A Culture of Safety is more than just a corporate mission statement...It's when a group of people collectively realize that keeping each other from harm matters above all else.
The material presented within is provided solely as a tool for physicians who have obtained approved laser privileges within Elliot Health Systems (EHS), for re-training of laser SAFETY material only. It is not intended to be used as a substitute for initial laser training, training in the use of any laser system, or training for the delivery of laser energy. This material has been approved by a review group of the EHS Laser Safety Committee.

There is a 20-question assessment test in four slides at the of this training module, slides 44, 45, 46 and 47. Please submit your answers for the assessment test to the Laser Safety Officer (LSO). Instructions to submit the assessment are in the final slide of this presentation.
How Lasers Work

About Laser Energy

Light is electromagnetic energy; it is a radiant energy on the electromagnetic spectrum. Visible light is only part of the electromagnetic spectrum. Ultraviolet light radiation is an example of light energy most people are familiar with, as well as x-ray radiation and microwave radiation.

The acronym LASER is the process by which one form of energy is converted into an organized light energy.

The Light of the electromagnetic spectrum is Amplified when Stimulated by the Emission of Radiation; it then becomes an organized form of energy.

NOTE: Laser radiation is not ionized or mutagenic like x-ray radiation, and there are no maximum exposure limits.
Electromagnetic spectrum: The range of all frequencies of electromagnetic radiation, from Gamma Rays to Radio Waves

Most healthcare laser system wavelengths operate within the range of 200-10,600 nm on the electromagnetic spectrum of light radiation.
How Lasers Work

Components of Light

Components of laser light are described in the following terms:

1. Wavelength – distance between repeating units of wave form
2. Amplitude – height of the wave crest
3. Frequency – number of wave peaks per second
Laser Light Characteristics

Laser light has the following characteristics which are specific to lasers:

**Monochromatic**—Laser energy produces highly purified color of light. Laser energy is composed of photons that emit the same color and wavelength.

**Collimated**—Light beams are parallel, travel together tightly in one direction, and do not diverge significantly.

**Coherent**—Light waves travel in phase, in the same direction in an orderly manner. All peaks and troughs move in synchrony with each other in time and space.

**Compared to Ordinary Light:**
- Multiple colors in visible light spectrum
- Light Not Collimated
- Not Coherent
**How Lasers Work**

**Basics of a Laser System**

The medium of a laser consists of a solid, liquid, gas, or diode. The laser name usually includes the type of medium (CO2, Holmium, Argon, etc.).

When activated, electrons become excited then return to their lower energy state. During transition to a lower energy state, a photon of light energy is emitted. This stimulates a chain reaction with other electrons, with more photons emitted. Light photons reflect off the mirrors, align with each other, and become coherent. They are then emitted through the aperture of the output mirror, as a single coherent beam.
Laser Energy Concepts

Laser Energy Terminology

• **Active Laser Medium**: Material which is stimulated by energy from the excitation mechanism, converts this energy with resultant emission of coherent radiation of laser energy.

• **Energy**: Capacity for doing work; output from lasers is generally expressed in joules.

• **Joule (J)**: Unit of energy which describes power of energy delivery over timed duration of delivery: 1 joule = 1 watt x 1 second

• **Watt (W)**: The power of a laser is measured in watts: 1 W = 1 joule / 1 second

• **Hertz (Hz)**: Unit of Frequency – cycles per second. 1 Hz = 1 cycle per second

• **Power**: Rate of energy delivery, expressed in watts (W).

• **Power Density**: Amount of power that is concentrated into a spot. Power Density = Watts/cm$^2$
Laser Energy Concepts

Laser Energy

Power density (irradiance) – power per unit area upon a surface (spot size), usually expressed in Watts/cm²

- Power density is an important factor in the application of laser energy and impacts the laser's effect on the tissue (i.e. vaporize, cut, coagulate)

The larger the spot, the greater the power setting required to maintain the same power density (irradiance).

In this example based on CO2 power settings, for the larger spot it will take 40 watts to achieve a power density close to the power density achieved with 10 watts for the smaller spot size.

When switching from a larger spot size to a smaller spot size, if the energy remains the same the power density will be greater - as well as the effect on tissue.
An accessory lens can focus the laser beam to hit the tissue at its intended focal point, or smallest diameter, dependent on the size of the lens that is used.

An accessory lens can also defocus the beam, increasing the diameter of the spot size.

Focusing the beam increases intensity of the laser beam, useful in cutting tissue. Defocusing the beam reduces laser beam intensity, used in ablating tissue.
Laser Energy Concepts

Laser Light Energy – Reflection

The energy of the laser beam, when directed at a surface, can result in:

- **Energy Reflection**: Angle of reflection is equal to angle of oncoming beam.
- **Diffuse Reflection**: Light reflected but beam reflection is dispersed from irregular angles of surface.
- **Energy Absorption**: Laser energy absorbed by tissue, creating thermal changes.
- **Energy Scatter**: Tissue can cause beam to scatter and weaken, can backscatter into an endoscope, resulting in damage to optics and scope.
- **Energy Transmission**: Beam can pass through certain tissue with no thermal effect until reaching target tissue (example – through sclera to retina).
**Laser Energy Concepts**

**Laser Light Energy - Reflection**

Your vision is precious – **protect it!** NEVER look directly into any laser beam! Never aim the beam at anything other than the intended target tissue!

