LASER SAFETY MANUAL

University of Notre Dame
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Section 1

Introduction

The purpose of this manual is to ensure the safe use of lasers in research and instructional laboratories at the University of Notre Dame. To achieve this goal, the University had adopted the American National Standard for Safe Use of Lasers, ANSI Z136.1-2000. ANSI Z 136.1-2000 is recognized as a minimum standard for laser safety.

Most lasers are capable of causing eye injury form the direct beam and specular reflections. Class 4 lasers are also capable of causing eye injury from diffuse reflections, burning exposed skin, igniting flammable materials and generating hazardous air contaminants. Equipment used to produce the lasing action and control and direct the laser beam introduce additional hazards associated with high voltage, high pressure, cryogenics, noise, radiation and toxic gases.

Scope

This program applies to all Class 3b and 4 lasers and to all employees either working with or in the vicinity of those lasers used in research and instructional laboratories at the University of Notre Dame.

Responsibilities

A. Principal Investigators are responsible for:

- Supervising laser use in the laboratory.
- Implementing and enforcing the safety recommendations and requirements outlined in this manual.
- Developing standard operation procedures (SOPs) for the laboratory.
- Providing laser operators with training in operating, administrative procedures and alignment procedures.
- Ensuring that all lasers in the laboratory are properly classified and labeled.
- Registering all lasers with the Risk Management and Safety Department
- Attending and ensuring users attend laser safety training.
- Ensuring all users take part in medical surveillance program if working with Class 3b or Class 4 lasers.
- Notifying Risk Management and Safety immediately in the event of an exposure to a Class 3b or Class 4 laser beam.
- Placing copies of operator and safety manuals in areas accessible to users.

B. Laser Operators are responsible for:
- Following laboratory standard operating procedures (SOPs).
- Informing the Principal Investigator of any departure from the SOPs.
- Notifying the Principal Investigator in the event of an exposure incident.
- Attending laser safety training.
- Registering for the medical surveillance program if working with Class 3b or Class 4 lasers.

C. The Risk Management and Safety Department is responsible for:
- Developing a laser safety policy and revise it when necessary.
- Conducting safety audits of Class 3b or 4 laser laboratories on an annual basis.
- Providing assistance in evaluating and controlling hazards.
- Updating the Laser Safety Manual.
- Maintaining records of all Class 3b or 4 laser operations.
- Conducting laser safety training for all personnel working with Class 3b or 4 lasers.
- Participating in accident investigations involving lasers.
- Maintaining records of the medical surveillance program.

Section II

Personnel Training and Qualifications

A. Only qualified personnel are permitted to operate a laser. The Principal Investigator will identify qualified personnel based on departmental training, technical training and other appropriate learning experience.

B. All staff and students operating Class 3b and Class 4 lasers are required to attend laser safety training conducted by the Risk Management and Safety Department prior to working with lasers.

C. Before operating a Class 3b or 4 laser, staff and student shall:
- Review the Laser Safety Manual
  ANSI 2136.1 requires written standard operating, maintenance, and service procedures for all Class 4 lasers, and recommends the same for Class 3b lasers. These written SOPs shall be maintained with the laser equipment for reference by the operator, and maintenance or service personnel.

Most laser equipment is provided with instructions for safe operation by the manufacturer, however, sometimes these are not well suited to a specific application due to special use conditions. If this is the case, or if you are missing these instructions, please contact the Risk Management and Safety Department for help in establishing SOP's. Written SOP's should be available for review during laboratory and laser equipment audits. (See Appendix C.)

- Receive training from the Principal Investigator or laboratory supervisor covering safe operation of the laser to be used, administrative procedures, alignment procedures and other applicable SOPs.
- Have a baseline eye exam conducted by an ophthalmologist. (See Section VI, Medical Surveillance.)

Section III

Laser Classification

Lasers and laser systems are classified based on their capability of injuring personnel.

A. Lasers manufactured after August 1, 1976 are classified and labeled by the manufacture. The Principal Investigator shall classify lasers and laser systems that are constructed or modified in the laboratory.

B. There are five laser hazard classes:

- Class 1 lasers and laser systems cannot emit accessible levels of radiation that are capable of causing eye injury under any normal operating condition. (A more hazardous laser may be embedded in a Class 1 product that is not accessible during normal operating conditions, but may be during service and maintenance.
- Class 2 lasers and laser systems are visible lasers with an accessible output $\leq$ 1 mW. Class 2 lasers and laser systems are incapable of causing eye injury unless intentionally viewed directly for an extended period.
- Class 3a lasers and laser systems have an accessible output between 1-5 mW and do not pose a serous eye hazard unless viewed through optical instruments.
- Class 3b lasers and laser systems have an accessible output 5-500 mW for continuous wave lasers and < 0.125 J within 0.25 second for a pulsed laser. Class 3b lasers and laser systems pose a serious eye hazard from viewing the direct beam or specular reflections.
- Class 4 lasers and laser systems have an accessible output > 500 mW for a continuous wave laser and > 0.125 J within 0.25 second for a pulsed laser. Class 4 lasers and laser systems pose a serious eye hazard from viewing the direct beam, specular reelections and diffuse reflections. Class 4 lasers and laser systems also pose skin and fire hazards.

