Laser Information and Safety

What is a laser? A laser is a device that emits light (electromagnetic radiation) through a process of optical amplification based on the stimulated emission of photons. Electromagnetic radiation consists of electromagnetic waves, this includes radio waves, infrared, visible light, ultraviolet, x-rays, and gamma-rays. The term “laser” is from the acronym for **Light Amplification by Stimulated Emission of Radiation**. The Laser was a great technical discovery, but in the beginning this technology did not have much purpose.

![The Visible Light Spectrum](image)

According to the **National Academy of Engineering**, “Adaptation is nothing new in medicine, and physicians always seemed ready to find...
new uses for technology’s latest offspring. Lasers are perhaps the best case in point.” The Academy said that not long after its invention, it was taken up by the medical field and has become one of the most effective surgical tools of the 20th centuries last three decades.

The **Optical Cavity** contains the media to be excited with mirrors to redirect the produced photons back along the same general path.

The **Pumping System** uses photons from another source as a xenon gas flash tube (optical pumping) to transfer energy to the media, electrical discharge within the pure gas or gas mixture media (collision pumping), or relies upon the binding energy released in chemical reactions to raise the media to the metastable or lasing state.

The **Laser Medium** can be a solid (state), gas, dye (in liquid), or semiconductor. Lasers are commonly designated by the type of lasing material employed.

Laser utilizes the natural oscillations of atoms or molecules between energy levels for generating a beam of coherent electromagnetic radiation usually in the ultraviolet, visible or infrared regions of the spectrum.
Spatial (relating to, occupying, or having the character of space) coherence typically is expressed through the output being a narrow beam which is diffraction-limited, often a so-called “pencil beam”. Laser beams can also be focused into a very small spot or dot, which creates a very high irradiance. Irradiance is the power of electromagnetic radiation per unit of area (radiative flux) incident on a surface. The SI units for all of these quantities are watts per square meter (W/m²).

Temporal (or longitudinal) coherence implies a polarized wave at a single frequency, whose phase is correlated over a relatively large distance (the coherence length) along the beam. A beam produced by a thermal or other incoherent light source has instantaneous amplitude and phases which vary randomly with respect to time and position, thus a very short coherence length.

Each laser can be manipulated to achieve different effects. Each laser has a mode for the specific interaction and delivery to tissue. Common operational modes are:

1. Continuous mode: A steady state of power from the laser. Output persists at a constant uninterrupted time interval. This can be set to a “pulse” by setting a duration and interval time.
2. Pulsed: A short single burst of power usually lasting 0.25 seconds or less. It cannot maintain a high power in a steady state. Designed into the laser and is not a selection.
3. Single pulsed mode: Produces one spot at a time.
4. Super pulsed mode: Produces a train of pulses at a very fast rate.
5. Q switched/mode locking: Pulsing techniques that deliver peak powers with very high watts for a very short nanosecond. This is produced in a sequenized phase.
**Pulses:**

Timed pulses are good for maintain surgical control.

<table>
<thead>
<tr>
<th>Time Scale For Pulses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seconds</td>
</tr>
<tr>
<td>Milliseconds</td>
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<tr>
<td>Microsecond</td>
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<td></td>
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<tr>
<td>Nanosecond</td>
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<tr>
<td>Picosecond</td>
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</tbody>
</table>

1 of 18 Charts

**Laser Delivery Devices:**

Laser light can be delivered to the surgical site (field) by various means. Delivery systems must be handled with care and protected. Lenses must be kept dust free and clean with no smudges. They have protective coatings that must be cleaned with special cleaning agents so as to not destroy or damage the lens protective coating. The beam exiting the laser arm remains collimated until a focusing lens delivery devise is attached to the arm.

The delivery device use may consist of a hand – piece or micromanipulator with microscope setup. The HCLS should not be activated if there is a faulty aiming system, a misaligned beam or non-functioning aiming beam. Appropriate beam alignment testing following the manufactures recommendations should be completed prior to using the system. Most laser issues happen during the testing phase.

The most common delivery systems / devices are:

1. Articulating arms:
• Primarily for CO\textsubscript{2} lasers
• Laser beam travels thru a hollow tube that contains mirrors positioned at various joints that reflect the beams forward.
• The treatment laser and the aiming beam laser must be in the same alignment. Most incidents occur during the alignment phase.
• Bumping or mishandling the articulating arms can cause the mirrors to become misaligned; this can cause the treatment laser beam to be off the target site.

2. Laser handpiece:
• Connected to the articulated arm to deliver the laser beam to the tissue.
• Used in freehand style, like a scalpel.
• Handpiece is a lens device that allows a laser beam to be focused onto the tissue in a small spot.
• They are available in various sizes providing various spot sizes.
• Laser beam spot size can affect whether cutting or coagulating is occurring.
• Some handpieces have a tubing connection that allows air and CO₂ to purge the barrel to prevent smoke or splatter from coating or clouding the focusing lens.

3. Micromanipulator:

• Attached to the laser for either a microscope or colposcope.
• The focal length of the microscope lens must coincide with the focal length of the laser lens. The micromanipulator allows the focal point to be adjusted to provide coordination with the lens being used on the scope, i.e., 250 lens, 400mm lens on the scope.
• The laser beam is moved within a small area by rotating a “joystick” that runs a mirror to reflect the laser beam to the tissue.
4. Laser split lamp:

- A regular split lamp is generally used in clinics for eye exams.

- A laser spit lamp is attached usually to a laser unit.
- Allows angled viewing paths and high resolution of the fundus and peripheral viewing along with depth.

5. Laser indirect Ophthalmoscope (LIO)
Figure 9

- Ophthalmoscope that is connected to the laser unit via a cord.
- An LIO is placed on the surgeon’s head, similar to a headlight and tightened in place.
- The LIO is heavier due to the mirrored optics in the front. Care must be used when handling it so as not to break or damage either the mirrored optics or the cord or possibly both.
- The LIO must be used with a hand held focal lens.

Figure 10

6. Fiber Optics laser:

- A long and thin hand piece.
- It is made of flexible hollow material containing thousands of small internal reflective surfaces thru which the laser light is conducted from the laser unit to the end tip of the fiberoptic.
- It has a protective outer surface that shields the laser beam exposure along the shaft.
- Fiberoptics can be disposable single use items or reusable.
• Handle them with care, do not break or the laser beam may show thru the broken area.
• Tips must be inspected for integrity.
• Scissors and strippers are available to trim tips if needed.
• These fibers come in various diameters and spot sizes.

7. Contact rods and tips:

![Optics Planet.com](https://i.imgur.com/3Q5Q5Q5.png)

- Various sized and shaped glass rods or tips that are connected to a receptive hand piece.
- Used for contact laser application - where the tip actually touches the tissue.

**This history of lasers:**

Albert Einstein (14 March 1879-18 April 1955) was a theoretical physicist who developed the theory of general relativity.
Einstein was often thought of as the father of modern physics. We all know him for his mass-energy equivalence formula \( E=mc^2 \) (The world’s most famous equation). Einstein won the Nobel Prize in 1921 in physics for his service to theoretical physics, and his discovery of the law of photoelectric effect. This was considered pivotal in establishing quantum theory within physics. Prior to the Nobel Prize in 1917 Einstein established the theoretic foundations for the laser and the maser in the paper *Zur Quantentheorie der strahlung* (On the Quantum Theory of Radiation); via a re-derivation of Max Planck’s law of radiation, conceptually based upon probability coefficients (Einstein coefficients) for the absorption, spontaneous emission, and stimulated emission of electromagnetic radiation. Stimulated Emission is the SE part of the laser acronym.

Albert Einstein visited the United States when Adolf Hitler came to power in 1933 and did not go back to Germany, where he had been a professor at the Berlin Academy of Sciences. He became a citizen in 1940. He had citizenship in many countries prior to the US. An interesting fact is that he helped alert President Franklin D. Roosevelt to the notion that Germany might be developing an atomic weapon, and recommended that the U.S. begin similar research. This information lead to what was called the Manhattan Project.

Rudolf W. Ladenburg, in 1928, confirmed the existence of the phenomenon of stimulated emission and negative absorption.

In 1953, Charles Townes and graduate students James P. Gordon and Herbert J. Zeiger, in 1953 produced the first microwave amplifier. This device operated on similar principles to the laser, but amplifying microwave radiation instead of infrared or visible radiation. Townes
and Arthur Schawlow in 1954, invented the maser\(^2\) (microwave amplification by stimulated emission of radiation). The maser used ammonia gas and microwave radiation and was invented before the (optical) laser.

In 1958, Charles and Arthur theorized and published papers about a visible laser, an invention that would use infrared and/or visible spectrum light. They, however, never did any research toward this technology. On March 24, 1959 they were granted a patent for the maser, which was used to amplify radio and as an ultrasensitive detector for space research. In 1964 Charles Townes, Nikolay Basov and Aleksandr Prokhorov shared the Nobel Prize in Physics, “for fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the maser-laser principle”.

Theodore Maiman, in 1960 at Hughes Research Laboratories, invented the Ruby Laser, which is considered to be the first successful optical or light laser. The Ruby Laser uses a synthetic ruby crystal as its gain medium.

Example of a Ruby Laser

Gordon Gould in 1958 was inspired to build his optical laser. He was the first person to use the word laser while at a conference in 1959. Gould
published the term laser in the paper *The LASER, Light Amplification by Stimulated Emission of Radiation*. Gould’s notes included the possible applications for a laser, including spectrometry, interferometry, radar and nuclear fusion. However, he failed to file for a patent for his invention until 1959, at which time his request was refused. Bell Labs had already been awarded a patent in 1960 which lead to Gould’s technology being exploited by others. Gould also filed a lawsuit that lasted twenty eight years over the patent. Controversy states that Gould should have been first, yet, even with this patent issue, historians still claim Mainman as the first inventor of the optical laser. It was not until 1977 that Gordon finally won his patent war and received his first patent for the laser.

Ali Javan, was born in Tehran to Iranian Azeri parents from Tabriz. Javan moved to the United States, in 1948 right after the war. He received his PhD in physics from Columbia University in 1954 under his thesis advisor Charles Townes. In 1955 Javan held a position as a Post-Doctoral in the Radiation Laboratory and worked with Townes on the Atomic clock research. Javan also used microwave atom beams spectrometer to study the hyperfine structure of atoms like copper and thalium.

At MIT in the early 1960’s he worked as a physicist, starting a project at extending microwave frequency measuring techniques into the infrared, from which he developed the first “Absolutely Accurate” measurement of the speed of light. On December 12, 1960, he tested his invention of the first helium neon gas laser. The gas laser was the first continuous-light laser and the first to operate “on the principle of converting electrical energy to a laser light output.” This laser has been
used in many practical applications. The gas laser laid the foundation for fiber optic communication.