- **Direct (primary) Intrabeam viewing**
  - This viewing is **most hazardous**

- **Specularly reflected (secondary) Intra-beam viewing**
  - Beam from a curved surface reflector

- **Extended source viewing**
  - Normally diffuse reflection, hazardous with very high power Class IV lasers

- **Specularly reflected (secondary) Intra-beam viewing**
  - Beam from a flat surface

**Always Use Appropriate Laser Protective Eyewear**

- **LASER**
- **CURVED MIRROR**
- **FLAT MIRROR**

Laser Light Energy - Reflection
The depth of tissue penetration depends on several factors:

- Laser wavelength
- Chromophore, color and consistency of tissue treated
- Reflectance of tissue
- Water content of tissue
- Laser power settings
- Duration of beam exposure
- Spot size of beam exposure

**CO2 laser energy absorption is not dependent on tissue color, highly absorbed by water and by soft tissues with high water content.**

**Ho:YAG laser energy is absorbed by water.** The laser creates a high pressure steam bubble which collapses on itself creating acoustic shock wave pressure (cavitation) which can be used to fragment stones.

**Argon laser energy absorbed selectively by red or dark tissue.**

**Nd:YAG laser energy exhibits color selectivity for darker tissues, red pigment (hemoglobin).**
Laser Energy Concepts

Bio-Effects of Laser - Mechanism of Action

Laser Light, Chromophores and Target Tissue:

-The monochromatic characteristic of laser light is essential for selective targeting of tissue chromophores. Chromophores are molecules within tissue which have their own unique preferentiality to absorb certain wavelengths of light. The chromophore of the target tissue is a determining factor in selecting a laser for treatment of that tissue. Some of the most commonly targeted chromophores within tissue include water, hemoglobin, melanin, and tattoo ink. When delivering laser energy to or through the skin layer, it is important to consider the differences in skin color when determining laser of choice, delivery method, and power settings, as the differences in melanin content can impact delivery of energy.

-Because of the relationship between monochromaticity of laser light and the chromophore of the target tissue, laser energy can be delivered to the target tissue after passing through tissue without the target chromophore. For example, the target chromophores for the 532 nm laser include melanin and hemoglobin, not water. This allows the laser energy of this wavelength to pass through the cornea and lens without effect, and to the retina where it is absorbed.

Photosensitivity:

There are certain medical conditions (e.g., xeroderma pigmentosum, herpes simplex) which may lower the MPE threshold for biological effects in the skin, cornea, lens and retina from exposure to ultraviolet and near ultraviolet radiation. In addition, certain chemicals, known as photosensitizing agents, can effect an increase in skin sensitivity from ultraviolet exposure.
The depth of tissue penetration and effect of the laser energy is highly dependent on the laser wavelength and the chromophore of the target tissue, the color and consistency of the tissue, as well as the power of the beam, duration of beam exposure, and beam spot size.

The temperature produced by the laser affects the degree of thermal damage on the tissue.

<table>
<thead>
<tr>
<th>Temp</th>
<th>Biological Change</th>
<th>Visual Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 °C</td>
<td>Vaporization, Carbonization</td>
<td>Smoke Plume</td>
</tr>
<tr>
<td>90 – 100 °C</td>
<td>Drying</td>
<td>Puckering</td>
</tr>
<tr>
<td>65 – 90 °C</td>
<td>Protein Denaturization</td>
<td>White/Grey</td>
</tr>
<tr>
<td>60 - 65 °C</td>
<td>Coagulation</td>
<td>Blanching</td>
</tr>
<tr>
<td>37 - 60 °C</td>
<td>Warming</td>
<td>None/Erythema</td>
</tr>
</tbody>
</table>
Continuous Wave (CW): Laser beam delivers a steady stream of laser energy when the device is activated. Controlling the duration of the energy by selecting a setting on the console or activating a switch is referred to as gating the continuous wave of the laser.

Pulse Mode: Using the pulse mode of a laser allows the user to set the length of the duration of the delivery of laser energy as well as to set the length of the interval between energy delivery when the device is activated. The pulse duration determines the time the laser energy will be delivered, affecting the thermal effect on tissues; decreasing the pulse duration limits the thermal spread to surrounding tissues. The interval between each pulse allows time for tissue to cool; a longer interval time between pulses provides additional time for tissue to cool.

Q-Switched Mode: A pulsing technique to deliver high peak powers in short durations to disrupt tissue, with an interval between pulses. Because of the short duration there is no thermal effect or spread to the surrounding tissue. Commonly used in ophthalmic cases for a photo-acoustic effect.
**Laser Energy Concepts**  
*Bio-Effects of Laser - Mechanism of Action*

**Photomechanical (Photoacoustic) Effect:**
- Sudden heating causes thermal expansion; acoustic/shock waves rupture cells.
- Heating with evaporation of water leads to expansion and imploding of vapor bubble (cavitation effect) with resultant shock wave activity (effective on calculi).

**Photoablatative (Disruptive) Effect:**
- Mechanical breakdown of cells, dissociation of the molecules; tissue components are vaporized. No thermal diffusion.