Section IV

Laser Bio-Effects

The site of damage and threshold at which damage occurs depends on the wavelength, whether it is a small or extended source, the exposure duration, whether it is continuous wave or pulsed, and, if pulsed, the pulse length and pulse repetition frequency.

Operating lasers under reduced external light conditions increases the optical hazards because of pupil dilation.

The Maximum Permissible Exposure (MPE) is the level of laser radiation that a person may be exposed to without experiencing adverse health effects. Contact the Risk Management & Safety Department for assistance in calculating the MPE.

A. **Eye**
Bio-effects of the eye are summarized in the following table:

SPECTRUM	LOCATION	EFFECT
UV-C (200-280 nm)	Cornea	Photokeratitis
UV-B (280-315 nm)	Cornea	Photokeratitis
UV-A (315-400 nm)	Lens	Cataract
Visible (400-780 nm)	Retina	Retinal injury*
IR-A (780-1400 nm)	Retina, Lens	Retinal burn, cataract
IR-B (1400-3000 nm)	Cornea, Lens	Corneal burn, cataract
IR-C (3000-1000000 nm)	Cornea	Corneal burn
* Retinal injury can be thermal acoustic or photochemical.		

Skin
Bio-effects of the skin are summarized in the following table:

SPECTRUM	LOCATION
UV-C (200-280 nm)	Erythema, cancer, accelerated aging
UV-B (280-315 nm)	Erythema, increased pigmentation, cancer, accelerated aging
UV-C (315-400 nm)	Erythema, increased pigmentation, skin burn
Visible (400-780 nm)	Photosensitive reactions, skin burn
IR-A (780-1400 nm)	Skin burn
IR-B (1400-3000 nm)	Skin burn
IR-C (3000-1000000 nm)	Skin burn

Section V

Registering Lasers

A. When a class 3b or Class 4 laser arrives on campus, the Principle Investigator must notify the Risk Management & Safety Department, and provide the following information.
- Manufacturer of the unit
- Model number
- Serial number
- Date of manufacture
- Class
- Location of use (Laboratory Building and Room Number)

B. When a laser light show is anticipated to occur on University Property, the operator of that show must complete the form in Appendix E of this manual, and send one copy to Risk Management and Safety, and one copy to the Food and Drug Administration at the address listed at the bottom of that form.

Section VI

Medical Surveillance

A. All users of Class 3b and Class 4 lasers are to undergo a baseline eye exam. This exam may be done by any ophthalmologist, and must include a visual acuity test, a macular function test, and a color vision test. A review of current and past medications that may cause photosensitization should be done.

Section VII

Exposure Incidents

Seek medical attention in the event of an exposure or suspected exposure to laser radiation capable of causing an eye or skin injury. Personnel should go immediately to University Health Services, or, if that facility is closed, the St. Joseph Medical Center Emergency Room.

Notify the Principal Investigator and the Risk Management and Safety Department when an exposure incident occurs. Personnel involved in the incident are to complete an "Injury/illness Investigation Report" form and forward it to Risk Management and Safety. A copy of the form as found in Appendix D. Injured employees will be required to complete the "Indiana Worker's Compensation - First Report of Injury" form and return the form to Risk Management and Safety. A copy of this form is also found in Appendix D.

Section VIII

Laser Hazard Evaluation

Different high-power lasers have different individual hazards, including optical hazards, UV radiation, high voltages, ozone generation, toxic chemicals and gases, etc.

A laser hazard evaluation shall be performed to identify all hazards associated with a laser or laser system and to determine the necessary control measures. The Risk Management and Safety Department can provide assistance in performing the hazard evaluation.

The hazard evaluation will take into account the following aspects:

- The laser or laser system's capability of injuring personnel.
- The environment in which the laser is used.
- The personnel who may use or be exposed to laser radiation

Section IX

Operation, Maintenance and Service

It is important to distinguish between operation, maintenance and service when considering control measures. Lasers and laser systems are classified based on the level of accessible laser radiation during normal operation. Maintenance tasks are performed to support routine performance of the laser or laser system, such as cleaning and replenishing expendables. Maintenance tasks may or may not involve access to the beam. Service occurs less frequently than maintenance and often requires access to the beam. Service tasks include replacing laser resonator mirrors and replacing or repairing faulty components.

