TEXAS STATE UNIVERSITY

RADIATION SAFETY

LASER OPERATOR TRAINING

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OBJECTIVES

IDENTIFY what the acronym LASER means and briefly DESCRIBE how a laser performs it function. (EHSRM.011.OBJ.01)

LIST the characteristics of a laser beam. (EHSRM.011.OBJ.02)

DIFFERENTIATE between a Continuous Wave Laser and a Pulsed Laser. (EHSRM.011.OBJ.03)

LIST the five types of lasers and briefly DESCRIBE their attributes. (EHSRM.011.OBJ.04)

IDENTIFY the American National Standards Institute Laser Classifications. EHSRM.011.OBJ.05

LIST three areas in which lasers have been used. EHSRM.011.OBJ.06

DESCRIBE the two common types of laser pointers. EHSRM.011.OBJ.07

LIST the criteria used by the FDA to determine laser pointer classification and the required labeling on each class of laser pointer. EHSRM.011.OBJ.08

IDENITFY the primary mechanisms of tissue injury associated with laser radiation exposure. EHSRM.011.OBJ.09

MATCH the specified laser wavelength to the part of the eye that is most affected. EHSRM.011.OBJ.10

IDENTIFY the three basic categories of controls used in laser environments to provide a degree of protection from possible laser radiation injury and GIVE several examples of each type of control. EHSRM.011.OBJ.11

IDENTIFY other non-beam hazards that are possible in laser environment and GIVE an example of each. EHSRM.011.OBJ.12

IDENTIFY the Texas Administrative Codes applicable to laser operations and the purpose of each. EHSRM.011.OBJ.13

IDENTIFY the purpose of select excerpts of 25TAC§289.301. EHSRM.011.OBJ.14

MATCH the following laser related terms to their corresponding meaning:
- Accessible Exposure Limit
- Diffuse Reflection
- Intrabeam Exposure
- Irradiance
- Maximum Permissible Exposure
- Nominal Hazard Zone
- Specular Reflection
- Radiant Exposure
- Peak Power
- Optical Density

EHSRM.011.OBJ.15

I. TxState | San Marcos Laser Safety Program

- This manual is intended to give the reader a basic understanding of lasers and laser safety. The TxState laser Safety Program requires users to read and use the information in this manual.

- Laser Safety Manual
  Your Principal Investigator has a copy of the Texas State University Laser Safety manual available for your reference. You should review this document prior to starting work with any classification of laser.

- 25 TAC §289.301 Registration and Radiation Safety Requirements for Lasers
  Your Principal Investigator has a copy of the Texas Department of State Health Services, Bureau of Radiation Control document available for your reference. This document is also available for your reference on line at: <http://www.dshs.state.tx.us/radiation/pdffiles/301fn_04.pdf >

II. Laser Characteristics

IDENTIFY what the acronym LASER means and briefly DESCRIBE how a laser performs it function. (EHSRM.011.OBJ.01)

Laser, acronym for light amplification by stimulated emission of radiation. Lasers are devices that amplify light and produce coherent light beams, ranging from infrared to ultraviolet. A light beam is coherent when its waves, or photons, propagate in step with one another. Laser light, therefore, can be made extremely intense, highly directional, and very pure in color (frequency). Laser devices now extend into the X-ray frequency range. See Appendix A for a glossary of common laser terms.

The basic operating concept of the laser is simple. Electrons in the atoms of the lasing medium are moved from a ground state into a higher energy state by absorbing energy from an energetic excitation source. For a laser to work, more electrons must be in an excited state than in a ground state. When these electrons descend to their ground state, photons of a specific wavelength are emitted in a process called “spontaneous emission.” These photons are allowed to oscillate inside a mirrored resonator. This increases the laser radiation intensity through stimulating the emission of additional photons with the same wavelength and phase. Finally, the photons are allowed to escape via an output coupler as an intense laser beam.

LIST the characteristics of a laser beam. (EHSRM.011.OBJ.02)

Lasers harness atoms to store and emit light in a coherent fashion. The electrons in the atoms of a laser medium are first pumped, or energized, to an excited state by an energy source. They are then "stimulated" by external photons to emit the stored energy in the form of photons, a process known as stimulated emission. The photons emitted have a frequency characteristic of the atoms and travel in step with the stimulating photons. These photons in turn impinge on other excited atoms to release more photons. Light amplification is achieved as the photons move back and forth between two parallel mirrors, triggering further stimulated emissions. The intense, directional, and monochromatic laser light finally leaves through one of the mirrors, which is only partially silvered.

Laser light has the following properties.

- The light released is monochromatic. It contains one specific wavelength (color) of light. The light wavelength is determined by the amount of energy released when the electron drops to a lower orbital.
- The light released is coherent. It is “synchronized”, each photon moves in step with the others. This means that all of the photons have wave fronts that launch in unison.
- The light is directional. A laser light has a very tight, strong, concentrated beam. It can traverse great distances without diffusing. A flashlight on the other hand releases its light in many directions and is therefore very weak and diffuse.

Differentiate between a Continuous Wave Laser and a Pulsed Laser. (EHSRM.011.OBJ.03)

Continuous Wave Lasers - a laser whose output is operated in a continuous mode for at least a period of .25 seconds. Continuous Wave Lasers are expressed as the average power (watts). An important factor in determining the hazard of a continuous wave laser is the irradiance (power density) of the laser beam. Irradiance is normally expressed in W/cm^2 and is a function of the beam power divided by the beam area. Beam area is dependent upon: the beam size at the aperture, the divergence (spreading) of the beam and the distance from the aperture. Focusing or defocusing the laser will dramatically affect the irradiance. The greater the irradiance the greater the potential hazard.

Pulsed Lasers **-** a laser that delivers energy in the form of a single pulse or train of pulses, which is delivered in less than .25 seconds. These lasers cannot be characterized by their irradiance and we instead refer to their radiant exposure (energy density) that is expressed in $joules/cm^2$. Radiant energy is a function of power density, pulse duration, and pulse frequency. The greater the radiant exposure the greater the potential hazard.

Section II Review:

1. Laser, acronym for ____.

2. Lasers are devices that _____________ ____________ and produce coherent light beams, ranging from infrared to ultraviolet.

3. Lasers harness atoms to ____________ and ____________ light in a coherent fashion.

4. Irradiance is normally expressed in W/cm^2 and is a function of the

   ___________ ____________ divided by the _____________

   _____________.

5. Radiant energy is a function of power ____________, ____________

   duration, and pulse ___________________.

CHECK YOUR ANSWERS

LIST the five types of lasers and briefly DESCRIBE their attributes. (EHSRM.011.OBJ.04)

III. Laser Types

Based on the laser medium used, lasers are generally classified as solid state, gas, semiconductor, or liquid.

