Laser Safety Training Module

Southern Illinois University

Carbondale, Illinois

1st Edition

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Prepared by
Laser Safety Committee
Southern Illinois University
Carbondale, Illinois

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Section 1 – SIU Laser Safety Program

A. Introduction

The purpose of the Southern Illinois University – Carbondale Laser Safety Program is to assure that all activities related to the ownership, use, or operation of lasers are conducted with the proper precautions and are in compliance with applicable governmental regulations. These requirements are based on State and Federal safety standards and guidelines, which include the Illinois Division of Nuclear Safety (IDNS) regulations Part 315, Standards for Protection Against Laser Radiation; the American National Standard for the Safe Use of Lasers, ANSI Z136.1–2000 and the American National Standard for the Safe Use of Lasers in Health Care Facilities, ANSI Z136.3–1996.

This Laser Safety Training Module was developed to provide a basic understanding of laser hazards, laser procedures, and recommendations for the safe use of Class 3b and Class 4 lasers and details health and safety guidelines designed to protect Southern Illinois University (SIU) employees who work with lasers. The requirements and recommended details of this Module are applicable to all SIU employees who use Class 3b and 4 lasers in clinical and/or research facilities.

Although Physicians and Principal Investigators (P/PI) bear the ultimate responsibility for the safe conditions and procedures for laser use in their respective areas, each member of a group involved in laser activities is responsible for reviewing and applying the information put forth in this Module. Since lasers are used in a variety of applications throughout the SIU campus, this Module should not be considered a comprehensive review of all potential hazards. If you need additional information or assistance, contact the Laser Safety Officer (LSO) at 536-2015 or jkane@siumed.edu.

B. Laser Safety Manual

The Laser Safety Manual addresses the safety policies, responsibilities, and procedures for the safe use of lasers at SIU. The P/PI should have a copy of the Laser Safety Manual available for your reference. This document and other laser related information is also available online from the Office of Radiological (ORC) Website at: http://www.siumed.edu/adraf/orc.html.

In addition, the P/PI should have available, a Standard Operating Procedures (SOP) document. The SOP is written procedures that specify the safe operation and protection instructions specific to each laser. Each SIU employee should review the contents of the SOP prior to starting work with a laser or laser system.

C. Laser Safety Training Requirements

Laser Safety Training is mandatory for all SIU employees who use or assist in the operation of Class 3b or 4 lasers. Therefore, individuals are required to review both the Laser Safety Manual and the Laser Safety Training Module. To verify these documents have been read and understood, each individual must complete a short quiz, sign a training certificate, and send the quiz and the certificate to the University Laser safety Officer (LSO). The quiz and training certification document can be found in Appendix A. A Certificate of Achievement will be issued from the LSO to each employee who has successfully completed the safety course.

1. **Annual Refresher Training**

Each employee will be required to complete annual refresher training to keep up-to-date with the latest regulations and University policies. The ORC safety department will assist you in meeting this requirement.

Section 2 – The Unique Nature of Laser Radiation

A. Introduction to Lasers

LASER is an acronym, which stands for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. Laser light is a form of electromagnetic radiation (Figure 1). Lasers produce light by a process that involves changes in energy states within the atoms of certain materials. Atoms that have been promoted to higher energy states release this energy in the form of light by a process called *stimulated emission*. The laser light is amplified by reflecting it back and forth in the lasing medium with a pair of mirrors. The laser light is then released in a stream or pulse through the partially transmitting mirror at one end of the cavity. The color of laser light is normally expressed in terms of the laser's wavelength. The most common unit used in expressing a laser's wavelength is a nanometer (nm). There are one billion nanometers in one meter.

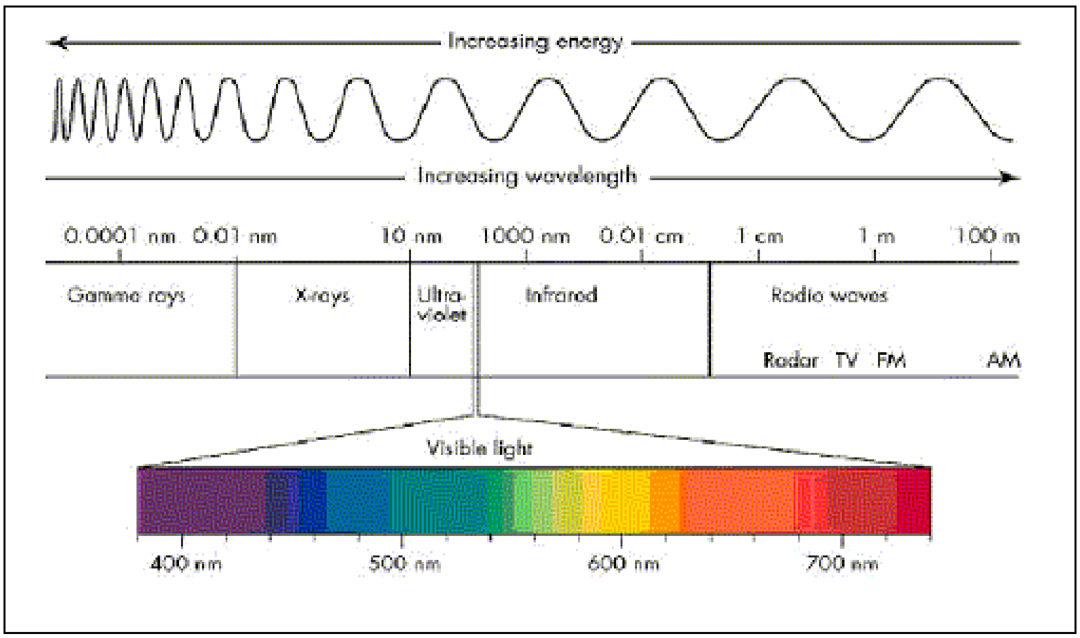


Figure 1 Electromagnetic Spectrum

B. Characteristics of Lasers

Laser light emitted from a laser has fundamental characteristics, which distinguishes it from natural light. Laser produced light is extremely *intense, coherent, monochromatic* and highly *collimated*. Wavelengths are typically released in the portion of the electromagnetic spectrum that extends through the ultraviolet, visible, and infrared regions.

1. Intensity

Laser light contains a high concentration of energy per unit area of the beam. Lasers that emit only a few milliwatts (mW) of power can produce a highly intense beam 1-2 millimeters in diameter that will not diverge over a very long distance. Although lasers produce highly intense light, only a few types of lasers are truly powerful because intensity is defined as power per unit area. By comparison, an ordinary light bulb is more powerful than a typical laser, but the light is not collimated and consequently spreads out. For example, the light irradiance from a 1 mW He-Ne laser can be ONE BILLION TIMES greater than that from a 100 W incandescent light bulb.

2. Coherency

Ordinary light is incoherent or out of phase; light waves start at different times and move in all directions. Laser light, however, is coherent because it is the result of stimulated emission. All the waves produced by the laser are lined up or in phase with each other (Figure 2). The crests and troughs of each wave line up exactly and reinforce each other. The new light wave starts out exactly in phase with the photon that stimulated it.

3. Monochromaticity

Unlike ordinary light, which is composed of all the colors of the spectrum, laser light is composed of only one color. All the light waves in the beam are composed of the same wavelength. Each laser produces its own characteristic color of light. Some lasers are tunable and can be adjusted to produce several different colors, but they can emit only one color at a time. Laser light is approximately 10 million times more monochromatic than conventional light sources.

4. Collimation

Because laser light is coherent it is highly collimated or directional. Laser beams are narrow, travel in virtually parallel lines, and will not spread out or diverge as light from most normal sources. Because of this small divergence the intensity of laser light, unlike ordinary light, is fairly constant over long distances. This property of lasers significantly increases the hazard potential of the beam. The beam can be easily focused to a small point by a simple lens, dramatically increasing the energy concentration of the beam.

Reflections, however, reduce the collimation of the laser beam and result in beam divergence. Laser beams are reflected to some extent from all surfaces. If the reflecting surface is mirror-like, the reflection is termed *specular*. The reflection is called *diffuse* if the reflecting surface is rough. The spreading is greater when the reflection is from a rough or diffuse spreading surface.

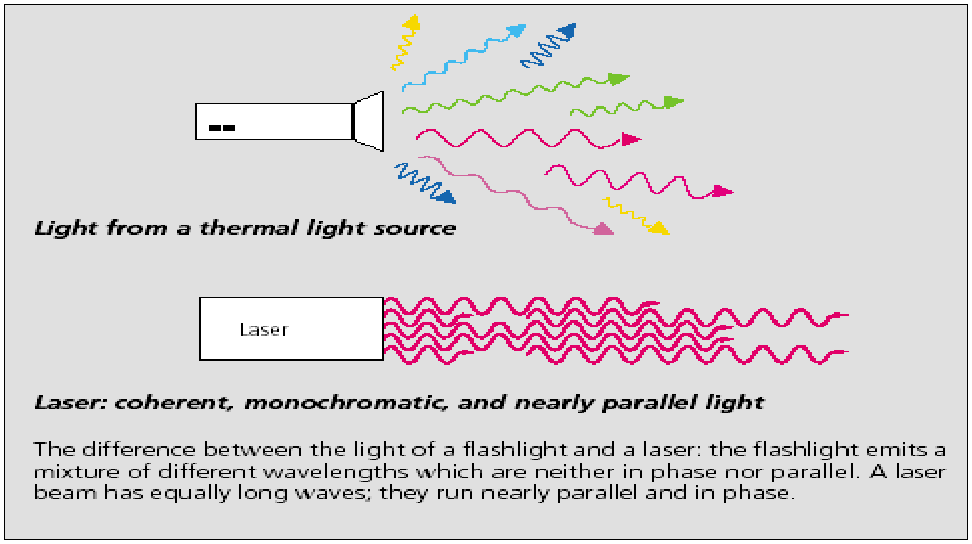


Figure 2 Characteristics of laser light

Section 3 – Understanding the Laser

A. Basic Operation of the Laser

The basic operating concept of the laser is very simple (Figure 3). Laser light is produced by changes in the energy levels of electrons. Under normal conditions electrons occupy the lowest energy state in an atom, known as the ground state. Electrons, however, can move from one energy level to another by the absorption or emission of energy.

For the laser to work, more electrons must be at an excited state than in a ground state (population inversion). Energy must be pumped into the system to excite the lasing material and promote electrons to higher energy states. Although electrons can absorb energy from a variety of external sources, two methods are most commonly used. The first occurs when an electron absorbs the energy from a photon of light. The laser may be optically pumped from sources such as flash lamps. The excess energy causes the electrons to jump to a higher energy level, resulting in an excited or metastable state. Electrons absorb only those photons that contain the exact amount of energy needed to pump it to another energy level. In gas lasers, electrons are pumped to higher energy states by an electrical discharge. In this method, energy is supplied by collisions with electrons that have been accelerated to a specific energy. In addition to optical and electrical energy, some lasers are also pumped by chemical and nuclear energy.

Once in a higher energy state the atom can return to the ground state by releasing excess energy as heat or light. The wavelength of light released is approximately equal to the energy difference between the excited and ground states. When these electrons descend to their ground state, photons of specific (monochromatic) wavelength are emitted in a process called *spontaneous emission*. Light emitted from phosphorescent materials is an example of spontaneous emission. These materials are excited to higher energy states by light from the sun or a lamp. Photons are released when the electrons drop to a lower energy level. Because the source of energy usually contains many wavelengths, the electrons can be excited to several energy levels. The released photons will be out of phase and composed of different wavelengths.

In 1917, Einstein theorized that a photon released from an excited atom could trigger another excited atom to release an identical photon. These two photons could trigger other atoms to release photons, resulting in a cascade of photons. All of these photons would be of the same frequency, energy, direction, and in phase with the original triggering photon. This process is termed *stimulated emission*. The more atoms that can be brought into an excited state, the greater the probability of stimulated emission. A population inversion occurs when the number of atoms in an excited state is greater than in the ground state.