Section X

Control Measures for all Laser Classes

The purpose of control measures is to prevent exposure to laser radiation above the MPE. Use engineering controls whenever possible. When engineering controls are not able to reduce exposure below the MPE, administrative controls and personal protective equipment should be used.

A. Protective Housing

- Place lasers in protective housings whenever practical. When protective housings are not practical, Risk Management & Safety shall perform a hazard analysis to ensure that control measures are implemented to ensure safe operation.
- Protective housings or service panels enclosing embedded Class 3b and 4 lasers shall be interlocked or fastened closed requiring special tools for removal.
- When it is necessary to remove protective housings or service panels, a temporary laser controlled area shall be established. A temporary laser controlled area will not have the built-in protective features that are part of a laser-controlled area, but shall provide all safety requirements to protect personnel within and outside the area. Requirements for the temporary laser controlled area include, but are not limited to:

    1. Restricted access to the area.
    2. Control of the beam to prevent the beam and reflections from extending beyond the area.
    3. Removal of reflective materials in and near the beam path.
    4. Appropriate laser eye protection if there is a possibility of exposure to laser radiation above the MPE.
    5. A warning sign posted outside the area. (See Section XIX for the warning sign requirements.)

B. Collecting Optics

Collecting optics used to view the laser beam or its interaction with a material shall have permanently attached attenuators, filters or shutters to prevent hazardous level of radiation from entering the eye.

C. Beam Control

- Ensure the beam height is not at the normal eye position of a person in a standing or seated position.
- Position the laser so that the beam is not directed toward doorways or aisles.
- Securely mount the laser system to maintain the beam in a fixed position during operation and limit beam movements during adjustments.
- Ensure beam path is well defined and controlled.
- Terminate the beam at the end of its useful path.
- Confine beams and reflections to the optical table. The addition of beam-stopping panels to the sides of the optical table is recommended.
- If the beam path extends beyond the optical table, a physical barrier shall be used to prevent accidental exposure.
- Have only diffusely reflection materials in or near the beam path, where feasible.
- Absorb unwanted reflections. Scatter is not permitted.

Section XI

Additional Control Measures for Class 3b and Class 4 Lasers and Laser Systems

All of the control measures outline in Section X must be met. The following are additional requirements for Class 3b and Class 4 lasers and laser systems.

A. Nominal Hazard Zone (NHZ)

A NHZ shall be established for Class 3b and Class 4 laser applications which require an open beam. The NHZ is the area in which the level of direct, reflected or scattered laser radiation exceeds the MPE. The Risk Management and Safety Department can assist in defining the NHZ.

B. Laser-Controlled Area

A laser-controlled area shall be established for Class 3b and Class 4 lasers. The laser-controlled area will contain the NHZ, if needed. The walls, ceiling and floor of the room often define the laser-controlled area.

- Class 3b Laser Controlled Area
  1. Only personnel trained in the operation of the laser and laser safety shall be permitted to operate the laser or laser system.
  2. An individual knowledgeable in laser safety shall directly supervise the laser-controlled area.

3. The area shall be posted with the appropriate warning signs. (See Section XIX)
4. Restrict access to the laser controlled area.
5. Control the beam to prevent any misdirected beams or reflections. (See Section X.C. Beam Control)
6. Provided eye protection for all personnel working in the laser-controlled area.(See Section XVIII)
7. Cover all windows and other openings to prevent laser radiation from extending beyond the laser-controlled area.

- Class 4 Laser-Controlled Area

All of the requirements for a Class 3b laser-controlled area must be met. In addition, one of the following entryway controls must be incorporated into a Class 4 laser.

1. Non-Defeatable Entryway Safety Controls: Non-defeatable safety latches or interlocks that deactivate the laser or reduce the output to levels below the MPE in the event of unexpected entry are the preferred method of entryway control.

2. Defeatable Entryway Safety Controls: if non-defeatable controls limit the intended use of the laser, defeatable entryways safety controls may be used. Defeatable entryway controls allow authorized personnel to override the controls. Defeatable entryway controls may be used only if there is no laser radiation hazard at the point of entry. Personnel must be properly trained and provided with adequate personal protective equipment.

3. Procedural Entryway Controls: if safety latches or interlocks are not feasible, procedural entryway controls may be used. When procedural entryway controls are used, the following conditions must be met:
    1. All authorized personnel shall be adequately trained.
    2. Personal protective equipment shall be provided.
    3. A door, barrier, screen or curtains shall be used to block or attenuate the laser radiation below the MPE at the entryway.
    4. The entryway shall be equipped with a lighted laser warning sign that indicates the laser is operating.

