CHAPTER 4

LASER SAFETY OFFICER TRAINING

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- Types of Lasers
- Eye Parts
- Laser Classifications
- Signs of Exposure and Degrees
- Beam Hazards
- Laser Safety Practices
- ANSI Guidelines

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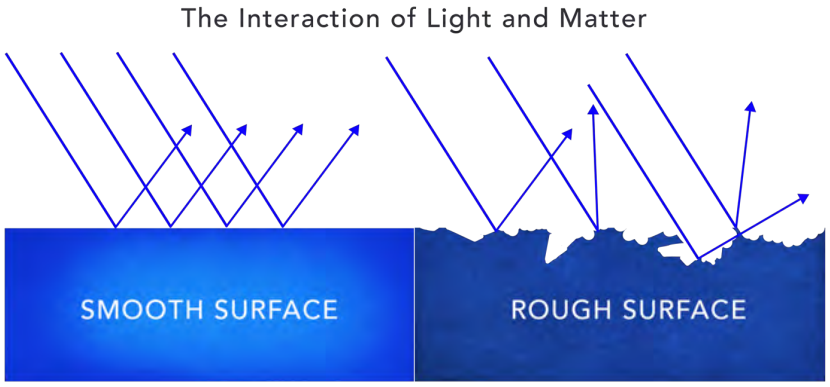
LSO Introduction

- The term **LASER** is an acronym for: **L**ight **A**mplification by the **S**timulated **E**mission of **R**adiation
  - The laser is a device that emits a collimated (pencil-like) beam of either visible or invisible electromagneti radiation (light).
  - Lasers posses hazards, capable of causing great injury to the skin and to the eyes.



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Types of Lasers

There are many types of lasers available for research, medical, industrial and commercial uses. The major types of lasers are:

- Gas
- Pumped solid state
- Dye
- Diode
- Gas lasers use a gas as the active medium. Common gas lasers are HeNe, CO2, N2, ion, and excimer. Solid state lasers, such as Nd:YAG, Nd:glass, and ruby, use crystal doped with heavy Multi-electron atoms as the active media.
- Tunable dye lasers use a dye in a liquid active medium. Diode lasers use semiconductor materials as the active media.

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Laser Bio-Effects: The Eye

The possibility of eye injury is the biggest concern regarding laser treatment.

- To consider potential damage, the practitioner needs to consider the amount and direction of exposure.
  - The safest reflection to mitigate potential injury is diffuse reflection - a reflection off of a surface that spreads out the laser radiation reducing its irradiance. But do not count on it to otherwise prevent injury.
- The largest danger for laser radiation injury stems from the beam directly entering the eye
- The energy density (measure of energy per unit of area, called fluence) increases as the spot size decreases.
- Even a low power laser in the milliwatt range can cause a burn if focused directly onto the retina.

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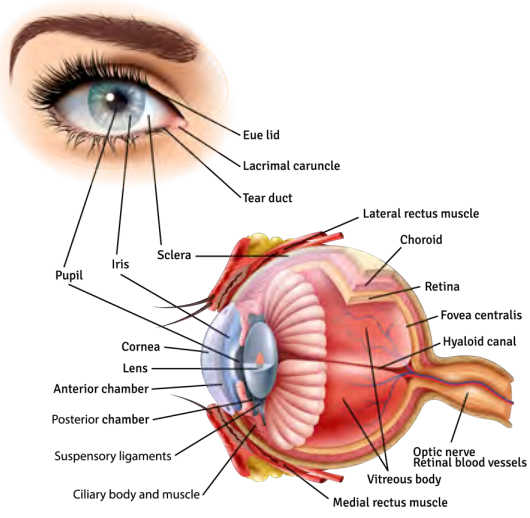
Eye Parts

- **CORNEA** - the clear layer of tissue that covers the eye. Damage to the outer cornea is painful but heals quickly. However, damage to the deeper layers can cause permanent injury.
- **LENS** - It focuses light to form images onto the retina. As one grows older, so does the lens which makes it harder to focus on near objects.
- **RETINA** - the layer of nerve cells that receives the image and sends signals to the brain.
- **FOVEA** - the most sensitive area of the retina because it has the greatest concentration of cones. Rods and cones are the photoreceptors.
- **OPTIC NERVE** - The nerves leading from the rods and cones exit at the back of the eye through this.
- **PIGMENT EPITHELIUM** - a layer at the back of the retina that absorbs light. The heat generated by the absorption of even environmental light in the pigment epithelium is removed by the blood flow in the choroid located just behind the retina.