In 1962, Bosov and Javan proposed the semiconductor laser diode concept. Javan received the Albert Einstein Award in 1993. Javan has been ranked number 12 on the list of the top 100 living geniuses and in 2006 was inducted into the National Inventors Hall of Fame.

Robert Hall, in 1962, created a new revolutionary type of laser (semiconductor injection laser) that is still used in many of the electronic appliances and communications systems that we use every day. He demonstrated the first laser diode device, made of gallium arsenide and emitted at 850 nm the near-infrared band of the spectrum.

Later in 1962, Nick Holonyak Jr. demonstrated the first semiconductor laser with a visible emission. The first semiconductor laser could only be used in pulsed-beamed operation, and when cooled to liquid nitrogen temperatures (77K).

Again, in 1962, H.L. Rosomoff and F. Carroll were the first to report the use of a laser in clinical neurosurgery and the laser was initially used in the treatment of brain tumors.

Kumar Patel, in 1964, invented the Carbon Dioxide Laser.

Hildreth “Hal” Walker, born in Alexandria, Louisiana in 1933, faced major challenges as a young black boy in this era. While growing up, his family forbade him from seeing his estranged father and isolated him from significant social or academic advancement. But on the sly, young Walker still on the sly would visit his dad, and once received a toy Buck
Rogers ray gun as a gift. He also befriended a white family who let him work as an informal apprentice at their vacuum cleaner repair shop.

Hal’s family soon moved to Los Angeles, and throughout high school sharpened his skills in mechanics and electronics. Walker wanted to go into the film industry, but could only find work with the Navy, installing radar systems in fighter planes. After the Korean War ended it took a few years before he got his big break and RCA hired him to help develop the US government’s Ballistic Missile Early Warning System, designed to warn the US in the event of Soviet nuclear attack (1959).

Walker went on to direct global telecommunications projects, including the first television broadcast transmitted from Earth to a satellite and back to Earth again in 1962.

1965, Lasers were introduced into the field of neurosurgery when Arthur Earl Walker Neurosurgeon, Neuroscientist and Epileptologist and Fine et al demonstrated that a single focused 20 J or unfocused 100 pulse from a ruby laser for 1 ms on mice cranium. During this same time Stellar investigated the effects of ruby laser pulses on the exposed brain, spinal cord and peripheral nerves of Cats.

In 1966 James Hobart was an employee of Trion Instruments, the first commercial LASER Company founded by Lloyd G. Cross in 1961. He went on to be the founder of the first commercial CO₂ LASER Company.

In 1969 came Walker’s greatest success. He would lead a team that adapted a Ruby Laser for measuring the distance from the Earth to the Moon during the Apollo 11 mission. In 1981, Walker joined Hughes Aircraft where he developed the first laser targeting systems for the US
Army. The equipment used for the experiment in now on permanent exhibit in the Smithsonian’s National Museum of American History.

Walker since retiring has founded his own international laser systems consulting firm, Tech plus (1990). In addition he and his wife, Bettye, co-founded” the African-American Male Achievers Network, Inc.,” which uses hands-on projects to encourage and support boys and girls who are interested in careers in math, science and business.

Zhores Alferov in the USSR, and Izuo Hayashi and Morton Panish of Bell Telephone Laboratories, in 1970, independently developed room, continual-operational diode lasers, using the Herojuction structure.

Doctor Steven Trokel patented the Excimer laser for vision correction. The Excimer laser was originally used for etching silicone computer chips in the 1970’s. Working at the IBM research laboratories in 1982, Rangaswamy Srinivasin, James Wynne and Samuel Blum saw the potential of the Excimer laser in interacting with biological tissue. Srinivasin and the IBM team realized that you could remove tissue with a laser without causing any heat damage to the neighboring material.

It took the observations of Dr. Fyodorov, in a case of eye trauma in the 1970’s, to bring about the practical application of refractive surgery through radial keratotomy.

Steven Trokel, in 1987, made the connection to the cornea and performed the first laser surgery on a patient’s eye in 1987. The next 10 years were spent perfecting the equipment and techniques used in laser eye surgery. In 1996 the first Excimer laser for ophthalmic refraction use was approved in the US.
<table>
<thead>
<tr>
<th>Date</th>
<th>Name</th>
<th>Laser Advancement or Accomplishment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>Max Ernst Ludwig Plank (1858-1947)</td>
<td>Gave us the understanding that light is a form of electromagnetic radiation.</td>
</tr>
<tr>
<td>1928</td>
<td>Rudolph W Landenburg (1882-1952)</td>
<td>Confirmed the existence of stimulated emission and negative absorption.</td>
</tr>
<tr>
<td>1947</td>
<td>Willis E Lamb (1913-2008)</td>
<td>Induced (stimulated) emission suspect in hydrogen spectrum, made and demonstrated first stimulated emission.</td>
</tr>
<tr>
<td>1951</td>
<td>Charles H Townes (1915-2012 Awarded the Golden Goose award)</td>
<td>The inventor of the MASER at Columbia University- Awarded the Nobel prize In 1964 first device based on emission.</td>
</tr>
<tr>
<td></td>
<td>James P. Gordan (1928- present)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nikolai G. Basov (1922-2001)</td>
<td></td>
</tr>
<tr>
<td>1956</td>
<td>Nicolas Bloembergan 1920-present</td>
<td>First proposal for a three-level solid state MASER at Harvard Univerisity</td>
</tr>
<tr>
<td>Year</td>
<td>Name(s)</td>
<td>Description</td>
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<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Charles H Townes</td>
<td></td>
</tr>
<tr>
<td>1959</td>
<td>Gordon Gould</td>
<td>Applies for Laser related Patents and is refused.</td>
</tr>
<tr>
<td>1959</td>
<td>John D. Myers</td>
<td>Created first Stroboscopic X-ray system at Penn State University. Precursor to the LASER.</td>
</tr>
<tr>
<td>1960</td>
<td>Peter P Sorokin Mirek Stevenson</td>
<td>First Uranium LASER, Second LASER in this time frame, November 1960 IBM Labs.</td>
</tr>
<tr>
<td></td>
<td>William Bennett (1930-2008)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Donal R. Harriot (1928-2007)</td>
<td></td>
</tr>
<tr>
<td>Cont.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1961</td>
<td>Lloyd G. Cross</td>
<td>First commercial laser company, Trion Instruments was founded in March, First spinning prism Q-switched RUBY Laser. Third RUBY LASER, Trion became Siergler, Laser Systems Center in 1962.</td>
</tr>
<tr>
<td>1961</td>
<td>Robert Rempel</td>
<td>Co-founder Spectra-Physics, which became the second company to make LASERS.</td>
</tr>
<tr>
<td>1961</td>
<td>AG Fox and Tingye LI</td>
<td>Theoretical analysis of optical resonators at Bell Labs.</td>
</tr>
<tr>
<td>Year</td>
<td>Inventor(s)</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
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<tr>
<td>1961</td>
<td>Ralph R. Soden, Scotch Plains Le Grand “Larry” G. Van Uitert</td>
<td>First continuous wave operation of rare earth doped crystal LASER at Bell Labs. Patent Number 3,177,155</td>
</tr>
<tr>
<td>1962</td>
<td>Fred J. McClung</td>
<td>First electro-optic Kerr cell Q-switch.</td>
</tr>
<tr>
<td>1962</td>
<td>Robert Hall, Nick Holonyak</td>
<td>Invention of semi-conductor LASER at General Electric Labs.</td>
</tr>
<tr>
<td>1962</td>
<td>Alan White, Dane Rigden</td>
<td>First helium neon (HeNe) visible CW LASER at Bell Labs.</td>
</tr>
<tr>
<td>1962</td>
<td>Fred Brech, Lloyd G. Cross</td>
<td>First LASER Induced Breakdown Spectroscopy (LIBS) chemical analysis system at Jarrell-Ash &amp; Trion Instruments.</td>
</tr>
<tr>
<td>1963</td>
<td>Robert Keyes, Theodore Quest</td>
<td>First Diode pumping solid state LASER, uranium doped calcium fluoride at MIT Lincoln Labs.</td>
</tr>
<tr>
<td>1963</td>
<td>Kumar N. Patel</td>
<td>Obtained laser Action in CO₂.</td>
</tr>
<tr>
<td>1964</td>
<td>John D. Myers</td>
<td>First Gigawatt LASER (RUBY) oscillator/amplifier system at Cornell Aeronautical Laboratory.</td>
</tr>
<tr>
<td>1964</td>
<td>John D. Myers</td>
<td>First field demonstration of a RUBY Laser rangefinder/ceilometer at Cornell Aeronautical Laboratory.</td>
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<tr>
<td>Year</td>
<td>Name(s)</td>
<td>Event</td>
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<tr>
<td>1964</td>
<td>Elias Snitzer</td>
<td>First fiber LASER &amp; first LASER amplifier at American Optical.</td>
</tr>
<tr>
<td>1964</td>
<td>Kumar N Patel</td>
<td>Inventor of CO₂ LASER at Bell Labs.</td>
</tr>
<tr>
<td>1964</td>
<td>William Bridges</td>
<td>Invention of Argon Ion LASER at Hughes Labs.</td>
</tr>
<tr>
<td>1965</td>
<td>John D. Myers</td>
<td>First dual frequency LASER ceilometer at Lear Siegler Laser System Center.</td>
</tr>
<tr>
<td>1965</td>
<td>George Pimental, J V V Kasper</td>
<td>First chemical LASER at University of California, Berkley, CA.</td>
</tr>
<tr>
<td>1965</td>
<td>John D. Myers</td>
<td>First frequency-doubled LASER rangefinder At Lear Siegler Laser System Center.</td>
</tr>
<tr>
<td>1966</td>
<td>Ed Gerry, Arthur Kantrowitz</td>
<td>First 10+ KIlowatt CO₂ LASER at Avco Everett Research Lab.</td>
</tr>
<tr>
<td>1966</td>
<td>James Hobart</td>
<td>Founded first commercial CO₂ Laser company Coherent Radiation (now Coherent Inc.)</td>
</tr>
<tr>
<td>1966</td>
<td>William Silfvast, Grant Fowlers &amp; Hopkins</td>
<td>First metal vapour LASER – Zn/Cd – at university of Utah</td>
</tr>
<tr>
<td>1966</td>
<td>John D. Myers</td>
<td>First plane position indicating LASER radar</td>
</tr>
<tr>
<td>Year</td>
<td>Inventor(s)</td>
<td>Event Description</td>
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<tr>
<td>------</td>
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</tr>
<tr>
<td>1966</td>
<td>Peter Sorokin, John Lankard</td>
<td>First Dye LASER action at Hughes Research Labs.</td>
</tr>
<tr>
<td>1966</td>
<td>Mary L. Spaeth</td>
<td>First tunable dye LASER at Hughes Research Labs.</td>
</tr>
<tr>
<td>1967</td>
<td>Bernard Soffer, B. B. McFarland</td>
<td>First wavelength tunable dye LASER at Korad.</td>
</tr>
<tr>
<td>1968</td>
<td>Laser Institute of America (LIA)</td>
<td>LIA the professional society for laser application and safety is founded.</td>
</tr>
<tr>
<td>1968</td>
<td>Dr. Bhaum</td>
<td>First CO₂ LASER application for refractive eye surgery.</td>
</tr>
<tr>
<td>1969</td>
<td>Khee M. Siegel</td>
<td>First commercial fusion LASER research program at KMS Industries.</td>
</tr>
<tr>
<td>1969</td>
<td>G M Delco</td>
<td>First industrial installation of three LASERS for automobile application.</td>
</tr>
<tr>
<td>1970</td>
<td>Nikolai Basov</td>
<td>First Excimer LASER at Lebedev Labs, Moscow based on Xenon (Xe₂) only.</td>
</tr>
<tr>
<td>1972</td>
<td>Charles H. Henry</td>
<td>First quantum well Laser</td>
</tr>
<tr>
<td>1973</td>
<td>ManiLal Bhaumik</td>
<td>First eximer LASER application for refractive eye surgery.</td>
</tr>
<tr>
<td>1973</td>
<td>Lloyd Cross</td>
<td>First commercial LASER hologram company</td>
</tr>
<tr>
<td>Year</td>
<td>Name(s)</td>
<td>Event</td>
</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td>1973</td>
<td>John Myers</td>
<td>Formed Kigre, inc, where Myers remained active in laser glass research, leading to over a dozen novel laser glasses compositions. Including Phosphate laser glasses licensed Owens-Illinois.</td>
</tr>
<tr>
<td>1975</td>
<td>Ewing and Brau</td>
<td>Report LASER action on KrF an XeCl.</td>
</tr>
<tr>
<td>1976</td>
<td>Jim Hsieh</td>
<td>First InGaAsP diode Laser at MIT Lincoln Labs.</td>
</tr>
<tr>
<td>1980</td>
<td>Geoffrey Pert’s Group</td>
<td>First report of X-ray LASER action, Hull University, UK.</td>
</tr>
<tr>
<td>1982</td>
<td>Peter F. Moulton</td>
<td>First titanium sapphire LASER at MIT Lincoln Labs.</td>
</tr>
<tr>
<td>1984</td>
<td>Dennis Matthew’s Group</td>
<td>First reported demonstration of a “laboratory” X-ray Laser from Lawrence Livermore Labs.</td>
</tr>
<tr>
<td>1985</td>
<td>John D. Myers</td>
<td>First commercial LASER eye surgery device and method, US patent Number 4,525,942 and UK patent number GB 2 157 483 A at Kigre, Inc.</td>
</tr>
<tr>
<td>1985</td>
<td>Dennis Matthews and Rosen</td>
<td>Demonstrate first x-ray LASER</td>
</tr>
<tr>
<td>1987</td>
<td>David Payne</td>
<td>First erbium fiber LASER amplifier</td>
</tr>
<tr>
<td>1988</td>
<td>Patricia Bath</td>
<td>First African American women to patent a medical invention patent # 4744360. The LASER phaco Probe.</td>
</tr>
<tr>
<td>Year</td>
<td>Name(s)</td>
<td>Achievement</td>
</tr>
<tr>
<td>------</td>
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<td>-----------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1994</td>
<td>Nikolai Ledentsov</td>
<td>First quantum dot LASER at Ioffe Physico-technical Institute.</td>
</tr>
<tr>
<td>1996</td>
<td>Wolfgang Keterle</td>
<td>First pulsed atom LASER at MIT.</td>
</tr>
<tr>
<td>1996</td>
<td></td>
<td>First Petawatt LASER at Lawrence Livermore National Labs.</td>
</tr>
<tr>
<td>1997</td>
<td>Wolfgang</td>
<td>First atom LASER at MIT Lincoln Labs.</td>
</tr>
<tr>
<td>2004</td>
<td>Ozdal Boyraz, Bahrom Jalai</td>
<td>First silicon Raman LASER at the University of California, Los Angeles.</td>
</tr>
<tr>
<td>2006</td>
<td>John Bowers</td>
<td>First silicon Laser</td>
</tr>
<tr>
<td>2008</td>
<td>Fumio Koyoma</td>
<td>IEEE winner for contributions to development of theories of strained quantum-well lasers</td>
</tr>
<tr>
<td>2007</td>
<td>John Bowers, Brian Koch</td>
<td>First Mode-locked silicone evanescent LASER</td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td>First 10 Petawatt Laser At Lawrence Livermore National Labs.</td>
</tr>
<tr>
<td>2010</td>
<td>Wood-Hi Cheng</td>
<td>Wood-Hi Cheng a Taiwan engineer received the IEEE Photonics Engineering Achievement for Exceptional engineering contribution with significant development of laser and electro optics technology. Awarded two US and one Taiwan patents for green light LASER.</td>
</tr>
<tr>
<td>2010</td>
<td>Dieter Bimberg</td>
<td>IEEE award winner for demonstration of quantum dot lasers</td>
</tr>
<tr>
<td>Year</td>
<td>Institution</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>----------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>2011</td>
<td>Harvard medical school and General Hospital in Boston, MA.</td>
<td>June 2011, created the world’s first biological LASER by merging light-emitting proteins from Jellyfish with a single human cell. Believing that such a laser can study a specific body cell or treating diseases.</td>
</tr>
<tr>
<td>2011</td>
<td>Yale University</td>
<td>Announced in February that they had built the first ANTI-LASER, incoming beams of light cancel each other out.</td>
</tr>
<tr>
<td>2012</td>
<td>Pangolin</td>
<td>Won ILDA Technical Achievement for a “LASER System”. 8 July 2012</td>
</tr>
<tr>
<td>2012</td>
<td>Josef Bille</td>
<td>From Germany, Wins lifetime achievement awards from European patent office for an Intelligent Surgical LASER (ISL) a Femtosecond LASER for Intrastromal ablation.</td>
</tr>
<tr>
<td>2012</td>
<td>Mark Oxborrow</td>
<td>Physicist at the UK National Physical Laboratory Built the first Practical Maser (Microwave Laser) using a pink crystal.</td>
</tr>
<tr>
<td>2012</td>
<td>SPIE</td>
<td>Many Senior members involved in LASER development.</td>
</tr>
</tbody>
</table>