C. Permanently Attached Beam Stop or Attenuator

Same lasers or laser systems have long warm-up times, and it may not be practical to turn the power off to the laser when the laser is not in use. In these cases, Class 3b lasers should be equipped with a permanently attached beam stop or attenuator and Class 4 lasers shall be equipped with a permanently attached beam stop or attenuator. The beam stop or attenuator must limit accessible laser radiation to below the MPE and be employed when the laser is not in use. For lasers that do not require warm-up time, turn the power off to the laser when not in use.

D. Standard Operating Procedures

Written Standard Operating Procedures (SOP's) are required for operating, alignment, maintenance and service activities. The SOP's shall be written by the Principal Investigator and available to the Risk Management and Safety Department. SOP's shall be reviewed with all laser personnel and be posted in the area of the laser or laser system.

The manufacturer's operating manual is not a substitute for a SOP.

SOP's must include: (See Appendix C for a sample SOP)

- Laser data
- Contact information
- Laser application
- Control measures
- Personal protective equipment
- Start up and shut down procedures
- Experimental procedures
- Emergency procedures
- Storage
- Non-beam hazards

E. Output Emission Limitations

Operate the laser or laser system at the lowest level of power or radiant energy required for the application.

Section XII

Additional Control Measure for Class 3b and Class 4 Single Pulse of Intermittent Operations

An alarm, a warning light or a verbal " countdown" command shall be used during activation or startup of single pulse or intermittent operations.

Section XIII

Additional Control Measures for Class 3b and Class 4 Ultraviolet and Infrared Lasers

All of the control measures in Section X-XII must be met. The following are additional control measures for Class 3b and Class 4 ultraviolet and infrared lasers:

- Visible or audible warning devices shall be installed in areas where accessible laser radiation may exceed the MPE. These warning devices shall be clearly identified and visible from all areas of potential exposure.
- Wear gloves, long sleeves and a face shield when manipulating UV beams.
- Install shielding that will attenuate UV radiation levels to below the MPE.
- Infrared beam enclosures or backstops shall be constructed of infrared absorbent materials. Enclosures, backstops or other materials that may contact a Class 4 infrared laser shall also be fire resistant.

Section XIV

Alignment

More laser accidents occur during beam alignment than any other laser manipulation. Use the following techniques to prevent accidents.

- Exclude unnecessary personnel from the laser controlled area during alignment.
- Perform alignment at the lowest possible power level.
- Use low-power visible lasers for path simulation of high-power visible or invisible lasers, when possible.
- Use a temporary beam attenuator over the beam aperture to reduce the level of laser radiation below the MPE, when possible.
- Wear laser safety eyewear during alignment. Alignment eyewear may be used when aligning a low power visible laser. (See Section XVIII)
- Use beam display devices (image converter viewers or phosphor cards) to locate beams when aligning invisible lasers.
- Use shutters or beam blocks to block high-power beams at their source except when needed during the alignment procedure.
- Use beam blocks to block high-power beams downstream of the optics being aligned.
- Use beam blocks or protective barriers when alignment beams could stray into areas with uninvolved personnel.
- Place beam blocks behind optics such as turning mirrors to terminate beams that may miss the mirrors during alignment.

- Locate and block all stray reflections before proceeding to the next optical component or section.
- Ensure that all beams and reflections are terminated before resuming high-power operation.

Section XV

Enclosing Beam Path to Convert Laser or Laser System to Class 1

A laser or laser system in which the entire beam path is enclosed and the enclosure fulfills all requirements of a protective housing is considered to be Class 1 and no further controls are needed. However, if the protective housing is removed, a temporary laser controlled area must be established and control measures applicable to the class of the embedded laser must be implemented. (See Section X.A. Protective Housing)

Modifications to commercial laser systems must be evaluated by the Risk Management and Safety Department.

A. Requirements for Protective Housings:

- Protective housings shall limit the accessible laser radiation below the MPE
- Protective housings shall prevent access to the laser during normal operations
- Protective housings shall be equipped with safety interlocks whenever the protective housing can be opened, removed or displaced.
- The safety interlocks shall be designed to prevent access to laser radiation above the MPE. (For example, the interlock may be electrically or mechanically interfaced to a shutter that interrupts the beam when the protective housing is opened or removed.)
- The safety interlock shall be fail-safe. The use of redundant electrical series connected interlocks would fulfill this requirement.
- Adjustments or procedures during service shall not cause the interlocks to be inoperative when the laser is placed back in operation.
- The protective housing shall be labeled in accordance with ANSI XI136. 1-2000. (See Section XIX.C.)
- The embedded laser shall be labeled in accordance with ANSI Z136.1-2000. (See Section XIX.C.)