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Blink and Aversion Response

- This is a self defense mechanism of the eye.
- Eyes automatically close when there is very bright light.
- The response is scientifically assumed to occur within 0.25 sec and only applies to visible laser wavelengths.
- This response defends the eye for low power lasers but not necessarily for higher power lasers.
- **Advice: NEVER look directly at the beam. And do not rely upon the Aversion Response Time to save injury. You're not faster than the speed of light and injury is likely to occur! And don't forget:**
- **Just because you don't see it doesn't mean that it's not there. (Nd: YAG laser)**

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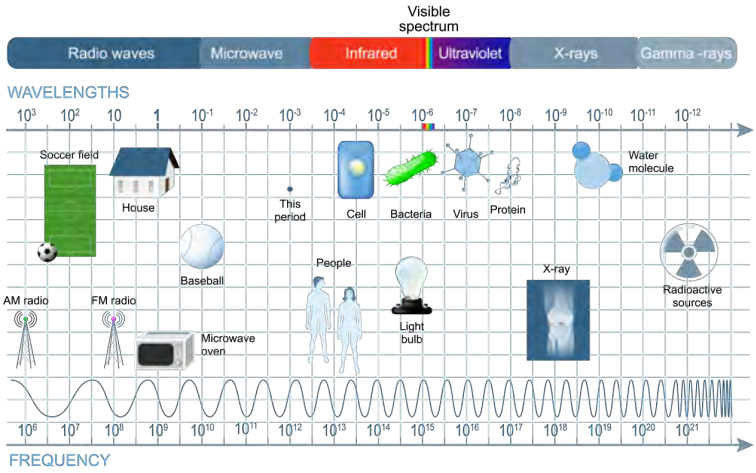
Electromagnetic Spectrum

Regions of the optical radiation spectrum

- Ultraviolet (UV)100 to 400 nm
  - UV-C100 to 280 nm
- UV-B 280 to 320 nm
  - UV-A320 to 400 nm
- Visible (Light)400 to 700 nm
  - Near Infrared700 to 1400 nm
- Far Infrared 1400 nm to 1 mm



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Laser Classifications

Lasers and laser systems are assigned one of the four broad classes depending on the potential for causing potential damage.

Class 1: "Safe" for all reasonably anticipated use. Example: Laser printers, CD-Rom players/drives. Output levels: Less than 400nm.


Class 2: May exceed class 1 exposure limits if viewed more than 0.25 seconds [aversion respond time], but still not pose a significant eye hazards. Output levels: 400-700nm.


Class 3A: Up to 5 times stronger than class 1 or 2. eye hazard if viewed using collecting optics, e.g., telescopes, microscopes, or binoculars.

Class 3B: Eye hazards if beams are viewed directly or specular reflections are viewed.



Class 4: The highest class of laser radiation. It can cause significant eye and skin damage and sometimes cause a fire. Output levels: 500 mW. Example: Laser Hair Removal Machine.

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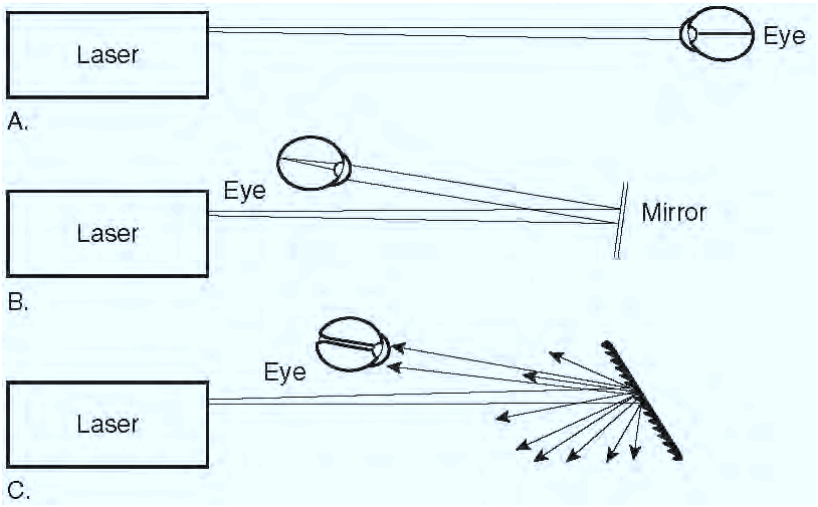
Viewing Laser Radiation