**Who sets our standards for Laser use:**

American National Standards Institute (ANSI) is the approved American National standard for safe use of lasers in health care. AORN also sets the standards for lasers in the Operating Room.

In 1968, the American National Standards Institute (ANSI) approved the initiation of the Safe Use of Lasers Standards Projects under the sponsorship of Telephone Group. Laser Institute of America (LIA) is the secretariat and publisher of the American National Standards Institute.
(ANSI) Z136 series of the laser safety standards. ANSI Z136 series is recognized by OSHA, and is the authoritative series of laser safety documents in the United States.

Prior to 1985, Z136 standards were developed by ANSI Committee Z136 and submitted for approval and issuance as ANSI Z136. Since 1985 Z136 standards are developed by the ANSI Accredited Standards Committee (ASC) Z136 for Safe Use of Lasers. A Copy of the procedures for development of these standards can be obtained from the secretariat, Laser Institute of America, 13501 Ingenuity Drive, Suite 128, Orlando, FL 32826 or viewed at www.z136.org.

The Present scope of ASC Z136 is responsible for the development and maintenance of this standard.

ASC Z136 is responsible for the development and maintenance of this standard. In addition to the consensus body, ASC Z136 is composed of standards subcommittees (SSC) and technical subcommittees (TSC) involved in Z136 standards development and an editorial working group (EWG).

The six standards currently issued as of the date this paper was written are:

Federal Regulatory Considerations

1. General:

The Federal Food and Drug Administration (FDA) Center for Devices and Radiologic Health (CDRH) has the responsibility for implantation and enforcing the laws and regulations that apply to radiation producing electronic products and medical devices.

Medical devices, including laser systems for medical applications, require clearance or premarket approval by the FDA in order to be introduces commercially in the United States. Clearance can follow the review of a premarket notification under section 510(K) of the Federal Food, Drug and cosmetic Act (FFDCA) for a device that is substantially equivalent to a device that was in commercial distribution in the U.S. prior to May 1976 (enactment date of the Medical Device Amendment
to the FFDCA), or to previously cleared devices. All other devices require FDA approval of a premarket approval application (PMA). Clearances and premarket approvals are device specific, and for the indication claimed in the cleared or approved labeling.

2. Federal Laser Production Performance Standard (FLPPS):

Manufacturers of laser products are required to certify that their products comply with the Federal Laser Product Performance Standard (Title 21, Code of Federal Regulations, and Part 1040) promulgated and enforced by CDRH. Under provisions of the Radiation Control for Health and Safety Act (RCHSA) this standard is intended to ensure that unnecessary access to laser and collateral radiation is prevented and that each laser product provides adequate safety-related engineering control features, labeling, and instructions for use. A classification scheme which is very similar, but not identical, to that used in ANSI Z136.1 determines which performance features and labels the manufacturer must provide.

Products certified by their manufacturers to be in compliance with the FLPPS may be considered as fulfilling all the classifications and performance requirements of this standard since the FLPPS is generally more restrictive. In cases where the laser or laser system classification is not provided by the manufacturer, has been modified or is not being used as originally intended, the classification of the laser or laser system must be effected by the LSO. Following classification, the appropriate safety control measures can then be instituted.

Laser and laser systems that are made by a practitioner or in-house by an HCF or the in-house modification of certified laser products with subsequent use on patients are acts of manufacture and introduction
into commerce. Such devices must be certified and reported to CDRH in accordance with federal regulations.

CDRH has been moving toward harmonization of the requirements of its standard for laser products, IEC 60825-1 and the particular standard for classes 3B and Class 4 medical laser products, IEC 60601-2-22. As an interim measure, CDRH issued its guidance document; laser Notice 50, stating that it would not object to conformance with the IEC standard in lieu of conformance with specified requirements of the FLPPS. Laser Notice 50 is available at www.cdrh.fda.gov.

3. Medical Devices

The Medical Device Amendments (MDA) to the FFDCA requires that medical lasers be regulated as medical devices. The amendment places all medical devices in one of three classes (I, II, or III), which are not related to the laser hazard classification schemes of the FLPPS or this standard. Rather they refer to the degree of regulatory control necessary to ensure that each device is safe and effective.

