



#### ABSTRACT

The Laser safety Manual provides guidance to faculty, staff, students and visitors for the safe use of lasers and laser systems.

RISK MANAGEMENT SERVICES

Emergency Telephone Numbers	
Department	Phone Number
Radiation Safety Officer (RSO)	940-565-4196
X-ray and Laser Safety Officer	940-565-4196
Risk Management	940-565-2109
University Police	940-565-3000
University Health Center	940-565-2333
UNT Fire and Emergency	9-911
Denton Fire Department	9-911

In case of incidents involving unusual radiation exposure or laboratory accidents involving lasers and laser system, all personnel are required to notify the Radiation Safety Officer immediately.

**ANY QUESTIONS OR CONCERNS PERTAINING TO THE CONDUCT OF THE LASER SAFETY PROGRAM AT THE UNIVERSITY OF NORTH TEXAS SHOULD BE DIRECTED TO RISK MANAGEMENT SERVICES AT 940-565-2109.**

After hours or weekends, the University Police (940-565-3000) will assist in contacting the Radiation Safety Officer.

#### RECORD OF CHANGES

Change #	Date of Change	Change Entered by	Description
25-01	02/2025	Todd Germain	Adding Record of Changes, changing font, contact list/information updated

## Table of Contents

1	Introduction.....	5
1.1	Purpose.....	5
1.2	Objectives.....	5
2	Administration and Responsibilities.....	6
2.1	Administration.....	6
2.2	The Radiation Safety Committee.....	6
2.3	Laser Safety Officer (LSO).....	6
2.4	Principal Investigator (PI).....	7
2.5	Responsibilities Of Individual Users.....	7
3	Laser acquisition, Transfer And Disposal.....	8
3.1	Laser Acquisition.....	8
3.2	Laser Transfer.....	8
3.2.1	On-campus transfers.....	8
3.2.2	Off-campus transfer.....	8
3.3	Laser Disposal.....	8
4	Laser Classification.....	9
4.1	Laser Classification.....	9
4.2	Laser Pointers.....	11
4.3	Embedded Systems.....	11
5	Laser Safety.....	11
5.1	Introduction.....	11
5.2	Beam Hazard.....	12
5.2.1	Eye Injuries.....	13
5.2.2	Skin Injuries.....	14
5.3	Non-Beam Hazards.....	14
5.3.1	Electrical Hazard.....	14
5.3.2	Explosion Hazard.....	15
5.3.3	Compressed Gases.....	15
5.3.4	Laser Dyes and Solvents.....	15
5.3.5	Fire Hazards.....	15
5.3.6	Laser generated air contaminants (LGAC).....	15
5.3.7	Collateral radiation.....	15
		2

5.3.8	Noise .....	16
6	CONTROL MEASURES .....	17
6.1	General Laser Safety Requirements .....	18
6.2	Engineering Controls.....	19
6.2.1	Beam Enclosures.....	19
6.2.2	Protective Housings .....	19
6.2.3	Safety Interlocks .....	19
6.2.4	Controlled Access .....	19
6.2.5	Activation Warning Systems .....	20
6.2.6	Emission Delay .....	20
6.2.7	Viewing Optics .....	20
6.2.8	Window and Door Barriers.....	20
6.2.9	Controlled Area.....	20
6.2.10	Beam Stops .....	20
6.2.11	Remote Operations.....	20
6.3	Administrative and Procedural Controls .....	20
6.3.1	Standard operating procedures (SOPs).....	20
6.3.2	Output Emission Limitations .....	21
6.3.3	Education and Training.....	21
6.3.4	Authorized Personnel.....	21
6.3.5	Personal Protective Equipment.....	21
6.3.6	Service Personnel.....	21
6.3.7	Visitors and Spectators .....	21
7	Laser Control Areas .....	22
7.1	Class IIIb controlled area .....	22
7.2	Class IV controlled area .....	22
7.3	Temporary controlled areas.....	23
8	Personal Protective Equipment (PPE) .....	24
8.1	Protective Eyewear.....	24
8.1.1	Selecting Protective Eyewear .....	24
8.1.2	Types of Protective Eyewear .....	25
8.1.3	Protective Eyewear for Multiple Wavelengths .....	25
8.1.4	Protective Eyewear for Ultra-Fast (Femtosecond) Lasers .....	25

8.1.5	Inspection and Cleaning of Protective Eyewear .....	25
8.2	Skin Protection .....	27
9	Warning Signs and Equipment Labels.....	28
9.1	Warning Signs .....	28
9.2	Lighted Warning Signs.....	29
9.3	Equipment Label .....	29
9.4	Protective Equipment Labeling.....	29
10	Medical Surveillance .....	30
11	Training.....	30

# 1 INTRODUCTION

## 1.1 PURPOSE

This manual defines the University of North Texas Laser Safety Program. This program has been developed to provide guidance to faculty, staff, students and visitors for the safe use of lasers and laser systems.

The purpose of the Laser Safety Program is to ensure that no laser radiation in excess of the maximum permissible exposure (MPE) limit reaches the human eye or skin. In addition, the program is designed to ensure adequate protection against non-beam (collateral) hazards that can be associated with lasers.

The UNT Laser Safety Program follows the safety guidelines established by the Texas Department of State Health Services and American National Standards Institute (ANSI) Z136 series, Standards for the Safe Use of Lasers.

This manual is intended to serve as a quick reference guide through which all University personnel may familiarize themselves with the policies and safety precautions necessary for the safe use of lasers. It is by no means a complete or all-encompassing source of laser safety.

## 1.2 OBJECTIVES

The primary objective of the UNT laser safety program is to ensure that no laser radiation in excess of the maximum permissible exposure (MPE) limit reaches the human eye or skin. Additionally, the program is designed to ensure that adequate protection against collateral hazards is provided. These collateral hazards include the risk of electrical shock, fire hazard from a beam or from use of dyes and solvents, and chemical exposures from use of chemicals and vaporization of targets.

The University of North Texas requires that all Class IIIb and 4 lasers and laser systems (whether purchased, borrowed, fabricated, or brought in for use by others) be operated in accordance with the requirements established by the Texas Department of State Health Services, American National Standards Institute (ANSI) Z136 series, Standards for the Safe Use of Lasers and this Laser Safety Manual. Laser operators are required to follow the guidance of this manual.

---

## **2 ADMINISTRATION AND RESPONSIBILITIES**

### **2.1 ADMINISTRATION**

The laser safety program is a part of the University Radiation Safety program. As such, laser use is under the general direction and authority of the Radiation Safety and the Radiation Safety Committee. Risk Management Services has ultimate responsibility for oversight of the Radiation Safety Program. To ensure safety.

The RSC is a University standing committee consisting of faculty and administration that sets safety procedures, approves program changes, and performs audits and assessments of program implementation of the Radiation Safety Program. The members of the RSC are appointed by the Senior Vice President for Finance and Administration.

### **2.2 THE RADIATION SAFETY COMMITTEE**

The Radiation Safety Committee (RCS), appointed by the Senior Vice President for Finance and Administration directs the University's Radiation Safety Program. The term of the Chair of the Radiation Safety Committee and each member shall be three years, and members shall be eligible for re-appointment. Members of the RCS includes the Chair, the Associate Vice President of Research and Innovation or a representative, faculty members who are knowledgeable about the ionizing and non-ionizing radiation, the Radiation Safety Officer (RSO) and other safety professionals at the discretion of the RSO.

Authorities and Responsibilities of the Radiation Safety Committee

- i. Establish procedures and standard of practice for the Radiation Safety Program
- ii. Establish procedures designed to protect faculty, staff, students, visitors and the public from the harmful effect of radioactive material and ionizing radiation devices.
- iii. Review and approval of all proposals for use of Class IIIb and Class IV lasers and limiting conditions of their use as identified by the laser safety program.
- iv. Ensuring that only qualified individuals are permitted to use these specified devices, or that other users are supervised by qualified individuals.
- v. Review the laser safety program to determine that all activities are being conducted in accordance with radiation safety policy, this manual and regulatory requirements.
- vi. Review laser safety incidents, issues, and violations, and recommend corrective actions.