- Solid State
  The most common solid laser media are rods of ruby crystals and neodymium-doped glasses and crystals. The ends of the rod are fashioned into two parallel surfaces coated with a highly reflecting nonmetallic film. Solid-state lasers offer the highest power output. They are usually operated in a pulsed manner to generate a burst of light over a short time. Bursts as short as 12×10^{-15} seconds have been achieved, useful in studying physical phenomena of very brief duration. Pumping is achieved with light from xenon flash tubes, arc lamps, or metal-vapor lamps. The frequency range has been expanded from infrared (IR) to ultraviolet (UV) by multiplying the original laser frequency with crystal-like potassium dihydrogen phosphate, and X-ray wavelengths have been achieved by aiming laser beams at an yttrium target.

- Gas Lasers
  The laser medium of a gas laser can be a pure gas, a mixture of gases, or even metal vapor and is usually contained in a cylindrical glass or quartz tube. Two mirrors are located outside the ends of the tube to form the laser cavity. Gas lasers are pumped by ultraviolet light, electron beams, electric current, or chemical reactions. The helium-neon laser is known for its high frequency stability, color purity, and minimal beam spread. Carbon dioxide lasers are very efficient, and consequently they are the most powerful continuous wave (CW) lasers.

- Liquid (Dye) Lasers
  The most common liquid laser media are inorganic dyes contained in glass vessels. They are pumped by intense flash lamps in a pulse mode or by a gas laser in the CW mode. Tunable dye lasers are a type for which frequency can be adjusted with the help of a prism inside the laser cavity.

- Excimer Lasers
  The name is derived from *excited* and *dimers*. Use reactive gases such as chlorine and fluorine mixed with inert gases such as argon, krypton, or xenon. When electrically stimulated, a pseudomolecule or dimer is produced and when lased produces light in the ultraviolet range.

- Semiconductor Lasers
  The most compact of lasers, the semiconductor laser usually consists of a junction between layers of semiconductors with different electrical conducting properties. The laser cavity is confined to the junction region by means of two reflective boundaries. Gallium arsenide is the most common semiconductor used. Semiconductor lasers are pumped by the direct application of electrical current across the junction, and they can be operated in the CW mode with better than 50 percent efficiency. A method that permits even more-efficient use of energy has been devised. It involves mounting tiny lasers vertically in such circuits, to a density of more than a million per square centimeter. Common uses for semiconductor lasers include compact audio digital disk (CD) players and laser printers.

- Types of Excitation Sources
  Flash lamps, plasma discharge tubes, high voltage current and radio frequency devices are all energy sources used to excite the lasing media. Some laser beams are used to "pump" (excite) other lasers (liquid dyes, Ti-Sapphire, etc.). It is important to remember that the excitation device itself can present a serious non-beam hazard (radiation, electrical, etc.).

Section III Review:

1. _____________ - ____________ lasers offer the highest power output.

2. ______________ ______________ lasers are very efficient, and consequently they are the most powerful continuous wave (CW) lasers.

3. The most common liquid laser media are ______________ ______________ contained in glass vessels.

4. Common uses for _______________________ _________________ lasers include compact audio digital disk (CD) players and laser printers.

5. ____________ lamps, plasma discharge tubes, ____________

   ____________ current and ____________ frequency devices are all energy

   sources used to excite the lasing media.

CHECK YOUR ANSWERS

IDENTIFY the American National Standards Institute Laser Classifications. (EHSRM.011.OBJ.05)

IV. Laser Classifications

ANSI and LIA Classification **-** The American National Standards Institute (ANSI Z136.1-2000) has developed four categories of hazard potential. The classification scheme is based on the ability of optical emissions from a laser system to produce injury to personnel. The higher the classification number, the greater the hazard potential. The Laser Institute of American (LIA) Laser Safety Guide describes each class as follows:

- <u>Class I</u>
  Denotes lasers or laser systems that do not, under normal operating conditions, pose a hazard. Typically continuous wave (cw) 0.4 mW at visible wavelengths. Since lasers are not classified on beam access during service, most Class I Industrial lasers will consist of a higher class laser enclosed in a properly interlocked and labeled protective enclosure.

- <u>Class II</u>
  Denotes low-power visible light (400 to 700 nm) lasers or laser systems that, because of the normal human aversion response (i.e. blinking, eye movement, etc.), do not normally present a hazard, but may present some potential for hazard if viewed directly for extended periods of time (similar to many conventional light sources). A Class II laser emits above Class I levels (0.4 mW) but at a radiant power $\leq$1 mW.

- <u>Class IIIA</u>
  Denotes an intermediate power laser (cw: 1 to 5 mW). Lasers or laser systems that normally would not injure the eye if viewed for only momentary periods (within the aversion response period (0.25 seconds)) with the unaided eye, but may present a greater hazard if viewed using collection optics. Class IIIA lasers must carry a caution label. Another group of Class IIIA lasers have DANGER labels and are capable of exceeding permissible exposure levels for the eye in 0.25 seconds and still pose a low risk of injury.

- <u>Class IIIB</u>
  Denotes a moderate power laser (cw: 5 to 500 mW). Lasers or laser systems that will produce eye damage if viewed directly. This includes intrabeam viewing of specular reflections. Normally, Class IIIB lasers will not produce a hazardous diffuse reflection nor will they be a fire hazard.

- <u>Class IV</u>
  Denotes a high power laser (cw: 500 mW, pulsed: 10 J/cm^2). Lasers or laser systems that produce retinal damage from direct or specular reflections, but may also produce hazardous diffuse reflections. Such lasers may produce significant eye and skin radiation hazards as well as fire hazards.

Section IV Review:

1. Class I denotes a laser or laser system that does not, under _______________ _______________ conditions, pose a hazard.

2. Class II denotes low-power ____________ ____________ laser or laser system that, because of the normal human aversion response, does not normally present a hazard.

3. Class IIIA denotes an intermediate power laser or laser system that normally would not injure the eye if viewed for only _______________ _______________ with the unaided eye.

4. Class IIIB denotes a moderate power laser or laser system that will produce eye damage if _______________ _______________.

5. Class IV denotes a high power laser or laser system that produce retinal damage from _______________ or _______________ reflections, but may also produce hazardous ________________ reflections.

CHECK YOUR ANSWERS

LIST three areas in which lasers have been used.
(EHSRM.011.OBJ.06)

V. Laser Applications

- Industry
  Lasers have become valuable tools in industry, scientific research, communication, medicine, the military, and the arts. Powerful laser beams can be focused on a small spot with enormous power density. Consequently, the focused beams can readily heat, melt, or vaporize material in a precise manner. Lasers have been used, for example, to drill holes in diamonds, to shape machine tools, to trim microelectronics, to heat-treat semiconductor chips, to cut fashion patterns, to synthesize new material, and to attempt to induce controlled nuclear fusion. The powerful short laser pulse also makes possible high-speed photography with an exposure time of several trillionths of a second. Highly directional laser beams were also used for alignment in the construction of the Bay Area Rapid Transit system in San Francisco.
  Lasers are used for monitoring crustal movements and for geodetic surveys. They are also the most effective detectors of certain types of air pollution. In addition, lasers have been used for precise determination of the earth-moon distance and in tests of relativity. Very fast laser-activated switches are being developed for use in particle accelerators, and techniques have been found for using laser beams to slow down atoms for extremely precise studies of their spectra.