**Class I** devices are subject to general controls only, including Good Manufacturing Practices (GMPs), registration and listing, and other requirements listed in 21 CFR 860.3 (c) (1). Medical lasers are not usually placed in class I.

**Class II** devices are those which have been designated as requiring special controls such as performance standards to ensure safety and effectiveness or other control measures described in 21 CFR 860.3 (c) (2). Most medical lasers are placed in Class II.

**Class III** medical devices require or will require premarket approval (PMA) by the FDA before they can be promoted. All clinical data
required to support a PMA for Class III device must be obtained within the investigational device regulations as described in the Federal regulations (Title 21, Code of Federal Regulations Part 812).

The use of a new or unclear device in a clinical investigation to obtain data to support a PMA or FDA market clearance requires that there be an investigation protocol limited in scope and duration that includes the following:

1) Approval by an Investigational Review Board (IRB)
2) Approval by the FDA for investigations of devices of significant risk
3) Informed patient consent

The device may not be promoted to patients or to potential purchasers as safe or effective for any indications that have not been approved by the FDA.

The requirements of this standard are applicable to the investigational use of an HCLS. Additional precautions generally should be taken by the investigator who is the user, and the LSO, because the instructions for safe use normally provided by the manufacturer may not be adequate for the specific investigator if there is no commercial interest in the investigation or the device.

Sponsors and investigators involved in clinical studies are urged to carefully review the outline of the Investigative Device Exemption (IDE) regulations (21 CFR 812). Questions concerning the status of medical laser devices should be directed to the FDA, CDRH, Office of Device Evaluation, 10903 New Hampshire Avenue, WO 66-1521, Silver Spring MD 20993-0002. The FFDCA does not prevent a health care practitioner from using a device in a procedure for which it has not been approved
or cleared. However, the health care facility may require the practitioner to obtain its approval of any such “off label” use.

**IMPORTANT PROPERTIES OF A LASER: TRANSITIONS**

- Most lasers are monochromatic with narrow line width
- Some lasers emit light at different wavelengths under different conditions.
- Some laser emit at two or more wavelengths at once (multiline lasers).

Type of transitions:

<table>
<thead>
<tr>
<th>Type of Transition</th>
<th>Typical Energy (eV)</th>
<th>Wavelength Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic</td>
<td>» 1-10</td>
<td>Near IR·visible·UV</td>
</tr>
<tr>
<td>Vibrational</td>
<td>» 0.1-2</td>
<td>Middle IR</td>
</tr>
<tr>
<td>Rotational</td>
<td>» 10⁻⁵-10⁻³</td>
<td>Far IR·microwave</td>
</tr>
</tbody>
</table>

The definition of power is 

\[
P = \frac{dE}{dr} = \frac{\Delta(\text{energy})}{\Delta(\text{time})}
\]

Output power can range from mW-MW for cw lasers and up to PW pulsed.

- Laser output is pulsed or continuous
- Pulse durations 10⁻³ to 10⁻¹⁵s.
- Repetition rate varies from 1 min⁻¹ to 10s⁻¹.
- Energy per pulse: Energy = ∫ Power dt (Joules) (i.e. Area under a plot of power vs. time)
Light waves are coherent if they are all in phase with one another (a).

Conventional sources of light (sun, light bulb) are incoherent (b).

A. Coherent light  
B. Incoherent light

· Temporal coherence: phase correlation at a given point in space at two different instances of time (depends on the frequency bandwidth of the source).

· In order to be temporal coherent, light waves have to be monochromatic (the more monochromatic, the more coherent)

· Spatial coherence: Phase correlation of two different points across a wavefront at a given time (related to the apparent dimensions of the source).
### Major Wavelengths of Highly Used LASERS

<table>
<thead>
<tr>
<th>Type</th>
<th>Wavelength (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon - fluoride excimer</td>
<td>192</td>
</tr>
<tr>
<td>Krypton - fluoride excimer</td>
<td>249</td>
</tr>
<tr>
<td>Xenon - Chloride excimer</td>
<td>308</td>
</tr>
<tr>
<td>Nitrogen gas (N₂)</td>
<td>337</td>
</tr>
<tr>
<td>Organic dye (in solution)</td>
<td>320 - 1000 (tunable)</td>
</tr>
<tr>
<td>Helium - Cadmium</td>
<td>325, 442</td>
</tr>
<tr>
<td>Argon - ion</td>
<td>275 - 303, 330 - 360, 450 - 530</td>
</tr>
<tr>
<td>Krypton - ion</td>
<td>330 – 360, 420 - 800</td>
</tr>
<tr>
<td>Helium - Neon</td>
<td>543, 632, 1150</td>
</tr>
</tbody>
</table>
This demonstrates that there are so many Lasers available to us today. We can further break these down into many subcategories. The main difference between the types of laser has to do with the wavelengths. The different laser wavelengths (colors of light) target different medical issues, thus creating the need for so many different lasers to address these many tissue needs. This leads to the possibility of a combination of several different lasers that maybe recommended by a physician or surgeon to address all of the issues of the patients medical issues.

**Gas Lasers:** Uses an electric current that is discharged through a gas to produce coherent light. The gas laser was the first continuous-light laser and the first laser to operate on the principle of converting electrical energy to a laser light output.

<table>
<thead>
<tr>
<th>Laser gain medium &amp; Type</th>
<th>Operation Wavelength(s)</th>
<th>Pump Source</th>
<th>Applications and notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium-neon</td>
<td>632.8 nm (543.3 nm, 593.9 nm, 611.8 nm)</td>
<td>Electrical</td>
<td>Interferometry, Holography, Spectroscopy,</td>
</tr>
<tr>
<td>Laser</td>
<td>Wavelengths/Remarks</td>
<td>Laser Mode</td>
<td>Remarks</td>
</tr>
<tr>
<td>------------------------</td>
<td>------------------------------------------------------------------------------------</td>
<td>---------------------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Laser</td>
<td>1.1523 µm, 1.52 µm, 3.3913 µm</td>
<td>discharge</td>
<td>Barcode scanning, alignment, optical demo’s.</td>
</tr>
<tr>
<td>Argon Laser</td>
<td>454.6 nm, 488.0 nm, 514.5 nm, (351 nm, 363.8, 457.9 nm, 465.8 nm, 476.5 nm, 472.7 nm, 528.7 nm, also frequency doubled to provide 244 nm, 257 nm)</td>
<td>Electrical discharge</td>
<td>Retinal phototherapy (for diabetes), lithography, confocal microscopy, spectroscopy pumping other lasers.</td>
</tr>
<tr>
<td>Krypton</td>
<td>416 nm, 530.9 nm, 568.2 nm, 647.1 nm, 676.4 nm, 752.5 nm, 799.3 nm</td>
<td>Electrical discharge</td>
<td>Scientific research, mixed with argon to create “white – light” Laser, light shows</td>
</tr>
<tr>
<td>Xenon ion</td>
<td>Many lines throughout visible spectrum extending into the UV and IR.</td>
<td>Electrical discharge</td>
<td>Scientific research.</td>
</tr>
<tr>
<td>Carbon dioxide laser</td>
<td>10.6 µm, (9.4 µm)</td>
<td>Transverse (high power) or longitudinal (low power) electrical discharge</td>
<td>Material processing (cutting, welding, etc.), surgery.</td>
</tr>
<tr>
<td>Carbon monoxide laser</td>
<td>2.6 to 4 µm, 4.8 to 8.3 µm</td>
<td>Electrical discharge</td>
<td>Material processing (engraving, welding, etc.), photoacoustic spectroscopy.</td>
</tr>
<tr>
<td>Excimer laser</td>
<td>193 nm (ArF), 248 nm (KrF), 308 nm (XeCl), 353 nm (XeF)</td>
<td>Excimer recombination via electrical discharge</td>
<td>Ultraviolet lithography for semiconductor manufacturing, laser surgery, LASIK.</td>
</tr>
</tbody>
</table>
**Chemical Lasers:** Uses its energy from a chemical reaction. These lasers can reach megawatt levels, with continuous wave output. They are used in industrial cutting and drilling.

<table>
<thead>
<tr>
<th>Laser gain medium &amp; type</th>
<th>Operation Wavelength (s)</th>
<th>Pump Source</th>
<th>Applications and notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen fluoride laser</td>
<td>2.7 to 2.9 µm for hydrogen fluoride (&lt;80% Atmospheric transmittance)</td>
<td>Chemical Reaction in a burning jet of ethylene and nitrogen trifluoride (NF₃)</td>
<td>Used in research for laser weaponry by the U.S. DOD, operated in continuous wave mode, can have power in the megawatt range.</td>
</tr>
<tr>
<td>Deuterium Flouride laser</td>
<td>~3800 nm (3.6 to 4.2 µm) (~90% Atm. transmittance)</td>
<td>Chemical reaction</td>
<td>MIRCL, Pulsed Energy Projectile &amp; Tactical High Energy Laser</td>
</tr>
<tr>
<td>Coil (chemical oxygen – iodine laser)</td>
<td>1.315 µm ( &lt;70% Atmospheric transmittance)</td>
<td>Chemical reaction of chloride atoms with gaseous hydrazoic acid, resulting in excited molecules of nitrogen chloride, which then pass their energy to the iodine atoms.</td>
<td>Laser weaponry, scientific and materials research, laser used in the U.S. military’s Airborne laser, operated in continuous wave mode, can have power in the megawatt range.</td>
</tr>
<tr>
<td>Agil (all gas – phase iodine laser)</td>
<td>1.315 µm ( &lt;70% Atmospheric transmittance)</td>
<td>Chemical reaction of chlorine atoms with gaseous hydrazoic acid, resulting in excited molecules of nitrogen chloride, which then pass their energy to the iodine atoms.</td>
<td>Scientific, weaponry, Aerospace.</td>
</tr>
</tbody>
</table>
DYE Lasers: Uses an organic dye as a lasing medium, usually a liquid solution. Dye lasers use a much wider range of wavelengths. The reason they are suitable for tunable and pulsed lasers is because of the wide bandwidth. The dyes used can be interchanged to create different wavelengths with the same laser.

<table>
<thead>
<tr>
<th>Laser gain medium &amp; type</th>
<th>Operation Wavelength (s)</th>
<th>Pump Source</th>
<th>Applications and notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dye Lasers</td>
<td>390 – 435 nm (stilbene), 460 – 515 nm (coumarin 102), 570 – 640 nm (rhodamine 6G), many others</td>
<td>Other laser, flashlamp</td>
<td>Research, laser medicine, [²] spectroscopy, birthmark removal, isotope separation. The tuning range of the laser depends on which dye is used.</td>
</tr>
</tbody>
</table>

Metal – vapor lasers: These lasers use metal in its vapor state as the medium to generate coherent light across the spectrum. They may use precious metals. Metal-vapor lasers generate deep ultraviolet wavelengths.