The key component in making the laser operate properly is the optical cavity. The purpose of the optical cavity is to provide optimal amplification and stability for the laser beam. Most of the stimulated photons strike the walls of the optical cavity and are lost. However, those photons that are released in a direction parallel to the optical cavity can interact with other atoms causing further stimulated emissions.

By placing mirrors at the end of the optical cavity, photons are reflected back and forth into the lasing medium; dramatically increasing the number of photons. The mirrors must be highly reflective and all scattering from other surfaces in the cavity must be kept low. In a typical laser, one mirror is flat with a reflectance greater than 99.9%. The other mirror is curved with a reflectance of 99% and a transmission of 1%. The beam emerges from the partially transmitting curved mirror. The lasing action will continue as long as energy is supplied to the lasing medium.

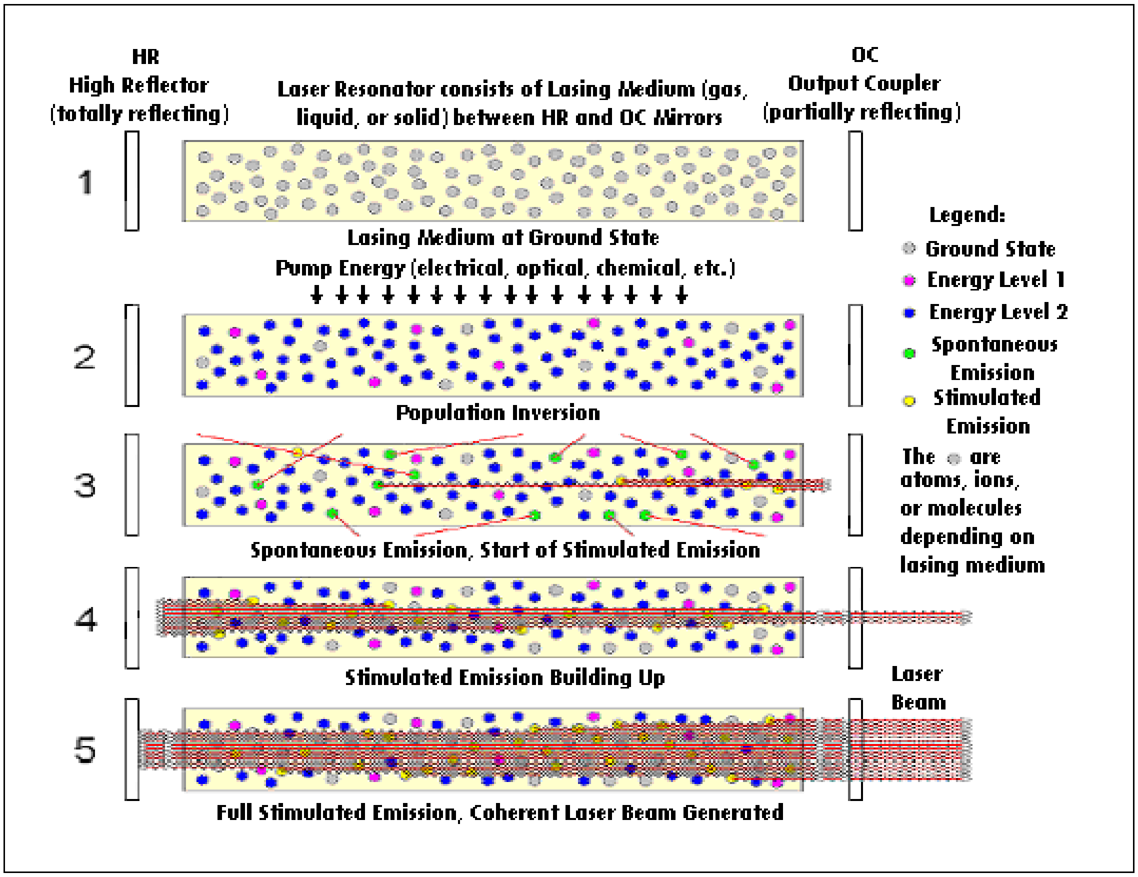


Figure 3 Laser Operation

B. Types of Lasing Media

The lasing medium is a substance that can be stimulated to an excited state by the addition of energy. The substance must be transparent to the light it produces and able to exist in a metastable state. The lasing medium may be a solid (state), gas, dye (suspended in a liquid), or semiconductor. See Appendix D for a listing of laser types (media) typically in use.

1. Solid State

This type of laser contains a solid lasing medium embedded with atoms of the lasing material. Solid state lasers, because of a higher density of lasing atoms, can produce more power output per unit volume than gas lasers. One method of exciting the atoms in lasers is to illuminate the solid laser material with higher-energy light than the laser produces. This procedure, called pumping, is achieved with brilliant strobe light from xenon flash tubes, arc lamps, or metal vapor lamps.

The first material used to make a laser was a synthetic ruby crystal. This crystal is made from aluminum oxide into which a small amount of chromium oxide has been added as an impurity. The chromium acts as the active material in the laser and a xenon flashtube surrounds the crystal. One end of the rod-shaped crystal is silvered and the other end is partially silvered. A burst of light from the flashtube excites the chromium atoms and raises them to an excited state, creating a population inversion. Some of the excited atoms release the excess energy in the form of light photons and return to the ground state. The photons travel between the reflecting ends of the rod and trigger other excited atoms through stimulated emission to release photons, which results in an avalanche of photons. This stream of photons is discharged through the partially mirrored end in a pulse of coherent light. The entire sequence takes only a few milliseconds.

Another example of a solid state laser is the Neodymium: YAG (yttrium aluminum garnet) laser. The neodymium is added as an impurity to the YAG crystal. The YAG laser is the most common type of crystal laser in use today. Like the ruby crystal, the YAG laser is pumped by a flash lamp and can emit continuous beams or pulses. Continuous power outputs range from a few milliwatts to greater than 100 watts. Pulsed energies can result in power levels of 5,000 megawatts per pulse.

2. Gas

The lasing medium of a gas laser can be a pure gas, or a mixture of gases. Gas lasers produce highly coherent light when an electric current is passed through the medium. The most common type of gaseous laser is the helium-neon. This laser is commonly used at construction sites, in teaching laboratories, and supermarkets. The helium-neon laser is constructed of a long tube filled with helium and neon under low pressure. A few milliamps of direct current applied at several kilovolts is used to excite the helium atoms. The helium atoms in turn excite the neon atoms to a higher energy state by means of electron collisions and create a population inversion. Neon atoms fall to the ground state and release excess energy in the form of a light photon. Photons travels back and forth between the reflecting end mirrors and stimulate other neon atoms to release light photons. This results in a continuous stream of laser light known as a continuous wave. A bright beam of visible red light emerges from the exit mirror. The helium-neon laser can emit light continuously for thousands of hours. However, they are extremely inefficient, converting only 0.1% of the input energy to the laser beam.

Other examples of gaseous lasers include argon, krypton, and carbon dioxide lasers. Argon and krypton both emit a wide range of wavelengths, mostly in the visible region. The two gases can be mixed to generate most of the visible spectrum. Argon lasers are commonly used both in industry and research and krypton-argon lasers are typically used in light shows

The most powerful continuous wave laser is the carbon dioxide laser. It can continuously emit powers from less than a watt to hundreds of kilowatts. Carbon dioxide lasers can also produce extremely short pulses of even higher powers. The laser is pumped by an electrical discharge and emits invisible far-infrared light.

Carbon dioxide lasers operate slightly differently from other lasers. Instead of raising electrons to higher energy levels, the energy used to excite carbon dioxide atoms causes the atoms to vibrate at a different energy level. The carbon dioxide laser is widely used in the medical field and in industry to drill, cut, and weld materials because of its high power, high efficiency (up to 30%) and its ease of removing excess heat.

3. Excimer

The excimer laser is another example of a gaseous laser. An excimer is a molecule that can exist only in an electronically excited state. The excimer state does not exist in nature and exists for only a few nanoseconds in the laboratory. Electrons deposit energy in the laser gas causing an inert gas (argon, krypton, or xenon) to react with a halogen (chlorine, bromine, fluorine, or iodine) to form an excimer. The excimer then breaks up into its constituent atoms and releases the excess energy as light. These lasers are important because they can produce powerful pulses in the ultraviolet region. Excimer lasers are used both in the medical field and in industry applications.

4. Dye Lasers

Many liquid organic dyes will lase if pumped with ultraviolet light. The dyes are dissolved in a liquid such as alcohol to form a solution. The energy levels of the dyes are spaced so close together that they form a continuum. This allows the dye molecules to release a wide range of wavelengths, mostly in the visible spectrum. The most important characteristic of a dye laser is its tunability. A single wavelength in the dye's range can be selected or several dyes can be mixed to create a laser that can be tuned across the entire visible range. Dye lasers can also produce extremely short pulses of light.

5. Semiconductor Lasers

Lasing action can, under certain circumstances, be initiated by passing an electric current through a semiconductor. Semiconductor lasers, also known as diode lasers, are characterized by their small size, small power, high efficiency, and long life. A diode laser operates predominantly through stimulated emissions. These devices are composed of tiny semiconductor crystals in which the end facets have been cut to reflect light. The diode laser is pumped by a high intensity electric current and a very small amount of light of a desired frequency is produced which stimulates an excited electron to fall to a lower energy state, giving off laser light. Unlike other lasers, beam divergence is high, and output power is measured in microwatts. Semiconductor lasers are made chiefly from gallium arsenide or gallium aluminum arsenide. These lasers are used in laser printers, video disks, audio disks, and fiber optics communication systems.

C. Mode of Operation

Lasers can operate in one of the following three modes:

1. Continuous Wave (CW)

Continuous wave lasers produce a steady stream of photons. Energy is pumped into the system at a rate that equals the light output. Beam characteristics are easily measured because the laser has reached a steady state condition. While most CW lasers use a gas medium, they can be constructed in a wide variety of lasing materials. An extensive array of wavelengths may be produced. The He-Ne laser was the first CW laser. Power levels can range from a few milliwatts for He-Ne lasers to several kilowatts for carbon dioxide lasers.

The output power in a continuous wave laser beam is measured in watts. The power density of a beam, also called irradiance or flux, is defined as watts per square centimeter (W/cm^2). It is calculated from the output power of the beam and the beam diameter. Power densities can vary from a few watts to hundreds of watts per square centimeter.

2. Pulsed

These lasers release their energy in highly concentrated pulses of light. The pulse can be created by chopping a small portion of a continuous wave beam mechanically or electrically, or by pumping with short intense flashes of light. The energy is concentrated in small bursts delivered in 0.1 to 10 milliseconds per pulse. Pulsed lasers can damage biological tissues by mechanical blast interactions. Even low energies in the ocular focus region (0.4 to 1.4 um) can produce retinal damage. Pulsed beams can also be created by chemical means. Terms associated with pulsed beams are choppers, Q-switched, and mode locked. An example of a laser operating in the pulsed mode is the ruby laser.

The term used to evaluate a pulsed beam is output energy; measured in joules. The joule is equal to the power in watts multiplied by the time in seconds. The energy intensity or radiant exposure within a pulsed beam is expressed in joules per square centimeter (J/cm^2).

3. Q-Switching

Extremely high power levels can be obtained by using a technique known as "Q-switching" that momentarily stores excess energy. A shutter is placed in the optical path to prevent laser emission until a very large population inversion has built up. When the shutter is opened the electrons rapidly fall to the ground state releasing a tremendous pulse of energy that lasts only a few nanoseconds. Powers in the megawatt range can be produced by this technique. Q-switching is commonly used with ruby and neodymium solid lasers.