**Photothermal (Thermal) Effect:**
- Light energy of laser absorbed by target tissue and converted to heat; heating can coagulate or vaporize tissue.

**Photochemical (Dissociative) Effect:**
- Light energy is used to activate photosensitive drugs that catalyze oxidation of tissue to destroy target cells. (e.g., Photodynamic Therapy)
Solid State Laser: The lasing medium is distributed in a solid matrix, such as a crystal or glass. One frequently used solid matrix, YAG (yttrium aluminium garnet) is a synthetic crystal material which can be doped with a laser medium such as Neodymium, Erbium or Holmium. Examples of these lasers are the Nd:YAG, Er:YAG and Ho:YAG lasers.

Diode Laser: A laser diode with an electrical current flowing through a junction of doped semiconductor materials. Two of the semiconductor materials used in medical lasers include GaAlAs (gallium aluminium arsenide) and InGaAs (indium gallium arsenide).

Gas Laser: Laser in which gas, sometimes in a mix with other substances, is the active medium. The CO2 (carbon dioxide), Excimer, and Argon lasers are examples of gas lasers.

Dye Laser: A liquid flowing dye is the active medium in this laser, often pumped by another laser, such as Argon, Excimer, a frequency-doubled solid state laser, or a with a flash lamp. Many dyes are a fire hazard, as well as poisonous and carcinogenic, requiring additional laser safety measures.

Frequency Doubled Laser: In some instances a laser beam wavelength of one frequency can be passed through a crystal which generates a twofold increase in frequency (halving the wavelength - doubling the frequency). One example is a 1064 nm wavelength Nd:YAG beam passing through a KTP (potassium titanyl phosphate) crystal with a resulting doubling in frequency emitting the 532 nm wavelength laser beam.
### Laser Safety Concepts

**Examples of Health Care Laser Systems**

<table>
<thead>
<tr>
<th>Laser</th>
<th>Wavelength (Spectrum)</th>
<th>Various Treatment/Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon</td>
<td>488 nm, 514 nm (Visible – Blue/Green)</td>
<td>Remove port wine birthmarks and spider veins, eye surgery, ear surgery, photodynamic therapy</td>
</tr>
<tr>
<td>CO2</td>
<td>10,600 nm (Infrared)</td>
<td>Cutting/vaporizing tissue, scalpel, endoscopy, neurology procedures, dental treatments, dermatology treatments</td>
</tr>
<tr>
<td>Diode</td>
<td>650-1,550 nm (Infrared)</td>
<td>Hair removal, periodontal surgery, superficial vein removal, eye surgery, tissue coagulation and ablation</td>
</tr>
<tr>
<td>Er:YAG</td>
<td>2940 nm (Infrared)</td>
<td>Removal of prominent veins, scalpel, red/orange tattoo removal, endoscopy, hemorrhoids, keloids, laser discectomy, prostatectomy</td>
</tr>
<tr>
<td>Excimer</td>
<td>308 nm (Ultraviolet)</td>
<td>LASIK, eye surgeries, psoriasis, endovascular, dermatology procedures</td>
</tr>
<tr>
<td>Ho:YAG</td>
<td>2140 nm (Infrared)</td>
<td>Urological procedures, orthopedic, ENT, oral and laryngeal procedures, dental applications</td>
</tr>
<tr>
<td>KTP/YAG (Greenlight)</td>
<td>532 nm (Visible – Green)</td>
<td>Removal of prominent veins, cuts tissue, red/orange tattoo removal, endoscopic surgery, hemorrhoids, keloids, laser discectomy, prostatectomy, podiatric procedures, pigmented lesions</td>
</tr>
<tr>
<td>Nd:YAG</td>
<td>1064 nm (Infrared)</td>
<td>Tattoo removal, hair removal, condyloma acuminate, dentistry, endometrial ablation, heel spurs, hemorrhoids, neurology procedures, laser angioplasty</td>
</tr>
</tbody>
</table>
Laser Energy Concepts

Laser Delivery Devices

• **Articulated arm** – hollow tubes with mirrors at each moveable joint to reflect and direct laser beam in desired path: i.e. CO2 (10,600 nm)

• **Flexible fibers** – fiber core ‘light tunnel’ with reflective inner cladding to increase internal reflection, with protective outer jacket: i.e. Excimer (308 nm), Argon (514 nm), Purepoint (532 nm), Greenlight (532 nm), Evolve (980/1470 nm), Holmium (2100 nm), CO2 (10,600 nm)

• **Micromanipulator** – mirrored device attaches to laser and microscope, allows physician to manipulate laser beam for line-of-sight delivery with adjustment of mirror: i.e. CO2 (10,600 nm)

• **Laparoscope** – i.e. CO2 (10,600 nm)

• **Laser Indirect Ophthalmoscope** – i.e. Argon (514 nm), Purepoint (532 nm), Iridex (810 nm)
A laser delivery device is the mechanism which is manipulated to direct the laser energy to its intended target. Delivery devices vary in styles and structure, dependent upon laser type and intended treatment.

Accessories may be used with the laser or delivery device, which can include lenses, filters, connectors, tips, and couplers.

Laser delivery devices and accessories may fail due to damage, misalignment, mechanical issue or fiber breakage. Failure of laser delivery devices increase risk for laser hazards, including unintended laser beam exposure injuries and fire.