<table>
<thead>
<tr>
<th>Laser gain medium &amp; type</th>
<th>Operation wavelength(s)</th>
<th>Pump Source</th>
<th>Applications and notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium – cadmium (HeCd) metal – vapor laser</td>
<td>441.563 nm, 325 nm</td>
<td>Electrical discharge in metal vapor mixed with</td>
<td>Printing and typesetting applications, fluorescence excitation (i.e. in U.S. paper currency printing). Scientific</td>
</tr>
<tr>
<td>Laser gain medium &amp; type</td>
<td>Operation wavelength(s)</td>
<td>Pump Source</td>
<td>Applications and notes</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-------------------------</td>
<td>-------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td><strong>Ruby laser</strong></td>
<td>694.3 nm</td>
<td>Flashlamp</td>
<td>Holograph, tattoo removal. The first type of visible light</td>
</tr>
</tbody>
</table>

**Solid – State Lasers:** uses a gain medium that is a solid state.
<table>
<thead>
<tr>
<th>Laser Type</th>
<th>Wavelength(s)</th>
<th>Power Source</th>
<th>Typical Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nd; Yag laser</td>
<td>1.064 µm, (1.32 µm)</td>
<td>Flashlamp, laser diode</td>
<td>Material processing, range finding, laser target designation, surgery, research, pumping other lasers (combined with frequency doubling to produce a green 532 nm beam). One of the most common high power lasers. Usually pulsed (down to fractions of a nanosecond).</td>
</tr>
<tr>
<td>NdCrYag laser</td>
<td>1.064 µm, (1.32 µm)</td>
<td>Solar radiation</td>
<td>Experimental production of nanopowders.[5]</td>
</tr>
<tr>
<td>Er: Yag laser</td>
<td>2.94 µm</td>
<td>Flashlamp, laser diode</td>
<td>Periodontal scaling, Dentistry</td>
</tr>
<tr>
<td>Neodymium YLF (Nd: YLF) solid-state laser</td>
<td>1.047 and 1.053 µm</td>
<td>Flashlamp, laser diode</td>
<td>Mostly used for pulsed pumping of certain types of pulsed Ti: Sapphire lasers, combined with frequency doubling</td>
</tr>
<tr>
<td>Neodymium doped Yttrium orthovanadate (Nd: YVO₄) laser</td>
<td>1.064 µm</td>
<td>Laser diode</td>
<td>Mostly used for continuous pumping of mode-locked Ti: Sapphire or dye lasers, in combination with frequency doubling nd: YVO₄ laser is also the normal way of making a green laser pointer.</td>
</tr>
<tr>
<td>Neodymium doped Yttrium calcium oxoborate Nd: Yca₄0 (B0₃)₃ or</td>
<td>~1.060 µm (~530 nm at second)</td>
<td>Laser diode</td>
<td>Nd: YCOB is a so called “self-frequency doubling” or SFD laser material which is both capable of lasing and</td>
</tr>
<tr>
<td>Laser Material</td>
<td>Wavelength Range</td>
<td>Power Source</td>
<td>Applications</td>
</tr>
<tr>
<td>----------------</td>
<td>------------------</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Nd: YCOB simply harmonic</td>
<td>~1.062 µm (Silicate glasses), ~1.054 µm (Phosphate glasses)</td>
<td>Flash lamp, laser diode</td>
<td>which has nonlinear characteristics suitable for second harmonic generation. Such materials have the potential to simplify the design of high brightness green lasers.</td>
</tr>
<tr>
<td>Neodymium glass (Nd: Glass) laser</td>
<td>~1.062 µm (Silicate glasses), ~1.054 µm (Phosphate glasses)</td>
<td>Flash lamp, laser diode</td>
<td>Used in extremely high power (terawatt scale), high energy (megajoules) multiple beam systems for inertial confinement fusion. Nd: Glass lasers are usually frequency tripled to the third harmonic at 351 nm is laser fusion devices.</td>
</tr>
<tr>
<td>Titanium sapphire (Ti: sapphire) laser</td>
<td>650 – 1100 nm</td>
<td>Other laser</td>
<td>Spectroscopy, LIDAR, research. This material is often used in highly – tunable mode – locked infrared lasers to produce ultrashort pulses and in amplifier lasers to produce ultrashort and ultra – intense pulses.</td>
</tr>
<tr>
<td>Thulium YAG (Tm: YAG) laser</td>
<td>2.0 µm</td>
<td>Laser diode</td>
<td>Optical refrigeration, materials processing, ultrashort pulse research, multiphoton microscopy, LIDAR</td>
</tr>
<tr>
<td>Ytterbium:₂₀₃ (glass or ceramics) laser</td>
<td>1.03 µm</td>
<td>Laser diode</td>
<td>Ultrashort pulse research, [°]</td>
</tr>
<tr>
<td>Laser Material</td>
<td>Wavelength</td>
<td>Pumping Method</td>
<td>Description</td>
</tr>
<tr>
<td>----------------</td>
<td>-------------</td>
<td>----------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Ytterbium doped glass laser (rod, plate/chip, and fiber)</td>
<td>1.µm</td>
<td>Laser diode</td>
<td>Fiber version is capable of producing several – kilowatt continuous power, having ~70 – 80% optical –to- optical and ~ 25% electrical –to- optical efficiency. Material processing: Cutting, welding, marking; nonlinear fiber optics: broadband fiber – nonlinearity based sources, pump for fiber Raman lasers; distribution Raman amplification pump for telecommunications.</td>
</tr>
<tr>
<td>Holmium YAG (Ho: YAG) laser</td>
<td>2.1 µm</td>
<td>Laser diode</td>
<td>Tissue ablation, kidney stone removal, dentistry.</td>
</tr>
<tr>
<td>Chromium ZnSe (Cr:ZnSe) laser</td>
<td>2.2 – 2.8 µm</td>
<td>Other laser (Tm fiber)</td>
<td>MWIR laser radar, counter measure against heat – seeking missiles etc.</td>
</tr>
<tr>
<td>Cerium doped lithium strontium (or calcium) aluminum fluoride (Ce: LiSAF, Ce: LiCAF)</td>
<td>~280 to 316 nm</td>
<td>Frequency quadrupled Nd: YAG laser pumped, excimer laser pumped, copper vapor laser pumped.</td>
<td>Remote atmospheric sensing, LIDAR, optics research</td>
</tr>
</tbody>
</table>
| Promethium 147 doped phosphate glass (¹⁴⁷Pm⁺³: Glass) Solid – state laser | 933 nm, 1098 nm | unknown | Laser material is radioactive. Once demonstrated in use at LLnL in 1987, room temperature 4 level lasing in ¹⁴⁷ PM doped into a lead – indium –
<table>
<thead>
<tr>
<th>Cont.</th>
<th>Chromium doped chrysoberyl (alexandrite) laser Cont.</th>
<th>Typically tuned in the range of 700 to 820 nm</th>
<th>Flashlamp, laser diode, mercury are (for CW mode operation)</th>
<th>Dermatological uses, LIDAR, laser machining.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Erbium doped and erbium – ytterbium codoped glass lasers</td>
<td>1.53 – 1.56 µm</td>
<td>Laser diode</td>
<td>These are made in rod, plate/chip, and optical fiber form. Erbium doped fibers are commonly used as optical amplifiers for telecommunications.</td>
</tr>
<tr>
<td></td>
<td>Trivalent uranium doped calcium fluoride (U: CaF$_2$) solid – state laser</td>
<td>2.5 µm</td>
<td>Flashlamp</td>
<td>First 4 – level solid state laser (November 1960) developed by Sorokin and Stevenson at IBM research labs; second laser invented overall, liquid helium cooled.</td>
</tr>
<tr>
<td></td>
<td>Divalent samarium doped calcium fluoride (Sm:CaF$_2$) laser</td>
<td>708.5 nm</td>
<td>Flashlamp</td>
<td>Invented by Sorokin and Stevenson at IBM research labs. Liquid helium cooled</td>
</tr>
<tr>
<td></td>
<td>F – Center laser</td>
<td>2.3 – 3.3 µm</td>
<td>Ion laser</td>
<td>Spectroscopy</td>
</tr>
</tbody>
</table>

**Semiconductor lasers:** This is a solid-state tools that are composed of dual outside semiconductor layers produce laser radiation when charged in layers (with opposite polarity) – one from the top and one from the bottom and then meet via the central layer. They are also known as diode lasers.
<table>
<thead>
<tr>
<th>Laser gain medium &amp; type</th>
<th>Operation wavelength(s)</th>
<th>Pump source</th>
<th>Application and notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semiconductor laser diode (general information)</td>
<td>0.4 – 20 µm, depending on active region material.</td>
<td>Electrical current</td>
<td>Telecommunications, holography, printing, weapons, machining, welding, pump sources for other lasers.</td>
</tr>
<tr>
<td>GaN</td>
<td>0.4 µm</td>
<td></td>
<td>Optical discs, 405 nm is used in Blu-ray Discs reading/recording.</td>
</tr>
<tr>
<td>AlGalnP , AlGaAs Cont.</td>
<td>.63 – 0.9 µm</td>
<td>Electrical current</td>
<td>Optical discs, laser pointers, data communications, 780 nm compact disc, 650 nm general DVD players and 635 nm DVD for authoring recorder laser are the most common lasers type in the world. Solid – state laser pumping, machining, medical.</td>
</tr>
<tr>
<td>InGaAsP</td>
<td>1.0 – 2.1 µm</td>
<td></td>
<td>Telecommunications, solid – state laser pumping, machining medical.</td>
</tr>
<tr>
<td>Lead salt</td>
<td>3 20 µm</td>
<td></td>
<td>Telecommunications</td>
</tr>
<tr>
<td>Vertical cavity surface emitting laser (VCSEL)</td>
<td>850 – 1500 nm, depending on material</td>
<td></td>
<td>Research, future applications may include collision - avoidance radar, industrial – process control and medical diagnostics such as breath analyzers.</td>
</tr>
<tr>
<td>Quantum cascade laser</td>
<td>Mid – infrared to far infrared.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Other Types of Lasers

<table>
<thead>
<tr>
<th>Laser gain medium &amp; type</th>
<th>Operation wavelength(s)</th>
<th>Pump Source</th>
<th>Application and notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free electron laser</td>
<td>A broad wavelength range (0.1 nm – several nm); a single free electron laser maybe tunable over a wavelength range.</td>
<td>Relativistic electron beam</td>
<td>Atmospheric research, material science, medical applications.</td>
</tr>
<tr>
<td>Gas dynamic laser</td>
<td>Several lines around 10.5 µm; other frequencies may be possible with different gas mixtures</td>
<td>Spin state population inversion in carbon dioxide molecules caused by supersonic adiabatic expansion of mixture of nitrogen and carbon dioxide</td>
<td>Military application; can operate in CW mode at several megawatts optical power.</td>
</tr>
<tr>
<td>“Nickel – like” Samarium laser</td>
<td>X–rays at 7.3 nm wavelength</td>
<td>Lasing in ultra – hot Samarian plasma formed by double pulse terawatt scale irradiation fluences created by Rutherford Appleton Laboratory’s.</td>
<td>First demonstration of efficient “saturated” operation of a sub – 10nm X–ray laser, possible applications in high resolution microscopy and holography, operation is close to the water window at 2.2 to 4.4 nm where observation of DNA structure and the action of viruses and drugs on cells can be examined.</td>
</tr>
<tr>
<td>Raman laser uses inelastic stimulated Raman scattering in a nonlinear media, mostly fiber, for amplification</td>
<td>1 – 2 µm for fiber version</td>
<td>Other lasers, mostly Yb – glass fiber lasers</td>
<td>Complete 1 – 2 µm wavelength coverage; distributed optical signal amplification for telecommunications; optical solitons</td>
</tr>
</tbody>
</table>
Regulatory Compliance Labeling on Laser Units:

There are regulatory compliance labels that must be in place on each laser.