### **2.3 LASER SAFETY OFFICER (LSO)**

The duties, responsibilities, and authority of the Laser safety Officer consist of:

- i. Day-to-day coordination and management of the Laser Safety Program;
- ii. Executing the established policies of laser safety and ensuring compliance with Federal, State and Local regulations;
- iii. Supervising laser control activities as required by the Laser Safety Program and the RSC;

- iv. Investigating proposals for Class IIIb and Class IV laser device use, use conditions, and the transmittal of proposals to the RSC, with recommendations for approval or disapproval;
- v. Providing provisional approval to satisfactory proposals in accordance with guidelines of the RSC;
- vi. Halting operations involving laser devices if unsafe or unacceptable conditions exist (operations may resume only when authorized by the RSC);
- vii. Reviewing laboratory operations to determine compliance with safety programs and permits;
- viii. In certain cases of noncompliance, suspending authorizations to use permitted devices in accordance with guidelines established by the RSC, and authorizing provisional reinstatement following achievement of compliance pending review and final action by the RSC;
- ix. Maintaining records of program operations that are suitable for inspection by regulatory agencies and can be retrieved and distributed.

## 2.4 PRINCIPAL INVESTIGATOR (PI)

The Principal Investigator is an individual authorized to use and supervise the use of lasers and laser systems. They are directly responsible for the acquisition, use and maintenance of a particular laser/laser system. PI are responsible for:

- i. Reading and complying with University laser safety manual and procedures.
- ii. Being familiar with content of LIA Laser Safety Guide for Class IIIb/IV and ANSI Standard Class IV.
- iii. Training all users about specific safe use of laser.
- iv. Providing adequate supervision of all laser users.
- v. Notifying RMS of all laser users' names for Class IIIb and IV.
- vi. Complying with medical surveillance program.
- vii. Having written standard operating procedures for use of Class IIIb and Class IV lasers.
- viii. Submitting a copy of SOPs to RMS. Notifying RMS of any changes in their Laser Use Authorization procedures.
- ix. Notifying RMS of any changes to enclosed laser systems.
- x. Posting appropriate signage.
- xi. Report accidents/injuries to University Health Services and OEHS within 24 hours.

## 2.5 RESPONSIBILITIES OF INDIVIDUAL USERS

- i. To read and comply with University Laser Safety manual and procedures.
- ii. To be familiar with the content of LIA Laser Safety Guide Class IIIb/4 and ANSI standard Class IV.
- iii. To participate in medical surveillance program.
- iv. To comply with written SOP established by Principal Investigator.



- v. To NOT permit entry by ancillary services personnel into a room or area where a Class IIIb or 4 laser system is operating.
  - vi. To report all accidents or injuries to PI and RMS within 24 hours.
  - vii. To avoid working alone with high voltage or energy storage [capacitor banks] systems.
  - viii. To see PI for any specific laser training, questions, supervision and before modifying the system.
- 

## 3 LASER ACQUISITION, TRANSFER AND DISPOSAL

### 3.1 LASER ACQUISITION

PI must notify the LSO of all Class IIIb or Class IV lasers/laser systems by submitting an Authorization to Use Lasers form for each laser/laser system. A form must be re-submitted when significant modifications are made to the original laser/laser system. The LSO will conduct a hazard evaluation of the laser work area and make necessary recommendations.

### 3.2 LASER TRANSFER

#### 3.2.1 On-campus transfers

The LSO must be notified when a Class IIIb or IV laser is transferred from the jurisdiction of one PI to another PI on campus. A person who does not have appropriate training, does not understand the associated hazards of the laser or does not have proper protective equipment could result in injuries. The transferor and transferee shall both contact the LSO to initiate the transfer. The new PI must complete an Authorization to Use Lasers form.

#### 3.2.2 Off-campus transfer

Contact the LSO before transferring Class IIIb and IV lasers off-campus. Sales or donation of lasers off-campus requires that certain safety steps be taken. The transfer document shall warn persons that the device may emit hazardous laser light, which could cause injuries, and that the University neither offers nor implies any warranty as to the safety of its use.

### 3.3 LASER DISPOSAL

The LSO must be notified when a Class IIIb or IV laser is sold or disposed of and will coordinate with the hazardous Waste Program, as appropriate.

---

## 4 LASER CLASSIFICATION

The word LASER is an acronym for "**L**ight **A**mplification by the **S**timulated **E**mission of **R**adiation" which describes how laser light is generated at the atomic level. Laser radiation or light is coherent electromagnetic radiation characterized by one or more specific wavelength(s), the values of which are determined by the composition of the lasing medium. Laser radiation may be emitted in the ultraviolet (0.18 to 0.40  $\mu\text{m}$ ), visible (0.40 to 0.70 $\mu\text{m}$ ) or infrared (0.70 $\mu\text{m}$  to 1mm) regions of the electromagnetic spectrum.

The energy emitted by laser radiation can be transmitted, absorbed, or reflected, depending upon the characteristics of the material with which the laser light comes into contact. Materials that transmit laser beams are said to be transparent. Conversely, opaque materials either absorb or reflect the laser energy.

### 4.1 LASER CLASSIFICATION

Laser systems are classified into four. These classifications are based on the potential for the direct beam or reflected beam to cause biological damage to the eyes and/or skin and/or potential for causing fires from direct exposure to the beam or from reflections from diffuse reflective surfaces. The manufacturer provides the classification for most lasers.

- A. **Class I Lasers:** are considered to be incapable of producing damaging radiation levels, and are therefore exempt from most control measures or other forms of surveillance. Example: some laser printers.
- B. **Class II Lasers:** emit radiation in the visible portion of the spectrum, and protection is normally afforded by the normal human aversion response (blink reflex) to bright radiant sources. They may be hazardous if viewed directly for extended periods of time. Example: laser pointers.
- C. **Class 3a Lasers:** Class 3a lasers are those that normally would not produce injury if viewed only momentarily with the unaided eye. They may present a hazard if viewed using collecting optics, e.g., telescopes, microscopes, or binoculars. Example: HeNe lasers above 1 milliwatt but not exceeding 5 milliwatts radiant power; some laser pointers.
- D. **Class IIIb Lasers:** Class IIIb lasers may cause severe eye injuries through direct or specular exposure. Examples: continuous lasers not exceeding 500[mW] for any period greater than 0.25[s]; pulsed visible lasers not emitting more than 30[mJ] per pulse; pulsed IR or UV lasers not emitting more than 125[mJ] during any period less than 0.25[s]."
- E. **Class IV Lasers:** are a hazard to the eye from the direct beam and specular reflections and sometimes even from diffuse reflections. Class IV lasers can also start fires and can damage skin. Example: Lasers operating at power levels greater than 500 mW for continuous wave lasers or greater than 0.03 J for a pulsed system.

**Table 4.A. Laser Classification, Injury and Risk Level.**

Type	Injury or Risk	Risk Level
Class 1	Low energy levels, not hazardous to skin or eyes. Safe during normal operation	Low
Class 1M	Safe during normal operation but may cause eye injury if viewed with optical instrument	Low-Medium

Class 2	Visible wavelength only, natural blink response provides eye safety	Low-Medium
Class 2M	Visible wavelength only, blink response provides eye safety for unaided viewing	Medium

Class 3R	Transitional zone between safe and hazardous laser products. Direct viewing of beam may be hazardous as well as certain specular reflections.	Medium-High
Class 3B	Direct viewing and specular reflection can cause eye injury. Diffuse reflections are usually safe.	High

Class 4	Can cause severe skin and eye injury through any direct exposure, specular reflections and sometimes from diffuse reflection. Often a fire hazard as well.	Extreme
---------	--	---------

## 4.2 LASER POINTERS

Laser pointers were originally classified under the old standard as Class 3A. They are now typically classified as Class IIIR. The FDA requires a warning on the product label about the potential hazard to the eyes. These devices should not be used by minors unless under the supervision of trained users.

The recommended power level for these devices is 1.0 mW. If this guideline is followed, then no control measures are required. However laser pointers can have power outputs up to 5.0 mW. Laser pointers are excluded from the requirements of warning signs or postings in the area of use.

Laser pointer awareness should be covered in general laboratory safety training laser pointer users should be instructed not to point the laser into a person eye and to avoid pointing the device at others in order to circumvent any potential ocular exposure. Eye injuries are possible with these lasers despite common assumptions that these are innocuous low power devices.

## 4.3 EMBEDDED SYSTEMS

Class II, 3 or 4 lasers or laser systems contained in a protective housing and operated in a lower classification mode may be classified at a lower classification. Specific control measures may be required to maintain the lower classification. For embedded systems that are non-commercial design and construction, the University LSO shall determine the classification. For the purposes of laser safety, a direct laser beam which has been deflected from a mirror or polished surface is considered to be as intense as the direct beam. Laser beams which hit flat or non-mirror like surfaces are considered to be diffuse and the diffusely reflected beam is not as intense or as well defined as the direct beam.