Ocular Exposure Hazard

(A)Direct

(B) Reflected

(C) Scattered



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Laser Exposure Limits

- **Maximum Permissible Exposure (MPE)**
  - Defined as the level of laser radiation to which a person may be exposed without hazardous effect or adverse biological changes in the eye or skin. The MPE of a specific laser is determined based on the wavelength and exposure duration.
- Where the MPE is exceeded, that defines the Nominal Hazard Zone (NHZ).
- For wavelengths that transmit into the eye, the exposure to the surface is multiplied by 100,000 times to compare to the MPE.

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

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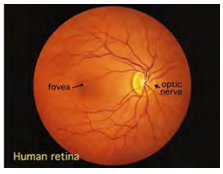
Signs of Exposure and How To Detect Them

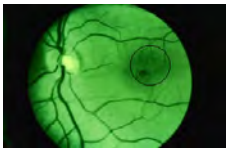
❖ **This is what a normal eye looks like.**

- After laser exposure, symptoms include headache, watering of the eyes, and floaters in vision.
- Floaters: those swirly distortions that sometimes happen after blinking or closing eyes.



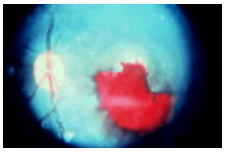
❖ **This is a large retinal burn from diffuse laser exposure Area of retinal burn.**

- Can be detected by the "pop" you can hear at the time of exposure.



❖ **This is what a Vitreal hemorrhage looks like.**

- Can be detected by a bright color flash of the emitted wavelength and an after-image of its complementary color.



❖ **This is a blood pool 1 week post injury.**

Photos: courtesy of Berkley Lab

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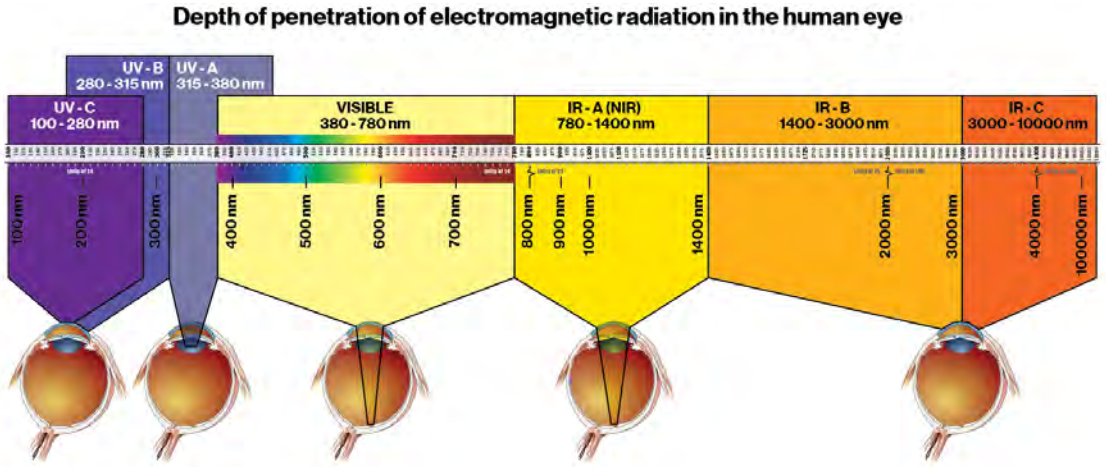
Depth Eye Penetration



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Thermal Damage

- Thermal damage occurs because of the conversion of laser energy into heat.
- Since the laser only focus on small points in diameter, high power densities can be confined to heat target tissues.
- Depth of penetration into the tissue varies with wavelength of the incident radiation, determining the amount of tissue removal and bleeding control.
- Since the ANSI standard is designed to account only for exposure to laser light, if a UV light from a pump light or blue light from a target interaction is emitted, additional precautions must be taken.