Section XVI

Confocal Microscopes

Laser scanning confocal microscopes are Class 1 laser systems that contain embedded Class 3 or Class 4 lasers. When the confocal mircroscope is used as intended, no control measures are necessary.

If the protective housing is removed for alignment, maintenance or service activities, a temporary laser-controlled area shall be established and control measures appropriate to the class of the embedded laser shall be implemented.

Section XVII

Controls for Non-Beam Hazards

A. Electrical Hazards

The use of lasers or laser systems presents an electric shock hazard. Most lasers contain high-voltage power supplies and capacitors or capacitor banks that store lethal amounts of electrical energy. Exposures may occur from contact with energized components operating at potentials of 50 volts and above. These exposures most often occur during set up or installation, maintenance, modification and service when protective covers are removed.

To reduce electrical hazards:

- Lasers and associated electrical equipment must be designed, constructed, installed and maintained in accordance with the latest revision of the National Electric Code (NEC.)
- When protective housings or covers will be removed, potentially exposing energized components, the following measures must be followed:
  1. Adhere to the University's Lock Out Tag Out Policy (Available on the Risk Management and Safety web page.)
  2. Enclose high voltage sources and terminals whenever possible.
  3. Turn off power and ground all high voltage points before working on power supplies.
  4. Check that each capacitor is discharged and grounded prior to working near the capacitor. (Capacitors must be equipped with bleeder resistors, discharge devices or automatic shorting devices.)
  5. Do not wear rings, watches or other jewelry when working with or near electrical equipment.

B. Laser-Generated Air Contaminants(LGAC)

Air contaminants may be generated when Class 4 and some Class 3b laser beams interact with matter. The quantity, composition and chemical complexity of the LGAC depend on the target material, cover gas and beam irradiance. Materials such as plastics, composites, metals and tissues may release carcinogenic, toxic and noxious air contaminants. Ozone is produced around flash lamps and can build up with high repetition rate lasers. Special optical materials used for far infrared windows and lenses may also release hazardous air contaminants.

Concentrations of LGAC must be maintained below the exposure limits specified by OSHA, NIOSH or ACGIH. There are three major control measures to reduce the concentration of LGAC to acceptable levels:

- use local exhaust ventilation to remove the LGAC at the point of generation. Local exhaust ventilation should be vented to the outside.
- Isolate the process whenever possible.
- Respiratory protection shall be used only when engineering controls are not feasible. The Risk Management and Safety Department must be contacted prior to wearing a respirator. Refer to the University's Respiratory Protection Program for more information.

C. Collateral and Plasma Radiation

Collateral radiation (radiation not associated with primary laser beam) may be produced by system components such as power supplies, discharge lamps and plasmas tubes. Radiation may be in the form of X-rays, UV, visible, IR, microwave and radiofrequency (RF.)

When high power pulsed laser beams (peak irradiance of 10^{12} W/cm^2 or greater) are focused on a target, plasma is generated that may also emit collateral radiation. Contact the Risk Management and Safety Department for evaluation of these hazards. A Health Physicist will evaluate hazards associated with ionizing radiation.

D. Fire Hazards

Class 4 laser beams can ignite flammable solvents, gasses and combustible materials.

To reduce fire hazards:

- Terminate laser beams with non-combustible materials
- Bring only necessary materials into the laser area.
- Store flammable and combustible solvents and materials properly and away from the laser beam.

E. Explosion Hazards

High-pressure arc lamps, filament lamps and capacitor banks may explode if they fail during operation. The laser target and elements of the optical train may shatter during operation.

To reduce explosion hazards:

- Enclose high-pressure arc lamps and filament lamps in housing that can withstand an explosion if the lamp disintegrates.
- Enclose the laser target and optical train in protective housing during laser operation.
- Ensure that capacitors are equipped with current-limiting devices and are shielded.

F. Compressed Gasses

Hazardous gases are used in some laser applications including chlorine, fluorine, hydrogen chloride and hydrogen fluoride. Refer to Section 18.5 of the Chemical Hygiene Plan (Available on the Risk Management and Safety web page) for more information on compressed gas safety.

G. Laser Dyes and Solvents

Laser dyes are complex fluorescent organic compounds that are dissolved in a solvent to form a lasing medium. Some dyes are highly toxic or carcinogenic. Most solvents suitable for dye solutions are flammable and toxic by inhalation and/or skin absorption.

The following measures shall be followed when working with dyes:

- Whenever possible, do not use dimethysulfoxide (DMSO) as a solvent for cyanine dyes because it aids in the transport of dyes through the skin and into the blood stream. If DMSO must be used, wear gloves. Disposable nitrile gloves may be worn if prolonged contact with DMSO is not anticipated. Other glove choices include neoprene, natural rubber and butyl gloves. PVA and PVC gloves are not recommended for use with DMSO. See the Chemical Hygiene Plan Section 18.0 for more information.