---

# 5 LASER SAFETY

## 5.1 INTRODUCTION

The term laser is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. Laser is an unusual light source generated through a process of optical amplification based on the stimulated emission of electromagnetic radiation. This radiation is emitted over a wide range of the electromagnetic spectrum from the ultraviolet region through the visible to the infrared region.

The range of commonly available lasers is from 180 nanometers to 10.6 micrometers. Laser radiation may be emitted as a continuous wave or in pulses.

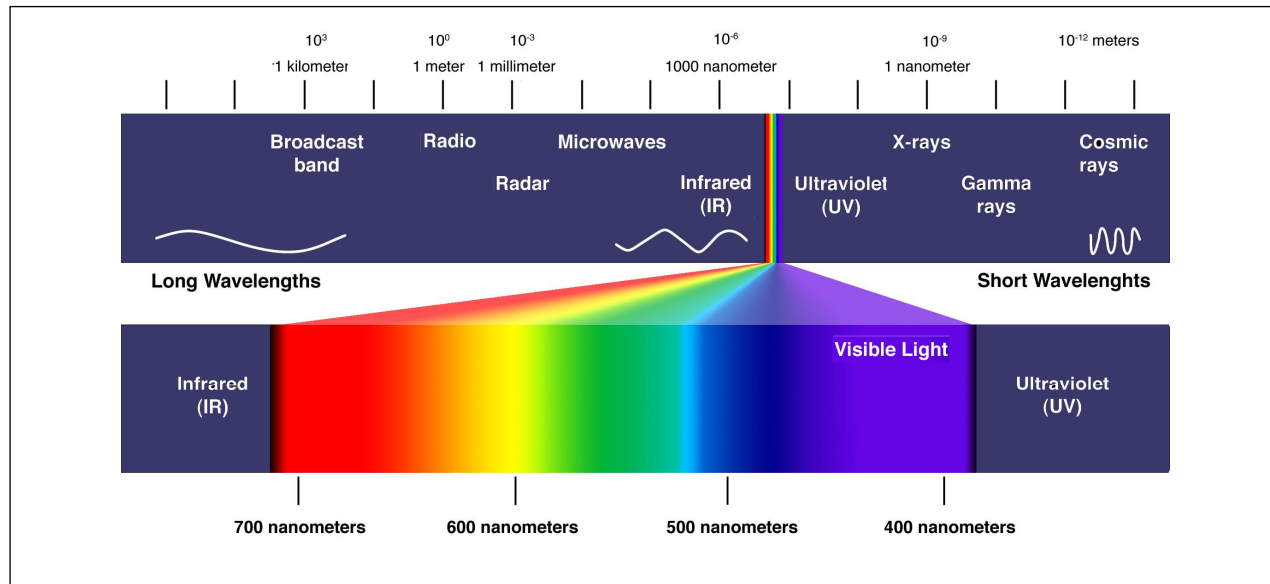


Figure 5.A. The shortest and longest wavelength of the electromagnetic spectrum radiation diagram defines the distance between two consecutive series of lines and express in SI units like meters, millimeters, micrometers, or nanometers.

Lasers produce radiation that may damage the eyes and the skin through heat absorption. In the ultraviolet region laser damage may be induced by thermal and photochemical effects. The potential hazards depend upon the type of laser, the wavelength, the power, and the uses of the laser system.

Laser users encounter many hazards in the use of a laser. Unless the user takes active precautions to minimize these hazards, there can be significant effects for a personal account of a laser accident.

## 5.2 BEAM HAZARD

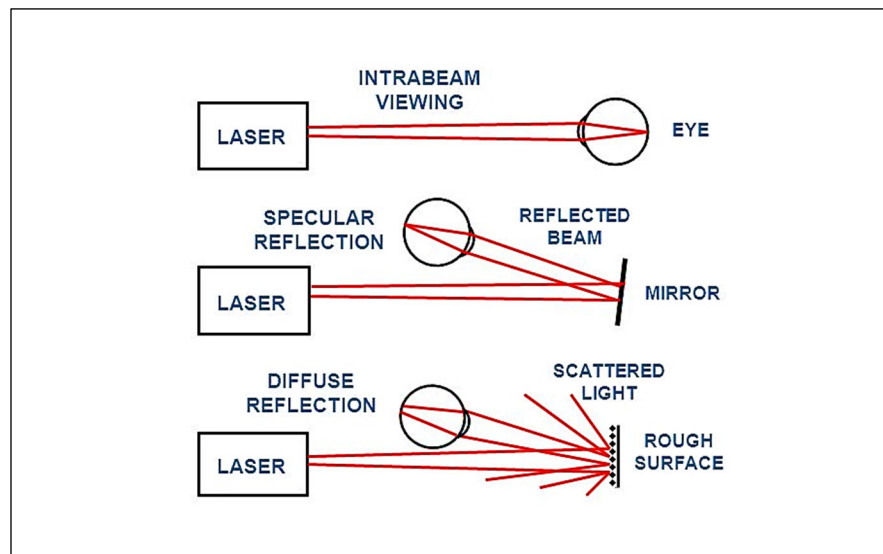
Direct beam related injuries result from three types of effects;

- i. Thermal effects are caused by heating of tissues as a result of the absorption of laser energy. Thermal burns can occur at all wavelengths.
- ii. Acoustical effects happen when the laser beam causes localized vaporization of tissue, causing a shockwave similar to ripples.
- iii. Photochemical effects happen when photons interact with tissue cells. It depends greatly on wavelength.

The primary sites of beam damage are the eyes and skin. Exposure to the laser beam is not limited to direct beam exposure. Especially for high powered lasers, exposure to beam reflections may be just as harmful as exposure to the primary beam.

The following Beam exposure can also occur;

- i. Intrabeam viewing exposure means that the eye is exposed directly to all or part of the laser beam producing the smallest focused spot on the retina. This is the greatest eye hazard.
- ii. Diffuse or Specular Reflection from mirror surfaces can be as harmful as direct exposure to the beam when the surface is flat. Curved mirror-like surfaces will widen the beam such that while the exposed eye or skin does not absorb the full impact of the beam, there is a larger area for possible exposure.
- iii. Rough Surfaces: surfaces that are not completely flat will reflect laser beam in many directions. Diffuse reflection do not carry the full power or energy of the primary beam. Diffuse reflections from Class 4 lasers are capable of initiating fires.



*Figure 5.B. Exposure to a laser beam may occur in several ways direct exposure, mirror (specular) reflection and diffuse surface reflection.*

Direct intrabeam exposures and specular reflections from class 3B and 4 lasers may blind people, burn their skin, set fires, and laser generated air contaminants (LGAC). Diffuse reflections from class 4 lasers may also cause these hazards.

### 5.2.1 Eye Injuries

The eye is the organ most sensitive to light. Light reflects off an object and if the object is in the field of vision, it enters the eye. The light passes through the cornea, focusing the light, then passes through the aqueous humor, pupil, vitreous and finally the retina, which lines the back of the eyes.

The major hazard of laser light is beams entering the eye. The adverse effects from laser exposure can cause retinal and corneal burns, which lead to loss of sight and cataracts.

#### Corneal

- At Far Ultraviolet (UVB) 280 - 315 nm and (UVC) 100 - 280 nm, most of the radiation is absorbed in the cornea. Keratococonjunctivitis (snow blindness/welder's flash) will result if sufficiently high doses are absorbed.

- At Far Infrared (1400 nm - 1 mm), most of the radiation is transmitted to the cornea. Overexposure to these wavelengths will cause corneal burns.

#### Retinal

- At Visible (400 -760 nm) and Near Infrared (760 - 1400 nm) wavelength, most of the radiation is transmitted to the retina. Overexposure may cause flash blindness or retinal burns and lesions.

#### Lens

- At Near Ultraviolet Wavelengths (UVA) 315 - 400 nm, most of the radiation is absorbed in the lens of the eye. The effects are delayed and do not occur for many years (e.g. cataracts).

Eye hazards are easily controlled by using laser safety eyewear that is appropriate for the specific laser system, or by other engineering safety controls.

### 5.2.2 Skin Injuries

Skin is the largest organ of the body, therefore, the greatest probability for coming in contact with the laser beam. The most likely skin surfaces to be exposed to the beam are the hands, head, or arms. Skin burns are possible from acute exposure to high levels of laser radiation, especially in the infrared region. Erythema (skin reddening), skin cancer, and accelerated skin aging are possible effects in the ultraviolet wavelength range. Shielding the beam and reflections or covering the skin with opaque materials will help prevent skin effects.

## 5.3 NON-BEAM HAZARDS

There are other hazards related to the operation of a laser besides exposure to the beam or its reflection. Many of these non-beam-related hazards can be far more dangerous than the beam itself, therefore, the other associated hazards described below must be understood to ensure the safe use of a laser or laser system.