- Scientific Research
  Because laser light is highly directional and monochromatic, extremely small amounts of light scattering or small frequency shifts caused by matter can easily be detected. By measuring such changes, scientists have successfully studied molecular structures of matter. With lasers, the speed of light has been determined to an unprecedented accuracy, chemical reactions can be selectively induced, and the existence of trace substances in samples can be detected.

- Medicine
  Intense, narrow beams of laser light can cut and cauterize certain tissues in a small fraction of a second without damaging the surrounding healthy tissues. They have been used to "weld" the retina, bore holes in the skull, vaporize lesions, and cauterize blood vessels. Laser techniques have also been developed for lab tests of small biological samples.

- Military
  Laser guidance systems for missiles, aircraft, and satellites are being studied and constructed. The use of laser beams has been proposed against hostile ballistic missiles, as in the defense system urged by President Ronald Reagan in 1983. The ability of tunable dye lasers to excite selectively an atom or molecule may open up more efficient ways to separate isotopes for construction of nuclear weapons.

- <u>Communication</u>
  Laser light can travel a large distance in outer space with little reduction in signal strength. Because of its high frequency, laser light can carry, for example, 1000 times the television channels today carried by microwaves. Lasers are therefore ideal for space communications. Low-loss optical fibers have been developed to transmit laser light for earthbound communication in telephone and computer systems. Laser techniques have also been used for high density information recording. For instance, laser light simplifies the recording of a hologram, from which a three-dimensional image can be reconstructed with a laser beam. Lasers are also used to play audio compact disks and videodiscs.

DESCRIBE the two common types of laser pointers. EHSRM.011.OBJ.07

- <u>Laser Pointers</u>
  Pointers are not dangerous when used with care, but the brightness of laser light can damage the eyes of anyone who looks directly into the beam for more than a minute and a half. A split-second look can result in a condition called flash blindness. This is similar to the effect you get during flash photography, where the image of the flash remains in your eyes for a few seconds, and then fades away. The effect is temporary. Your vision returns to normal after a few moments, and there are no long-term effects.

  However, a longer look can cause serious damage to your eyes. It's worse if the laser beam is being projected through a piece of optical equipment, such as a telescope or a pair of binoculars. In these situations, the laser beam could actually burn a tiny spot, or cut open a blood vessel, on the retina at the back of your eye. In a worst-case scenario, you could go blind

  The most common laser pointers are red, they come in 3 standard wavelengths:

Wavelength	Range in Total Darkness	Comments
670 nm	1000 ft (300 m)	rarely sold today, the cost of manufacture is only slightly less than that of a 650nm pointer
650 nm	2000 ft (600 m)	adequate for most purposes
635 nm	4000 ft (1220 m)	useful outdoors (unless the sun is shining brightly) and wherever the brightest possible indoor beam is required

A second common laser pointer new to the market is green. The green laser has a wavelength of 532 nm, which the eye is much more sensitive to than the red lasers. That is the reason for the exceptionally brilliant visibility of the green beam. The generator of the green laser beam is what is called a "frequency-doubled" diode, which means that it is an infrared diode with a frequency of 1064nm (2 X 532). When approximately 500mW of power is passed through a crystal the resulting power of the green laser beam is only a few mW because the crystal conversion efficiency is very low.

LIST the criteria used by the FDA to determine laser pointer classification and the required labeling on each class of laser pointer. EHSRM.011.OBJ.08

The FDA regulates laser pointers according to their power output, not by wavelength. The cost of manufacture of a 1 mW diode is nearly the same as a 5mW diode. As a result, almost all pointers are rated at just less than 5 mW INPUT (Class IIIa) in order to achieve maximum brightness while meeting FDA requirements. Class II pointers are used only for special electronic applications or to avoid the FDA requirements for a WARNING label.

Power Output	**Class**	**Labeling**
< 1 mW	II	CAUTION label
1 – 5 mW	IIIa	WARNING label

Section V Review:

1. List three areas that lasers have been used.

2. Laser pointers are __________ ______________ when used with care, but the brightness of laser light can damage the eyes of anyone who looks directly into the beam for more than _____________________.

3. The most common laser pointers are ____________, they come in ____________ standard wavelengths.

4. The green laser has a wavelength of _______________, which the ____________ is much more sensitive to than the red lasers.

5. The FDA regulates laser pointers according to their ____________ ____________, not by wavelength.

CHECK YOUR ANSWERS

VI. Biological Effects of the Laser Beam

IDENITFY the primary mechanisms of tissue injury associated with laser radiation exposure. (EHSRM.011.OBJ.09)

- Tissues at Risk and Mechanisms of Injury
  The tissues that are normally considered to be at risk are the eyes and the skin. There are three primary mechanisms of tissue injury associated with laser radiation exposure. These are: thermal effects, photochemical effects, and acoustical transient effects (eye only).

  Thermal effects can occur at any wavelength and are a function of the irradiance or radiant exposure and blood flow cooling potential of the tissue.

  In air, photochemical effects occur between the 200 to 400 nm ultraviolet and the 400 to 470 nm “blue light” wavelengths. Photochemical effects are related to the duration and repetition of the exposure as well as related to the irradiance or radiant exposure.

  Acoustical transient effects are related to pulse duration and may occur in short duration pulse (up to 1 ms), depending on the specific wavelength of the laser. The acoustical transient effect is poorly understood, but it can cause retinal damage that cannot be accounted for by thermal injury.

MATCH the specified laser wavelength to the part of the eye that is most affected. (EHSRM.011.OBJ.10)

- Eye Injury Potential (Appendix C)
  Because of the high degree of beam collimation, a laser serves as an almost ideal point source of intense light. A laser beam of sufficient power can theoretically produce retinal intensities at magnitudes that are greater than conventional light sources, and even larger than those produced when directly viewing the sun. Permanent blindness can result.

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

  Wavelengths shorter than 300 nm or longer than 1400 nm are absorbed in the cornea.

  Wavelengths between 300 and 400 nm are absorbed in the aqueous humor, iris, lens, and vitreous humor.

  Wavelengths between 400 and 1400 nm are focused on the retina.

Laser retinal injury can be severe because of the focal magnification (optical gain) of the eye that is approximately 10^5. This means that an irradiance of 1 mW/cm^2 entering the eye will be effectively increased to 100 W/cm^2 when it reaches the retina.

Thermal burns (lesions) in the eye are caused when the choroids layer blood flow cannot regulate the heat loading of the retina. Secondary bleeding into the vitreous humor may occur as a result of burns that damage blood vessels. This bleeding can obscure vision well beyond the area of the lesion.

- Skin Injury Potential

Skin injuries from lasers fall primarily 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 direct beam, specular reflections, or even diffuse reflections. The effect can be minor or severe sunburn, and prolonged exposure may promote the formation of skin cancer. Proper protective eyewear and clothing may be necessary to control UV skin and eye exposure.

- Other

Other damage mechanisms have been demonstrated for specific wavelength ranges and/or exposure times. For example, photochemical reactions are the principal cause of threshold tissue level damage following exposures to either actininc ultraviolet radiation (200 nm to 315 nm) for any exposure time or “blue light” visible radiation (400 to 550 nm) when exposure times are > 10 seconds.