The laser delivery device and accessories can effect the power density of the laser beam delivered and the resultant effect on tissue.

A surgeon has the responsibility to select the laser delivery system, power settings and accessories appropriate for the procedure to be performed, and only those laser systems for which the physician has training and is credentialed.
Technology has advanced with development of various types of optical fibers for specific laser systems to allow effective delivery of laser energy along flexible fibers and probes to the target tissue. This allows more precise access to areas of the body not reached by direct line-of-site laser delivery.
Lasers used in dermatologic treatment have multiple delivery devices allowing for treatment of a variety of skin conditions, including:

- facial veins
- red spots
- rosacea
- vascular birthmarks
- vitiligo
- atop dermatitis
- pruritus
- alopecia areata
- reduction of scars
- psoriasis of skin, hair and nails
- reduction of wrinkles and fine lines

Many of these specially designed handpieces may be used with systems which cool the epidermis to prevent collateral damage to epidermal structures from laser light intended to target deeper structures.
Laser Energy Concepts
Laser Delivery Devices

The CO2 laser has multiple delivery devices and accessories.

These handpieces, scope and micromanipulator are some of the types of delivery devices for a wide variety of specialty laser applications.

Micromanipulator attaches to CO2 laser arm and microscope.

Attach to laser arm.

Micromanipulator.

Mirror reflects laser beam.

Arm manipulates mirror for direction of laser beam to target tissue.
Laser Safety Concepts
Laser Classification

FDA: • The Food and Drug Administration’s (FDA) Center for Devices and Radiologic Health regulates all laser products.
• Four major hazard classes (1 to 4) of lasers are recognized by the FDA, with three subclasses (2a, 3a, and 3b). The higher class indicates the higher potential to pose serious danger if used improperly.
• Laws, regulations, and standards require engineering controls and communication of risk to aid in the management of hazards associated with each laser class. The Federal Laser Product Performance Standard (FLPPS), Code of Federal Product Regulation, requires manufacturers to provide information on laser data including class, operation, calibration, hazards, and maintenance. All laser products in the United States must comply with the FLPPS.

ANSI: The American National Standard Z136 is a series publications regarding laser safety standards. The American National Standard for Safe Use of Lasers in Health Care (ANSI Z136.3), part of this series, is a voluntary standard that applies to the use of health care laser systems (HCLS), written to provide specific processes to achieve the safe use of HCLS in various treatment settings.

OSHA: Occupational Safety and Health Administration (OSHA), recognizes ANSI laser standards, requires that all organizations using lasers have a Laser Safety Program that meets the requirements of the ANSI Standard.

IEC: International Electrotechnical Commission. International Standards and Conformity Assessment for all electrical, electronic and related technologies. International standards which apply to the manufacture and use of lasers have not been adopted by the United States, though lasers classified and labeled in accordance with IEC may be sold in the United States.
<table>
<thead>
<tr>
<th>LASER CLASS</th>
<th>LASER CLASS IEC</th>
<th>LASER PRODUCT HAZARD</th>
<th>PRODUCT EXAMPLES</th>
<th>PROCEDURAL AND ADMINISTRATIVE CONTROLS</th>
<th>LASER TRAINING</th>
<th>LASER SAFETY OFFICER</th>
</tr>
</thead>
</table>
| 1           | 1M              | Considered non-hazardous. Hazard increases if viewed with optical aids, including magnifiers, binoculars, or telescopes. | • laser printers  
• CD players  
• DVD players | 1 NOT REQUIRED  
1M REQUIRED | 1 NOT REQUIRED  
1M APPLICATION DEPENDENT | 1 NOT REQUIRED  
1M APPLICATION DEPENDENT |
| 2a, 2       | 2M              | Hazard increases when viewed directly for long periods of time. Hazard increases if viewed with optical aids. | • bar code scanners | 2 NOT REQUIRED  
2M REQUIRED | 2 NOT REQUIRED  
2M APPLICATION DEPENDENT | 2 NOT REQUIRED  
2M APPLICATION DEPENDENT |
| 3a          | 3R              | Depending on power and beam area, can be momentarily hazardous when directly viewed or when staring directly at the beam with an unaided eye. Risk of injury increases when viewed with optical aids. | • laser pointers | 3R NOT REQUIRED  
3R NOT REQUIRED  
3R NOT REQUIRED | 3R NOT REQUIRED  
3R NOT REQUIRED  
3R NOT REQUIRED | 3R NOT REQUIRED  
3R NOT REQUIRED  
3R NOT REQUIRED |
| 3b          | 3B              | Immediate skin hazard from direct beam and immediate eye hazard when viewed directly. | • laser light show projectors  
• industrial lasers  
• research lasers  
• Health Care Laser Systems | 3B REQUIRED  
3B REQUIRED  
3B REQUIRED | 3B REQUIRED  
3B REQUIRED  
3B REQUIRED | 3B REQUIRED  
3B REQUIRED  
3B REQUIRED |
| 4           | 4               | Immediate skin hazard and eye hazard from exposure to either the direct or reflected beam; may also present a fire hazard. | • laser light show projectors  
• industrial lasers  
• research lasers  
• lasers used to perform LASIK eye surgery  
• Health Care Laser Systems | 3B REQUIRED  
3B REQUIRED  
3B REQUIRED | 3B REQUIRED  
3B REQUIRED  
3B REQUIRED | 3B REQUIRED  
3B REQUIRED  
3B REQUIRED |
**Laser Safety Concepts**

**Laser Hazards – Hazard Zones**

**Maximum Permissible Exposure (MPE):** The level of laser light radiation one may be exposed to without risk for laser hazards, injury, or adverse changes of the eye or skin.