Section 4 – Classification

A. Laser Classification

Since August 1976 Federal law has required manufacturers to properly classify and label lasers. Thus, for most lasers, measurements or calculations to determine the hazard are not necessary. In addition, the laser safety standards establishes certain engineering requirements for each class and requires warning labels that state the maximum output power. Lasers are classified according to the ability of the primary or reflected beam to injure the eye or skin. The appropriate class is determined from the wavelength, power output, and duration of pulse (if pulsed). There are four laser classes, with Class 1 representing the least hazardous. All lasers, except Class 1, must be labeled with the appropriate hazard classification.

1. Class 1 laser

A Class 1 laser is a laser that is incapable of emitting laser radiation in excess of 0.4 microwatts (μW). This applies to very low power devices such as those in some semi-conductor diode lasers. Class 1 laser devices cannot produce damaging radiation levels to the eye even if viewed accidentally. Prolonged staring at the laser beam however, should be avoided as a matter of good practice. A completely enclosed laser of a higher classification is categorized as a Class 1 laser if emissions from the enclosure cannot exceed Class 1 limits. Some of these include laser videodisc players, laser printers, and optical fiber communication systems. If the enclosure is removed during repair, control measures for the class of laser contained within are required.

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

2. Class 2 – Low Power Lasers

Class 2 lasers are incapable of causing eye injury within the duration of the blink, or aversion response (0.25 sec). Although these lasers cannot cause eye injury under normal circumstances, they can produce injury to the retina of the eye if viewed directly for a prolonged period of time. Class 2 lasers are therefore considered to pose a *theoretical* hazard but not a *realistic* hazard in most situations. Class 2 lasers only operate in the visible range (400 nm to 700 nm) and have power outputs between 0.4 uW and 1 mW for CW lasers. The majority of Class 2 lasers are helium-neon devices.

In industrial settings, Class 2 lasers are typically used for alignment or to mark the path of more powerful invisible lasers. This application is readily used in the medical setting as well.

3. Class 3 – Medium Power Lasers

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

Class 3a

Class 3a lasers are similar to the Class 2 devices and cannot damage the eye within the duration of the blink or aversion response. However, injury is possible if the beam is viewed using collecting optics or by staring at the direct beam. Class 3a lasers emit energy within the visible spectrum but have power outputs between 1.0 and 5.0 mW. They also include some wavelengths in the ultraviolet and infrared regions as long as the power output is not more than five times the maximum power output of a Class 1 laser. Visible CW HeNe lasers, such as laser pointers, are an example of this class. Class 3a lasers must be operated in a location where access to the beam can be controlled with the potential for viewing of the direct or specularly reflected beam minimized.

Class 3b

Class 3b lasers include any continuous-wave device with power outputs above 5.0 mW and less than or equal to 500 mW. These lasers can produce accidental injuries to the eye from viewing the direct beam or a specularly reflected beam. Except for higher power Class 3b lasers, this class will not produce a hazardous diffuse reflection unless viewed through collecting optics. Additional performance requirements and safety measures must be taken to provide protection from the energy emissions of these lasers. Some of these precautions include appropriate eye protection for the wavelength being used, beam controls (safety interlocks, enclosures, barriers, etc.), and emergency procedures.

State regulations require registration of Class 3b lasers. In addition, there must be clearly defined Standard Operating Procedures (SOP), and documented training of all personnel involved in the operation of Class 3b lasers. Contact the LSO for more information on the proper methods and requirements for using Class 3b lasers.

4. Class 4 – High Power Lasers

Class 4 lasers are the most hazardous lasers. The primary hazards to the skin and eyes come from direct beam exposure, and specular and diffuse energy reflections. In addition, Class 4 lasers can ignite flammable targets, create hazardous airborne contaminants and usually contain a potentially lethal high voltage supply. The power output for CW lasers operating in all wavelength ranges is greater than 500 mW. All pulsed lasers operating in the ocular focus region (400 nm to 1400 nm) should be considered Class 4. Most research, medical, and surgical lasers are categorized as Class 4.

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

Section 5 – Biological Effects of Laser Light

A. Eye Injury Potential

The most common area for laser beam damage is the eye. The eye is relatively unique because of its structural fragility. In addition, with some lasers, the eye actively focuses the incident beam onto the retina creating a hazardous concentration of laser energy.

The biological effects of laser light on the eye depend predominantly upon wavelength and power output. Laser energy cannot damage a tissue unless it can both reach and be absorbed in that tissue. For this reason, light rays in the visible and near infrared bands of the spectrum will be transmitted through the clear media of the eye and strike the retina (Figure 4). This energy can be amplified as much as 100,000 times causing significant damage to the areas of the retina responsible for acute vision. The high-resolution area of the retina, called the macula, has a center, the fovea, which is the size of only fractions of a square millimeter. If either of these small areas is damaged as a result of hazardous energy exposure, significant vision loss will occur.

More powerful lasers (Class 3b and 4) can cause damage to tissues in the anterior portion of the eye without reaching the retina. Apart from the retinal area in the eye, the other areas that can be damaged by selective absorption of laser energy are the cornea and lens.

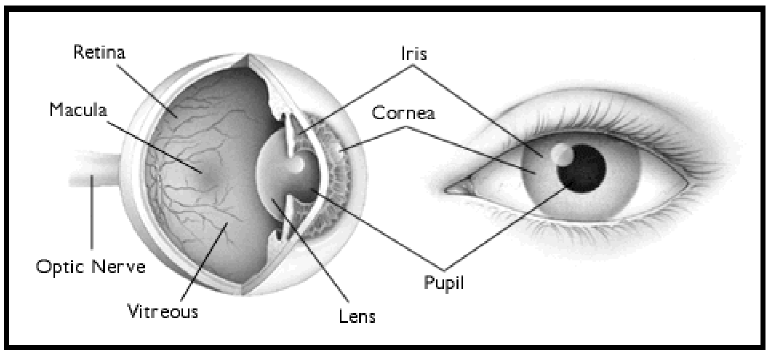


Figure 4 Eye Component Diagram

The cornea is a living membrane, very thin and only composed of epithelial cells over a supporting matrix. There is no blood supply and, because of this, the epithelial cells have no defense system and are easily damaged thermally and mechanically. If corneal injury is minor, then re-growth of epithelium can occur without any permanent abnormality. If more extensive injury occurs, then corneal scarring may ensue with loss of the capacity of the cornea to conduct clear images.

The ocular lens does not have an active turnover, and is not repairable by body mechanisms. Over the course of repeated minor injury, or indeed, one major injury, the lens may become progressively more opaque, leading to the condition known as cataract formation. While this is a process frequently seen with aging, it is accelerated by exposure to certain light energies including lasers.

The potential location of injury in the eye is directly related to the wavelength of the laser radiation. For laser radiation entering the eye:

- Wavelengths in the visible to near infrared spectrum (400 – 1400 nm) can cause damage to the retina.

- Wavelengths in the ultraviolet (200 – 400 nm) spectrum or longer than 1400 nm in the infrared spectrum can cause damage to the cornea and/or to the lens.

Examples of biological effects from different wavelengths of light are shown in Table 1.

Electromagnetic Spectrum Region	Wavelength Range	Affected Organ
Ultraviolet	**200 – 400 nm**	**Cornea, Lens, Skin**
UV - C	**200 – 280 nm**	**Cornea & Conjunctiva**
UV - B	**280 – 315 nm**	**Cornea & Conjunctiva (cataract formation)**
UV - A	**315 – 400 nm**	**Lens (cataract formation)**
Visible Light	**400 – 780 nm**	**Retina**
Near Infrared	**780 – 1400 nm**	**Retina, Lens, Skin**
IR - B	**1.4 – 3.0 μm**	**Cornea & Skin**
IR - C	**3.0 – 1.0 mm**	**Cornea & Skin**

Table 1 Laser Output Wavelengths And Organs Affected

Although the retina can repair minor damage, major injury to the macular region of the retina may result in temporary or permanent loss of visual acuity or blindness. Injury to the cornea by ultraviolet exposure may result in photokeratoconjunctivitis (often called welders flash or snow blindness). This painful condition may last for several days and is very debilitating. Long term UV exposure can cause cataract formation in the lens..

The duration of exposure also plays a role in eye injury. For example, if the laser is a visible wavelength (400 to 700 nm), the beam power is less than 1 mW and the exposure time is less than 0.25 second (the human aversion response time), no injury to the retina would be expected to result from an intrabeam exposure. Class 1 and 2 lasers fall into this category and do not normally present a retinal hazard. Unfortunately, intrabeam or specular reflection viewing of Class 3b or 4 lasers and diffuse reflections from Class 4 lasers may cause an injury before the aversion response can protect the eye.

Although one of the main mechanisms for natural eye protection is the blink reflex (aversion response) and is the major reason the He-Ne laser pointers do not cause eye injury. It must be remembered that some individuals do not have a blink reflex, due to neuro-muscular problems with the eye, and therefore are at serious risk from this laser exposure.

B. Skin Injury Potential

Laser radiation injury to the skin is normally considered less important than injury to the eye, despite the fact that injury threshold for the skin and eyes are comparable, except in the minimal hazard region (400 – 1400nm). In the far infrared and far ultraviolet spectrum region where optical radiation is not focused on the retina, skin injury thresholds are approximately the same as corneal injury thresholds.

Obviously the possibility of exposure of the skin is greater than the eye because of its greater surface area. Injury to the eye is considered of greater significance since functional loss of the eye is more debilitating than with the skin.

Injury thresholds resulting from exposure of less than 10 seconds to the skin from far infrared and far ultraviolet radiation are very superficial and may involve changes to the outer dead layer of the skin. A temporary skin injury may be painful if sufficiently severe but will eventually heal often without any sign of injury. Burns to larger areas of the skin are far more serious as they may lead to serious loss of body fluids. Hazardous exposure of large areas of the skin is unlikely to be encountered in normal laser work.

A sensation of warmth resulting from the absorption of laser energy normally provide adequate warning to prevent thermal injury of the skin for almost all lasers except some high power far infrared lasers. Exposure to UV lasers has been shown to cause long term delayed effects such as accelerated skin aging and skin cancer. Such effects may occur from long-term exposure to radiation from UV lasers.

Skin injuries from lasers primarily fall into two categories: thermal injury (burns) from acute exposure to high power laser beams and photochemically induced injury from chronic exposure to scattered ultraviolet laser radiation.

- Thermal injuries can result from direct contact with the beam or specular reflections. These injuries (although painful) are usually not serious and are normally easy to prevent through proper beam management and hazard awareness.

- Photochemical injury may occur over time from ultraviolet exposure to the direct beam, specular reflections, or even diffuse reflections. The effect can be minor or severe sunburn, and as stated, prolonged exposure may promote the formation of skin cancer. Proper protective eyewear and clothing may be necessary to control UV skin and eye exposure.

Section 6 – Laser Beam Hazards and Control Methods

A. General Considerations

The primary hazard associated with the laser is eye injury caused by intrabeam viewing or the viewing of specular or diffuse reflections. Hazard controls are primarily intended to prevent the laser beam from entering the eye or contacting the skin. These control methods are divided into three areas: administrative controls (signs, labels, SOP procedures, etc.), engineering controls (barriers, beam blocks, interlocks, etc.), and personal protective equipment (laser protective eyewear, skin covering, etc.).

Experience has shown that reliance on any one of these control methods is not as effective as using a combination of the methods. For this reason, the SIU Laser Safety Program requires the use of a broad range of controls.

B. Administrative Controls

Administrative controls are useful in promoting laser safety in the laboratory and clinical environment. Each specific SOP provides information on the administrative controls to be used for the laser.