### 5.3.1 Electrical Hazard

The most lethal hazards associated with lasers are the high-voltage electrical systems required to power lasers. Electrical equipment in general presents three potential hazards – shock, resistive heating, and ignition of flammable materials. Accepted electrical safety practices should be followed by those working with high-voltage components of laser systems.

The following is a list of recommended electrical safety practices:

- Prior to working on electrical equipment, de-energize the power source. Lock out and tag out the disconnect switch.
- Do not wear rings, watches, or other metallic apparel when working with electrical equipment.
- When working with high voltage, regard all floors as conductive and grounded.
- Do not handle electrical equipment when hands or feet are wet or when standing on a wet floor.
- Be familiar with electrocution rescue procedures and emergency first aid.

- Check that each capacitor is discharged and grounded prior to working in the area.
- Use shock prevention shields, power-supply enclosures, and shielded leads in all experimental or temporary high-voltage circuits.

#### 5.3.2 Explosion Hazard

High-pressure arc lamps, filament lamps, and capacitors may explode violently if they fail during operation. These components shall be enclosed in a housing that is able to withstand the maximum explosive force that may be produced. Laser targets and some optical components also may shatter if heat cannot be dissipated quickly enough. Adequate mechanical shielding shall be used when exposing brittle materials to high intensity lasers.

#### 5.3.3 Compressed Gases

Compressed gases used in or with lasers also present potential health and safety hazards. Problems may arise when working with unsecured cylinders, cylinders of hazardous materials not maintained in ventilated enclosures, and when certain gases (toxins, corrosives, flammables, and oxidizers) are stored together.

#### 5.3.4 Laser Dyes and Solvents

Lasing medium sometimes incorporates dyes which are complex organic compounds mixed in solution with certain solvents. Some dyes are highly toxic or carcinogenic and safety measures must be considered when handling them. Safety Data Sheets must be made available to anyone working with these dyes.

#### 5.3.5 Fire Hazards

Combustible material such as research logs and cardboard boxes can be ignited by the beam. Other potential fire hazards include electrical components and the flammability of Class IV laser beam enclosures. The risks of fire can be reduced by using only fire resistant materials near radiation beams and scatter of class IV lasers.

#### 5.3.6 Laser generated air contaminants (LGAC)

Air contaminants may be generated when certain Class IIIb and Class IV laser beams interact with matter. Whether contaminants are generated depends greatly upon the composition of the target material and the beam irradiance. When the target irradiance reaches approximately 107 W·cm<sup>-2</sup> (Watt per square centimeter), target materials including plastics, composites, metals, and tissues may liberate carcinogenic, toxic and noxious airborne contaminants. The LSO (Laser Safety Officer) is responsible for evaluating this potential industrial hygiene hazard.

#### 5.3.7 Collateral radiation

Radiation other than that associated with the primary laser beam is called collateral radiation. Examples are x-rays, UV, plasma, radio frequency emissions, and ionizing radiation. X-rays could be produced from two main sources in the laser laboratories: electric-discharge lasers and high-voltage vacuum tubes of laser power supplies.

Take precautions to eliminate or reduce collateral radiation hazards, shield ultraviolet radiation emitted from laser discharge tubes and pumping lamps (i.e., not part of the primary laser beam). Consider additional protection requirements for operators exposed to plasma emissions. Plasma



emissions created during a laser-welding process may have sufficient ultraviolet or blue light content (1.8 to 5.5  $\mu\text{m}$ ) to raise concern for operators viewing a process on a long-term basis.

Recommended additional protection for plasma emission may include distance, shielding and personal protection equipment.

#### 5.3.8 Noise

If there is difficulty hearing or understanding a “normal” tone of voice at a distance of about three feet, noise levels are probably exceeding safe levels therefore hearing protection should be worn. Please contact EH&S for an evaluation.

---

## **6 CONTROL MEASURES**

This guidelines may or may not be applicable for each type of laser and laser system. Laser hazard is related to the wavelength intensity, and intended use of the laser, the guidelines may be relaxed accordingly. For example, a class IV laser placed into a properly constructed enclosed beam path system may be reclassified as class I or II. The required safety measures would then be reduced. For all lasers, use the minimum amount of laser radiation possible to accomplish the experimental objective.

**DIRECT EXPOSURE OF THE EYE BY A LASER BEAM SHOULD ALWAYS BE AVOIDED WITH ANY LASER, NO MATTER HOW LOW THE POWER.**

## 6.1 GENERAL LASER SAFETY REQUIREMENTS.

### A. Class I Laser Control Measures

- i. Control measures or warning labels are not required, needles direct exposure of the eyes should be avoided.

### B. Class II Laser Control Measures

- i. An appropriate warning label must be placed on the housing.
- ii. Do not stare into the beam or allow other persons to do so.

### C. Class III A or B Laser Control Measures

- i. The laser must have a protective housing such that laser light emerges from the aperture only.
- ii. A Key switch interlock system should be used to prevent unauthorized use of the laser.
- iii. The direct or mirror-reflected beam should not be viewed with the naked eye or with optical instruments such as telescopes.
- iv. Do not align the beam with the naked eye.
- v. A beam stop must be provided to adequately stop the beam with the absence of scattered light emission.
- vi. Laser goggles may be necessary. Be certain that the goggle in use is appropriate both in the attenuation factor provided by the goggle and that the goggle is for the proper wavelength. **LASER GOGGLES MUST BE MATCHED TO THE WAVELENGTH(S) OF THE LASER SYSTEM(S) BEING USED!** Be aware of the dangers that reflected lasers can pose. In addition to mirrors, many smooth surfaces can reflect lasers.
- vii. Spectators must be limited.
- viii. The laser system should be installed in a sole use laboratory and the door kept closed during operation. The door should be labeled.
- ix. Be certain that scattered laser radiation is not escaping through a window to the outside.
- x. Label high voltage areas and investigate for other associated hazards.
- xi. Eye examinations may be required prior to the use of such laser systems.

#### D. Class IV Laser Control Measures

- i. All of the measures outlined in Class 3 above should be followed in addition to the measures below.
- ii. Goggles are required when such systems are in operation.
- iii. Spectators are prohibited.
- iv. The entrance to such areas must be interlocked such that entry shuts the beam down.
- v. Such systems must be in sole use areas.
- vi. Access to such lasers shall be controlled by keyed access to both the room and the power panel to the laser. Such key will be kept in the possession of the Principal Investigator and access will be the Principal Investigator's responsibility.
- vii. Eye examinations are required prior to the use of such laser systems.
- viii. Radiation Safety may institute additional control measures as deemed necessary for the safe operation of the laser.

## 6.2 ENGINEERING CONTROLS

Engineering controls for Class IIb and IV lasers are listed below. Unless otherwise approved by the LSO, all Class IIb and IV lasers at UNT must have the following design features:

### 6.2.1 Beam Enclosures

Beam enclosures should be used whenever practical. Use of enclosures will significantly reduce the need for other engineering or administrative controls.

### 6.2.2 Protective Housings

A protective housing shall be provided for each laser system.

### 6.2.3 Safety Interlocks

The protective housing shall be interlocked such that removal of the protective housing will prevent exposure to laser radiation greater than the MPE. Interlocks shall not be defeated or overridden during normal operation of the laser.

For pulsed lasers, interlocks shall be designed to prevent unintentional firing of the laser. An example of this would be by dumping the stored energy into a dummy load.

For continuous wave (CW) lasers, the interlocks shall turn off the power supply or interrupt the beam (for example, by means of shutters).

Service access panels that allow access to the beam during normal operation shall either be interlocked or require a special tool for removal and have an appropriate warning label. All commercially manufactured lasers come equipped with such interlocks and labels.

Class IIb lasers should be provided with a remote interlock connector. Class IV lasers shall have a remote interlock connector. The remote interlock connector will decrease the laser beam power to a safe level when activated.

### 6.2.4 Controlled Access

A Class IIb laser should have a key controlled master switch. A Class IV laser must have a key controlled master switch. The PI shall control access to the key. All lasers shall be disabled by removing the key when it is not in use.

#### 6.2.5 Activation Warning Systems

In the laser control area, an alarm (for example, an audible sound), a warning light (visible through protective eyewear), or a verbal “countdown” command must be used with Class IIIb and IV lasers or laser systems during activation or startup. Distinctive and clearly identifiable sounds that arise from auxiliary equipment (such as a vacuum pump or fan) that are uniquely associated with the emission of laser radiation are acceptable as an audible warning. A warning light outside the control area must be used with Class IIIb and IV lasers.