- Obtain material safety data sheets (MSDSs) for all dyes and solvents prior to working with them. MSDS resources are available at the Risk Management and Safety Office.
- Prepare and handle dye solutions in a fume hood.
- Use disposable bench covers

- Wear a lab coat, safety glasses and gloves. Contact Risk Management and Safety for assistance with glove selection.
- Pressure test all dye laser components before using dye solutions. Pay particular attention to tubing connections.
- Install spill pans under pumps and reservoirs.
- See the Chemical Hygiene Plan for more information regarding safe chemical work practices.

H. Noise

Noise levels from some lasers, such as pulsed excimer lasers, may be high enough to require hearing protection. All University employees whose potential exposure to sound levels averaging greater than 85 dBA (see Appendix A of Notre Dame's Hearing Conservation Program Written Policy) for 8 hours per day, 40 hours per week or to periodic sounds that exceed 115 dBA, are required to participate in the University's Hearing Conservation Program.

Section XVIII

Laser Safety Eyewear

Enclosure of the laser equipment or the beam path is the preferred method of control. However, when enclosures are not feasible and there is a potential exposure to the beam or reflected beams at levels above the MPE, it may be necessary to wear protective eyewear.

A. Availability and Use of Laser Safety Eyewear

- Laser safety eyewear shall be available and worn by laser operators, incident personnel and visitors in laboratories where a Class 3b or Class 4 laser is present and there is a potential exposure to the beam or reflected beams at levels above MPE.
- Laser safety eyewear is not required for Class 2 or Class 3a lasers unless intentional long-term (>.25 seconds) direct viewing is required.
- The Principal Investigator is responsible for ensuring that the appropriate eyewear is available and worn.

B. Selecting Laser Safety Eyewear

- Laser safety eyewear is wavelength specific.
- The following information is needed to select the appropriate laser safety eyewear.
    1. Wavelength(s)
    2. Mode of operation (continuous wave or pulsed)
    3. Maximum exposure duration (assume worst case scenario)
    4. Maximum irradiance (W/cm2) or radiant exposure (J/cm2)
    5. Maximum permissible exposure (MPE)
    6. Optical density (OD)
- Contact the Risk Management and Safety Department for assistance in calculation the MPE and OD and selecting appropriate eyewear.
- Laser safety eyewear shall be chosen based on the level of protection needed to protect the eyes from a worst case scenario. If several laser safety eyewear products offer sufficient protection, the following factors should also be considered:
    1. Visible light transmission
    2. Effect on color vision
    3. Field of view provided by the design of the eyewear
    4. Reversible bleaching of absorbing media
    5. Need for prescription lenses
    6. Fit and comfort
    7. Impact resistance
- Types of Laser Safety Eyewear
    1. Glass: Glass laser eyewear is heavier and more costly than plastic, but it provides better visible light transmittance. There are two types of glass lenses, those with absorptive glass filters and those with reflective coatings. Reflective coatings can create specular reflections and the coating can scratch, minimizing the protection level of the eyewear.
    2. Polycarbonate: Polycarbonate laser eyewear is lighter, less expensive and offers higher impact resistance than glass, but allows less visible light transmittance.
    3. Diffuse Viewing Only (DVO): As the name implies, DVO eyewear is to be used when there is a potential for exposure to diffuse reflections only. DVO eyewear may not provide protection from the direct beam or specular relections.

4. Alignment Eyewear: Alignment eyewear may be used when aligning low power visible beams. Alignment eyewear transmits enough of the specified wavelength to be seen for alignment purposes, but not enough to cause damage to the eyes. Alignment eyewear cannot be used during operation of highpower or invisible beams and cannot be used with pulsed lasers.

C. Laser Safety Eyewear for Multiple Wavelengths

One pair of laser safety eyewear may not be sufficient when working with tunable or multiple wavelength lasers. Always check the OD and wavelength prior to use. Eyewear with multiband filters and flip-up eyewear are available for some applications.

D. Laser Safety Eyewear for Ultra-Fast (Femtosecond) Lasers

Temporary bleaching may occur from high peak irradiances from ultra-fast laser pulses. Contact the manufacturer of the laser safety eyewear for test data to determine if the eyewear will provide adequate protection before using them.

E. Labeling of Laser Safety Eyewear

Laser safety eyewear shall be labeled with the optical density and the wavelength(s) the eyewear provides protection for. Additional labeling may be added for quick identification of eyewear in multiple laser laboratories.