1. Standard Operating Procedures (SOP)

The Laser Safety Program requires the development, documentation, and use of SOPs for alignments, maintenance and normal operations. These SOPs are the logical place to document in-house administrative controls. The SOPs should then be used to train laser users in the facility.

It must be stressed that administrative controls will not positively impact the laser safety environment unless they are kept up-to-date and are reinforced by the P/PI through example and action.

2. Posting and Labeling of Laser Systems

The posting and labeling of laser hazards on campus is intended to comply with the IDNS 32 Ill. Adm. Code Part 315 regulations which require the following:

All access doors to rooms that contain Class 3b or 4 lasers are to be posted with a sign marked with the word "DANGER", the international laser symbol; the laser sunburst and a description of the laser Class. See Figure 5 and 6 for sign requirements.

- For a Class 3b laser, the words “LASER RADIATION – AVOID DIRECT EXPOSURE TO THE BEAM” must be listed above the tail of the sunburst.
- For a Class 4 laser, the words “LASER RADIATION – AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION” must be listed above the tail of the sunburst. Examples are also shown in Appendix IV of the Laser Safety Manual.

A room containing more than one laser may include information for several lasers on the same sign. For some Class 3b or 4 laser systems, the Laser Safety Committee (LSC) may require that an interlocked lighted sign (that blinks on and off when the laser is operating) be located outside of the laser facility to further warn staff of the presence of laser radiation.

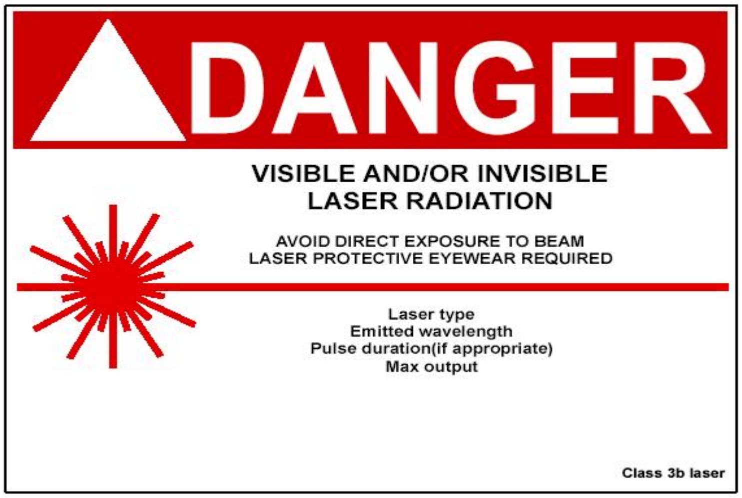


Figure 5 Class 3b Laser Sign

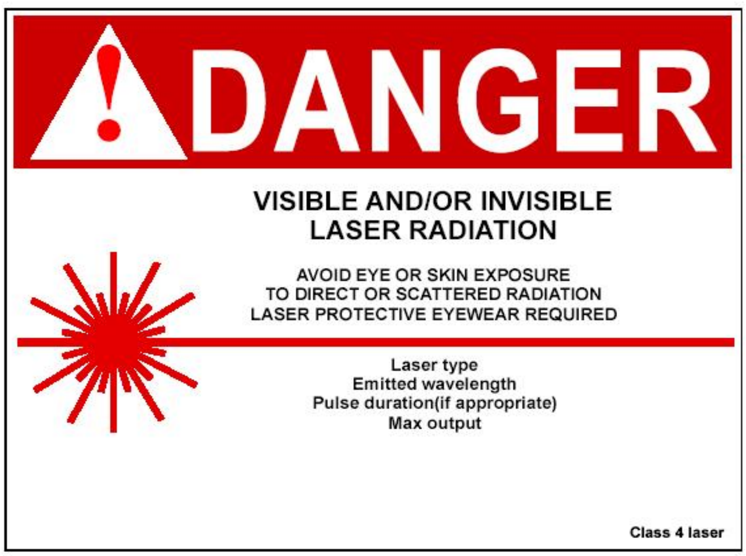


Figure 6 Class 4 Laser Sign

B. Engineering Controls

Engineering controls are the priority means of minimizing the possibility of accidental exposures to laser hazards. If engineering controls are impractical or inadequate, then safety should be supported through the use of administrative procedures and personnel protective equipment. Engineering controls that may prove useful and effective in improving the safety of a laser system are provided in this section.

1. Controlling Access to Laser Facilities

All Class 3b and 4 laser facilities are required to have appropriate access controls to prevent unauthorized personnel from entering the facility while the laser is in operation. Key or combination locks are appropriate for this purpose. Doorways to laser facilities are to be kept closed at all times, and locked when the laser user is not in direct attendance. The LSC may require that the doorways to the laser facility be properly interlocked to the laser shutter if it becomes apparent that locked doors alone can not meet access control requirements. If a door interlock is required, it must not be disabled except with the approval of the LSC.

2. Protective Housings, Interlocks and Shutters

All Class 3b and 4 lasers are required to have a non-combustible protective housing sufficient to contain the beam and excitation device. It is strongly recommended that the housing be interlocked so that the laser cannot normally be operated with the cover removed. If a housing interlock is required, it must not be disabled except with the approval of the LSC.

Most Class 3b and 4 lasers are equipped with a shutter mechanism that prevents the beam from leaving the housing when activated. If the laser has a shutter, it is not to be disabled except with the approval of the LSC.

3. Key Operation, Power On Indication, and Power Meters

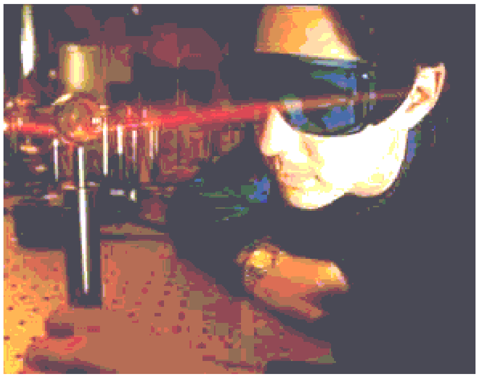
Many laser systems are equipped with key switches that prevent operation when the key is removed. If a key switch is required, it must not be disabled except with the approval of the LSC. In order to prevent unauthorized personnel from operating the laser, the key should be removed from the laser control and stored in a secure location whenever the laser is not being used.

All class 3b and 4 lasers need to have a lighted "power on" indicator clearly visible to persons in the laser facility. The "power on" indicator should be interlocked to prevent the laser from being operated if the indicator is not functioning.

It is highly recommended that each laser system have a power meter available to measure the operating power of the laser.

4. Optical Tables, Beam Alignment and Remote Viewing Systems

Most research laser use entails the use of optical tables and optical devices to manipulate beams. To assure a safe laser-operating environment, the optical components and the optical table environment must be evaluated for hazards. The primary intent of this evaluation is to prevent the laser beam from leaving the tabletop. Optical components must be aligned and properly secured to assure beam control. Be aware of secondary reflections from optical devices by performing physical surveys and assure all stray beams are properly contained.



Beam height should be planned to avoid eye level (both standing and sitting) in the laser facility. In situations where the beam needs to be directed to another area, it is important to consider enclosing the beam, using fiber optics, or directing the beam well above eye level as a precaution against accidental exposure. Beams being directed between optical tables must employ a properly marked physical barrier to prevent personnel contact with the beam.

Beam alignment is the most hazardous aspect of laser use and most laser eye injuries occur during alignments. For this reason beam alignment, as described in the SOP must be carefully thought out, documented, and users properly trained on the procedures. Beam alignment should be performed at the lowest visible beam power. Alignments are normally performed by carefully fixing a diffuse reflecting card in the beam path, turning the beam power up slowly until the beam can just be imaged and carefully aligning the optical components. If the beam is invisible, UV or IR cards or viewers may be required to image the beam.

NOTE: IR and UV viewers do not protect the eye and must be used with appropriate laser eye protection.

If the beam power cannot be reduced, it is recommended that a low powered alignment laser (Class 2/3a HeNe or diode) be used to align the optics. The user is required to use appropriate laser protective eyewear during the alignment procedure. This eyewear will normally be of minimal optical density at the wavelength of interest. This will enable viewing of a diffuse reflection of the beam while providing some protection from a momentary specular reflection (intrabeam viewing is not allowed). Alignments must be done so that the user is never looking directly into the beam.

When possible, it is advisable to have two users work together when performing alignments to remind each other of safety considerations. One of the safest methods to use for viewing the beam is the use of a remote camera system. Remote viewing, although expensive, virtually eliminates eye hazards associated with alignment procedures.

5. Enclosures, Beam Barriers, Beam Stops and Collimators

Whenever possible, enclose as much of the beam as possible without interfering with the application. Enclosures do not have to be sophisticated, but must contain the beam safely and be marked to indicate the presence of the beam inside the enclosure. By totally enclosing the beam, you may eliminate the need for other safety precautions. For example, you might effectively change a Class 4 laser system into a Class 1 system with proper enclosures and interlocks. Be careful not to use combustible enclosure materials with Class 4 laser systems.

Another effective and versatile tool for reducing the hazard from stray laser radiation is the use of beam barriers or beam curtains to surround all or part of the laser system or optical bench. Labyrinth designs can be used to limit the hazard while maintaining ready access to laser systems. Be sure the barrier materials will reduce the beam power below the MPE and do not use combustible barrier materials with Class 4 laser systems. For exposed beam paths, appropriate beam stops must be used behind optical devices used to change the direction of the beam. The use of these stops will prevent the beam from leaving the table should the beam become misaligned. Again, do not use combustible beam stops with Class 4 laser systems.

Beam collimators or tubes can be useful in restricting the path of the beam should misalignment occur. Many optical devices have a metal ring surrounding the device that will act as a beam collimator. All optical supports, collimators, etc. should be surfaced, treated, or painted so as to reduce the potential for specular reflections.

6. Beam Condensation, Enlargement and Focusing

Manipulation of the beam diameter will change the hazard from intrabeam exposure. For example, beam enlargement will reduce the irradiance or radiant exposure level, but will increase the probability of scattering due to the enlarged cross section of the beam as it passes through optics.

A focused beam will present a greatly increased hazard at the focal point, but will expand quickly past the focal point, substantially reducing the irradiance or radiant exposure level (as compared to the initial beam).

7. Beam Filtration, Nonlinear Optics and Pumping Lasers

Beam power and other characteristics may be manipulated through the use of filtration devices. Do not rely on filters to reduce or eliminate beam hazards unless they are expressly designed for that purpose. Be aware that prolonged exposure to laser radiation may bleach filter devices, changing their absorption and their ability to reduce hazards.

Nonlinear optics used to manipulate the frequency of the incident laser radiation are now extremely common. The use of these optics may present multiple laser wavelengths on the optical bench top. All laser wavelengths must be considered when assessing hazards. The issue of multiple wavelengths also applies to the use of lasers to pump other lasers and amplifiers. Whenever possible, it is advisable to enclose unused beams (of differing wavelengths) to limit the number of laser hazards.

8. Preventing and Controlling Reflections

Any item placed in the beam path may result in a specular or diffuse reflection of the laser beam. For this reason, it is important to restrict the items on the optical bench to those intended to manipulate the beam path. Good housekeeping should not be overlooked as a source of laser hazard control. Tools, unused optical devices, and other items should not be left on the optical table.

For invisible beams, the nature of reflection and absorption at the particular wavelength should be considered in order to adequately control reflections on various surfaces.

Section 7 – Ancillary Hazards and Control Methods in Research Labs

A. Toxic Dye Hazards

The fluorescent dyes (used with dye lasers) can present substantial hazards due to their toxicity. Some of these dyes are suspected of being carcinogenic or mutagenic. The solvents used for mixing the dyes may be flammable, toxic, or present other health hazards. Material Safety Data Sheets (MSDS) on dyes or solvents are available from the manufacturer or by contacting the

SIU – Environmental Health and Safety (EHS).