3 Nd: YAG pulses

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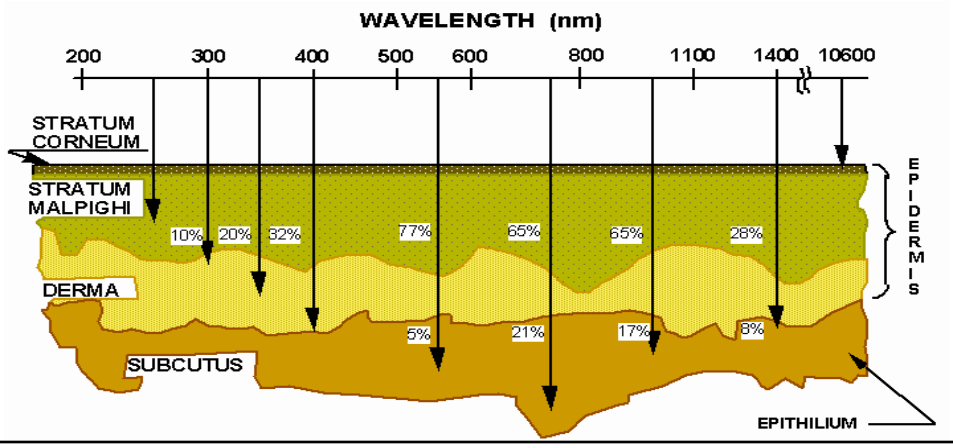
Laser Radiation Effects on Skin

- Normally considered less serious than injury to the eye, since the functional loss of an eye is more devastating.
- In the far-infrared and far-ultraviolet regions of the spectrum, where optical radiation is not focused on the retina, skin injury thresholds are about the same as corneal injury thresholds.



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Non-Beam Hazards: Electrical

- It is not just laser beams that cause damage. There are many other elements involved in the process.
- The associated hazards can be broken down into categories: physical, chemical, biological, mechanical, and ergonomic/human factors.
- Electrical Safety Precautions:
  - Use one hand when working around power supplies, capacitors or other electrical equipment. DO NOT SERVICE UNLESS QUALIFIED. PFNs and other laser components are known to cause death!
  - Avoid wearing metallic items.
  - Never handle electrical equipment when hands are wet or when standing on wet ground.
  - With high voltages, regard all floors as conductive and grounded for high voltages unless they are covered with well-maintained dry rubber matting of a type suitable for electrical work.
  - Be familiar with the following rescue procedures for application to apparent victims of electrocution:
    - Kill the circuit.
    - Remove the victim with a non-conductor if he is still in contact with an energized circuit.
    - Initiate artificial mouth-to-mouth resuscitation immediately (or the technique of heart-lung resuscitation if known) and continue until relieved by a physician.

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Non-Beam Hazards:
Chemical, Biological, Physical

CHEMICAL

Item	Possible Source
Toxic substances	Laser dyes
Carcinogenic substances	Solvents
Irritant substances	Samples
Dust and particulates	Crack optics
Fire	From ignition

BIOLOGICAL

Item	Possible Source
Microbiological Organism	From target interaction
Viruses	Released from target interactions

PHYSICAL

Item	Possible Source
Noise	Constant pinging of pulse laser
Pressure	Vacuum chamber, gas cylinders
Incoherent radiation	Broadband light source
X-rays	Target interaction
High temperature	Ovens in lab
Low temperature	Cryogenic use
Electricity	Power supplies, PFNs

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Non-Beam Hazards:
Mechanical

ERGONOMIC

Item	Possible Source
Trailing cables & Pipes	Housekeeping
Sharp edges	Razor blades
Moving parts	
Water high pressure	Cooling lines

Item	Possible Source
Workstation layout	Hitting head on table shelves
Manual handling	Lifting of lasers
Treatment Technique	Bending over too much
Shift patterns	Working too many hours

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Non-Beam Hazards: Explosions, Fire

Explosions

- High-pressure arc lamps, filament lamps, and capacitors may explode violently if they fail during operation.
- Laser targets and some optical components also may shatter if heat can not be dissipated quickly enough.
- Care must be used to provide adequate mechanical shielding when exposing brittle materials to high intensity lasers.

Fire

- Class 4 lasers represent a fire hazard. Depending on the construction material, beam enclosures, barriers and beam stops are potentially flammable if exposed to high beam irradiance (>10 W/cm2) or beam powers in excess of 0.5 W for more than a few seconds. To prevent fire hazard:
  - Beam enclosures should be constructed of flammable resistant materials.
  - Electrical circuitry shall be evaluated for the potential to cause fire.
  - Water available for quenching flames (irrigation solutions on back stand are OK)
  - Fire extinguisher immediately available (does not have to be in the room)
  - Check with local fire marshal for local requirements and standards.