1. A smaller version of the warning sign below must be on the laser. It is usually in yellow. (You can compare your entrance warning sign to this information label to ensure the correct laser sign is posted.)
2. Location of the laser aperture (site the beam will emit)
3. Emergency stop (Always know where this control is in case of emergency need!)
4. The letters CE and DHHS or US FDA marks means it is a registered product, in compliance with regulations.
5. Contact information for the company.
7. Interlock receptacle.
8. Cable receptacles and foot switch receptacles.
9. Lasers also have pictures / symbols for various parts or functions of the laser.

Possible laser hazards and safety tips:

<table>
<thead>
<tr>
<th>Laser Hazards</th>
<th>Safety Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment malfunction Causes:</td>
<td>1. Laser unit should have a yearly PMI – check to see it has been completed.</td>
</tr>
<tr>
<td>- Improper care of the unit or</td>
<td></td>
</tr>
</tbody>
</table>

12 of 18 Charts
<table>
<thead>
<tr>
<th>accessories.</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Age “wear and tear” of the unit or accessories.</td>
</tr>
<tr>
<td>- NO communications of problems to appropriate staff.</td>
</tr>
<tr>
<td>- Broken or frayed wires / optics.</td>
</tr>
<tr>
<td>Negative outcomes:</td>
</tr>
<tr>
<td>- Broken units</td>
</tr>
<tr>
<td>- Broken or frayed electrical wires.</td>
</tr>
<tr>
<td>- Potential for tissue damage to the patient / staff.</td>
</tr>
</tbody>
</table>

| 2. At any time a unit malfunctions or parts are damaged – tag it and remove from service. Contact the Biomed engineer to check out the laser.  |
| 3. Move the laser unit with care – do not bump it into other objects.  |
| 4. Gently wrap cords and foot pedals in place on the unit. Inspect cords and foot pedals for damage.  |
| 5. Lock laser in place during use.  |
| 6. If a microscope is used, check the optics and ensure attachments are correctly and securely mounted.  |
| 7. Check the fiberoptic for integrity.  |

<table>
<thead>
<tr>
<th>Electrocution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causes:</td>
</tr>
<tr>
<td>- Many lasers use high voltage to generate laser action and require water cooling to dissipate the heat. Water must remain in the proper compartment.</td>
</tr>
<tr>
<td>- Water in contact with the laser unit.</td>
</tr>
<tr>
<td>- Staff opening back laser panels.</td>
</tr>
<tr>
<td>- Exposed or damaged wires.</td>
</tr>
<tr>
<td>Negative Outcomes:</td>
</tr>
<tr>
<td>- High voltage exposure can lead to electrocution which can cause tissue damage wires.</td>
</tr>
<tr>
<td>- Sparks can generate a fire.</td>
</tr>
</tbody>
</table>

| 1. Only “qualified personnel” should open a laser for repair and maintenance.  |
| 2. Water levels of the water cooled lasers should be monitored and refilled as needed by “qualified personnel”.  |
| 4. Keep water off of the laser unit.  |
| 5. Do not plug the laser into an extension cord. Only use the grounded was socket.  |
| 6. Do not use the laser if there are any damaged or exposed wires.  |

<table>
<thead>
<tr>
<th>Improper usage or inadvertent laser activation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. An LSO / specialist should be available during the laser</td>
</tr>
</tbody>
</table>
**Cause:**
- Key left in laser – making it available to turn on.
- Untrained staff controlling and using laser.
- Unmonitored use of the laser during a surgical procedure.
- Laser foot pedal near other pedals and mistakenly used.

**Negative outcomes:**
- Potential damage to the laser unit.
- Potential damage to the patient / staff.

---

**Procedure:**
- All staff that will be involved with laser use will be trained in the use of the laser.
- Surgeons will have laser training.
- Keys to the laser will be kept in a key cabinet. Remove them prior to the use and return them after procedure is completed.
- During procedure the laser will be constantly monitored.
- Laser will be kept in the “standby” mode whenever not in use during the surgical procedure.
- Laser pedals will be marked and placed separately from other pedals. Surgeon will be notified of the position of the foot pedal.

---

**Fire, Burns and Explosions**

**How do fires or explosions occur?**

**Causes:**
- Heat is generated from the laser
- Presence of flammable liquids, gases, vapors and drapes.
- Presence of intestinal methane gas.
- Patient has not been protected from the laser beam.
- High oxygen levels.
- Laser beam and aiming beam are not in alignment causing the laser to strike the wrong area.

**Negative outcomes:**
- Can cause tissue damage to the patient and / or staff.
- Can cause tracheal fires.

**SAFETY STEPS**

1. Alcohol based prep solutions should not be used. However, if it must be used, one should allow it to dry before any laser work is commenced.
2. Use nonflammable drapes.
3. Place wet drapes / towels / gauze around laser sites.
4. Water soluble jelly can be placed on hair, mustache or beard.
5. Do not use flammable anesthetics.
6. Decrease the oxygen percentage and use air during procedures in the upper respiratory tract.
| - Can damage the laser equipment. | 7. Align and / or test fire laser prior to use.  
8. A basin of water should be available on the back table to readily extinguish a fire if needed. A large syringe and cannula available to inject the water in an upper airway / bronchoscope.  
9. A fire extinguisher should be in the room during the laser procedure.  
10. Laser units and OR beds to be locked. Patients position to be maintained. Prevent inadvertent movements of the target area.  
11. Use laser ET tubes during upper airway cases.  
12. Have a trach set readily available for upper airway cases. |

Airway surgical fires usually include the head, neck and chest procedures. Surgical fires can cause serious or fatal injuries to patients. An airway explosion could potentially occur during a microlaryngoscopy or oral airway procedure involving an ET tube. As described above, anyone involved in a laser case should know and understand ignition sources and preventative measure that will decrease the possibility of laser related fires. Of the approximate 650 surgical fire that happen every year, 34% of those fires are caused by lasers. During a surgical procedure more than 23% oxygen is present in the oro-pharynx. This Oxygen enriched environment contributes to 74% of cases.

Methane gas explosion potentially can occur from the intestinal release of flatus (gas), which has the possibility of igniting with the exposure to
a laser beam. This is why extreme caution must be used when using a laser around the rectal or genital area. The rectum may be packed with wet saline or water saturated sponges and towels around the rectum and genital area. A bowel prep may be considered before the surgery is to be completed.

**LASER Safety:**

Laser safety starts with Laser standards. It requires each institution that uses lasers to have a policy and procedure based on the laser applications and safety set by ANSI and complies with these standards. Policies and Procedures (P & Ps) are governed by institutional policy, and are developed, modified, and maintained in accordance with the needs of each individual facility. Information that maybe used is the HCLS manufacturer or distributor manuals. P & Ps may start with a general policy for all lasers and then included an individual P & P for each laser used.

It is reasonable to expect that the needs of hospitals with multiple laser systems and users are different from individual practitioners needs. The manufactures of the HCLS will supply safety information that can serve as the basis of the P & Ps, but should never be the only source used when constructing P & Ps. The FDA facilitates the information related to safety information of each laser. Each facility should have a laser safety officer who will help in creating and maintaining all P & Ps. Larger facilities will also have committees which will be a part of P & Ps approval as well.
Once the P & Ps are established control measures should be set up. Based on the recommendation of the ANSI Z 136.1 standard there are four basic categories of useful controls in a laser environment. These are:

1. Engineering controls
2. Personal protective equipment
3. Administrative and procedural controls
4. Special controls.

Import in all controls is the distinction between the function of operation, maintenance and service. Laser systems are classified on the basis of level of the laser radiation accessible during operation. Maintenance is defined as those tasks specified in the user instructions for assuring the performance of the product and may include items such as routine cleaning or replenishment of expendables. Service functions are usually performed with far less frequency than maintenance functions (e.g., replacing the laser resonator mirrors or repair of faulty components) and often require access to the laser beam by those performing the service functions.

Each state has a minimal standard that it must set; our state recognizes the AORN as its minimal standard. Therefore AORN recommendations become the minimal standard set by our state. All nurses must follow the minimal standard set by the state that has issued that particular nursing license. It is up to each nurse to know what the state standard is.
AORN recognizes the numerous types of settings in which perioperative and clinical nurses practice. These recommended practices are intended as guidelines adaptable to various practice settings using lasers. These practice settings include traditional operating rooms, ambulatory surgery units, physicians’ offices, cardiac catheterization suites, endoscopy suites, radiology departments, and all other areas where operative and other invasive procedures may be performed. These Recommendations are from the AORN.

Recommendation I

A laser safety program should be established for private practitioners and/or health care facilities.

According to ANSI, facilities in which laser procedures are performed must develop a laser safety program to include, but not be limited to,

- Delegation of authority and responsibility for supervising laser safety to a laser safety officer;
- Establishment of use criteria and authorized procedures for all health care personnel working in laser nominal hazard zones;
- Identification of laser hazards and appropriate control measures;
- Education of personnel (ie, operators and others) regarding assessment and control of hazards; and
- Management and reporting of accidents or incidents related to laser procedures, including action plans to prevent recurrences.

2. Incidents of safety regulations violation should be reported to the laser safety officer and reviewed by the safety committee.