**Nominal Hazard Zone (NHZ):** The calculated laser treatment area in which laser exposure presents a risk for hazards, injury and/or adverse changes of the eye and skin. Within this area the direct, reflected, or scattered laser radiation during normal laser operation **exceeds** the maximum permissible exposure (MPE), increasing risks. Control measures and safety precautions are REQUIRED within the NHZ.

Outside the designated laser treatment area (beyond the NHZ) there is no risk for laser exposure injury (laser exposure is below the MPE).

*To avoid the need for laser barrier curtains and calculation of nominal hazard zone within a treatment area, it is acceptable to designate the entire room where the laser procedure is conducted as the NHZ; HOWEVER, all windows and entryways must be blocked to contain the laser beam within the NHZ, as many lasers can transmit long distances and through glass.*
Laser Safety Concepts
Laser Hazards – Hazard Zone

• Warning signs shall be posted at every entry to a laser treatment controlled area. Information shall include the appropriate warning for laser class in use (Danger or Caution), type of laser, wavelength emitted, maximum output, and class of laser. Warning signs shall be covered or removed when laser is not in use.

• Restrict treatment area access (Nominal Hazard Zone) to appropriate personnel.

• Appropriate wavelength specific safety eyewear, with information printed on eyewear, shall be available at each main entry to a laser treatment area.
Laser Safety Concepts

Laser Hazards – Unintentional Laser Beam Exposure

Unintentional laser beam exposure and injury can be caused by:

- Failure to take appropriate laser safety precautions (signage, moist drapes, standby mode, etc.)
- Failure to use appropriate laser safety items (protective eyewear, barriers, etc)
- Non-adherence to standard operating procedures during alignment and operation
- Equipment failure (broken laser fiber, mirror, etc.)
- Insufficient training or untrained personnel in laser use area
- Improperly functioning laser and/or laser accessories

**NEVER FIRE LASER WITHOUT AIMING BEAM**
- Failing to take necessary precautions to contain laser beam and reflection within the nominal hazard zone (window barriers, nonreflective instruments, etc.)

The laser user should be the only one to activate laser device.
Place laser in standby mode when not actively performing treatment.
Place laser footplate convenient to laser user and separate from other footplates (i.e. electrocautery, x-ray)
**Laser Safety Concepts**

**Laser Hazards – Unintentional Laser Beam Exposure**

**Skin Exposure Biological Effects:** Erythema, skin cancer, accelerated skin aging, increased pigmentation, pigment darkening, skin burn, photosensitive reactions

**Eye Exposure Biological Effects:** Photokeratitis, photochemical and thermal retinal injury, retinal burn, corneal burn, aqueous flare, cataract formation

**ALWAYS USE APPROPRIATE LASER PROTECTIVE EYEWEAR FOR EVERYONE IN THE LASER TREATMENT AREA - YOURSELF, YOUR PATIENT AND YOUR TEAM**

All laser protective eyewear is labeled for use with specific laser wavelength(s). Some are labeled only for one wavelength, others are labeled and appropriate for a range of wavelengths. Always check and use the eyewear specific to the laser wavelength in use. Patient eye protection can include laser protective eyewear or eye shields.

Optical Density (OD) is the blocking ability of an optical filter, the measurement of the extent to which a substance allows light to filter through. All laser protective eyewear (LPE) must be labeled with the optical density as well as laser wavelength for which it is appropriate.

The wavelength of the laser output is the most important factor in determining the type of eye protection to be used.
Laser Safety Concepts
Laser Hazards – Unintentional Laser Beam Exposure - Eyes

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Eye Structure Injury</th>
<th>Wavelength (nm)</th>
<th>Eye Structure Injury</th>
<th>Wavelength (nm)</th>
<th>Eye Structure Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>200-280</td>
<td>Corneal Burn</td>
<td>315-400</td>
<td>Photochemical</td>
<td>400-780</td>
<td>Photochemical and Thermal</td>
</tr>
<tr>
<td>280-315</td>
<td>Corneal Burn</td>
<td>780-1400</td>
<td>Cataract</td>
<td>780-1400</td>
<td>Retinal Burn</td>
</tr>
<tr>
<td>1400-3000</td>
<td>Corneal Burn</td>
<td>1400-3000</td>
<td>Possible Cataract</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3000-10^6</td>
<td>Aqueous Flare</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Corneal Burn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Always Use Appropriate Laser Protective Eyewear for Patient and Team

Ultraviolet Keratitis /Photokeratitis—corneal flash burn (also called welder’s flash or snow blindness) can be considered to be a sunburn of the eye surface.

Cataract—clouding of the lens in the eye that results in blurred vision. Can result from continual low power exposure to the laser beam.

Scotoma—blind spot in the field of vision, on the fovea. Caused by direct exposure to the laser beam to retina.