To the skin, UV-A (315 to 400 nm) can cause hyperpigmentation and erythema.

Exposure to UV-B range is most injurious to the skin. In addition to the thermal injury caused, there is the possibility of radiation carcinogenesis from UV-B (280 to 315 nm) either directly on DNA or from effects of potential carcinogenic intracellular viruses.

Exposure in the shorter UV-C (200 to 280 nm) and longer UV-A ranges seems less harmful to human skin. The shorter wavelengths are absorbed in the outer dead layers of the epidermis and the longer wavelengths have an initial pigment darkening effect followed by erythema if there is exposure to excessive levels.

Table 1
Summary of Laser Radiation Effects on the Eye & Skin

Photobiological Spectral Domain	Eye Effects	Skin Effects
UV-C (200 to 280 nm)	Photokeratitis	Erythema (sunburn)
UV-B (280 to 315 nm)	Photokeratitis	Accelerated skin aging Increased pigmentation Skin cancer
UV-A (315 to 400 nm)	Photochemical UV cataract	Pigment darkening Skin burn
Visible (400 to 780 nm)	Photochemical and thermal retinal injury	Photosensitive reactions Skin burn
Infrared A (780 to 1400 nm)	Cataract, retinal burns	Skin burn
Infrared B (1400 to 3000 nm)	Corneal burn Aqueous flare IR cataract	Skin burn
Infrared C (3000 to 10^6 nm)	Corneal burn	Skin burn

Section VI Review:

1. The tissues that are normally considered to be at risk are the _______________ and the ____________.

2. Thermal effects can occur at any wavelength and are a function of the irradiance or radiant exposure and ____________ ___________cooling potential of the tissue.

3. In air, photochemical effects occur between the 200 to 400 nm ____________ and the ________ to _______ nm "blue light" wavelengths.

4. The acoustical transient effect is poorly understood, but it can cause ____________ ____________ that cannot be accounted for by thermal injury.

5. Laser retinal injury can be severe because of the ______________ _______________ of the eye that is approximately 10^5.

6. Thermal injuries can result from ____________ ___________ with the beam or ______________ reflections. These injuries, although painful, are usually not serious and are normally easy to prevent through proper ____________ _____________ and _____________ ____________.

CHECK YOUR ANSWERS

VII. Laser Safety

Laser safety is the responsibility of each individual who works with and in the vicinity of lasers. There are three basic categories of controls useful in laser environments. These are engineering controls, administrative and procedural controls, and personal protective equipment. Relying on a single category to provide all the protection from a laser hazard is not recommended, some type of all three categories should be used in order to maintain a safe environment. See Appendix B for a summary of Texas State University safe laser practices guidelines.

> IDENTIFY the three basic categories of controls used in laser environments to provide a degree of protection from possible laser radiation injury and GIVE several examples of each type of control. (EHSRM.011.OBJ.11)

- Engineering Controls
  Engineering controls are normally designed and built into the laser equipment to provide for safety. They include a wide range of controls. The following is brief list of some of the controls that may be required; there are many other types of controls that can also be used:
  - a protective housing enclosing the laser source,
  - interlocks on the housing to prevent opening the enclosure while the laser is energized
  - a master key switch that will only permit operation when a key is inserted and turned to the on position
  - beam stops or attenuators
  - an activation warning system to alert people in the area of pending laser operation,
  - doors that are interlocked with the laser control that terminate laser operation in the event someone enters the area
  - airborne emissions controls to remove obnoxious or hazardous laser generated fumes

- Administrative and Procedural controls
  Does not necessarily provide a physical barrier, but if used properly will provide an additional method to prevent accidental exposure to laser hazards. This category includes but is not limited to the following:
  - Posting of areas
  - Standard operating procedures for laser operation
  - Maintenance procedures
  - Administrative procedures
  - Alignment procedures

- Personal Protective Equipment

  - Eye Protection
    The exclusive use of laser protective eyewear has, in the past, often been stressed as the best method of eye safety in the laser laboratory. *Laser protective eyewear is only one of many required laser safety control measure*. In general it is better to control laser hazards through the use of engineering controls (enclosures, beam blocks, etc.) and administrative controls (postings, procedures, etc.) rather than to rely solely on laser protective eyewear.

    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 events from occurring.
    Either of the following two methods can be employed to prevent exposure above Maximum Permissible Exposure limits during alignment are:
    - Use of a temporary beam attenuator placed over the beam aperture to reduce the level of accessible laser.
    - Use a low power visible laser for path simulation of higher power lasers.

    The methods should be detailed for the individual lasers in their approved maintenance procedures.

    All laser protective eyewear must be marked with the absorption wavelength and the optical density (OD) at that wavelength.

    Selection of appropriate laser protective eyewear is very important. Several different laser protective eyewear styles are available depending on the needs of the user. The protective eyewear selected must have the appropriate OD at the wavelength(s) of concern and must be comfortable enough to wear as required.

  - Skin Protection
    UV laser systems or UV excitation sources can present severe hazards to exposed skin surfaces. If the UV source cannot be enclosed to prevent scattered radiation exposure, it may be necessary to wear appropriate coverings to protect the skin. These coverings may include gloves, UV face shield, lab coat, etc.

Section VII Review:

1. _______________ _______________ are normally designed and built into the laser equipment to provide for safety.

2. Laser protective eyewear is _____________ during the beam _______________ process.

3. The protective eyewear selected must have the appropriate OD at the _______________ of concern and must be _________________ enough to wear as required.

4. __________________ and ________________ controls do not necessarily provide a physical barrier, but if used properly will provide an additional method to prevent accidental exposure to laser hazards.

5. UV laser systems or UV excitation sources can present __________________ ______________severe hazards to exposed skin surfaces.

CHECK YOUR ANSWERS

IDENTIFY other non-beam hazards that are possible in laser environment and GIVE an example of each.
(EHSRM.011.OBJ.12)

VIII. Non-Beam Laser Hazards

In some laser operations, particularly in the research laboratory, general safety and health guidelines should be considered.

- Industrial Hygiene
  Potential hazards associated with compressed gases, cryogenic materials, toxic and carcinogenic materials and noise should be considered. Adequate ventilation shall be installed to reduce noxious or potentially hazardous fumes and vapors, produced by laser welding, cutting, and other target interactions to levels below the appropriate threshold limit values.

- Explosion Hazards
  High-pressure arc lamps and filament lamps or laser welding equipment shall be enclosed in housings that can withstand the maximum pressure resulting from lamp explosion or disintegration. The laser target and elements of the optical train which may shatter during laser operation shall also be enclosed.

- Non-Beam Optical Radiation Hazards
  This is related to optical beam hazards other than laser beam hazards. Shielding is required on items such as laser discharge tubes that may emit ultraviolet light, pumping lamps and laser welding plasmas.