Because the dyes normally come in a dry powder form, they are readily dispersible and should be handled and mixed with great care. A lab coat, disposable gloves, safety glasses or goggles, and a properly functioning chemical fume hood must be used when handling or mixing the dyes. Good housekeeping should be maintained before, during, and after the mixing. Use double containment adequate to contain the entire volume of the dye solution when they are being mixed, stored, and used. Clean up any spills immediately using the appropriate protective equipment. Contact EHS if you need additional information.

B. Hazards from Laser Generated Air Contaminants (LGAC)

LGACs are byproducts of the interaction of usually high-powered lasers (Class 3b or 4) with targeted matter. These contaminants are usually found in the vapors generated by the interaction between the beam and the target (also called the plume). Although the chemical composition of the LGACs depends upon the target, the exact type of contaminants, which will be released, is difficult to predict. Some studies suggest that the general composition of LGACs vary from toxic chemical byproducts (polycyclic aromatic hydrocarbons, hydrogen cyanide, benzene, etc.) to mutagenic agents. Adequate general and local ventilation must be utilized to avoid the accumulation of potentially toxic or hazardous fumes and vapors. PIs must coordinate activities with the LSO and EHS so that the proper engineering controls and PPE can be used to limit exposure to LGACs.

C. Cryogen Hazards

Some lasers and laser systems may require the use of cryogenic liquids (liquid nitrogen, oxygen, hydrogen, etc.). These liquids present skin and eye hazards from their extremely low temperatures and should not be handled without insulated gloves, goggles and a face shield. Clothing should have no pockets or cuffs to catch spilled cryogenics. If a spill occurs on the skin, the area should be flooded with large quantities of water.

If the cryogenic liquid is allowed to warm to room temperature, the resulting gas can expand to more than 600 times the volume in the liquid state. Once it expands to become a gas, the gas may present an additional hazard (toxic, asphyxiant, etc.). Adequate ventilation should be present in areas where cryogenic liquids are used. The specific hazards of the cryogen can be found in the MSDS. EHS should be consulted prior to the use of cryogenic liquids.

D. Compressed Gas Hazards

The use of compressed gases is common in the laser laboratory. Some lasers use either pure gases or gas mixtures as the lasing media. The high pressure of the gas translates into substantial potential energy stored in the cylinder. If this pressure is released in an uncontrolled manner (such as broken nozzle) the cylinder can become an unguided missile. Compressed gas cylinders must be properly restrained to prevent damage to the nozzle or regulator.

The gases themselves may present a variety of hazards if they leak from the cylinder. Depending on the gas, it may be toxic, corrosive, flammable, etc. Again, refer to the MSDS for detailed information to the gas in question. If the hazards are sufficient, it may be necessary to provide a gas cabinet under negative pressure to control the hazard in the case of a leak. Inform EHS if compressed gases are to be used in the laser facility.

E. High Voltage Power Hazards

The high voltage power supplies associated with laser systems have been responsible for serious injuries and electrocutions. For this reason, it is important to know the hazards associated with your laser and the laser's power supply. Capacitor systems are of particular concern because they can remain hazardous long after the main power is disconnected. Capacitor systems should be safely discharged several times with the main power off to reduce the hazard before beginning work.

Only qualified persons should perform high voltage laser or power supply maintenance or repair. As a precaution, a second person (knowledgeable in high voltage safety and CPR) should always be in attendance when high voltage work is being performed.

F. Fire and Explosion Hazards

As mentioned before, Class 4 lasers can present fire hazards. Lasers being operated in a CW mode with a beam power that exceeds 0.5 Watt can ignite or cause off gassing in combustible materials left in the beam path. Beam stops, barriers, and curtains used with Class 4 lasers must be made of non-combustible materials. All Class 4 laser use in lab areas should have an ABC Type extinguisher readily available as a fire precaution. Laser users should receive fire prevention training. Contact EHS for information on fire prevention training.

Explosion hazards in the laser lab include: the storage and use of flammable solvents and gases (both compressed and cryogenic) and the implosion potential from dewars and excitation flash lamps. Proper storage and control of these sources should reduce the potential hazard.

G. Collateral Radiation Hazards

Laser excitation systems and power supplies may produce hazardous collateral radiation of various types. These hazards are normally controlled by the equipment housings, and are usually a problem only if the protective housings are removed.

The laser excitation device may produce very intense UV/Visible/IR radiation that can be hazardous. Collateral ultraviolet radiation may injure both the eye and the skin if the exposure duration is long enough. Blue light presents a special hazard because of its ease of absorption in the retina. This "Blue Light Hazard" is thought to create photochemical injury in the retina. Exposure to any very intense visible light source can seriously degrade color vision and night vision capabilities. Exposure to these intense light sources should be carefully controlled or eliminated by leaving the housings in place.

Laser power supplies capable of creating energies greater than 15 kVp may be a source of x-rays if they contain high voltage vacuum tubes. Electric discharge excitation sources in lasers may also be a source of x-rays. Generally, these x-rays are low energy and are shielded by the equipment housings.

H. Noise Hazards

Some laser systems create significant levels of noise in the laser laboratory. If the noise level seems unpleasant or painful, contact EHS to have a noise survey done.

Section 8 – Personal Protective Equipment

A. Laser Protective Eyewear

The exclusive use of laser protective eyewear has often been stressed as the best method of eye safety in the laser laboratory. At SIU, laser protective eyewear is only one of many required laser safety control measures. In general, it is better to control laser hazards through the use of engineering controls (enclosures, beam blocks, etc.) and administrative controls (posting, standard operating procedures, etc.) rather than to rely solely on laser protective eyewear.

Enclosure of the laser equipment or beam path is the preferred method of control, since the enclosure will isolate or minimize the hazard. When engineering controls do not provide adequate means to prevent access to direct or reflected beams at levels above the MPE, it may be necessary to use personal protective equipment. Note that use of personal protective equipment may have serious limitations when used as the only control measure with higher power Class 4 lasers or laser systems. The protective equipment may not adequately reduce or eliminate the hazard and may be damaged by the incident laser radiation.

Figure 7 Protective Eyewear

The selection of appropriate laser protective eyewear is very important. Several different laser protective eyewear styles are available depending on the needs of the user (Figure 7). Eye protection may include goggles, face shields, spectacles or prescription eyewear using special filter materials or reflective coatings (or a combination of both) to reduce exposure below the MPE. Eye protection may also be necessary to protect against physical or chemical hazards.

The intensity of the beam and the ability of structures in the eye to either absorb laser energy or amplify beam power underscore the importance of using the appropriate eye protection. All Class 3b and 4 laser users must use eye protection designed for that laser's specific wavelength and optical density. The manufacturer in compliance with the ANSI Z-136.1 standard must print this information on the eyewear. Although many lasers are similar in power and design, their wavelengths may differ. For this reason, laser operators must not use protective eyewear interchangeably among different lasers. It is recommended that laser protective eyewear be color coded to the laser of concern with colored tape. This can prevent mishaps when several lasers of different wavelengths are being used.

Other factors that are important in the selection of eye protection are proper fit, comfort, and visual performance. Eyewear, which is not comfortable or is difficult to see through is not likely to be used and therefore increases the risk of exposure. Contact the LSO for additional information about the proper selection use of laser eyewear.

1. Beam Alignments

Laser protective eyewear is essential during the beam alignment process. Most laser accidents occur during beam alignments and wearing the appropriate laser protective eyewear can prevent these. The laser protective eyewear selected must allow proper viewing of the beam at or just below the MPE. Laser users commonly suffer eye injury when they remove their eyewear because they cannot properly view the beam.

B. Skin Protection

Skin effects can be of significant importance with the use of lasers emitting in the ultraviolet spectral region. The potential for skin injury from the use of high power lasers can present a potential hazard. For laser systems using an open beam, skin protection may be necessary. Covering exposed skin by using lab coats, gloves and an UV face shield will protect against UV scattered radiation. Adequate skin protection consisting of fire resistant materials may be required for certain applications using high power laser systems, such as Class 4 lasers.

Section 9 – Medical Laser Applications and Safety

A. Health Care Facilities

In addition to research applications, lasers are used for treatment, diagnoses, and/or surgical procedures in medical settings. The standard for the use of these lasers is the American National Standard for the Safe Use of Lasers in Health Care Facilities (ANSI Z136.3). This standard provides guidelines for the safe use of lasers in diagnostic and therapeutic applications in health care facilities and refers to these lasers as the entire system, and it is referred to as a Health Care Laser System (HCLS).

The HCLS pertains to the use of Class 4 and Class 3b lasers. For this reason some additional safety practices to compliment the guidelines for Class 3b and 4 lasers are necessary. These practices include engineering, procedural and administrative controls necessary for the safety of patient and health care professionals. These practices will be monitored during the bi-annual safety assessment of the laser facility.

The control measures outlined in this section are not intended to restrict or limit in any way the use of laser radiation of any type, which may be intentionally administered to an individual for diagnostic, therapeutic, or medical purposes, by or under the direction of qualified professionals engaged in health care. These qualified professionals retain the ultimate responsibility for the safe use of lasers and laser systems.

B. Clinical Environment

The Controlled Area is defined as the Nominal Hazard Zone (NHZ), the space within which the level of direct reflected, or scattered radiation during normal operation may exceed the applicable maximum permissible exposure (MPE). The Controlled Area is in most cases is the individual operating/procedure room. When an HCLS is in use, warning signs specific to the particular wavelength must be posted in view outside the room where the laser procedure is being performed. Authorized personnel, upon entry to an area where lasers are being used, should be provided with personal protective equipment.

C. Delivery Systems

The lasers commonly used in medicine today are listed below. Each has a wavelength producing unique absorption characteristics in tissue components. The wavelength determines the type of delivery system that can be used. Three types of delivery systems are in common use today:

1. Direct Delivery

With the advent of the laser diode and small gas lasers such as the HeNe, bio-stimulation lasers, laser pointers and similar devices have been developed typically with power output limited to a level where no mandatory requirement for a safety shutter to interrupt or control the laser beam is required. Laser energy is delivered directly from the emitting aperture to tissue. Output may be controlled by switching on or off via a press button or timer. Users should be aware of the power output and the need for wearing safety eyewear and protective clothing.

2. Articulated Arm

Since the carbon dioxide laser is absorbed by glass, it cannot normally be delivered through a glass fiber or make use of conventional glass lenses to focus the beam. A special articulated arm has been developed. More recent technological advances have modified delivery systems for CO_2 lasers incorporating hollow waveguides.

Because radiation from the carbon dioxide laser is invisible (far infrared) a low power, visible (typically HeNe) laser is used to designate target tissue and indicate spot size. Both the carbon dioxide and HeNe lasers are optically combined to be coincident at the laser source and propagate through the hollow arm, reflecting from special front surfaced mirrors at each joint to emerge at the distal end as a coincident, collimated beam. The articulated arm may couple to surgical accessories such as a hand piece, micromanipulator (microscope attachment), rigid fiber delivery system, waveguide or rigid endoscope. A lens in the accessory may focus the beam.

The micromanipulator and endoscopes both make use of a joystick to control a mirror and direct laser energy to the target tissue.

3. Fiber Optic

Fiber optic delivery systems have been developed in the communications industry. One fiber can simultaneously carry thousands of telephone channels interference free.

In medicine the flexible endoscope makes use of this fiberoptic technology for both vision and light source input. These same fibers can be used to deliver a number of different laser wavelengths. Argon, Nd: YAG, KTP, Holmium and Excimer lasers commonly use this technology in their delivery system.

Laser energy is focused by a lens into a glass fiber and is propagated through it by internal reflection off the fiber-cladding interface to emerge at the distal end as a divergent beam.