Retinal injuries—more likely to be permanent, including reduced vision or blindness.
Laser Safety Concepts

Laser Hazards – Airway Specific Hazards

Procedures in and around the airway require additional safety measures to prevent and manage airway fires. Endotracheal tubes (ETT) made of polyvinyl chloride (PVC) are extremely flammable, can be ignited by a laser beam, and will support combustion.

Take precautions to prevent airway fire:

• Use endotracheal tube made specifically for laser procedure & specific to laser wavelength in use
• **Use lowest possible concentration of oxygen** for laryngeal/tracheal procedures, try to limit oxygen concentration to less than 30%, and prevent leaks around ETT
• Do not use nitrous oxide to dilute oxygen – nitrous oxide supports combustion; helium is less dense, retards burning
• Use caution with equipment which can be flammable – tooth guard, face mask, suction catheters
• **Suction around ETT and under drapes prior to laser use to remove any concentrations of gases**
• Remove flammable lotion, cologne, hair spray or gel from patient hair or skin
• If lubricant needed, use water-based lubricants around laser treatment area
• Avoid alcohol-based preps; if used, must have adequate dry time prior to draping
• Avoid pooling of flammable liquid preparations
• Moistened gauze or towels around treatment area may dry; keep moist to avoid risk of fire
• A container of water or saline must be available for immediate dousing should fire occur
• **Emergency tracheotomy instruments/kit must be available in room for all laser airway procedures**
Use endotracheal tubes made specifically for laser procedures in and around the airway and specific to laser wavelength in use (Rusch Laser Tube, Mallinckrodt Laser-Flex, Medtronic Laser-Shield II). Always follow manufacturer recommendations (i.e. inflate with fluid, protect with wet cottonoid).

**Laser Safety Concepts**

**Laser Specific Endotracheal Tubes**

- **Laser Tube (Rusch)** with LATEX
- **Laser-Shield II (Medtronic)** CO2 (10,600 nm) and KTP (532 nm)
- **Laser Flex (Mallinckrodt)** Proven on CO2 and KTP
Laser Safety

Laser Hazards - Managing Airway Fire

When an airway fire is suspected act immediately!

Stop the gas flow
  • Disconnect breathing circuit – this is the quickest way to stop the gas flow. The fire's intensity reduces and may self-extinguish.

Remove the tube from the patient
  • Maintain airway patency
    Note: The above two steps should be done as quickly and simultaneously as possible.

Extinguish the fire
  • Operating Room personnel other than anesthesia personnel should extinguish the smoldering tube.
  • Remove segments of burned tube that may remain in the airway.
  • Douse with water or saline from back table or hand basin (water or saline clearly labeled should always be available)

Care for the Patient
  • Reestablish airway and resume ventilation with air until certain nothing remains burning in the airway; only then switch to increase to 100% O2.
  • Examine airway for the extent of damage.
  • May employ lavage and suction to remove soot and particles in the airway.
  • A tracheotomy may be necessary, for this reason an emergency tracheotomy tray and tube is always in the room when a laser case involving the airway is performed.
Airborne Hazards

- Laser Generated Airborne Contaminants (LGAC)
- Toxic Gases and Vapors
- Can cause headache, nausea, vomiting
- Small particles unable to be filtered by surgical masks
- Aerosolized bio-material
- Dead and live cell material
- Virus
- Irritant to eyes and upper respiratory tract
- Carcinogenic and mutagenic risks

Solutions

The PRIMARY PROTECTION from surgical smoke is local exhaust ventilation/suction within 2 inches of the smoke source by a smoke evacuation system with appropriate filtration

A fit-tested N95 surgical mask offers more protection than a high-filtration mask; however, the local exhaust ventilation/suction evacuation system is THE FIRST LINE OF PROTECTION against surgical airborne hazards

A study by Dr. Tomita and his team in demonstrated that using the CO2 laser on one gram of tissue is comparable to inhaling the smoke from 3 cigarettes in 15 minutes; using electrocautery on one gram of tissue is comparable to inhaling smoke from 6 cigarettes in 15 minutes (AORN, n.d.).

ALL TYPES OF SURGICAL SMOKE ARE HAZARDOUS, ADEQUATE PRECAUTIONS MUST BE TAKEN.
Laser Safety Concepts

Laser Hazards – Non-Beam Hazards

Personnel Hazards

• Non-credentialed provider with undetermined training performing laser procedure
• Personnel who are not adequately trained operating the laser
• Laser or laser accessory hazard not reported by team member during procedure
• Distracted personnel not taking adequate laser precautions

Solutions

• Laser key is secured and stored away from laser to prevent unauthorized use
• Administrative controls in place aligning with ANSI Z136.3 standards
• Only hospital credential laser users perform laser procedures—a listing is with each laser
• Laser operators have laser-specific training
• All personnel working in a laser procedure area receive laser education appropriate to their position.