- Electrical Hazards
  The intended application of the laser equipment determines the method of electrical installation and connection to the power supply circuit (e.g. conduit versus flexible cord). During maintenance of the laser the user must take caution to completely discharge all capacitors before opening a system and working on it. Failure to perform this task can result in the potential of a life-threatening electrical shock.

- Noise Hazards
  Some laser systems create significant levels of noise in the laser laboratory. If the noise level seems unpleasant or painful, contact Risk Management & Safety to have a noise survey done.

Section VIII Review:

1. _______________ _______________ shall be installed to reduce noxious or potentially hazardous fumes and vapors, produced by laser welding, cutting, and other target interactions to levels below the appropriate threshold limit values.

2. High-pressure arc lamps and filament lamps or laser welding equipment shall be _______________ _______ ______________ that can withstand the maximum pressure resulting from lamp explosion or disintegration.

3. During maintenance of the laser the user must take caution to completely ___________ all ________________ before opening a system and working on it.

4. Some laser systems create significant ______________ ________ _____________ in the laser laboratory.

CHECK YOUR ANSWERS

IDENTIFY the Texas Administrative Codes applicable to laser operations and the purpose of each. (EHSRM.011.OBJ.13)

IX. Texas Administrative Code

The use of Class 3B and Class 4 lasers is regulated by the Texas Department of State Health Services. A user must comply with the following regulations as delineated in Texas State's certificate of registration:

A. 25 TAC§289.203 Notices, Instructions, and Reports to Workers.

This section establishes requirements for notices, instructions, and reports by licensees or registrants to individuals engaged in activities under a license or certificate of registration, and options available to such individuals in connection with agency inspections of licensees or registrants to ascertain compliance with the provisions of the Texas Radiation Control Act (Act), Health and Safety Code, Chapter 401, and rules, orders, licenses, and certificates of registration issued thereunder regarding radiological working conditions. The requirements in this section apply to all persons who receive, possess, use, or transfer sources of radiation licensed by or registered with the agency in accordance with this chapter.

B. 25 TAC§289.204 *Fees for Certificates of Registration, Radioactive Material Licenses, Emergency Planning and Implementation, and Other Regulatory Services*

The requirements in this section establish fees for licensing, registration, emergency planning and implementation, and other regulatory services, and provide for their payment.

C. 25 TAC§289.205 *Hearing and Enforcement Procedures*

This section governs the following in accordance with the Texas Radiation Control Act (Act), the Texas Administrative Procedure Act, Texas Government Code, Chapter 2001, and the Formal Hearing Procedures, §§1.21, 1.23, 1.25, and 1.27 of this title (relating to the Texas Board of Health).

D. 25 TAC§289.231 *General Provisions and Standards for Protection Against Machine-Produced Radiation*

This section establishes standards for protection against ionizing radiation resulting from the use of radiation machines. The requirements in this section are designed to control the receipt, possession, use, and transfer of radiation machines by any person so the total dose to an individual, including doses resulting from all sources of radiation other than background radiation, does not exceed the standards for protection against radiation prescribed in this section. However, nothing in this section shall be construed as limiting actions that may be necessary to protect health and safety in an emergency.

E. 25 TAC§289.301 *Registration and Radiation Safety Requirements for Lasers and Intense-Pulsed Light Devices*

This section establishes requirements for protection against all classes of laser radiation and intense-pulsed light (IPL) device hazards. This section includes responsibilities of the registrant and the laser safety officer (LSO), laser and IPL device hazard control methods, training requirements, and notification of injuries.

This section establishes requirements for the registration of persons who receive, possess, acquire, transfer, or use Class 3b (IIIb), International Electrotechnical Commission (IEC) Class 3B and Class 4 (IV), IEC Class 4 lasers in the healing arts, veterinary medicine, industry, academic, research and development institutions. No person shall use Class 3b (IIIb), IEC Class 3B or 4 (IV), IEC Class 4 lasers or perform laser services except as authorized in a certificate of laser registration issued by the agency in accordance with the requirements of this section. Class 1 (I) lasers, IEC Class 1 and 1M, Class 2 (II) lasers, IEC Class 2 and 2M, and Class 3a (IIIa) lasers, IEC Class 3R and IPL devices are not required to be registered.

Section IX Review:

1. _______________________________ establishes requirements for notices, instructions, and reports by licensees or registrants to individuals engaged in activities under a license or certificate of registration

2. ________________________________ establish fees for licensing, registration, emergency planning and implementation, and other regulatory services, and provide for their payment..

3. ________________________________ establishes standards for protection against ionizing radiation resulting from the use of radiation machines.

4. ________________________________ establishes requirements for protection against all classes of laser radiation and intense-pulsed light (IPL) device hazards. This section includes responsibilities of the registrant and the laser safety officer (LSO), laser and IPL device hazard control methods, training requirements, and notification of injuries.

Check Your Answers

IDENTIFY the purpose of select excerpts of 25TAC§289.301.
(EHSRM.011.OBJ.14)

X. Excerpts from 25TAC§289.301

(f) Registration of use of Class 3b and 4 lasers and laser services.
  (1) Use of Class 3b or 4 lasers and laser services shall include, but may not be limited to:
  - possession and use of lasers in the healing arts, veterinary medicine, industry, academic, and research and development institutions;
  - alignment, calibration, and/or repair; or
  - laser light shows.

(g) Application Requirements
  (3) Application for use of Class 3b or 4 lasers in industrial, academic, and research and development institutions. Each applicant having a laser(s) for use in industrial, academic, and research and development institutions shall submit an application to the agency within 30 days after beginning operation of the laser.

(j) Responsibilities of registrant
  (1) The registrant shall notify the agency in writing within 30 days of a change in any of the following:
  - business name and mailing address;
  - street address where laser(s) will be used; or
  - laser safety officer (LSO).

  (3) Each registrant shall inventory all Class 3B and 4 lasers in their possession at an interval not to exceed one year. The inventory record shall be maintained for inspection by the agency and shall include:
  - manufacturer's name;
  - model and serial number of the laser(s);
  - description of the laser(s) (for example, yag, silicon, CO2, neon);
  - location of laser(s) (for example, room number); and
  - if using a provider of lasers as defined in subsection (d)(38) of this

  (4) Notification to the agency is required within 30 days of the following:
  - any increase in the number of lasers authorized by the certificate of laser registration.

  (8) Each registrant shall maintain records of receipt, transfer, and disposal of Class 3b or 4 lasers for inspection by the

agency. The records shall include the following information and shall be kept until disposal is authorized by the agency:

- manufacturer's name;
- model and serial number from the laser;
- date of the receipt, transfer, and disposal;
- name and address of person laser(s) received from, transferred to, or disposed of; and
- name of the individual recording the information.