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Control Measures: Administrative

- Administrative controls consist of procedures and information provided to personnel for the purpose of reducing laser hazards. They are:
- Warning signs and labels
  - Warning Signs must be posted on the outside of the door during laser operation.
  - The signs must be removed when the laser is not in use.
- Standard Operating Procedures (SOP)
- Training

➢ Finding a key in the laser machine when not in use can earn you a $5,000 fine during an OSHA inspection.

Standard Blank Warning Signs

LSL-CB-04

LSL-DB-04

Temporary Controlled Area

LSL-LR-01


LSL-INT-01

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Eye Protection: Eye Wear

- Corneal Hazards- Depends on Wavelength (all wavelengths which do NOT pass through fluid)
- From 1400nm on up, and 400nm on down
- Includes CO2, Er:Yag, Ho:Yag, and Ar:Fl excimer as corneal hazards.
- Safety Glasses Optical Density value is designed to keep the MPE below the hazard level.
- Laser Safety Glasses do NOT guarantee protection from direct impacts of the laser into the eyes through the glasses (reflections only).
- Should ALWAYS be worn within the NHZ
- Does NOT guarantee protection from direct impacts from the laser beam for retinal hazards (It is MOST IMPORTANT to not allow the beam to be directed toward one's face)
- Must be labeled according to the Wavelengths & Optical Density (O.D. or degree of protection)
- O.D. is a logarithm. I.E 104= OD 4, so a change from 4-7 is a 1,000-fold increase in attenuation. (tenfold for each unit of O.D.) Higher numbers offer more protection.

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Eye Protection: Eye Wear

- Laser safety eyewear is required for class 3b and 4 lasers.
- The amount of attenuation is measured by optical density (OD). For instance, OD 5 means that the incident beam is attenuated by a factor of 100,000. The greater the OD, the greater the attenuation.
- Eyewear is very wavelength dependent. Safety eyewear for one type of laser will not work for another type of laser. Eyewear stamped OD 5 for 488 & 514 nm [Argon] may be OD 0 for 633 nm [HeNe].
- Must be labeled with both wavelength ranges of protection, AND Optical Density (O.D.) of degree of protection.
- O.D. is a logarithm, so the differences in each unit of O.D. is a factor of 10. In other words, the difference of an O.D. of 4 to 6 is a factor of 100 in attention. High numbers are more protection.

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IPL Eye Hazards

- IPL's do NOT present the same level of risk as lasers because they are NOT point sources of light. (non-laser light sources).
- However, they DO still present eye hazards and eye protection is required.
- Used for a variety of procedures including hair removal, skin rejuvenation, treatment of pigmentary and vascular issues, etc.

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Skin Protection

- Designation of protective clothing for UV lasers should be considered, even if not class 3b or 4.
- Fire resistant material should be considered when class 4 lasers are being used.
- Remote firing and monitoring should also be considered as a method of skin protection.

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Safety Practices

- Glass Transmission.
- Lasers that don't transmit through glass include CO_2, Er:Yag, Ar:FL, and present superficial corneal burn hazards.
- Glass in optics of scopes & instruments afford protection to the viewer.
- Window glass affords protection to outside viewers so that no coverings are required (for those lasers listed above).

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Safety Practices: Administrative

- Supervisors are responsible for training users on any laser-specific safety procedures for the laser they are operating.
- Standard Operating Procedures shall be developed for class 4 lasers.
- Only authorized personnel allow in vicinity of laser.