In the case of the Holmium and the Nd: YAG laser a HeNe aiming beam is combined with the Nd: YAG beam at the source to produce a coincident beam. The Argon and KTP lasers are visible and can be heavily attenuated to provide a visible aiming beam for the surgeon, before the higher power surgical beam is used for treatment.

Typically the fiber delivery system is used in conjunction with a rigid or flexible endoscope. A special tip is often used to provide insufflation (flow of gas or fluid) to the surgical area and reduces the risk of fiber tip contamination and keeps fiber tip cool. This system can only be used in a non-contact mode.

D. Equipment Safety Procedures

1. HCLS Calibration and Alignment

Test all lasers, delivery systems, and safety equipment prior to having the patient in the room. Appropriate eyewear should be worn during such tests. The HCLS should be calibrated in accordance with manufacturer’s directions, and if the procedure is prolonged, it may be prudent to recalibrate during treatment.

Surgical lasers should not be activated if there is a faulty aiming system due to a misaligned beam or if infrared lasers such as CO_2 and Nd: YAG is used without an aiming beam. Alignment of the beams may be checked by testing laser modes in the center of a wet tongue depressor (or other appropriate testing device) prior to surgical use.

2. Laser Hand Piece

When using the laser hand piece in a sterile field, the sterile drape on the laser hand piece should be taped at least four centimeters (cm) above the aperture of the hand piece to prevent slippage and ignition of the sterile covering.

3. Instrument Draping

The use of microscope-linked laser directing systems requires careful attention to the probability of fallout dust and debris on the surgical field. Accordingly, appropriate draping techniques should be utilized to minimize the possibility of contamination from equipment, as it is brought into sterile operating field.

4. Fibers

Examine all fibers prior to use, for breakage or damage to the distal tip, proximal connector, or catheter sheath. Calibrate fibers according to manufacturer’s directions, to verify adequate transmission of power prior to procedure. Monitor fibers for distortion of the beam, accumulation of debris on the tip, loosening of the connector, or decreased power delivery.

Fibers break or may become disconnected during surgical procedures resulting in an ocular hazard. Therefore, the laser-controlled area may be designated as the entire clinical/operating room, even if the laser output was restricted to the body cavity by an endoscope or other devices. All involved personnel within the laser-controlled area during such procedures must wear laser protective eyewear.

5. Foot Pedals

All foot-controlled switches must be covered to prevent accidental activation of the HCLS. The operator should remove his/her foot from the shutter pedal and place the laser on standby while conversing or changing position.

E. Non-beam hazards

Many of the non-beam hazards concerns that arise could be resolved at an early stage by considering the applicability of the room design where the HCLS may be located or used. For example, consideration should be given to the more appropriate local exhaust ventilation system prior to the installation of the HCLS. Highly reflecting surfaces such as mirrors should be avoided in a laser installation. Windows and viewing areas should be limited, as they may extend the NHZ beyond the room in which the HCLS is installed. Other design issues of importance are water and electrical supply, drains, and potential fire hazards.

HCLS equipment should be positioned in the room not only to address traffic patterns, but also to minimize risk of falls, trips, and injuries to laser workers, as well as damage to the laser equipment.

1. Hazards from Laser Generated Airborne Contaminants (LGAC)

The interaction of the laser beam with target materials may produce toxic dusts, vapors or gases called LGAC. This is particularly true during the performance of surgical procedures using Class 3b and Class lasers. During surgical procedures, the thermal destruction of tissue creates a smoke byproduct. Research studies have confirmed that this smoke plume can contain toxic gases and vapors such as benzene, hydrogen cyanide, and formaldehyde, bio-aerosols; both dead and live cellular material (including blood fragments), and viruses. At high concentrations the LGAC can cause ocular and upper respiratory irritation, have unpleasant odors, create visual problems for the physician, and have shown to have mutagenic, and carcinogenic potential.

Toxic products resulting from laser applications must be properly controlled through the use of adequate ventilation and filtration. Research conducted by the National Institute of Occupational Health and Safety (NIOSH) has shown airborne contaminants generated by laser surgical devices can be effectively controlled.

2. Local Exhaust Ventilation

Recommended ventilation techniques include a combination of general room and local exhaust ventilation (LEV). General room ventilation is not by itself sufficient to capture contaminants generated at the source. The two major LEV approaches used to reduce surgical smoke levels for health care personnel are portable smoke evacuators and room suction systems. The LGAC must not be re-circulated, but completely trapped within a system or vented out of the area.

Smoke evacuators contain a suction unit (vacuum pump), filter, hose, and an inlet nozzle. The smoke evacuator should have high efficiency in airborne particle reduction and should be used in accordance with the manufacturer's recommendations to achieve maximum efficiency. A capture velocity of about 100 to 150 feet per minute at the inlet nozzle is generally recommended. It is also important to choose a filter that is effective in collecting the contaminants. A High Efficiency Particulate Air (HEPA) filter or equivalent is recommended for trapping particulates. Various filtering and cleaning processes also exist which remove or inactivate airborne gases and vapors. The various filters and absorbers used in smoke evacuators require monitoring and replacement on a regular basis and are considered a possible biohazard requiring proper disposal.

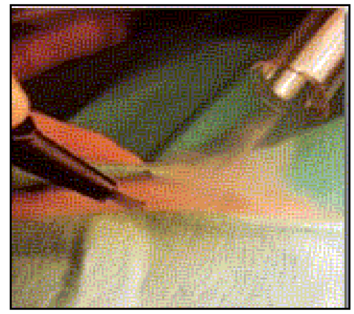


Figure 8 Effective smoke evacuation helps minimize unpleasant side-effects.

Users of smoke evacuators should realize that in addition to removal of LGAC from the surgical area, these devices will also improve the surgeon's field of view and reduce odors.

Room suction systems can pull at a much lower rate and were designed primarily to capture liquids rather than particulate or gases. Room suction may not be adequate since it may allow contaminants to escape into breathing zones. If these systems are used to capture generated smoke, users must install appropriate filters in the line, insure that the line is cleared, and that filters are disposed properly. The use of smoke evacuators is considered more effective than room suction systems to control the generated smoke from non-endoscopic laser surgical procedures

3. Smoke Evacuator Procedures

The smoke evacuator or room suction hose nozzle inlet must be kept within 2 inches of the surgical site to effectively capture airborne contaminants generated by laser surgical devices. The smoke evacuator should be ON (activated) at all times when airborne particles are produced during all surgical or other procedures. At the completion of the procedure all tubing, filters, and absorbers must be considered infectious waste and be disposed appropriately. New filters and tubing should be installed on the smoke evacuator for each procedure. While there are many commercially available smoke evacuator systems to select from, all of these LEV systems must be regularly inspected and maintained to prevent possible leaks. The LSO and EHS should be consulted whenever LGAC may result from the laser use.

4. Respiratory Protection

At present there is no suitable half-mask respirator (fitting over the nose and mouth) used for the specific purpose of excluding all laser generated plume particulates., bacteria, viruses or other irritants. Surgical masks are not designed to provide protection from plume contents. Surgical masks are intended to protect the patient from the surgeons' contaminated nasal or oral droplets. Therefore, the surgeon must rely on appropriate smoke evacuation techniques as the first line of protection for occupational exposure to LGAC.

5. Blood Borne Pathogens

LGAC can contain blood and blood by-products. Laser users need to be aware of the potential for such products during any medical/surgical procedures and utilize control measures such as universal precautions that are required by the Blood Pathogen Standard.

F. Fire and Explosion Hazards

Fire hazards associated with lasers take many forms. The most obvious is the use of flammable liquids. Oxidizing gases can also pose significant fire hazards. Not so obvious are the materials used in constructing the laser such as plastic parts and tubing that can enhance the spread of fire. Failure of electrical equipment is always a hazard as a potential source of ignition. While these forms of fire occur outside of the patient, it has to also be realized that fires can be created in patients undergoing laser surgical procedures due to the laser beam interacting with some material (i.e., methane gas in bowels, plastic tubing introduced into the airway).

When a Class 4 laser is used with drying agents, certain anesthetic preparation solutions, ointments, and plastic resins there is a potential for fire. Sponges, gauze pads, and swabs located near the operating field should be moistened with saline. Analysis of laser accidents has shown that two key considerations in the selection of a surgical drape for the use with HCLS, especially with Class 4 systems, are the flammability rating and the ability to produce LGAC.

1. Fire Control

Rooms where laser surgical procedures are performed should be equipped with a fire extinguisher that is readily accessible. In addition, an appropriate container of instantly available sterile normal saline or water should be available during the laser procedure to extinguish small fires should they occur in the vicinity of the patient or staff.

2. Endotracheal Tube Fires

When performing airway laser surgery in the presence of endotracheal tubes, the tube should have protection or special design to avoid the potential for fire. Fire hazards related to endotracheal tubes, plastic, plastic adhesive tape, ointment, and surgical preparatory solutions can be controlled by such methods as use of non-combustible instrumentation, Venturi ventilation techniques, shielding with wet substrates and use of low-combustion gas (Helox) mixtures. Anesthesia personnel should use nonflammable, specially wrapped or chemically treated (silicone) laser resistant tubes. Plastics and armored or wire tubes are particularly hazardous. FDA approved endotracheal tubes and endotracheal tube wrapping materials should be used when endotracheal anesthesia is the preferred method. Polyvinyl chloride tubes should not be used, either wrapped or unwrapped. The endotracheal tube cuffs should be inflated with liquid and externally protected with wet cloth covering.

3. Electrical Hazards

Use of any electrical system may give rise to electrical hazards, and consequently, proper grounding and insulation are imperative. For example, the potential hazard is increased during endoscopic and urological procedures in which the irrigating solution may wet the floor or equipment. Ensure that operating areas remain as dry as possible. In addition, an emergency shutoff switch must be available to the operator or the assistant to rapidly shutdown the equipment.

4. Endoscopic Delivery System

Care should be taken to avoid laser beam exposure on the sheaths of flexible-fiberoptic endoscopes since most of the sheaths are flammable. For metallic tubular delivery systems (i.e., laryngoscopes, bronchoscopes, and laparoscopes) avoid beam heating of the wall to preclude thermal damage of adjoining tissue.

H. Personal Protective Measures

Protective apparel, appropriate to the laser, must be provided to and worn by all persons entering the Controlled Area. Protective apparel worn by health care personnel may include both safety eyewear and clothing to shield skin surfaces.

1. Eye Protection

Protective eyewear must be worn of the optical density appropriate to the type of laser in use. Eye protection is available from many different manufacturers. In order to comply with the Standards for Protection Against Laser Radiation, optical density and wavelength should be clearly labeled on the protective glasses. Optical density is the critical parameter and refers to the ability of the glasses to attenuate laser energy of a specific wavelength. Users should ensure that the optical density of their protective eyewear offers adequate protection for the power of the laser in use. The protective eyewear should also offer side protection to ensure no direct path for laser energy to the eye.

At least one pair of appropriate eyewear must be maintained and be available outside of the entrance way for staff to enter the clinical room or operating theater safely during the laser procedure. Laser users in clinical areas where there is more than one laser in use (different wavelengths) must be made aware of the need to check that the protective eyewear is appropriate for the laser in use.

- **Carbon Dioxide Lasers**

  It should be noted that ordinary spectacles do not offer adequate protection against the carbon dioxide laser. Experiments conducted with certain optical lenses in conventional frames clearly show that the glass may simply shatter if exposed to a high-energy (>50 W) laser beam, offering no protection. In addition, conventional frames offer no side protection.

2. Skin protection

Skin protection is necessary whenever there is a potential hazard to the user. Usually thus means protection against thermal burns, as in the case when using high power surgical lasers such as CO_2 or YAG lasers.