(r) Requirements for protection against Class 3bor 4 lasers
(3) Engineering controls.
(A) Protective housing.
(i) Each laser shall have a protective housing that prevents human access during the operation to laser and to collateral radiation that exceeds the limits of Class 1 lasers as delineated in ANSI Z136.1-2000.
(ii) Wherever and whenever human access to laser radiation levels that exceed the limits of Class 1 is necessary, these levels shall not exceed the limits of the lowest laser class necessary to perform the intended function(s).
(B) Safety interlocks.
(i) A safety interlock that shall ensure that radiation is not accessible above MPE limits as delineated in ANSI Z136.1-2000 limits.
(ii) Adjustment during operation, service, testing, or maintenance of a laser containing interlocks shall not cause the interlocks to become inoperative or the radiation to exceed MPE limits outside protective housing except where a laser controlled area is established.
(iii) For pulsed lasers, interlocks shall be designed so as to prevent firing of the laser; for example, by dumping the stored energy into a dummy load.
(iv) For continuous wave lasers, the interlocks shall turn off the power supply or interrupt the beam; for example, by means of shutters.
(v) An interlock shall not allow automatic accessibility of radiation emission above MPE limits when the interlock is closed.
(vi) Either multiple safety interlocks or a means to preclude removal or displacement of the interlocked portion of the protective housing upon interlock failure shall be provided, if failure of a single interlock would allow the following:

- human access to levels of laser radiation in excess of the accessible emission limit of Class 3a laser radiation; or
- laser radiation in excess of the accessible emission limits of Class 2 to be emitted directly through the opening created by removal or displacement of that portion of the protective housing.

(C) Viewing optics and windows.

(i) All viewing ports, viewing optics, or display screens included as an integral part of an enclosed laser or laser product shall incorporate suitable means, (such as interlocks, filters, or attenuators, to maintain the laser radiation at the viewing position at or below the applicable MPE as delineated in ANSI Z136.1-2000, Safe Use of Lasers and the collateral limits listed in Title 21, CFR, §1040.10, under any conditions of operation of the laser.

(ii) All collecting optics, such as lenses, telescopes, microscopes, endoscopes, etc., intended for viewing use with a laser shall incorporate suitable means, such as interlocks, filters, or attenuators, to maintain the laser radiation transmitted through the collecting optics to levels at or below the appropriate MPE, as delineated in ANSI Z136.1-2000. Safe Use of Lasers. Normal or prescription eyewear is not considered collecting optics.

(D) Warning systems. Each Class 3b or 4 laser or laser product shall provide visual or audible indication during the emission of accessible laser radiation. In the case of Class 3b lasers, except those that allow access only to less than 5 milliwatt (mW) peak visible laser radiation, and Class 4 lasers, this indication shall be sufficient prior to emission of such radiation to allow appropriate action to avoid exposure. Any visual indicator shall be clearly visible through protective eyewear designed specifically for the wavelength(s) of the emitted laser radiation. If the laser and laser energy source are housed separately and can be operated at a separation distance of greater than two meters, both laser and laser energy source shall incorporate visual or audible indicators. The visual indicators shall be positioned so that viewing does not require human access to laser radiation in excess of the MPE, as delineated in ANSI Z136.1-2000, Safe Use of Lasers.

(t) Additional requirements for safe operation.

(1) Eye protection. Protective eyewear shall be worn by all individuals with access to Class 3b and/or Class 4 levels of laser radiation. Protective eyewear devices shall meet the following requirements:
   (A) provide a comfortable and appropriate fit all around the area of the eye;
   (B) be in proper condition to ensure the optical filter(s) and holder provide the required optical density or greater at the desired wavelengths, and retain all protective properties during its use;
   (C) be suitable for the specific wavelength of the laser and be of optical density adequate for the energy involved;
   (D) have the optical density or densities and associated wavelength(s) permanently labeled on the filters or eyewear; and
   (E) be examined, at intervals not to exceed 12 months, to ensure the reliability of the protective filters and integrity of the protective filter frames. Unreliable eyewear shall be discarded. Documentation of the examination shall be made and maintained in accordance with subsection (ee) of this section for inspection by the agency.

(2) Skin protection.
When there is a possibility of exposure to laser radiation that exceeds the MPE limits for skin as specified in ANSI Z136.1-2000 Safe Use of Lasers, the registrant shall require the appropriate use of protective gloves, clothing, or shields.

(u) NHZ.
Where applicable, in the presence of unenclosed Class 3b and Class 4 laser beam paths, an NHZ shall be established. If the beam of an unenclosed Class 3b and Class 4 laser is contained within a region by adequate control measures to protect personnel from exposure to levels of radiation above the appropriate MPE, as delineated in ANSI Z136.1-2000, that region may be considered to be the NHZ. The NHZ may be determined by information supplied by the laser manufacturer, by measurement, or by using the appropriate laser range equation or other equivalent assessment.

(v) Caution signs, labels, and posting for lasers and IPL devices.

(1) General requirements. Except as otherwise authorized by the agency, signs, symbols, and labels prescribed by this section shall use the design and colors specified in subsection (dd) of this section.

(2) Posting. The laser controlled area shall be conspicuously posted with a sign or signs as specified in paragraph (3) of this subsection and subsection (dd) of this section.

(3) Labeling lasers and posting laser facilities. All signs and labels associated with Class 2, 3a, 3b, and 4 lasers shall contain the following wording.

(A) The signal word "CAUTION" shall be used with all signs and labels associated with all Class 2 lasers and all Class 3a lasers that do not exceed the appropriate MPE, as designated in ANSI Z136.1-2000, Safe Use of Lasers. This signal word is used in accordance with the sign in subsection (dd)(1) of this section.

(B) The signal word "DANGER" shall be used with all Class 3a lasers that exceed the appropriate MPE, as designated in ANSI Z136.1-2000, and all Class 3b and 4 lasers.

(C) Position 1 in the signs shall contain the following information, as applicable:

- Class 2 lasers, the words "LASER RADIATION – DO NOT STARE INTO BEAM"
- Class 3a lasers that do not exceed the appropriate MPE, as designated in ANSI Z136.1-2000, the words "LASER RADIATION – DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS";
- for Class 3a and 3b lasers, the words "LASER RADIATION - AVOID DIRECT EYE EXPOSURE".
- for Class 4 lasers, the words "LASER RADIATION - AVOID EYE or SKIN EXPOSURE to DIRECT or SCATTERED RADIATION".

(D) Positions 2 and 3 in the signs in subsections (dd)(1) and (2) of this section shall contain the following information, as applicable.

- Position 2 shall contain the type of laser or the emitted wavelength, pulse duration (if appropriate), or maximum output.
- Position 3 shall contain the class of laser.

Section X Review:

1. The registrant shall notify the agency in writing within 30 days of a change in any of the following 3 items:

   ____

   ____

   ____

2. An inventory all Class 3B and 4 lasers in their possession once per year. The inventory shall include the following 5 items.

   ____

   ____

   ____

   ____

   ____

3. Each laser shall have a protective housing that prevents human access during the operation to laser and to collateral radiation that exceeds the limits of Class _____ lasers.

