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 (ex. 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 I accessible emission limit may be exceeded for longer exposure durations; avoid prolonged	**Class 2** Levels of (visible only) laser radiation considered a chronic viewing hazard.
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 rigorous controls are required to prevent exposure of the unprotected eye.	**Class 3b** Medium risk to eyes, low risk to skin.
Class IV Levels of 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.