#### 6.2.6 Emission Delay

For operation of Class IIIb or IV lasers, the warning system must be activated at a sufficient time prior to emission of laser radiation to allow appropriate action to be taken to avoid exposure to the laser.

#### 6.2.7 Viewing Optics

All viewing portals, display screens, and collecting optics shall be designed to prevent exposure to the laser beam above the applicable MPE for all conditions of operation and maintenance.

#### 6.2.8 Window and Door Barriers

All windows and doorways must be either controlled or restricted in such a manner as to prevent escape of potentially hazardous laser radiation. Laser safety curtains at doorways and window coverings are required for Class IIIb and IV lasers that have open beam configurations.

#### 6.2.9 Controlled Area

A controlled area shall be designated for all open beam paths. The controlled area is defined as the area where laser radiation is in excess of the MPE. Appropriate control measures must be implemented in laser controlled areas.

#### 6.2.10 Beam Stops

Class IIIb lasers should have a permanent beam stop in place. Class IV lasers shall have a permanent beam stop in place. Most laser heads come equipped with a permanently attached beam stop or attenuator that will lower the beam power to MPE at the aperture from the housing. Additional beam stops may be needed in the beam path to keep the useful beam confined to the experimental area.

#### 6.2.11 Remote Operations

Whenever possible, Class IV lasers should be operated and fired from a remote location.

### 6.3 ADMINISTRATIVE AND PROCEDURAL CONTROLS

Administrative and procedural controls are methods or instructions that specify rules, or work practices, or both, which implement or supplement engineering controls. Necessary administrative and procedural controls for Class IIIb and Class IV laser and laser systems include, but are not limited to:

#### 6.3.1 Standard operating procedures (SOPs)

Developing Standard Operating Procedures (SOPs) begins the planning process. This step requires each principal investigator or laboratory work group to identify and evaluate all chemical, biological, radiological, and physical hazards associated with laser operations and describe safety

precautions necessary to avoid employee exposures and injuries. **SOPs must be specific to each laboratory operation.**

SOPs must be reviewed by RMS and the PI or laboratory supervisor. Laboratory personnel must be trained on the elements of the SOP before performing an experiment or operation. See **Appendix I. Standard Operating Procedure template.**

#### 6.3.2 Output Emission Limitations

The minimum laser radiant energy or laser power level required for the application shall be used.

#### 6.3.3 Education and Training

All laser users that operate Class IIIb or IV lasers shall have the appropriate training in laser safety that is appropriate with the level of potential hazard. All laser must complete UNT's Laser Safety Training on RMS website.

#### 6.3.4 Authorized Personnel

Class IIIb and IV lasers shall be operated, maintained and serviced only by authorized personnel. The PI of the laser system is responsible for authorizing laser users and maintaining a listing of current laser users.

#### 6.3.5 Personal Protective Equipment

Personal protective equipment (such as eyewear, barriers, clothing and gloves) may be required to eliminate potential exposure in excess of the applicable MPE when other control measures are inadequate.

#### 6.3.6 Service Personnel

During periods of service or maintenance, control measures appropriate to the class of the embedded laser shall be implemented when the beam enclosures are removed and access to the beam is possible. The PI shall require that service personnel shall have the education and training commensurate with the class of the laser or laser system contained within the protective housing. A temporary laser controlled area shall be established by service personnel that provides the safety requirements for all personnel both within and outside of the area appropriate to the laser or laser system. A notice sign shall be posted outside the temporary laser controlled area to warn of the potential hazards.

#### 6.3.7 Visitors and Spectators

Visitors and spectators shall not be permitted within a laser controlled area during operation of a Class IIIb or IV laser or laser system unless:

- A. Specific protective measures for visitors and spectators have been approved by the LSO.
- B. The degree of hazard and avoidance procedure has been explained to the spectators.
- C. Appropriate protective measures have been taken.

## 7 LASER CONTROL AREAS

Class IIIb and Class IV lasers shall only be operated in laser control areas approved by the LSO. Laser control areas confine laser hazards to well-defined spaces that are entirely under the control of laser users. The control areas shall be equipped with the prescribed safety features.

If the beam of a Class IIIb or 4 laser is completely enclosed, the laser will meet the standard of a Class I laser (all areas below MPE), and no further restrictions will be required. If the beam path is not fully enclosed, then a Nominal Hazard Zone (NHZ) needs to be accessed and a controlled area established.

### 7.1 CLASS IIIb CONTROLLED AREA

Class IIIb lasers with an open beam configuration may only be operated in designated laser controlled areas. This is an attempt to prevent injury to those visiting and working near the laser controlled area. All personnel who require entry into a Class IIIb laser controlled area shall be appropriately trained. Class3B designated areas shall follow these control measures:

- i. Must be controlled such that lasers and laser systems can only be operated by authorized personnel.
- ii. Must be posted with the appropriate warning sign(s). See Warning Signs and Equipment Labels Section.
- iii. All area or entryway safety controls must be designed to allow rapid egress by laser personnel and admittance to the laser controlled area under emergency conditions.
- iv. Must be operated in a manner such that the laser beam path is well defined and projects into a controlled airspace when the laser beam must extend beyond an indoor controlled area, particularly to the outdoors under adverse atmospheric conditions, i.e. rain, fog, snow, etc.
- v. Must be under the direct supervision of an individual knowledgeable in laser safety.
- vi. Must have all windows, doorways, open portals, etc. either covered or restricted in such a manner as to reduce the transmitted laser radiation to levels at or below the applicable ocular MPE.
- vii. Must have only diffusely reflecting materials in or near the beam path where possible.
- viii. Must have appropriate personal protective equipment readily available (i.e., eye protection).

### 7.2 CLASS IV CONTROLLED AREA

Only appropriately trained personnel may enter a Class IV laser controlled area during the time a procedure utilizing the active beam is in progress. All personnel within the laser controlled area must be provided with appropriate protective equipment and are required to follow all applicable administrative controls.

The area designated as a laser controlled area for Class IV lasers shall meet the requirements of a Class IIIb control area (Section 4.1) and the following additional control measures:

- Operate Class IV lasers within a localized enclosure, in a controlled workplace;
- Enclose the entire laser beam path if possible;

- Operate indoor laser in a light-tight room (all windows are covered) with interlocked entrances to assure that the laser cannot emit energy while a door is open if a complete local enclosure is not possible;
- Wear appropriate eye protection when working within the controlled area;
- Use a suitable shielding between the laser beam and any personnel or flammable surfaces if the laser beam irradiance is sufficient to be a serious skin or fire hazard;
- Use remote firing with video monitoring or other remote (safe) viewing techniques when feasible;
- Use positive stops on the azimuth and elevation traverse on outdoor high-power laser devices such as satellite laser transmission systems and laser radar to ensure that the beam cannot intercept occupied areas or non-target aircraft;
- Use beam shutters, beam polarizers, and beam filters and limit use to authorized personnel;
- Shield flash lamps in optical pump systems to eliminate any direct viewing;
- Use backstops that are diffusely reflecting, fire resistant target materials;
- Use safety enclosures to contain hazardous reflections from the work area when micro welding and micro-drilling work pieces; and
- Minimize the risk of hazardous levels of laser radiation being reflected back through the optics by using microscopic viewing systems to study the work pieces.

### 7.3 TEMPORARY CONTROLLED AREAS

Temporary laser controlled areas can be created for the servicing and alignment of embedded lasers, enclosed lasers, and in special cases where permanent laser control areas cannot be provided.

---



## 8 PERSONAL PROTECTIVE EQUIPMENT (PPE)

Enclosure of the laser equipment or beam path is the preferred method of control. However, it may be necessary to use PPE when other control measures do not provide adequate means to prevent access to direct or reflected beams at levels above the MPE. Personal protective equipment may have its limitations and must be used only in conjunction with engineering and administrative controls, when working with Class IIIb and Class IV lasers and laser systems.

### 8.1 PROTECTIVE EYEWEAR

Appropriate eye protection shall be available and worn by laser operators, incident personnel and visitors in laboratories where a Class IIIb or Class IV laser is present and there is a potential exposure to the beam or reflected beams at levels above the MPE. Laser protective eyewear is usually not required for Class II or Class IIIR lasers or laser systems, except in conditions where planned long-term (>0.25 seconds) direct viewing is required. The Principal Investigator is responsible for ensuring that the appropriate eyewear is available and worn.

#### 8.1.1 Selecting Protective Eyewear

Eyewear must be specifically selected to withstand either direct or diffusely scattered beams and shall meet all provisions of ANSI Z87.1-1989. Laser eyewear should not be subjected to high-intensity beams. High average intensity and high peak intensity beams can physically damage the lenses, resulting in loss of eye protection. Contact the LSO for assistance in selecting protective eyewear.