F. Inspection and Cleaning of Laser Safety Eyewear

Laser safety eyewear should be inspected periodically for the following:

1. Pitting, crazing, cracking and discoloration of the attenuation material.
2. Mechanical integrity of the frame.
3. Light leaks.
4. Coating damage.

Follow manufacturers' instructions when cleaning laser safety eyewear. Use care when cleaning eyewear to avoid damage to absorbing filters or reflecting surface.

Section XIX

Warning Signs and Labels

A. Lighted Warning Signs

Entrances to all laboratories where a Class 4 laser is present shall have a lighted warning sign that is activated when the laser is energized.

B. Written Warning Signs

The following warning signs are required to be posted at the entrances to laboratories where lasers are present:

- All laboratories where a Class 3b or Class 4 laser is present shall have a Danger sign on the door(s) to the laboratory that conforms to ANSI Z136.1-2000.
- Laboratories with a Class 3a laser that generates a beam with an irradiance or radiant exposure equal to or greater than the MPE shall also have a "Danger" sign affixed to the door(s). The Danger sign shall indicate the precautionary instructions or protective actions required, the type of laser or wavelength, the pulse duration (if applicable), the maximum output and the class of the laser or laser system. The sign shall use the symbols, color and layout shown in the example below.

- All laboratories where a Class 2 or Class 3a laser is present shall have a Caution sign on the door(s) to the laboratory that conforms to ANSI Z136.1-2000. (Class 3a lasers that generate a beam with an irradiance or radiant exposure equal to or greater than the MPE shall have a "Danger" sign.) The Caution sign shall indicate the precautionary instructions, the type of laser or wavelength and the class of the laser system.

- The outside boundary of a temporary laser controlled area shall be posted with a Notice sign that conforms to ANSI Z136.1-2000. The Notice sign shall indicate the reason for the temporary controls, the precautionary instructions or protective actions required, the type of laser or the wavelength, the pulse duration (if applicable), the maximum output and the class of the laser. The sign shall use the symbols, color and layout shown in the example below.

C. Labels

Lasers shall be properly labeled as follows:

- All Class 2, Class 3a, Class 3b and Class 4 lasers and laser systems shall have a label conspicuously affixed to the housing that conforms with ANSI Z136.1-2000. The label shall indicate the precautionary instructions or protective actions required, the type of laser or the wavelength, the pulse duration (if applicable), maximum output and the class of the laser or laser system. The label shall incorporate the sunburst symbol. Manufacturers are required to label lasers in accordance with the Federal Laser Product Performance Standard (21CFR1040.10.) These labels satisfy this requirement. Contact the Risk Management and Safety Department for label specifications if the laser was not labeled by the manufacturer, or if it was modified or built in the laboratory.
- All removable protective housings shall have a label affixed in a conspicuous location that conforms to ANSI Z136.1-2000. The label shall indicate the hazard of the enclosed laser. This label does not need to contain the sunburst symbol. Contact the Risk Management and Safety department for label specifications.

Appendix A

Additional Resources

Information Resources
American National Standards Institute (ANSI) www.ansi.org
Laser Institute of America www.laserinstitute.org
Rockwell Laser Institute www.rli.com

Laser Safety Eyewear Resources
Glendale Protective Technologies www.glendale-laser.com
Lase-R Shield www.lase-rshield.com
UVEX www.uvex.com
University of Notre Dame:
- Chemical Hygiene Plan
- Personal Protective Equipment Plan
- Lock Out Tag Out Policy
- (all of the above policies are available at www.riskmgt.nd.edu/manuals/index.shtml)

Appendix B

Glossary

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

American National Standard for Safe Use of Lasers (ANSI Z136.1-2000.) Document that provides guidance for the safe use of lasers and laser systems by defining control measures for each of four laser classifications. The University of Notre Dame has adopted this standard as a minimum standard for laser safety.

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

Authorized personnel. Individuals approved by the Principal Investigator to install, operate or service laser equipment.

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

Aversion response. Closure of the eyelid or movement of the head to avoid an exposure to a noxious stimulant or bright light. Aversion response to an exposure from a bright laser source is assumed to occur within .25 s, including the blink reflex time.

Collateral radiation. Any electronic radiation, except laser radiation, emitted by a laser or laser system that is physically necessary for its operation.

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

Continuous wave (CW). The output of a laser that is operated in a continuous rather than a pulsed mode. For purposes of safety evaluation, a laser operating with a continuous output for a period > 0.25 s is regarded as a CW laser.

Controlled area. An area where the occupancy and activity of those within is subject to control and supervision for the purpose of protection from laser radiation and related hazards.

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

Embedded laser. An enclosed laser with an assigned class number higher than the inherent capability of the laser system in which it is incorporated, where the system's lower classification is the result of engineering features which limits the accessible emission.