The alert and observant laser team monitors the case, noting precautions are taken to prevent unintentional beam exposure, fire, electrical issues, possible environmental and chemical risks, and being watchful for potential hazards (i.e. broken fiber with stray laser beam, moistened sponges at surgical site drying out)
Laser Safety Concepts

Laser Hazards – Non-Beam Hazards

Electrical Hazards

- Cords or plugs are wet
- Electrical outlet inadequate power source
- Cord/Plug Damage
- Improperly grounded equipment
- Cords and wires kinked or knotted
- Liquids placed on laser
- Foot pedal exposure to water
- Cord pulled from outlet

Solutions

- Routine Inspections – inspect for intact and undamaged cords, plugs, and protective housing when assembling equipment and test-firing laser
- Follow manufacturers directions for installation, maintenance, operation
- Do not placed liquids on laser
- Cords and plugs are kept dry
- Protect foot pedal from exposure to liquids during procedure
- Do not allow cords to be knotted or kinked
- Use only approved power outlets
- Never use damaged laser equipment - remove from service until repaired

Lasers require high voltage supplies and present risk for electrical shock, electrocution, and fire. Take necessary precautions to prevent electrical hazards!
**Chemical Hazards**

- Laser dyes can be highly toxic and carcinogenic.
- Hazardous substances can reach high temperatures.
- Cooling systems used may contain hazardous substances.
- Inadvertent contact with skin or mucous membranes.

**Solutions**

- Avoid contact with skin.
- Follow manufacturer’s instructions.
- Access to chemical/dye MSDS for reference (i.e. for use, storage, spills, precautions, treatment if exposed).
- Proper storage and labeling practices enforced.
- Routine maintenance and inspection of dye lasers.
**Laser Safety Concepts**

**Laser Hazards – Non-Beam Hazards**

### Fire Hazards
- Combustible triad present: *oxygen, fuel, and ignition source*
- Direct laser beam
- Reflective surfaces directing laser beam onto flammable materials
- Combustible anesthetic gases
- Solvents/Dyes (in dye lasers) extremely flammable
- Flammable medications (i.e. brilliant green, ethyl alcohol, acetone) do not use in presence of laser
- Flammable preps (i.e. alcohol preps)
- Dry, flammable sponges and drapes

### Solutions
- Avoid high levels of oxygen in operative field
- Place laser system on standby when not in active use by provider
- Never place hot laser delivery device on dry drapes
- Use appropriate endotracheal tube for procedures involving laser use in the oral and tracheal areas
- Use fire retardant drapes or moisten draping material
- No dry combustible (sponges/drapes) at treatment site
- Use water-based lubricant at sites of laser treatment
- Use caution to avoid exposure to scopes when lasers are fired through rigid and flexible endoscopes
- Know facility fire safety protocols and RACE: **R**escue, **A**ctivation, **C**ontain, **E**xtinguish
- Use Halon Fire extinguishers for fire of the laser machine itself.
- Use non-alcohol prep and medications when available; let prep dry completely prior to draping

Follow fire safety measures according to facility, local, state and federal regulations
Laser Safety Concepts

Laser Hazards – Non-Beam Hazards

Environmental Hazards

- Trips and falls due to tangled and knotted cords
- Laser beam extending beyond nominal hazard zone (NHZ)
- Unable to access laser emergency switch during treatment
- Frequent opening of entryway with laser beam extending beyond NHZ
- Laser protective eyewear not used
- Unprotected personnel entering treatment area
- Unable to access or adjust laser or laser accessories

Solutions

- Manage cords flat on floor, without tangles
- Contain laser beam with approved window curtains and barriers.
- Minimize traffic in and out of treatment area
- Position equipment to prevent beam direction toward entry ways and reflective surfaces (metal/glass)
- Cover reflective surfaces of treatment area (windows, mirrors)
- Post laser-specific signs and protective eyewear at entries of laser treatment areas
- Provide amount of clean and well maintained laser protective eyewear and document use.
- Position equipment for free and clear access to adjust laser and accessories, monitor laser use and emergency switches at all times during treatment
Control Measures

Administrative Controls: Supplemental safety measures in addition to engineering controls which regulate work practice to support personnel and patient protection from laser hazards.

Administrative controls include, but are not limited to, the following:

- Facility Laser Policies and Procedures
- Laser Safety Officer and Safety Committee
- Laser Safety Training Program
- Facility-Authorized Laser Users (Appropriately credentialed for the safe use of the laser system)
- Maintenance and Service Schedules
- Standard Operating Procedures
- Laser Safety Checklists
- Laser Equipment Acquisition and Decommissioning
- Laser Utilization Logs
Laser hazards are varied and are associated with multiple sources, including:

- Unintentional laser beam exposure to eyes and/or skin from direct or reflected beam exposure
- Laser generated airborne contaminants (LGAC)
- Chemical exposure
- Electrical events
- Environmental risks
- Inexperience
- Fire occurrence from multiple sources
- Personnel action or inaction
- Failure to follow established policies and procedures for laser use

Any laser incident or injury must be reported to the Laser Safety Officer (LSO)
Laser Safety Concepts

Laser Hazards Review

Mitigate risk for hazardous events by practicing laser safety recommendations and:

- Adhere to administrative measures for lasers use included in facility policy and procedures
- Note emergency stop button, interlock, and fuse switches for quick responses
- Read and follow manufacturer’s recommendations and instructions
- Minimize hazards of laser beam reflection and scatter with use of nonreflective instruments
- Use specific airway safety precautions for laser treatments in or around the airway
- Attending laser training and re-training
- Read and follow laser standard operating procedures (SOP)
- Refer questions and inquiries, and report concerns to your laser safety officer (LSO)
- Communicate with your laser treatment team to maintain a safe environment.
- Only operate a laser system for which you have received training, and for which you have obtained facility privileges to operate!
Physician Laser Safety Training Assessment Test

You may send a copy of the final four slides with your answers indicated, or send only your answers to the 20 questions; be sure to include your name and contact information. Instructions for submitting are at the end of the test.