3. People working in a laser environment should have knowledge of the established laser safety program.
Recommendation II

Personnel working in laser environments should demonstrate competency commensurate with their responsibilities. Education programs should be specific to laser systems used and procedures performed in the facility.

1. Program criteria and content should be in accordance with applicable standards; the facilities policies and procedures; and the federal, state and local regulations.
2. Personnel should be required to demonstrate laser competency periodically and when new laser equipment, accessories or safety equipment is purchased or brought into the practice environment.
3. The laser safety program should provide participants with a thorough understanding of laser procedures and the technology required for establishing and maintaining a safe environment during laser procedures.
4. Educational activities should be documented and maintained on file in the facility.

Recommendation III

All people should know where laser are being used, and access to these area should be controlled.

1. A nominal hazard zone (ie, the space in which the level of direct, reflected, or scattered radiation used during normal laser operation exceeds the applicable maximum permissible exposure) should be identified to prevent unintentional exposure to the laser beam.
The laser safety officer can determine the nominal hazard zone with reference from ANZI Z136.1 and ANSI 136.3, as well as the safety information supplied by the laser manufacturer.

The nominal hazard zone usually is contained within the room but may extend through open doors and/or transparent windows, depending on the type of laser used.

Personnel in the nominal hazard zone should be aware of all laser safety precautions that are implemented to avoid inadvertent exposure to laser hazards.

2. Regulation laser signs should be placed at all entrances to laser treatment area when these areas are in service.
   - Recognizable warning signs specific to the type of laser being used should be designed according to the information described in *American National Standard for safe use of lasers in Health Care Facilities*.
   - Warning signs should be placed conspicuously to alert bystanders of potential hazards.
   - Signs should be removed when the laser procedure is completed.

3. Doors in the nominal hazard zone should remain closed, and windows, should be covered with a barrier that blocks transmission of a beam as appropriate to the type laser being used.

**Recommendation IV**

All people in the laser treatment area should be protected from unintentional laser beam exposure.
1. Procedures should be implemented to prevent accidental activation or misdirection of laser beams.
   - Access to laser keys should be restricted to authorized personnel skilled in laser operation.
   - Laser should be placed in standby mode when not in active use.
   - The laser foot switch should be placed in a position convenient to the operator, and the mechanism should be identified. Attention to proper placement of the foot switch and use of the standby switch can reduce unintended activation of the laser beam and potential injury to the patient, operator, and/or bystander(s). Removing unneeded foot switches prevents confusion and accidents related to inadvertent activation.
   - Laser operator managing the laser equipment should have no competing responsibilities that would require leaving the laser unattended during active use. Note that continual circulating responsibilities may preclude ability to assume the responsibility of laser operation.

2. Anodized, dull, nonreflective, or matte - finished instruments should be used near the laser site. Such instruments decrease the reflectivity of laser beams. Instruments that have been coated (ie, ebonized) should be inspected regularly to ensure the integrity of the coating.

3. Exposed tissues around the surgical site should be protected with saline - saturated or water - saturated materials (eg, towels, sponges) when thermally intensive lasers are being used. These materials should be remoistened periodically to ensure that they
do not dry out and become a source for ignition. The solution (eg, saline, water) absorbs or disperses the energy of the laser beam in area not intended for laser application.

4. Appropriate backstops (eg, titanium rods, quartz rods) or guards should be used during laser surgery to prevent the laser beam from striking normal tissue. Mirrors made of rhodium or stainless steel may be used in hard-to-reach areas. Mirrors made of glass are not laser energy and may shatter. Glass rods should not be used because thermal stress from laser beams may cause breakage.

5. When a fiber used to deliver laser energy through an endoscope, the end of the fiber should extend at least 1 cm past the end of the endoscope and be in view at all times during active use. When using lasers with flexible endoscopic delivery systems, care should be taken to avoid laser beam exposure within the sheath. Most flexible fiber-optic endoscopic sheaths are damaged easily by heat. Most flexible fiber-optic endoscope sheaths are flammable.

- Backscatter from the laser beam can cause thermal damage, resulting in lens pitting if the fiber is too close to the end of the endoscope.
- For rigid endoscopic delivery systems (eg, laryngoscopes, bronchoscopes, laparoscopes), care should be taken to avoid beam heating of the sheath wall. If the metallic tubular system is used improperly, the heat inside the endoscope will cause thermal damage to adjoining tissues.
Recommendation V

All people in the nominal hazard zone should wear appropriate eyewear approved by the laser safety officer.

1. People in the nominal hazard zone should wear protective eyewear of specific wavelength and density. Scattered, diffuse, and reflected laser beams, in addition to direct exposure from misdirected and damaged fibers, can cause eye injuries. Appropriate laser safety eyewear filters out the hazardous wavelength of laser radiation to prevent thermal eye injuries.
   - Eyewear must be labeled with the appropriate optical density and wavelength for the laser in use. Laser eyewear is not interchangeable for a variety of lasers.
   - A lens filter of appropriate laser wavelength may be used over the top of an endoscopic viewing port to protect the eye from laser backscatter. The other eye, however, would be left unprotected should a break in a light fiber occur. Using an eye lens filter does not reduce or cancel out the need for protective eyewear for other people in the nominal hazard zone.

2. Patients’ eyes and eyelids should be protected from the laser beam by a method approved by the laser safety officer.
   - Patients who remain awake during laser procedures should be provided other appropriate protection, such as wet eye pads or laser-specific eye shields.
   - Patients undergoing laser treatments on or around the eyelids should have their eyes protected by corneal eye shields.
Recommendation VI

Personnel working in the laser environment should avoid exposure to smoke plume generated during laser surgery.

1. To reduce smoke plume inhalation, local exhaust ventilation controls should be implemented. These controls include, but may not be limited to,
   - Wall suction units with in-line filters, and
   - Smoke evacuator units. Laser smoke plume should be removed by use of local exhaust ventilation. The collection device should be placed as near as possible to the point where plume is produced.
2. Personnel should wear high-filtration surgical masks designed for use during laser procedures that generate smoke plume. These specially designed masks help filter particulate matter and may reduce noxious odors. These masks should not be viewed as absolute protection from chemical contaminants.
3. In situations in which minimal plume is generated, a central wall suction units are designed to capture liquids, making the use of in-line filters necessary. Low suction rates associated with wall suction units limit their efficacy in evacuating plume, making them suitable for minimal plume only.
4. In circumstances in which large amount of plume are generated, a mechanical smoke evacuation system with a high-efficiency filter should be used to remove laser smoke plume according to manufactures’ instructions. The evacuator collection apparatus should be placed as close as possible to the laser site. Detectable odor during the use of a laser and smoke evacuation system is a signal that either smoke evacuation system is a signal that either
smoke is not being captured at the site, the air – flow through the system is too fast for absorption to occur, or the filter has exceeded its use – fullness and should be replaced.

5. Standard precautions should be used when working with the laser environment. Laser gas airborne contaminates produced during laser procedures have been analyzed are shown to contain gaseous toxic compounds, bioaerosols, and dead and living cell material. At some level these have been shown to have an unpleasant odor, may cause visual problems for physicians, cause ocular and upper respiratory tract irritation, and have demonstrated mutagenic and carcinogenic potential. The potential for bacterial and/or viral contamination of smoke plume remains controversial.

**Recommendation VII**

**All people in the laser treatment are should be protected from electrical hazards associated with laser use.**

1. The laser safety officer should approve laser systems and equipment before they are placed in service and after they are evaluated for electrical hazards.

2. Laser service and preventive maintenance should be performed on a regular basis by people who have knowledge of laser systems. Service and maintenance activities should be documented. The laser safety officer should review maintenance documents before allowing any laser to be reentered into service. Documentation of actions taken to ensure the reliability and safe operation of lasers assists the laser safety officer in maintaining a
safe laser environment. Recurring problems can be detected and solved with appropriate follow-up.

3. Solutions should not be placed on laser units. Lasers are high-voltage equipment that should be protected against short circuiting associated with spillage or splatter.

Recommendation VIII

All people in the laser treatment are should be protected from flammability hazards associated with laser use.

1. Personnel using lasers should be knowledge-able of the fire hazards associated with laser use. Fire is one of the most significant hazards of laser use. The intense heat of laser beams can ignite combustible / flammable solids, liquids, and gases. Flammable and combustible items in the laser environment include, but may not be limited to,
   - Flammable liquids or combustible ointments (eg, skin prep solutions, oil–based lubricants);
   - Gases (eg, oxygen, methane, anesthetic agents, alcohol vapor);
   - Plastics;
   - Paper or gauze material;
   - Surgical drapes;
   - Adhesive or plastic tapes; and
   - Endotracheal tubes.

   The presence of increased oxygen concentrations enhances combustion of these products and leads to rapid spread of
flames. Pooled skin prep solutions also can retain laser heat, resulting in patient tissue burns. Pooled solutions should be removed and / or patted dry. Prep solutions can be absorbed into linens and body fibers (eg, hair). These solutions should be allowed enough time to evaporate before drapes are applied. Alcohol – based skin prep vapors can become trapped under drapes and coverings, and the volatility of vapors can increase the risk of surgical drape fires.

2. Laser - appropriate fire extinguishers and water should be immediately available where laser are used. Immediate action can reduce the magnitude of injury.

3. Special ignition – resistant drapes and / or moistened, reusable fabrics should be used to drape around areas that are close to the laser treatment site to decrease the potential for fire.

4. Protected or specially designed endotracheal tubes should be used to minimize the potential for fire during laser procedures in the patient’s airway or aerodigestive tract. Standard endotracheal tubes are combustible and should not be used. Other flammable items associated with endotracheal tube use during laser procedures include
   - Plastic,
   - Plastic tape,
   - Ointment / lubricant, and
   - Surgical prep solution.

   Endotracheal tube cuffs should be inflated with dyed saline so that punctures can be recognized and action taken.
immediately. Moisten packs around the tube may provide additional protection.

**These recommendations are from 2010 Perioperative Standards and Recommended Practices.** Every institution that uses a laser should purchase a copy of the most recent AORN recommendations for the department to keep on hand for any questions about laser safety. To purchase a copy go to [www.AORNbookstore.org/](http://www.AORNbookstore.org/) to purchase a copy of the most recent recommendation. The issue now available is:

**2012 Perioperative Standards and Recommended Practices: For Inpatient and Ambulatory Settings**

There are also many benefits to becoming an AORN member, including discounted books full of valuable perioperative information.

There are many laser standards and regulatory agencies that are involved with lasers and laser safety. We have addressed ANSI which is the most important and AORN which we will include in this list. Here is a list of agencies and what their responsibilities, guidelines and goals are:

1) **American National Standards institute (ANSI):**
A nongovernmental organization consisting of experts from all fields and groups that utilize lasers. They have developed appropriate standards for the safe use of lasers. Each standard has its own number such as: “ANSI Z136”.