4. What classes of laser product are required to provide visual or audible indication during the emission of accessible laser radiationP

5. Protective eyewear devices shall meet the following requirements:

   ____

   ____

   ____

   ____

   ____

Check Your Answers

References:

- 25 TAC§289.203 Notices, Instructions, and Reports to Workers
- 25 TAC§289.204 Fees for Certificates of Registration, Radioactive Material Licenses, Emergency Planning and Implementation, and Other Regulatory Services
- 25 TAC§289.205 Hearing and Enforcement Procedures
- 25 TAC§289.231 General Provisions and Standards for Protection Against Machine-Produced Radiation
- 25 TAC §289.301 Registration and Radiation Safety Requirements for Lasers
- ANSI Z136.1, American National Standard for Safe Use of Lasers
- Microsoft Encarta Encyclopedia 99
- U.S. Department of Labor, OSHA Technical Manual, Section III: Chapter 6 – Laser Hazards
- DeHarpporte Trading Company
- University of Texas San Antonio, Laser Safety Training Supplement

MATCH the following laser related terms to their corresponding meaning:

- Accessible Exposure Limit
- Diffuse Reflection
- Intrabeam Exposure
- Irradiance
- Maximum Permissible Exposure
- Nominal Hazard Zone
- Specular Reflection
- Radiant Exposure
- Peak Power
- Optical Density

(EHSRM.011.OBJ.15)

APPENDIX A - 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 American National Standard for Safe Use of Lasers. The secretariat for the Z136.X series is the Laser Institute of America (LIA).
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.
Diffuse reflection	When an incident radiation beam is scattered in many directions, reducing its intensity.
Intrabeam exposure	Exposure involving direct on-axis viewing of the laser beam. Intrabeam viewing is a high risk practice and is not recommended on campus.
Infrared (IR) radiation	Invisible radiation with a wavelength between 780 nm and 1 mm. The near infrared (IR-A) is from 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	**L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. A monochromatic, coherent beam of radiation not normally believed to exist in nature.
Maximum permissible exposure (MPE)	The maximum level of radiation which human tissue may be exposed to without a harmful effect. MPE values may be found in the ANSI Z136.1 standard.
Nominal hazard zone (NHZ)	The area surrounding an operating laser were 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).

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.
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 relected 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.
Ultrviolet (UV) radiation	Invisible radiation with a wavelength between 10 nm and 400 nm. The near untraviolet (UV-A) is from 315 to 400 nm band, the mid untraviolet (UV-B) is the 280 to 315 nm band, the far untraviolet (UV-C) is the 100 to 280 nm band, and the extreme ultraviolet is the 10 to 100 nm band. Note: Wavelenghts below 200 nm are absorbed in the atmosphere and are known as the vacuum ultraviolet.
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 to 440 nm), blue (440 to 495 nm), green (495 to 545 nm), yellow (545 to 575 nm), orange (575 to 605 nm), and red (605 to 780 nm).

RETURN

Appendix A - Review

____	Irradiance	A.	The area surrounding an operating laser were access to direct, scattered, or reflected radiation exceeds the MPE.
____	Nominal Hazard Zone	B.	When an incident radiation beam is scattered in many directions, reducing its intensity.
____	Peak Power	C.	Exposure involving direct on-axis viewing of the laser beam. This type of viewing is a high risk practice and is not recommended on campus.
____	Diffuse Reflection	D.	Radiation whose waves are in-phase. Laser radiation is coherent and therefore very intense
____	Optical Density	E.	The power being delivered over the area of the laser beam. Also called power density, it applies to CW lasers and is expressed in W/cm^2
____	Intrabeam Exposure	F.	The highest instantaneous power level in a pulse. It is a function of the pulse duration. The shorter the pulse, the greater the peak power.
		G.	Also called transmission density, it is the base ten logarithm of the reciprocal of the transmittance (an OD of 2 = 1% transmittance).
		H.	The energy being delivered over the area of the laser beam. Also called energy density, it applies to pulsed lasers and is expressed in J/cm^2.

Check you answer

APPENDIX B - TxState Laser Safety Guidelines

OPERATION GUIDELINES

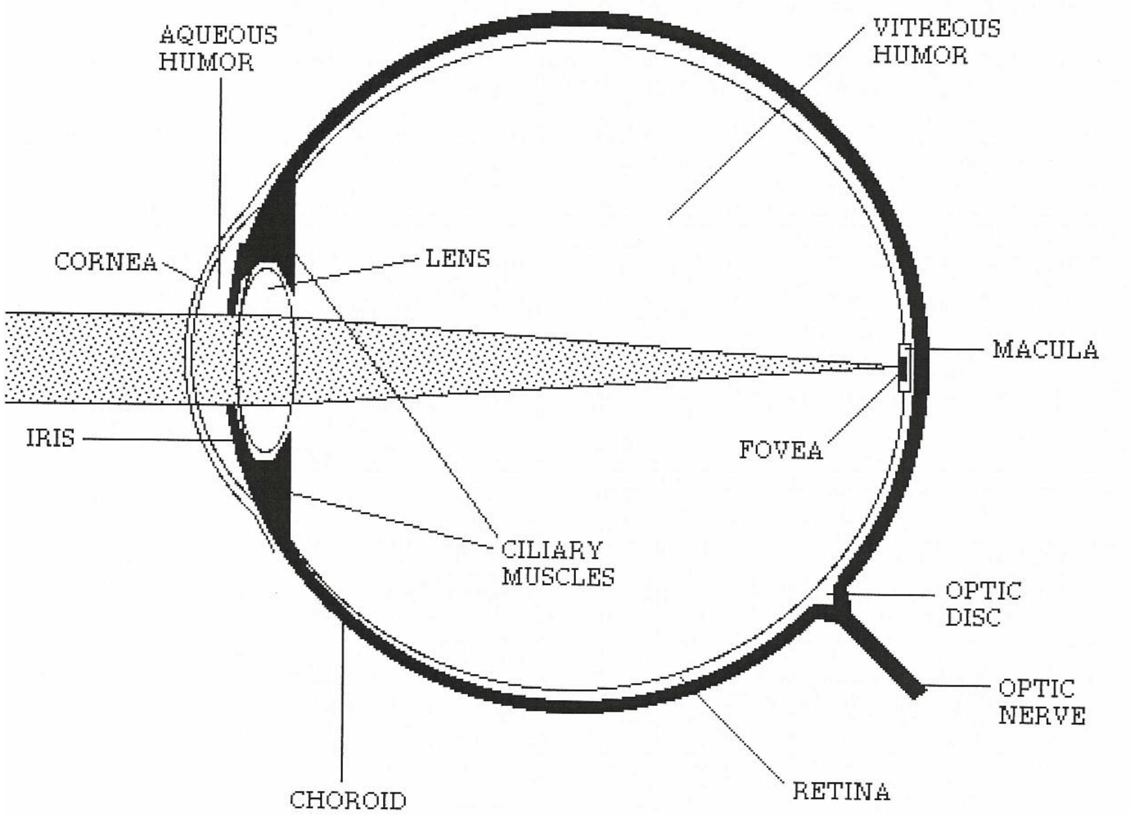
1. Intrabeam viewing of laser beams is not allowed on campus.
2. Never look directly into any laser beam for any reason.
3. Enclose the laser beam path whenever possible.
4. Use appropriate laser protective eyewear for all laser beam alignments.
5. Restrict unauthorized access to laser facilities.
6. 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 laser is not in operation.
12. Alert persons in 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.