Failsafe interlock. An interlock where the failure of a single mechanical or electrical component of the interlock will cause the system to go into, or remain in, a safe mode.

Incident personnel. Individuals working in areas where there is a potential for exposure to laser radiation from a Class 3b or Class 4 laser, but do not operate the laser.

Infrared radiation. Electromagnetic radiation with wavelengths that lie within the range 0.7 μm to 1 mm.

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

Laser operator. See Authorized Personnel.

Laser controlled area. See Controlled Area.

Laser Safety Officer (LSO). One who has the authority to monitor and enforce the control of laser hazards and effect the knowledgeable evaluation and control of laser hazards.

Laser system. An assembly of electrical, mechanical, and optical components that includes one or more lasers.

Maintenance. Performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser or laser system, which are to be performed by the user to ensure the intended performance of the product.

Maximum permissible exposure (MPE). The level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. MPE is expressed in terms of either radiant exposure (joules/cm2) or irradiance (watts/cm2). The criteria for MPE are detailed in Section 8 of ANSI Z136.1.

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

Operation. The performance of the laser or laser system over the full range of its intended functions (normal operation.)

Optical density. Logarithm to the base ten of the reciprocal of the transmittance. The higher the optical density, the lower the transmittance.

Pulsed laser. A laser that delivers its energy in the form of a single pulse or a train of pulses. The duration of a pulse is regarded to be < 0.25 s.

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

Repetitive pulse laser. A laser with multiple pulses of radiant energy occurring in sequence.

Reversible bleaching. The absorbing filter of laser eyewear may become temporarily saturated from an ultrashort laser pulse, causing the beam to pass through.

Service. The performance of those procedures or adjustments described in the manufacturer's service instructions that may affect any aspect of the performance of the laser or laser system. These are usually performed by qualified technical personnel provided by the manufacturer or other service companies.

Shall. The word “shall” is to be understood as mandatory.

Should. The word “should” is to be understood as advisory.

Specular reflection. A mirror-like reflection.

Ultraviolet radiation. Electromagnetic radiation with wavelengths smaller than those of visible radiation; for the purpose of this manual, 0.18 to 0.4 μm.

Visible radiation (light). Electromagnetic radiation that can be detected by the human eye. This term is commonly used to describe wavelengths that lie in the range 0.4 to 0.7 μm.

Wavelength (?). The distance between two successive points on a periodic wave which have the same phase.

APPENDIX C: Sample Standard Operating Procedure (SOP)

Principal Investigator:	Date:
Department:	Location:

1. LASER SAFETY CONTACTS

Principal Investigator: Phone:

Laser Safety Officer: Phone:

Service Contractor: Phone:

Emergencies: Phone:

2. LASER DESCRIPTION

Type: Wavelength: Classification:

Manufacturer: Model: Serial#:

Continuous Wave Laser

Maximum Power:

Pulsed Laser:

Maximum Energy: Pulse Duration:

Pulse Repetition Frequency:

Description of Application:

3. OPERATING PROCEDURES:

a. Laboratory preparation and start-up procedures.

b. Target area preparation.

c. Normal operating procedures.

d. Shut down procedures.

e. Special operating procedures, including alignment, interlock bypass, maintenance and service.

f. Emergency procedures.

4. CONTROL MEASURES

Y/N/NA	CONTROL	COMMENTS
	Entryway interlocks or controls are present.	
	Protective housing interlocks are present.	
	Enclosure interlocks are present.	
	Emergency stop/panic button is present.	
	Master switch is present.	
	Laser and associated equipment is secured to base.	
	Beam stops or attenuators are present.	
	Protective barriers are present.	
	Warning signs are posted.	
	Personal protective equipment is secured to base.	
	Nominal Hazard Zone is defined.	
	Manufacturer's operating manual is available.	

ADDITIONAL COMMENTS:

5. HAZARDS AND CONTROLS

Y/N/NA	HAZARD	CONTROL MEASURES
	Unenclosed beam.	
	Potential exposure to direct beam or reflections.	
	Laser positioned at eye level.	
	Reflective materials in beam path.	
	Exposure to ultraviolet or blue light.	
	Hazardous materials are used. (Dyes, solvents, etc.)	
	Hazardous waste is generated.	
	Laser generated air contaminants are generated.	
	Exposure to high voltage.	
	Compressed gases are used.	
	Fire hazards are present.	
	Plasma radiation is generated.	

ADDITIONAL COMMENTS:

6. PERSONAL PROTECTIVE EQUIPMENT (PPE)

Laser Eyewear

FOR THIS LASER			WEAR THIS EYEWEAR	
Laser	Wavelength(s) (nm)	Wavelength(s) Attenuated(nm)	Optical Density	Manufacturer

Other PPE Required