The following information is needed to select the appropriate laser safety eyewear:

- Wavelength(s)
- Mode of operation (continuous wave or pulsed)
- Maximum exposure duration (assume worst case scenario)
- Maximum irradiance (W/cm<sup>2</sup>) or radiant exposure (J/cm<sup>2</sup>)
- Maximum permissible exposure (MPE)
- Optical density (OD)

It is extremely important that laser users wear the appropriate laser safety eyewear correctly. For example, only eyewear such as goggles specifically designed to fit over prescription glasses may be worn with prescription glasses. In addition, prescription laser safety glasses are readily available from most vendors of laser safety eyewear. Other protective eyewear worn over prescription glasses may not provide complete eye protection. When wearing eyewear be aware that it is possible to be caught from behind by a reflected laser beam.

### 8.1.2 Types of Protective Eyewear

- A. 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.
- B. Polycarbonate: Polycarbonate laser eyewear is lighter, less expensive and offers higher impact resistance than glass, but allows less visible light transmittance.
- C. 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 reflections.
- D. Alignment Eyewear: Alignment eyewear may be used when aligning low power visible laser 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 high power or invisible beams and cannot be used with pulsed lasers.

### 8.1.3 Protective 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.

### 8.1.4 Protective 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.

### 8.1.5 Inspection and Cleaning of Protective 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.

Laser safety eyewear should be inspected periodically for the following:

- Pitting, crazing, cracking and discoloration of the attenuation material.
- Mechanical integrity of the frame.
- Light leaks.
- Coating damage.

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

Table 8.A. Optical Densities for Protective Eyewear for Various Laser Types					
Laser Type/ Power	Wavelength	OD	OD	OD for	OD for
	(mm)	0.25 seconds	10 seconds	600 seconds	30,000 seconds
<b>XeCl</b>	0.308 <sup>a</sup>	---	6.2	8	9.7
50 watts					
<b>XeFl</b>	0.351 <sup>a</sup>	---	4.8	6.6	8.3
50 watts					
<b>Argon</b>	0.514	3	3.4	5.2	6.4
1.0 watt					
<b>Krypton</b>	0.53	3	3.4	5.2	6.4
1.0 watt					
<b>Krypton</b>	0.568	3	3.4	4.9	6.1
1.0 watt					
<b>HeNe</b>	0.633	0.7	1.1	1.7	2.9
0.005 watt					
<b>Krypton</b>	0.647	3	3.4	3.9	5
1.0 watt					
<b>GaAs</b>	0.840 <sup>c</sup>	---	1.8	2.3	3.7
50 mW					
<b>Nd:YAG</b>	1.064 <sup>a</sup>	---	4.7	5.2	5.2
100 watt					
<b>Nd:YAG</b>	1.064 <sup>a</sup>	---	4.5	5	5.4
(Q-switch) <sup>b</sup>					
<b>Nd:YAG<sup>c</sup></b>	1.33 <sup>a</sup>	---	4.4	4.9	4.9
50 watts					
<b>CO<sub>2</sub></b>	10.6 <sup>a</sup>	---	6.2	8	9.7
1000 watts					

a. Repetitively pulsed at 11 Hertz, 12-nanosecond pulses, 20 mJ/pulse.

b. OD for UV and FIR beams computed using a 1-mm limiting aperture, which presents a "worst-case" scenario. All visible and NIR computations assume a 7-mm limiting aperture.

c. Nd:YAG operating at a less-common 1.33  $\mu\text{m}$  wavelength.

NOTE: All OD values determined using MPE criteria of ANSI Z 136.1 (1993).

## 8.2 SKIN PROTECTION

Skin protection can best be achieved through engineering controls. If potential skin damaging exposures exist, skin covers and or “sun screen” creams are recommended. Minimize exposure to UV radiation by using beam shields and clothing (opaque gloves, tightly woven fabrics, laboratory jacket or coat) which attenuate the radiation to levels below the MPE for specific UV wavelengths. Consider flame-retardant materials for Class IV lasers. Special attention must be given to the possibility of producing undesirable reactions in the presence of UV radiation (formation of skin sensitizing agents, ozone, etc.).

Acute exposure of the skin to large amounts of laser energy may cause skin burning that is similar to thermal or radiant burns. The incident radiation is converted to heat that is not dissipated rapidly enough due to poor thermal conductivity of the tissue. The resulting local temperature rise causes tissue protein denaturation. Skin injury depends on the wavelength of laser light, exposure time, and degree of skin pigmentation. Skin carcinogenesis may occur at some specific ultraviolet wavelengths (290-320 nm).

---

## 9 WARNING SIGNS AND EQUIPMENT LABELS

### 9.1 WARNING SIGNS

Lasers shall have warning labels with the appropriate cautionary or danger statement affixed to a conspicuous place on the laser housing, usually near the aperture of the laser beam. Laser warning signs must meet the standards of ANSI Z136.1. All signs and labels must be conspicuously displayed in locations which serve to warn personnel. Normally, warning signs are posted on doors, or at entryways into laser controlled areas

A warning sign must be posted near the entrance to any area or laboratory that contains a Class IIIB or IV laser or laser system. The sign and the wording must be corresponding with the highest-class laser contained within the area or laboratory.

Warning: Must be used with all signs and labels associated with all Class IIIR and most Class IV lasers and laser systems that exceed the appropriate MPE for irradiance, and all Class IIIB lasers and most Class IV laser systems.

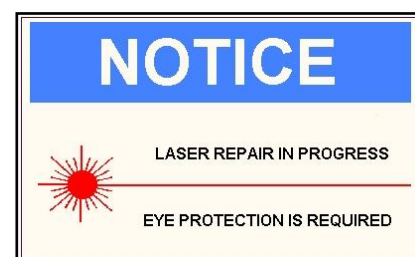
Danger: Must be used with all signs and labels associated with a Class IV laser and laser system with high power (multi-kW) or pulse energy.



Caution: Must be used with all signs and labels associated with Class II and IIR lasers and laser systems, and all Class IIIR lasers and laser systems that do not exceed the appropriate



Notice: Must be used on signs posted outside a temporary laser controlled area. The area within the temporary controlled area must also have appropriate signs posted (danger warning



## 9.2 LIGHTED WARNING SIGNS

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

## 9.3 EQUIPMENT LABEL

All lasers or laser systems (except Class I) must have appropriate warning labels affixed to a conspicuous place on both the housing and the control panel (if separated by more than 2 meters).

Laser equipment shall have the following labels:

- Class II lasers and laser systems, “Laser Radiation – Do Not Stare into Beam”
- Class IIIR lasers and laser systems (accessible irradiance does not exceed MPE based upon 0.25 second exposure for wavelengths between 0.4 and 0.7  $\mu\text{m}$ ), “**Laser Radiation – Do Not Stare into Beam or View Directly with Optical Instruments**”
- All other Class IIIa lasers or laser systems, “**Laser Radiation – Avoid Direct Eye Exposure**”
- Class IIIb lasers or laser systems, “Laser Radiation – Avoid Direct Exposure to Beam”
- Class IV lasers or laser systems, “Laser Radiation – Avoid Eye or Skin Exposure to Direct or Scattered Radiation”.

## 9.4 PROTECTIVE EQUIPMENT LABELING

Eyewear must be clearly labeled with the optical density and wavelength. Color-coding or other distinctive identification is recommended in multi-laser environments. Laser protective windows must be labeled with the optical density and wavelength(s) for which protection is afforded, and should be labeled with the threshold limit and exposure time for which the limit applies, and the conditions under which protection is afforded.

Laser protective barriers must be labeled with the barrier threshold limit and exposure time for which the limit applies, and beam exposure conditions under which protection is afforded.

---

## 10 MEDICAL SURVEILLANCE

Medical surveillance needs of personnel working in a laser environment are the same as for other potential health hazards. Medical surveillance examinations may include assessment of physical fitness to safely perform assigned duties, biological monitoring of exposure to a specific agent, and early detection of biologic damage or effect.

Medical surveillance is strongly recommended for laser operators of Class IIIb, and Class IV laser systems. Laser operators should have, at a minimum, a baseline examination of the following, as specified in ANSI Z136.1:

- Ocular history
- Visual acuity
- Macular function
- Color Vision
- Ocular Fundus with an Ophthalmoscope
- Skin

Any individual with a known or suspected eye injury should be immediately referred to an ophthalmologist. Individuals with skin injuries should be promptly seen by a physician.