1. The laser delivery device and accessories can affect the power density of the laser beam delivered and the resultant effect on tissue.
   a. True
   b. False

2. An accessory lens can focus or defocus the laser beam on a target and, if the energy settings remain unchanged, changing from a large spot size to a smaller spot size
   a. will result in an increase of the power density.
   b. will result in a decrease of the power density.
   c. will have no effect on the power density.

3. Occupational Safety and Health Administration (OSHA), recognizes ANSI laser standards as national standards.
   a. True
   b. False

4. Depth of tissue penetration from laser energy is dependent on
   a. only the laser wavelength.
   b. only the laser wavelength and energy settings.
   c. multiple factors, including laser wavelength, tissue chromophore, power settings, and duration of exposure.

5. Some of the most commonly targeted chromophores within tissue include water, hemoglobin, melanin, and tattoo ink.
   a. True
   b. False
6. Lasers in the 200-315 nm wavelength range are in the ultraviolet portion of the light spectrum and are most likely to cause injury the following portion of the eye:
   a. Cornea  
   b. Retina  
   c. Lens  

7. Laser energy can be delivered to the target tissue after being transmitted through tissue which does not contain the laser’s target chromophore.
   a. True  
   b. False  

8. Certain chemicals, known as photosensitizing agents, can affect an increase in skin sensitivity from ultraviolet exposure.
   a. True  
   b. False  

9. A physician has the responsibility to select the laser delivery system, power settings and accessories appropriate for the procedure to be performed, and only those laser systems for which that physician has training and is credentialed.
   a. True  
   b. False  

10. Special precautions are required with laser use in and around the airway, including
     a. remove flammable lotion, cologne or hair spray from patient hair or skin.  
     b. avoid pooling of flammable liquid preparations.  
     c. suctioning around endotracheal tube and under drapes to remove gaseous concentrations prior to use of laser.  
     d. when needed, use water-based lubricants around laser treatment area.  
     e. All of the above
Physician Laser Safety Training Assessment Test

11. The photothermal effect refers to light energy of a laser absorbed by target tissue and converted to heat, which can coagulate or vaporize the tissue, and can result in thermal spread to adjacent tissue.
   a. True
   b. False

12. In some instances a laser beam wavelength of one frequency can be passed through a crystal which generates a twofold increase in frequency (halving the wavelength - doubling the frequency). This is known as a
   a. frequency-doubled laser.
   b. half-wavelength laser.
   c. crystal flux laser.

13. Many lasers can transmit long distances and through glass; laser window barriers should be placed to prevent the laser beam from extending past the NHZ.
   a. True
   b. False

14. Which of the following is true?
   a. Laser manufacturers are self-regulated and hold themselves to high standards.
   b. Occupational Safety and Health Administration (OSHA) regulates laser manufacturers and products.
   c. The Food and Drug Administration’s (FDA) Center for Devices and Radiologic Health regulates all laser products.

15. Use of lasers classified as 3B or 4 requires all of the following except:
   a. Procedural and administrative controls
   b. Laser Training
   c. Laser Safety Officer
   d. Flashing light when the laser is in the ready mode
Physician Laser Safety Training Assessment Test

16. Class 4 lasers present an immediate skin and eye hazard from exposure to either the direct or reflected laser beam.
   a. True
   b. False

17. It is permissible to fire the laser even if the aiming beam is not working, as long as you know where you are directing the beam.
   a. True
   b. False

18. The wavelength of the laser output is the most important factor in determining the type of laser eye protection to be used by everyone in the laser treatment area, including the patient.
   a. True
   b. False

19. Which of the following laser wavelengths is most likely to cause retinal damage?
   a. 315-400 nm
   b. 400-780 nm
   c. 1400-3000 nm
   d. A & C
   e. None of the above

20. The primary protection from surgical smoke (laser and non-laser) is a local exhaust ventilation/suction device within 2 inches of the smoke and is the first line of defense from surgical and laser generated airborne contaminants, which can:
   a. cause headache, nausea, vomiting.
   b. be small particles which are unable to be filtered by surgical masks.
   c. present carcinogenic and mutagenic risks.
   d. include aerosolized biomaterial including dead and live cell material and virus.
   e. All of the above
You Have Completed The
Physician Laser Safety Training Assessment Test!

Please Submit Your Answers As Indicated Below

You may send a copy of slides 44 through 47 with your answers indicated, or send only your answers to the 20 questions; be sure to include your name and contact information when submitting your answers. The LSO will send results to you and inform EHS Medical Staff Affairs after receiving successful completion of this laser safety course assessment test.

At the time of the posting of this course, 9/2014, the EHS Laser Safety Officer is Jacqueline A DeMaio, RN, CNOR, CMLSO, who can be reached at 603-663-2293. Please submit the answers for the assessment test via one of the following:

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