ADMINISTRATIVE GUIDELINES

1. Mark all laser facility entrances with an ANSI laser hazard sign.
2. Complete, sign, and return a laser safety training certificate to EHSRM.
3. Report all accidents or suspected eye injuries to EHSRM.
4. Eye exams may be required for Class 3b and 4 laser users.
5. Laser facilities are inspected periodically by EHSRM.
6. Inform EHSRM of any transfer, or sale of lasers.
7. Inform EHSRM of any new, modified or relocated lasers.
8. Call EHSRM at 5-3616 any time you need laser safety assistance.

RETURN

APPENDIX C – Eye Component Diagram



NOTE: The diagram shows a laser beam entering the eye and being focused on the fovea. If the beam power is sufficient, this situation could cause blindness.

RETURN

Section II - Laser Characteristics Responses

1. Laser, acronym for light amplification by stimulated emission of radiation.

2. Lasers are devices that amplify light and produce coherent light beams, ranging from infrared to ultraviolet.

3. Lasers harness atoms to store and emit light in a coherent fashion.

4. Irradiance is normally expressed in W/cm^2 and is a function of the beam power divided by the beam area.

5. Radiant energy is a function of power density, pulse duration, and pulse frequency.

Return

Section III - Laser Types Responses:

1. Solid-state lasers offer the highest power output.

2. Carbon dioxide lasers are very efficient, and consequently they are the most powerful continuous wave (CW) lasers.

3. The most common liquid laser media are inorganic dyes contained in glass vessels.

4. Common uses for semiconductor lasers include compact audio digital disk (CD) players and laser printers.

5. Flash lamps, plasma discharge tubes, high voltage current and radio frequency devices are all energy sources used to excite the lasing media.

Return

Section IV - Laser Classifications Responses

1. Class I denotes a laser or laser system that does not, under normal operating conditions, pose a hazard.

2. Class II denotes low-power visible light laser or laser system that, because of the normal human aversion response, does not normally present a hazard.

3. Class IIIA denotes an intermediate power laser or laser system that normally would not injure the eye if viewed for only momentary periods with the unaided eye.

4. Class IIIB denotes a moderate power laser or laser system that will produce eye damage if viewed directly.

5. Class IV denotes a high power laser or laser system that produce retinal damage from direct or specular reflections, but may also produce hazardous diffuse reflections.

Return

Section V - Laser Applications Responses

1. List three areas that lasers have been used.

   Industry, scientific research, medicine, military, communication

2. Laser pointers are not dangerous when used with care, but the brightness of laser light can damage the eyes of anyone who looks directly into the beam for more than a minute and a half.

3. The most common laser pointers are red, they come in 3 standard wavelengths.

4. The green laser has a wavelength of 532 nm, which the eye is much more sensitive to than the red lasers.

5. The FDA regulates laser pointers according to their power output, not by wavelength.

Return

Section VI - Biological Effects of the Laser Beam Responses

1. The tissues that are normally considered to be at risk are the eyes and the skin.

2. Thermal effects can occur at any wavelength and are a function of the irradiance or radiant exposure and blood flow cooling potential of the tissue.

3. In air, photochemical effects occur between the 200 to 400 nm ultraviolet and the 400 to 470 nm "blue light" wavelengths.

4. The acoustical transient effect is poorly understood, but it can cause retinal damage that cannot be accounted for by thermal injury.

5. Laser retinal injury can be severe because of the focal magnification (optical gain) of the eye that is approximately 10^5.

6. 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.

Return

Section VII – Laser Safety Responses

1. Engineering controls are normally designed and built into the laser equipment to provide for safety.

2. Laser protective eyewear is essential during the beam alignment process.

3. The protective eyewear selected must have the appropriate OD at the wavelength(s) of concern and must be comfortable enough to wear as required.

4. Administrative and procedural controls do not necessarily provide a physical barrier, but if used properly will provide an additional method to prevent accidental exposure to laser hazards.

5. UV laser systems or UV excitation sources can present severe hazards to exposed skin surfaces.

Return

Section VIII – Non-Beam Laser Hazards Responses

1. Adequate ventilation shall be installed to reduce noxious or potentially hazardous fumes and vapors, produced by laser welding, cutting, and other target interactions to levels below the appropriate threshold limit values.

2. High-pressure arc lamps and filament lamps or laser welding equipment shall be enclosed in housings that can withstand the maximum pressure resulting from lamp explosion or disintegration.

3. During maintenance of the laser the user must take caution to completely discharge all capacitors before opening a system and working on it.

4. Some laser systems create significant levels of noise in the laser laboratory.

Return

Section IX - Texas Administrative Code Responses

1. 25 TAC§289.203 establishes requirements for notices, instructions, and reports by licensees or registrants.

2. 25 TAC§289.301 establishes requirements for protection against all classes of laser radiation and intense-pulsed light (IPL) device hazards.

3. 25 TAC§289.204 establishes fees for licensing, registration, emergency planning and implementation, and other regulatory services, and provide for their payment.

Return

Section X - Excerpts from 25TAC§289.301

1. The registrant shall notify the agency in writing within 30 days of a change in any of the following 3 items:
   - business name and mailing address;
   - street address where laser(s) will be used
   - laser safety officer (LSO)

2. An inventory all Class 3B and 4 lasers in their possession once per year. The inventory shall include the following 5 items.
   - manufacturer's name
   - laser model and serial number
   - laser description
   - laser location (e.g. room number)

3. Each laser shall have a protective housing that prevents human access during the operation to laser and to collateral radiation that exceeds the limits of **Class 1** lasers

4. What classes of laser product are required to provide visual or audible indication during the emission of accessible laser radiation?

   - Both Class 3b and Class 4 laser products

5. Protective eyewear devices shall meet the following requirements:
   - comfortable and appropriate fit
   - be in proper condition and retain all protective properties during its use
   - be suitable for the specific wavelength of the laser
   - have the optical density or densities and associated wavelength(s) permanently labeled on the eyewear
   - be examined, at intervals not to exceed 12 months

Return

Appendix A – Glossary of Laser Terms

__E_	Irradiance	A.	The area surrounding an operating laser were access to direct, scattered, or reflected radiation exceeds the MPE.
__A_	Nominal Hazard Zone	B.	When an incident radiation beam is scattered in many directions, reducing its intensity.
__F_	Peak Power	C.	Exposure involving direct on-axis viewing of the laser beam. This type of viewing is a high risk practice and is not recommended on campus.
__B_	Diffuse Reflection	D.	Radiation whose waves are in-phase. Laser radiation is coherent and therefore very intense
__G_	Optical Density	E.	The power being delivered over the area of the laser beam. Also called power density, applies to CW lasers and is expressed in W/cm^2
__C_	Intrabeam Exposure	F.	The highest instantaneous power level in a pulse. It is a function of the pulse duration. The shorter the pulse, the greater the peak power.
		G.	Also called transmission density, it is the base ten logarithm of the reciprocal of the transmittance (an OD of 2 = 1% transmittance).
		H.	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.

Return