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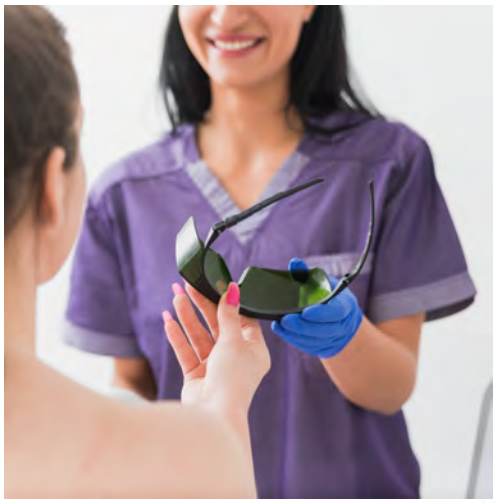
General Laser Safety Precautions

- Always consult with your laser manufacturer's guidelines for laser safety.
- Always use proper laser eye protection.
- Operate within a controlled area or secured enclosure only, unless the beam path is totally enclosed.
- Keep the beam path well above or below the eye level.
- Remove all unnecessary reflective surfaces from the area of the beam path.
- Permit only properly trained & authorized personnel to operate the laser.
- Enclose the entire beam path if possible.
- Use the entire beam path if possible.
- Use remote viewing methods where feasible (e.g. video monitoring) to accomplish any necessary view of the beam.



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Medical Laser Safety Officer

- Appointed by the facility administration.
- Administers the facility's Laser Safety Program.
- May or may not run actual equipment.
- No particular background nor education required.
- Utilizes many different resources in order to manage the Laser Safety Program.
- Required by ANSI in all health care facilities that utilize lasers (including medical spas and offices).

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Medical vs. Industry/Scientific LSO's

- Both are required by ANSI to be appointed by their respective facilities.
- Industrial/ Scientific based upon ANSI 136.1
- Medical based upon ANSI 136.3.
- Need for measurements and calculations to determine the NHZ and Laser Classification for Medical LSOs is minimized because of manufacturer pre-classification and information.

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Laser Safety

- Administrative Controls.
- LSO responsibilities.
- It is for overall management of the safety program to include education of staff, protective measures implemented (safety glasses), program monitoring, etc.
- It is NOT to establish or enforce clinical treatment parameters or protocols- they implement those established by their medical director.
- Laser Treatment Controlled Area (LTCA).
- The entire room, or designated are in a very large room.
- Signs required on all entryways.
- Safety glasses provided, but are not required to be worn until within the NHZ.
- Occupied only by authorized personnel trained in Laser Safety.

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Pregnancy in Workers or Patients

- Laser “Radiation” is electromagnetic but not ionizing like X-Rays and is of no actual risk to women in any stage of pregnancy-whether the patient or a technician running the equipment.
- In spite of this “no risk”, most services will NOT treat women with lasers for elective laser procedures because a certain percentage may miscarry or have other medical complications, and the practice does not want to be exposed to the potential liability.

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Window Coverings

- Must be flame retardant when used.
- Applies only to wavelengths that transmit through glass.
- Requires only when the window is located within the NHZ of the room.
- Any material opaque to the wavelength is sufficient.
- Consideration given to the use of barriers at doorways in special circumstances.

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Safety Practices- Instrument Reflections

- Not a major practical problem, but a consideration around sensitive areas (esp. the eye).
- Ebonizing instruments just creates a black color and does not affect the reflection much- especially from IR lasers.
- Anodizing an instrument creates a “roughened” micro-surface on the instrument that helps to disperse the reflection.
- The major problem is reflection from a flat metal surface in close proximity to a sensitive area (i.e. eye, teeth, etc.).

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Laser Safety

- Treatment beam & Guide-Light Alignments.
- Some lasers are infrared and therefore invisible to the eye. These lasers use visible (usually red) guide lights so that one can see where the treatment laser is aimed.
- ANSI standards require that the alignment of the treatment and aiming beams be checked prior to EACH case.

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Laser Plume (Smoke)

- Although Laser hair removal may produce odors, it generally does NOT produce laser plume that needs to be evacuated.
- ANSI standards require that whenever a laser plume is generated (such as ablative skin resurfacing) that “local exhaust ventilation” (smoke evacuators) be used.
- For odors generated by Laser or IPL hair removal, room electrostatic precipitators (room air cleaners) may be effective to eliminate odor.
- Masks that filter to viral sizes are generally considered by ANSI to be ineffective as the sole protection from Laser Plume.

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ANSI Guidelines

- ANSI Guidelines deal SOLELY with a laser safe environment for personnel.
- ANSI Guidelines DO NOT deal with ANY clinical treatment guidelines.
- Provided to ALL health care personnel responsible for ALL activities related to laser.
- Essentially this means that anyone that might be in the laser room, or even might HAVE OCCASION to be in the laser room shall be provided with Laser Safety training.

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