Skin protection can best be achieved through engineering controls (Section 5). In some laser applications, such as when using excimer lasers operating in the UV, skin cover must be used if repeated exposures are anticipated at exposure levels at or near the applicable MPE limits for the skin. A standard surgical glove will usually provide adequate protection in the far UV. Tightly woven fabrics and other materials may be necessary in the UV-A. A surgical gown can provide protection for the arms. Consideration should be given to the fire retardant material when a fire hazard exists. The use of sun block cream may not be adequate for these UV lasers.

I. Reflection Hazards

Instruments in or near the beam path should be ebonized, anodized or have a matte (beaded or roughened) surface. Reflective surfaces likely to be contacted by the laser beam path must removed or covered with moist sponges. Water-soluble jelly or moistened sponges may be placed over the surface of the instruments to dull surface diffusing or absorbing stray energy. Accessory instruments and other objects should not be allowed to pass in front of the laser beam. Drapes and endotracheal tubes must kept at a safe distance from the operative field. Alternate forms of protection to adjacent tissue include wrapping instrument with wet sponges and packing

1. Window/Reflective Surface Barriers

All windows, doorways, and open portals should be covered or restricted, as necessary, in such a manner as to decrease transmitted laser radiation to levels at or below the appropriate MPE. The laser firing mechanism should always be aimed away from windows, doorways and/or open portals when in use. This safety procedure also applies to carbon dioxide lasers.

J. Laser Signs

Ensure the appropriate laser "Danger" signs are posted (Section 5) at all entrances and are clearly visible to anyone entering the Controlled Area. Information on the sign should include, but is not limited to the laser radiation hazard; type of laser or wavelength and Class of the laser or laser system

K. Patient Safety

Laser safety with HCLS involve another important element, THE PATIENT. Patient safety is of paramount importance and therefore all necessary measures and controls designed to protect the patient health from unintended laser energy must be taken.

It is the responsibility of the Physician or surgeon to ensure the preparation of the patient prior and after the treatment or surgical procedure. This preparation includes but is not limited to:

1. Education of the patient on basics of the laser procedures and laser specific tissue effects The patient must be prepared according to the type of laser to be used. The target area must be exposed while protecting surrounding tissue with appropriate drape materials

2. When laser procedures are done at or near the patient's face, patient eye protection requires metal and acrylic shields be placed on the top of the cornea to protect the eye during laser treatment of facial areas particularly around the eyes.

Consideration for selection of protective eyewear includes but are not limited to:

a. Site of laser treatment.
b. Type of laser.
c. Method of anesthesia.

Protective glasses may interfere and/or allow leakage of laser radiation around the edges. When a CO_2 laser is used, a double layer of saline moistened eye pads placed over the eye should provide adequate protection.

3. Drapes, sponges, gauze pads, and swabs adjacent to the operating field must be saturated with saline or water prior to use and remoistened as necessary.

4. Tips for Nd: YAG fibers are not placed in close proximity to pacemakers.

5. For oral, nasopharyngeal, and ophthalmic procedures, hair in the operative field should be coated with water soluble lubricating jelly when oxygen and/or nitrous oxide are administered.

Section 10 – Summary

You must be aware of potential radiological risks and take appropriate protective measures to minimize them. Through an enhanced awareness of radiation risks and a sense of personal responsibility for minimizing those risks, you can contribute to maintaining exposures to laser radiation. You will be asked to complete a Certificate and Quiz that consists of questions on the material covered in this module. Submit the quiz to the Laser Safety Officer for grading when completed.

Individuals must score a minimum of 80% to meet the training requirements of this safety course.

Section 11 – Appendices

A. **Laser Safety Training Certificate and Quiz**

B. **Laser Safety Guidelines**

C. **Laser safety Checklist for Patient and Room**

D. **Laser Types and Wavelengths**

E. **Glossary of Laser Terms**

F. **Laser Protective Eyewear for Alignments**

G. **Emergencies and Incident Procedures**

Appendix A

Laser Safety Training Certificate and Quiz

Name (print): _________________________________ Department: __________________

Classification (*CP/PI, Faculty, Technician, etc.*): ___________________________________

Department Chairman/Supervisor: ____________________________ Phone: ___________

Type of Laser(s) Used: ____

Location of Laser: Building: _____________ Room: _______________

Laser User Registration (LUR) Number: ____

Laser Safety Training Certification Statement

I have now read and understood the SIU Laser Safety Training Module and Laser Safety Manual and have completed the attached quiz. I have also received instruction from the Clinical Physician/Principal Investigator (or designee) in the use of the laser system, associated optics, and laser safety systems. I am aware that I am responsible for following all established SIU safety standards and SOPs and that I am responsible for my own safety in the clinical/laboratory environment.

(Signed): ____ (Dated): ___________________

Please send the completed certificate and quiz to:

Laser Safety Officer
Office of Radiological Control
1325 Radio Drive
Carbondale, Illinois 62901-6898

QUIZ INSTRUCTIONS

Please carefully read the Laser Safety Manual and Laser Safety Training Module. These materials are available electronically on the web at http://www.siumed.edu/adraf/orc.html.

Please answer every question. You are encouraged to refer to the laser safety training materials to find answers you do not know. The quiz should take from 15 to 30 minutes to complete. The expectation is that you will answer all questions correctly without the assistance of other laser users. If you do not understand a question and need assistance, please contact the Laser Safety Officer at 536-2015.

(1) Visible lasers fall into what wavelength range?

A. 700 – 1m
B. 100nm – 400nm
C. 400nm – 700nm
D. None of the above

(2) Standard Operating Procedures should include:

A. Start up and shut down procedures
B. Emergency procedures
C. Specific operations
D. All of the above

(3) Incandescent and laser light are both monochromatic:

A. True
B. False

(4) Common sense, wearing eyewear and proper clothing is considered what type of control measure?

A. Personal protective
B. Administrative
C. Engineering
D. None of the above

(5) Ultraviolet B and C, and infrared B and C effect the:

A. Cornea
B. Retina
C. Lens
D. Fovea

(6) Direct viewing and specular and diffuse reflections can cause permanent damage from what class laser?

A. Class 1
B. Class 2
C. Class 3b
D. Class 4

(7) Most laser related eye injuries occur during beam alignments.

A. True
B. False

(8) Carbon dioxide (CO_2) laser beams used in clinical settings are:

A. Invisible with a visible aiming beam
B. Red in color
C. Green in color
D. None of the above

(9) Eyewear that works at one wavelength should provide adequate protection for all other wavelengths.

A. True
B. False

(10) Laser protective eyewear should always be checked before use for any flaws or scratches.

A. True
B. False

(11) The nominal hazard zone (NHZ) in a clinical setting is normally contained in:

A. The room where the laser is used
B. 5 ft from the laser
C. 2 in. from the laser
D. None of the above

(12) Instruments in or near the path of the laser beam can reflect the beam. Instruments should be ebonized, anodized or have a matte surface or covered with a wet sponge.

A. True
B. False

(13) Patients eyes should be protected from laser injury:

A. True
B. False

(14) The laser should be in "standby" mode when not actually being used.

A. True
B. False

(15) A basin of saline water should be placed in the field during laser procedures to distinguish small fires.

A. True
B. False

(16) The most common serious risk for personnel using lasers is eye injury to the cornea or retina from direct or reflected laser beams.

A. True
B. False

(17) Beam stops must be constructed from diffusely reflecting material?

A. True
B. False

(18) Provide an answer to each of the following questions as they apply to laser wavelengths.

a. If you are using a laser with a wavelength shorter than 300nm or longer that 1400nm the beam is absorbed in what part of the eye? ________________

b. If you are using a laser with a wavelength between 315nm and 400nm, the beam is absorbed in what part of the eye? ________________

c. If you are using a laser with a wavelength between 400nm and 1400nm, the beam is absorbed in what part of the eye? ________________

(19) Maximum permissible exposure (MPE) is defined as the minimum power that can cause damage to human tissue.

A. True
B. False

(20) Protective eyewear should be comfortable, prevent hazardous radiation, and must be clearly labeled with the optical density value and wavelength(s) to indicate the level of protection provided.

A. True
B. False

(21) Long term UV exposure can cause ________________ formation in the lens of the eye.

(22) In general, it is better to control laser hazards through the use of administrative (i.e. written procedures) and engineering (i.e. beam stops, barriers) controls rather than rely solely on laser protective eyewear.

A. True
B. False

(23) All doors to rooms that contain a Class 3b or 4 lasers are to be posted with a sign marked:

A. Warning
C. Danger
D. Caution
E. None of the above

(24) For wavelengths that focus in the retina (400nm to 1400nm), the human eye has an optical gain up to?

A. 10X
B. 25X
C. 100,000X
D. 100X

(25) LGAC is the acronym for:

A. Laser Gas Air Control
B Laser Generated Air Conditioning
C. Laser Generated Air Contaminants
D. Laser Gas Amplification Condition

(26) What is the name of the campus Laser Safety Officer?

(27) In laboratory and clinical laser applications, when is protective eyewear required?

A. Class 3b and 4 lasers
B. Class 2 lasers
C. Class 3a lasers
C. All of the above
D. None of the above

(28) Laser system fires can result from:

A. Flammable solvents
B. Improper beam enclosures
C. Electrical circuits
D. All of the above

(29) 0.25 seconds is:

A. The average time it takes a laser shutter to close
B. The time it takes laser radiation to burn the skin
C. The pulse duration of most Nd: YAG lasers
D. The blink or aversion time from bright (visible) light

(30) Which of the following can be a non-beam hazard associated with laser operations?

A. Electric shock
B. Noise
C. Radiation
D. Compressed gas
E. Fire hazardous material
F. All of the above
G. None of the above

Appendix B

SIU – LASER SAFETY GUIDELINES

OPERATION GUIDELINES

1) Intrabeam viewing of laser beams is not allowed on campus.
2) Never look directly into any laser beam for any reason.
3) Enclose the laser beam path whenever possible.
4) Use appropriate laser protective eyewear for all laser beam alignments.
5) Restrict unauthorized access to laser facilities.
6) Do not operate lasers at sitting or standing eye level.
7) Shield all laser light pumping sources.
8) Remove all reflective or combustible materials from the beam path.
9) Use diffuse (non-reflective) beam stops, barriers and enclosures.
10) Use low beam power (or an alignment laser) for alignments.
11) Remove all keys from interlocks when the laser is not in operation.
12) Alert persons in the area when the beam is operating.
13) Be aware of and protect users from all non-beam hazards.
14) Never override any laser system safety interlock.

ADMINISTRATION GUIDELINES

1) Mark all laser facility entrances with a laser (Danger) hazard sign.
2) Complete, sign, and return a laser safety-training certificate to ORC.
3) Report all accidents or suspected eye injuries to ORC.
4) Inform ORC of any transfer or sale of lasers.
5) Laser facilities are inspected periodically by ORC.
6) Inform ORC of any new, modified or relocated lasers.
7) Call ORC at 536-2015 any time you need laser safety assistance.

Appendix C

SIU – Laser Safety Checklist for Patient and Room

BEFORE BRINGING THE PATIENT INTO THE ROOM:

1) Bring the laser into the clinical room or operating room and gather necessary supplies.
2) Check electrical cord integrity before plugging the laser into an appropriate wall outlet.
3) Place laser-specific signs on the outside of all doors leading into the room. On each sign, include the word “DANGER” in large, bold print; the internationally recognized symbol for laser; the wavelength and maximum wattage for each laser; the class (usually class IV); and the words “Eye protection required.”
4) Hang a pair of safety glasses outside each entrance to for anyone who needs to enter during the procedure.
5) For all lasers except the CO_2, cover all windows to prevent transmission of laser energy.
6) Bring in a smoke evacuator and check the filters.
7) Obtain the laser key from a secured storage place. Never leave the key in the laser.
8) Check to see if the circuit breaker is in the “on” position. (This depends on the laser.)
9) Turn on the laser and allow it to run through its self-check program. Note any problems displayed on the screen.
10) Calibrate the laser if required.
11) Check all buttons to ensure proper functioning.
12) If using a CO_2 laser, test fire it. (See page 27.)
13) Check accessory tanks if necessary.
14) Examine your laser safety glasses for scratches.
15) Have laser masks available for all personnel.
16) Check the foot pedal cord for loose wires. Cover the foot pedal in plastic if the laser will be used in a fluid environment.
17) Make sure water is readily available in the sterile field.
18) When the patient’s eyes will be in the sterile field, have water-based eye lubricant, wet eye pads, and wet towels ready (all sterile). If the eyes will not be in the sterile field, have safety eyewear ready.
19) Make a mental note of the location of the nearest fire extinguisher.
20) Assist anesthesia with procuring laser-safe endotracheal tubes if necessary.
21) Make sure wet towels are available for draping the surgical area.