---

## 11 TRAINING

Principal investigators and/or laboratory supervisors are responsible for ensuring that all personnel are properly trained before they begin work in a laboratory and that they receive additional training when new hazards or procedures are introduced.

Only qualified and authorized personnel are permitted to operate laser systems. Therefore, all Class IIIb and Class IV laser users are required to complete laser safety training, read this manual, participate in a medical surveillance program. Laser users must complete retraining every three years.

# GLOSSARY

## **Absorption**

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

## **Beam**

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

## **Blink Reflex or Aversion Response**

The involuntary closure of the eyelid or movement of the head to avoid exposure to a noxious stimulant or bright light. It often occurs within 0.25 seconds, which includes the blink reflex time.

## **Coherent**

A beam of light characterized by a fixed-phase relationship (spatial coherence) or single wavelength

i.e., monochromatic (temporal coherence)

## **Continuous Wave (CW)**

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

## **Controlled Area (laser)**

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

## **Diffuse Reflection**

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

## **Enclosure**

A barrier used to enclose the laser beam.

## **Energy**

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

## **Fail-Safe Interlock**

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

## **Housing**

The protective enclosure that contains a laser. In the case of Class 3B and Class 4 lasers, this case is required to be interlocked.



**Infrared (IR) Radiation**

Electromagnetic radiation with wavelengths that lie within a range of 0.7  $\mu\text{m}$  to 1 mm.

**Intrabeam Viewing**

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

**Irradiance (E)**

Radiant power incident per unit area upon a surface, expressed in  $\text{W}/\text{cm}^2$ .

**Laser**

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

**Laser Classification**

An indication of the beam hazard level of a laser or laser system during normal operation or the determination thereof. The hazard level of a laser or laser system is represented by a number or a numbered capital letter. The laser classifications are Class 1, Class 1M, Class 2, Class 2M, Class 3R, Class 3B and Class 4. In general, the potential beam hazard level increases in the same order.

**Laser Operator**

An individual who has met all applicable laser safety training, medical surveillance, and approval requirements for operating a laser or laser system.

**Laser Safety Officer (LSO)**

The individual who has authority to monitor and enforce the safe use of lasers and laser systems.

**Laser Supervisor**

The responsible PI for a laser or laser system. See also Principal Investigator.

**Maximum Permissible Exposure (MPE)**

The level of laser radiation to which an unprotected 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 ( $\text{J}/\text{cm}^2$ ) or irradiance ( $\text{W}/\text{cm}^2$ ). The criteria for MPE are detailed in Section 8 of ANSI Z136.1.

**Nominal Hazard Zone (NHZ)**

A zone that describes 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.

**Optical Density ( $D_\lambda$ )** - Logarithm to the base ten of the reciprocal of the transmittance:

$D_\lambda = -\log_{10} \tau_\lambda$ , where  $\tau_\lambda$  is the transmittance at the wavelength of interest.

**Power**

The rate at which energy is emitted, transferred, or received in W or J/s.

**Principal Investigator (PI)**

The authorized laser user who assumes responsibility for the control and safe use of a laser or laser system.

**Pulsed Laser**

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

**Q-switch**

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

**Q-Switched Laser**

A laser that emits short ( $\sim 10$ -250 ns), high-power pulses by means of a Q-switch.

**Radiant Exposure (H)**

Surface density of the radiant energy received in units of J/cm<sup>2</sup>.

**Radiant Power ( $\Phi$ )**

Power emitted, transferred, or received in the form of radiation in units of watts (W). Synonym: radiant lux.

**Repetitive Pulse Laser**

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

**Specular Reflection**

A mirror-like reflection.

**Standard Operating Procedure (SOP)**

Formal written description of the safety and administrative procedures to be followed in performing a specific task. The procedure specifies measures which, if followed, will ensure safe and correct use of the laser or laser system.

**Transmittance**

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

**Ultraviolet (UV) Radiation (Light)**

For the purpose of this laser safety manual, electromagnetic radiation with wavelengths between 0.18 and 0.40  $\mu\text{m}$ .

**Visible Radiation (Light)**

Electromagnetic radiation that can be detected by the human eye. This term is commonly used to describe wavelengths of 0.4 to 0.7  $\mu\text{m}$ . Derivative standards may legitimately use 0.38 – 0.78  $\mu\text{m}$  for the visible radiation range.

**Wavelength**

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

# APPENDIX I: STANDARD OPERATING PROCEDURE TEMPLATE

Standard Operating Procedure  
Location  
Type of Laser(s) or experiment  
Date, version

## Instructions

*Black Text – is considered mandatory content*

*Red text – fill in appropriate information for factual accuracy*

*Blue Text – (sample text) may be retained, edited, or deleted as appropriate for factual accuracy*

### **I. Purpose**

This Standard Operating Procedure (SOP) outlines requirements to be considered by an authorized user of the **Type of Laser(s) or experiment** as well as describes the normal operation of the laser and any hazards that may be encountered during normal operation. Finally, the SOP explains how to minimize any hazards and how to respond in an emergency. This document is to be reviewed one year from the date of approval or as conditions warrant, whichever is the shorter period.

### **II. Personnel**

- A. Authorized Personnel: The **Type of Laser(s) or experiment** may be operated only by authorized personnel who are fully cognizant of all safety issues involved in the operation of such a device. These personnel are to ensure that the laser is only operated in the manner laid out in this document. To become an authorized user, one must:
1. Complete “EHS 301 – Laser Safety Training Initial” e-Course.
  2. Read and fully understand the SOP
  3. Receive hands-on training on the **Type of Laser(s) or experiment** by an authorized user.
  4. Sign the authorized user sheet to affirm that the above steps have been completed.
- B. Unauthorized personnel: No unauthorized personnel may enter **room location** during laser operation unless accompanied by an authorized user. All visitors must be briefed on proper safety protocol and must wear appropriate laser protective eyewear located on the premises.

### **III. Hazards**

- A. Laser Hazards: The **Laser Type** is a Class 4 or 3B (**list class**) laser. Severe eye damage (including blindness) and skin damage can result from direct beam and specular reflections. Eye damage can also result from diffuse reflections (Class 4).

- B. Electrical Hazards: electrical shock or electrocution could result from direct contact with high voltage. List types of electrical hazards associated with laser use, equipment, or experiment.
- C. Chemical: List types of chemical hazards associated with laser use, equipment, or experiment.
- D. Pressure Hazards: List types of pressure hazards associated with laser use, equipment, or experiment.
- E. Other: List types of other hazards associated with laser use, equipment, or experiment.

#### IV. Hazard Controls

##### A. Lasers

1. Only authorized personnel will operate lasers.
2. The laboratory doors will be closed and locked whenever laser is operating.
3. During alignments, the laboratory doors will be closed, locked, and a sign posted stating **“Laser alignment in progress. Do not enter. Laser Eye Protection required.”**
4. Unauthorized personnel will be only allowed entry to the laboratory during laser operation with the supervision of an authorized user under the terms specified in section 2.
5. Laser eye protection (LEP) for sufficient protection against (*list wavelengths used*) nm is available and is located at (*detail the location of where laser eye protection is in lab and also describes the different types of eyewear if multiple pairs are needed*). Laser eye protection is required to be worn for all beam alignments/beam manipulations or anytime there is an open beam that exceeds the maximum permissible value.  
Please note: Laser Eye Protection is wavelength specific and proper section is critical
6. Specular and diffuse reflections will be controlled using beam stops, beam barriers, beam housings and enclosures. All of these control methods must be in place during normal operation.
7. No jewelry or other reflective materials are to be worn while working with the Laser, especially on the hands and neck.
8. Personal in the laser lab should avoid bending over or otherwise putting their eyes at the level of the beam path while the laser is in operation.
9. Laser alignment must be performed only by following the steps outlined in the alignment procedure supplement or alignment section.
10. Perform physical surveys to determine if there are stray beams (specular or diffuse) emanating from each laser and its optics, and then document the beam surveys noting the location of stray beams and the measures taken to control them. *Please indicate method of documentation of survey (checklist or log, etc.)*
11. If the beam path must be changed significantly by relocating the laser or optics, all users must be notified of the change.
12. The same precautions that are taken for safe operation of the laser must also be followed when adjusting any of the optics in use with the apparatus.