AFTER BRINGING THE PATIENT INTO THE ROOM:

1) Offer a pair of glasses to everyone in the room.
2) Document individuals who refuse to wear safety glasses in the laser log.
3) Ensure proper use of alcohol-containing solutions.
4) Prevent escape of methane gas when needed.
5) Place the laser in standby when the physician is not actively using it.
6) Complete the laser log or the laser component of the clinical or operating room record.

Appendix D

LASER TYPES AND WAVELENGTHS

LASER MEDIA	**WAVELENGTH (nm)**
(ULTRAVIOLET)	**(100 nm - 400 nm)**
Fluorine (diatomic gas excimer)	157
Argon Fluoride (excimer)	193
Krypton Chloride (excimer)	222
Krypton Fluoride (excimer)	248
Xenon Chloride (excimer)	308
Helium Cadmium	325/354
Nitrogen	337.1
Krypton	351/356
Xenon Fluoride (excimer)	351
Argon	351/364
(VISIBLE)	**(400 nm - 700 nm)**
Helium Cadmium (blue)	442
Argon (blue)	458
Helium Selenium (tunable)	460 - 1260
Krypton (blue)	476
Argon (blue)	477
Argon (blue)	488
Rhodamine 6G (tunable dye)	500 - 650
Copper Vapor (green)	511
Argon (green)	515
Krypton (green)	531
Manganese Vapor (green)	534/1290
Helium Neon (green)	544
Erbium: YLF (green)	551
Krypton (yellow)	568
Copper Vapor (yellow)	578
Helium Neon (yellow)	594
Helium Neon (orange)	612
Gold Vapor (red)	628/312
Helium Neon (red)	633
Krypton (red)	647
Gallium Aluminum Arsenide (red diode)	670
Titanium Sapphire (tunable)	670 - 1130
Krypton (red)	676
Ruby (red)	694

(NEAR INFRARED)	**(700 nm - 1400 nm)**
Alexandrite (tunable)	700 - 815
Lead Vapor	723
Krypton	753
Chromium: LiSAF (tunable)	780 - 1010
Gallium Aluminum Arsenide (diode)	840
Calcium Vapor	852/866
Gallium Arsenide (diode)	905
Neodymium: YAG	1064/1320
Barium Vapor	1130/1500
Helium Neon	1152/3390

(FAR INFRARED)	**(1400 nm - 1 mm)**
Erbium: Glass	1540
Holmium: YLF	2060
Thulium: YAG	2010
Holmium: YAG	2100
Erbium: YAG	2490
Erbium: YSGG	2790
Hydrogen Fluoride	4000 - 6000
Carbon Monoxide	5000 - 5500
Carbon Dioxide	9.6/10.6 (um)
Water Vapor	118 (um)
Hydrogen Cyanide	337 (um)

Appendix E

Glossary of Laser Terms

Accessible exposure limit (AEL) – The maximum allowed power within a given laser classification.

American National Standards Institute (ANSI) – The technical body which releases the Z136.1 Standard for the Safe Use of Lasers. The secretariat for the Z136.X standard series is the Laser Institute of America (LIA).

Average power – The average power of a pulsed laser is the product of the energy per pulse (J/pulse) and the pulse repetition frequency (Hz or pulses/sec). The average power is expressed in Watts (J/sec).

Coherent radiation – Radiation whose waves are in-phase. Laser radiation is coherent and therefore very intense.

Continuous wave (CW) – A term describing a laser that produces a continuous laser beam while it is operating (verses a pulsed laser beam).

Diffuse reflection – When an incident radiation beam is scattered in many directions, reducing its intensity. A diffusely reflecting surface will have irregularities larger than the wavelength of the incident radiation beam. See specular reflection.

Health Care Laser System (HCLS) – Laser systems used in health care applications, and includes a delivery system to direct the output of the laser, a power supply with control and calibration functions, mechanical housing with interlocks, and associated fluids and gases required for the operation of the laser.

Intrabeam exposure – Exposure involving direct on-axis viewing of the laser beam. Looking into the laser beam would constitute intrabeam exposure. NOTE: Intrabeam viewing of lasers is not permitted on campus.

Infrared (IR) radiation – Invisible radiation with a wavelength between 780 nm and 1 mm. The near infrared (IR-A) is the 780 to 1400 nm band, the mid infrared (IR-B) is the 1400 to 3000 nm band, and the far infrared (IR-C) is the 3000 nm to 1 mm band.

Irradiance – The power being delivered over the area of the laser beam. Also called power density, irradiance applies to CW lasers and is expressed in W/cm^2.

Laser – Light **A**mplification by **S**timulated **E**mission of **R**adiation. A monochromatic, coherent beam of radiation not normally believed to exist in nature.

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 radiation hazards.

Laser User – Any person who uses a laser for any purpose on the SIU campus.

Laser Safety Manual – A document defining the SIU Laser Safety Program.

Laser Use Registration (LUR) – The mechanism used by the Office of Radiological Control to track lasers on campus. The LUR details the safety requirements for each Class 3b and 4 laser.

Laser Safety Committee (LSC)– The campus academic committee that makes laser safety policy and oversees the Laser Safety Program.

Laser Safety Officer (LSO) – A member of the ORC staff, the LSO is responsible for implementation of the Laser Safety Program.

Maximum permissible exposure (MPE) – The maximum level of radiation which human tissue may be exposed to without harmful effect. MPE values may be found in the IDNS Standard.

Material Safety Data Sheet (MSDS) – A document, required by law, which is supplied by the manufacturer of a chemical. The MSDS details the hazards and protective practices required for protection from those hazards, as well as other information.

Nominal hazard zone (NHZ) – The area surrounding an operating laser where access to direct, scattered or reflected radiation exceeds the MPE.

Optical density (OD) – Also called transmission density, the optical density is the base ten logarithm of the reciprocal of the transmittance (an OD of 2 = 1% transmittance).

Office of Radiological Control (ORC) – The Department responsible for implementation of the SIUSOM Laser Safety Program.

Peak power – The highest instantaneous power level in a pulse. The peak power is a function of the pulse duration. The shorter the pulse, the greater the peak power.

Plume – Aerosol created by vaporization of tissue or metals that may contain viable bacteria, virus, cellular debris, or noxious and possibly toxic metallic fumes.

Physician/Principal investigator (P/PI) – The person directly responsible for the laser and its use. The CP/PI has direct responsibility for all aspects of safety associated with the operation of laser systems in either the clinical or laboratory environment.

Radiant exposure – The energy being delivered over the area of the laser beam. Also called energy density, radiant exposure applies to pulsed lasers and is expressed in J/cm^2.

Specular reflection – Results when an incident radiation beam is reflected off a surface whose irregularities are smaller than the radiation wavelength. Specular reflections generally retain most of the power present in the incident beam. Exposure to specular reflections of laser beams is similar to intrabeam exposure. See diffuse reflection and intrabeam exposure.

Standard Operating Procedures (SOP) – A procedure that explains operating and safety practices specific to a laser or laser system.

Ultraviolet (UV) radiation – Invisible radiation with a wavelength between 10 nm and 400 nm. The near ultraviolet (UV-A) is the 315 to 400 nm band, the mid ultraviolet (UV-B) is the 280 to 315 nm band, the far ultraviolet (UV-C) is the 100 nm to 280 nm band, and the extreme ultraviolet is the 10 to 100 nm band.

Visible Light – Radiation that can be detected by the human eye. These wavelengths are between 400 and 780 nm. The colors (with approximate wavelengths) are: Violet (400 – 440 nm), Blue (440 – 495 nm), Green (495 – 545 nm), Yellow (545 – 575 nm), Orange (575 – 605 nm), and Red (605 – 780 nm).

Appendix F

Laser Protective Eyewear for Alignments

The Office of Radiological Control occasionally receives requests on selecting laser protective eyewear for alignment purposes. The information below should be helpful. If you have additional questions on laser protective eyewear or any other laser safety issue, please contact the LSO at 536-2015.

- Even if you are wearing laser protective eyewear, **never look directly into any laser beam.** Intrabeam viewing of lasers is not allowed except with the direct permission of the Laser Safety Committee. Contact the Laser Safety Officer if you feel that aligning your laser requires intrabeam viewing.

- The Standard Operating Procedure (SOP) document for each laser indicates if laser protective eyewear is required for alignment or use of the laser. If laser protective eyewear is required, the SOP specifies the OD (optical density) at the laser wavelength(s) being used. The OD specified is the minimum OD sufficient to protect the user against a momentary intrabeam or specular reflection exposure.

- For visible lasers, the minimum OD required to protect the user against intrabeam viewing should allow the viewing of a diffuse spot on a light colored surface. If the laser protective eyewear has an OD much larger than the specified minimum OD, it may be impossible to properly view a diffuse beam spot (or even see properly in the laser facility).

- In some instances (visible lasers from 400 – 450 nm and 650 – 700 nm), it may be preferable to reduce the OD below the specified intrabeam minimum OD to better view a diffuse spot. Reducing the OD by 1 or 2 should substantially improve viewing while still offering adequate eye protection (the intrabeam OD has a x10 safety margin calculated into the value which includes the human aversion (blink) response). Reducing the specified OD by a number greater than 2 may reduce the protection factor enough to allow eye injury should a specular reflection be viewed accidentally.

- For invisible lasers, the minimum OD for intrabeam viewing should not be reduced, as OD reduction will not aid in viewing the beam. Instead, the laser protective eyewear should be chosen to allow the wavelength produced by the viewing aid to be transmitted while absorbing the invisible beam. For example: a Nd:YAG beam at 1064 nm is being aligned with the use of an IR sensing card which absorbs some of the 1064 nm radiation and emits radiation at 550 nm. The calculated intrabeam OD for the Nd:YAG is 6.0. A good choice for laser protective eyewear would be a goggle with a UVEX type 06 filter. This goggle has a visible light transmission of 70% and should allow the diffuse spot to be easily viewed while giving excellent protection from the invisible Nd:YAG beam.
  NOTE: This eyewear would obviously not be a good choice if the Nd:YAG beam was frequency doubled to 532 nm.

- All laser protective eyewear should have a visible light transmission (VLT) sufficient to allow safe operation in the laser facility. It is recommended a VLT of at least 35% is appropriate. Laser protective eyewear with a low VLT will generally not be worn by users and so cannot provide any protection.

Appendix G

EMERGENCIES AND INCIDENT PROCEDURES

<u>EMERGENCIES</u>

For any emergency requiring police, fire or ambulance assistance, call 9-911.

EMERGENCIES OR INCIDENTS INVOLVING LASERS

In the event of an accident or unusual incident involving a laser: TURN OFF THE LASER.

If there is a serious injury or fire, call 9-911 and request paramedics or the fire department.

Notify the Laser Safety Officer or Office of Radiological Control (ORC) at 536-2015. If after working hours, contact University Police at 453-3771.

Notify the Physician or Principal Investigator.