13. When a new principal researcher/experimenter takes over use of the laser system, the new user must conduct a survey for unwanted stray or diffuse beams. Appropriate tools such as IR sensitive cards or IR viewer shall be used for locating the possibility of stray IR light.
  14. Experimental end stations should be treated the same as the laser system with regards to the proceeding safety procedures.
- B. Electrical (List controls used to mitigate the hazard)
1. Enclosures for protection against the high voltages of the laser power supply or laser head may only be removed after the power supply has been unplugged from the outlets and after following the safety procedures outlined in the safety and operations manual provided by the manufacturer.
  2. Only qualified personnel may perform all internal maintenance to the laser and more than one user must be present when performing said maintenance.
  3. Every portion of the electrical system, including the printed circuit cards, should be assumed to be at dangerous voltage level.
- C. Chemical List controls used to mitigate the hazard
- D. Pressure List controls used to mitigate the hazard
- E. Other List controls used to mitigate the hazard

## V. Normal Operation

(SAMPLE TEXT – text below may be retained, edited, or deleted as appropriate for factual accuracy)

- A. Inspect all electrical and water connections for damage and connectivity.
- B. Complete the “check-in” portion of the checklist included in this document as Appendix A. The checklist serves to confirm that all basic systems are operating within expected parameters and that basic safety mechanisms are in place. The laser run log is a set of forms adjacent to the experimental set up and is used to ascertain the current state of the laser. Log all use and add individual notes as necessary. Also, replacement of optics and other routine maintenance should be noted in the log. Once the checklist is complete, the laser may be turned on.
- C. Turn laser system on.
- D. System alignment. See the attached alignment procedure supplement/alignment section for details.
- E. Shutdown laser system.
- F. After a run is finished, complete the log entry and the checkout portion of the checklist in Appendix A.

## **VI. Emergency Procedures**

- A. Laser accidents: Follow the steps outlined in the Procedure for Laser Accidents in Appendix B.
- B. Power outage: If there is a power outage, turn off the laser to avoid a hazardous situation when power is restored.

## **VII. Integrated Safety Management**

### **Take ownership of your safety!**

Before starting any work, ask yourself:

1. What will I be doing?
2. Do I know what the hazards are?
3. Do I have everything I need to do the job safely?
4. Am I doing the job safely?
5. What can we do better?

### **Authorized Users**

I have read and understood the Standard Operating Procedures for **type of laser or experiment**

<b>Name (print)</b>	<b>Signature</b>	<b>Date</b>	<b>PI Initial</b>

## Appendix A – Checklist for using **Type of laser or experiment**

Check in: (SAMPLE TEXT – text below may be retained, edited, or deleted as appropriate for factual accuracy)

- Door is closed and all personnel are wearing the appropriate laser protective eyewear.
- Inspect the apparatus for any blockages or apparent misalignment.
- Confirm that the beam path is set up to hit the sample properly.
- Ensure that all beam enclosures and /or beam stops are placed properly in the work area.
- Record laser energy in the logbook.
- During the run, ensure that the laser is hitting the sample correctly.
- Record any anomalous behavior in the logbook.

Check out:

-Shut off the laser.

## Appendix B – Procedure for Laser Accidents

In the event of a laser accident, follow the procedure below:

1. Ensure that the laser is shut off.
2. Provide for the safety of the personnel (first aid, evacuation, etc.) as needed. Note — if an eye injury is suspected, have the injured person keep his/her head upright and still to reduce bleeding in the eye. A physician should evaluate laser injuries as soon as possible.
3. Obtain medical assistance for anyone who may be injured.
4. If there is a fire, pull the alarm, and contact the fire department by calling 911. Do not fight the fire unless it is very small and you have been trained in fire fighting techniques.
5. Inform the Office of Environment Health, & Safety (EH&S) as soon as possible.
6. During normal working hours, call the following:

Risk Management Services	940-565-2109
Laser Safety Officer	940-565-3282
Radiation Safety Officer	940-565-3282

After normal working hours, call 911 for

7. Inform **(PI NAME)** and the current group safety officer as soon as possible. If there is an injury, **(PI NAME)** will need to submit a report of injury to the Worker's Compensation Office.
8. After the incident, do not resume use of the laser system until the Non-Ionizing Radiation Safety Committee has reviewed the incident and approved the resumption of research.

## Appendix C - Alignment Procedures



#### A. Pre-Alignment Safety

1. Post the “Laser Alignment in Progress” notice sign outside the laser lab before beginning any alignment procedure.
2. Check that the laser curtain is securely closed with no gaps.
3. Only authorized personal are allowed in the laser lab during alignment.
4. All personal in the room must wear the appropriate laser protective eyewear during alignment.
5. To reduce accidental reflections, watches, rings, dangling badges, and other reflective jewelry or materials must be taken off before any alignment activity begins.
6. Alignment should only be performed when there is at least two authorized users present who have been trained to respond to a laser safety emergency.
7. Check for and remove any foreign objects in the beam path other than safety controls such as beam blocks. Remove all unnecessary equipment, tools, and combustible materials from the laser table and immediate area to minimize the possibility of stray reflections and non-beam accidents.

#### B. General Alignment Safety Concerns

1. Use of non-reflective alignment tools should be considered. When reflective tools are required, be mindful to keep tools out of the beam path.
2. Never allow the beam to propagate beyond the point to which you have aligned and always be aware of the full beam path.
3. Always block the beam upstream when inserting/removing anything into/from the beam path, such as alignment irises.
4. Use a pair of index cards when checking the alignment of the beam so that you never have to leave the beam unblocked to move a card past a mirror.
5. As alignment proceeds down the table, a beam block should always be placed downstream in a position to catch the beam directly after the pair of mirrors being aligned, preventing the beam from propagating through an unaligned path.
6. Be aware that all transmissive optics generate back reflections and some reflective optics have substantial leak through. When working with these components be sure to track, block, and record all stray beams. This is a particular concern with filters (We currently use both ND and Bandpass filters), which generate strong specular reflections that can propagate back up stream a long way before diverging off the beam path due to very slight miss alignments. When such a reflection travels back upstream and encounters a beam splitting optic a new beam path can be formed in an unexpected direction.
7. When working with focusing elements, it important to be aware that there may be sufficient intensity at the focus to burn skin and/or ignite combustible materials,

such as index cards. At sufficiently high powers the focus may create plasma in the air resulting in a loud “popping” noise at the repetition rate of the laser, a glowing white spot at the focus where nonlinear optical processes are occurring, and the creation of ozone that smells like electric discharge. This can be disconcerting when unexpected. If this occurs simply block the beam upstream from the focusing element and either reduce the power of the beam or change the focusing element to a less tightly focusing optic.

C. Internal alignment Mirrors

(SAMPLE TEXT – text below may be retained, edited, or deleted as appropriate for factual accuracy)

1. Ensure that all users are wearing appropriate laser protective eyewear, warning signs are posted, and laboratory doors are closed. Check that the laser path goes to the power meter and is enclosed.
2. Turn on the cooling water.
3. Turn on the power supply, checking that the water light comes on.
4. Turn to current mode/ full power; turn on the laser and press start.
5. Adjust vertical and horizontal knobs back to maximum power.
6. Turn off the laser and power supply.
7. Take off the lid and screw on safety overrides.
8. Test the power again (after turning the laser back on). Adjust to full power.
9. Use a non-reflective 7/16 wrench. Turn the vertical front knob to \_\_\_\_ power and adjust the back vertical knob in the opposite direction to see if power increases past the original power. If so, repeat. If not, turn the front knob in the other direction and repeat.
10. When the power is maximized, turn off the laser.
11. Replace the laser covering and let the cooling water run for 30 minutes.

## References:

Laser Safety Manual. University of South Carolina Beaufort, Environmental Health.  
<http://web.physics.ucsb.edu/~phys128/lasersafetyman.pdf>

Laser Safety Manual. Stanford, Environmental Health and Safety.  
<https://ehs.stanford.edu/manual/laser-safety-manual>

Laser Safety Manual. University of Pennsylvania, Environmental Health and Radiation Safety.  
<https://ehrs.upenn.edu/policies-resources/laser-safety-manual>

Laser Safety Manual. Harvard University, Environmental Health and Safety Radiation Protection.  
[https://www.ehs.harvard.edu/sites/default/files/laser\\_safety\\_manual.pdf](https://www.ehs.harvard.edu/sites/default/files/laser_safety_manual.pdf)

Laser Safety Manual. Iowa State University, Environmental Health and Safety.  
<http://publications.ehs.iastate.edu/lserm/files/assets/common/downloads/publication.pdf>

Laser Safety Manual. Case Western Reserve University, Environmental Health and Safety.  
Revised July 2018. [https://case.edu/ehs/sites/case.edu.ehs/files/2018-07/LASER-SAFETY-MANUAL\\_2018.pdf](https://case.edu/ehs/sites/case.edu.ehs/files/2018-07/LASER-SAFETY-MANUAL_2018.pdf)