2) American Society for Laser Medicine and Surgery (ASLMS):
- Their goal is to unite health care professional in clinical laser applications, laser education and laser research.
- They have developed standards and guidelines for the use of lasers in the healthcare setting.

3) Association of Peri – Operative Registered Nurses (AORN):
- Developed recommended practices to represent what is believed to the optimal level of practice for nurses who work with lasers in the Operating Room settings.

4) Center for Devices and Radiological Health (CDRH):
- This is the regulatory section of the US Food and Drug Administration (FDA).
- Lasers are considered medical devices, which are registered with the FDA.
- It regulates research in laser applications.
- This agency sets standards for the manufacturing of lasers.
- This agency requires specific labeling on the lasers informing the operator of the type of laser radiation and power.

5) Hospital / Facility and Department Policies and Procedures:
- The health care facilities are responsible for setting their own safety policies and procedures, often referencing the various standards from the above agencies.
- Hospitals are held liable for following their own standards.
Departments within the facilities may have more specific policies for the use within their department.

6) Joint Commission on Accreditation of Healthcare Organizations (JACHO):
   - They have set their own standards, based on ANSI standards and guidelines.
   - They Inspect facilities to determine whether the facilities comply with these standards.

7) Laser Institute of America (LIA):
   - An organization that has individual and corporate members dedicated to promoting laser safety standards in all fields of laser usage.
   - They use the ANSI regulations and publish guidelines on laser safety.
   - They provide education and training.
   - They provide laser safety audits to companies wishing to improve their safety program.

8) National institute for Occupational Safety and Health (NIOSHA):
   - Federally funded institute conducts research to prove hazards within the workplace.

9) Occupational Safety and Health Administration (OSHA)
   - Part of the US department of Labor responsible for ensuring worker safety during laser procedures.
   - Concentrates on worker physical environments.
   - Uses NIOSHA results to mandate compliance to minimize hazards within the workplace.

10) State and Local Requirements:
    - State and local regulations will vary from area to area.
Lasers may need to be registered.
Licenses may be required.

Now The Joint Commission (TJC), formerly the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) (renamed a second time in 1951) is a United States based nonprofit organization that accredits more than 19,000 health care organizations and programs in the United States, with official impact since 1965. A majority of state governments have come to recognize Joint Commission Accreditation as a condition of licensure and the receipt of Medicaid reimbursement. Survey (inspections) which can now happen at any time, will be made available to the public in an accreditation quality report available on the Quality Check Web site.

The reason for laser safety is to protect everyone involved with the laser procedure. This is to protect everyone in the room from the biological effects of the laser beam. Biological effects are:

A) Eye injury: Lasers have high optical intensities and also 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 be the result.

B) Thermal Injury: The most common cause of laser – induced tissue damage is thermal in nature, where the tissue protein are
denatured due to the temperature rise following absorption of laser energy.

1. The thermal damage process (burns) is generally associated with lasers operating at exposure times greater than 10 microseconds and in the wavelength region from the near ultraviolet to the far infrared (0.315 µm – 103 µm). Tissue damage may also be caused by thermally induced acoustic waves following exposures to sub-microsecond laser exposures.

2. With regard to repetitively pulsed or scanning lasers, the major mechanism involved in laser-induced biological damage is thermal process wherein the effects of the pulses additive. The principal thermal effects of laser exposure depend upon the following factors:
   - The absorption and scattering coefficients of the tissues at the laser wavelength.
   - Irradiance or radiant exposure of the laser beam.
   - Duration of the exposure and pulse repetition characteristics, where applicable.
   - Extent of the local vascular flow.
   - Size of the area irradiated.

C) Other:

1. Other damage mechanisms have also been demonstrated for other specific wavelength ranges and/or exposure times. Photochemical reactions are the principle cause of threshold level tissue damage following exposures to either actinic ultraviolet radiation (0.200 µm – 0.315 µm) for any exposure
time or “blue light” visible radiation (0.400 µm – 0.550 µm) when exposures are greater than 10 Seconds.

2. To the skin exposure, UV-A (0.315µm – 0.400 µm) can cause hyperpigmentation and erythema.

3. Exposure in the UV-B range is most injurious to skin. In addition to thermal injury caused by ultraviolet energy, there is the possibility of radiation carcinogenesis from UV-B (.028 mm – 0.315mm) either directly on DNA or from effects on potential carcinogenic intracellular viruses.

4. Exposure in shorter UV-c (0.200 µm – 0.280 µm) and the longer UV-A ranges seems less harmful to human skin. The shorter wavelengths are absorbed in the outer head layers of the epidermis (Stratum Corneum) and the longer wavelengths have an initial pigment – darkening effect followed by erythema if there is exposure to excessive levels.

5. The hazards associated with skin exposure are less importance than eye hazards; however, with the expanding use of higher power laser systems, particularly ultraviolet lasers, the unprotected skin of personnel may be exposed to extremely hazardous levels of the beam power if used in an unenclosed system design.

<table>
<thead>
<tr>
<th>Summary of Basic Biological Effects of Light</th>
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<tbody>
<tr>
<td><strong>Photobiological spectral domain</strong></td>
</tr>
<tr>
<td><strong>Eye effects</strong></td>
</tr>
<tr>
<td><strong>Skin effects</strong></td>
</tr>
<tr>
<td>Ultraviolet C (0.200 – 0.280 µm)</td>
</tr>
<tr>
<td>Photokeratitis</td>
</tr>
<tr>
<td>Erythema (sunburn)</td>
</tr>
<tr>
<td>Skin cancer</td>
</tr>
<tr>
<td>Ultraviolet B (.028 – 315 µm)</td>
</tr>
<tr>
<td>Photokeratitis</td>
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<tr>
<td>Accelerated skin</td>
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<tr>
<td>Spectrum Range (µm)</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Ultraviolet A (0.315 – 0.400 µm)</td>
</tr>
<tr>
<td>Visible (0.400 – 0.780 µm)</td>
</tr>
<tr>
<td>Infrared A (0.780 – 1.400 µm)</td>
</tr>
<tr>
<td>Infrared B (1.400 – 3.00 µm)</td>
</tr>
<tr>
<td>Infrared C (3.00 – 1000 µm)</td>
</tr>
</tbody>
</table>

Laser Bioeffects – Damage
- **Primary sites of damage:**
  - Eyes
  - Skin
- **Laser beam damage can be:**
  - Thermal (Heat)
  - Acoustic
  - Photochemical

UV risks with the range of 200 – 280nm is skin cancer. Photon energy is sufficient to cause photochemistry and therefore cell mutation. UV is usually short penetration depth.
A big part of laser safety will be posting laser signs. Signs must be posted when a laser is in use only, and taken down when no longer in use. Communication to others that a laser is in use is a critical laser safety precautionary measure. Regulations mandate that a warning sign be clearly posted outside all entrances to the laser treatment area. The laser warning sign must specify the laser type, operational characteristics and the class.

Here is an example of a laser safety signs.

![Figure 16](image1)

![Figure 17](image2)
Figure 18

Figure 19

Figure 20

Figure 21
Here are a few examples of an ANSI Z136.3-2011 P & P and how it could be set up and what to include:

**Controlled Access to the Laser room**

(Sample P & P)

**Purpose:** To define the area in which control measures must be applied, and to describe control measures necessary in order to maintain a safe environment for patients, and for health care personnel (HCP).

**Policy:** Class 3B and Class 4 lasers will be operated only in areas where traffic flow and compliance with all safety procedures can be monitored.

**Procedure:**

1) Laser signs will be posted at eye level on all doors that access a room where a laser will be operated. These signs will state all required information as described in the ANSI Z136.3 standard, and will be removed when the laser is not in use.

2) Safety goggles labeled with appropriated wavelength and optical density will be available at the entry where each door sign is posted.

3) Glass windows will be covered with shades or filters of appropriate optical density whenever a fiberoptic laser system is operational.

4) All safety procedures will be followed during service and demonstrations.

5) No one will be allowed into a laser room unless properly authorized and protected.

6) The laser should not be activated when it is necessary to open the door if the NHZ extends to doorway.

7) Laser keys will be kept in a secure area and signed out only by those authorized to do so.

Approved: ________________
ANSI has an example of an Ocular Safety P & P:

Ocular Safety

(Sample P & P)

**Purpose:** To prevent ocular injuries to patients receiving laser treatment, or to health care personnel (HCP) working with Class 3B and Class 4 lasers.

**Policy:** Within the nominal hazard zone (NHZ), all personnel will adhere to appropriate eye protection procedures during all laser applications.

NOTE- Under some conditions, the NHZ may occupy the entire room in which the laser procedure is performed. Under those conditions, the ocular safety procedures listed below apply to the entire room.

Service personnel, biomedical technicians and those involved in demonstrations of equipment, will follow all ocular safety procedures whenever a laser is in operation.

**Procedures:**

1) Appropriate laser protective eyewear (LPE) will be worn by everyone in the NHZ while the laser is in operation. Appropriate laser protective eyewear consists of glasses or goggles of sufficient optical density (OD) to prevent ocular injury at the laser
wavelength in use. Exception to this is the operator looking through an attached microscope with a lens that has the appropriate OD for the laser in use.

2) Prior to use, the user and ancillary personnel will be responsible for selecting and examining eyewear for comfort, proper fit, and presence of labels describing both wavelength and proper optical density.

3) If damage to the eyewear is observed or suspected, consult with the Laser Safety Officer (LSO) about using the eyewear.

4) Contact lenses are not acceptable as LPE. Prescription lens wearers must use appropriate LPE.

5) All goggles must have side shields to protect from peripheral injury and impact.

6) Any delivery system that is not shuttered must be capped, or the system turned off, when not connected to the hand piece or the operating microscope.

7) The laser system must be placed in standby mode when delivery optics is moved away from the target.

8) Metal or dry materials will be placed on the patient’s face or eyes only when indicated.

Approved: ______________________

Date: ___________________________ Date Reviewed: _______________
ANSI example of Fiber delivery P & P:

Handling of Laser Fiber Delivery Systems

(Sample P & P)

Purpose: To promote safe and proper handling of laser fiber delivery systems and to limit the potential for fiber breakage, damage and reduce efficiency during clinical laser procedures.

Procedure:

1) Appropriate eye safety filters will be used with endo/microscopes.
2) Laser room windows will be covered completely with appropriate filters, if necessary.
3) Fibers and associated equipment will be positioned to allow for safe traffic patterns in the room.
4) The fibers will be examined for breakage or damage of the distal tip, the proximal connector, and the catheter sheath. Fiber will be calibrated in accordance with manufacturer’s directions. If deficiencies or damage are noted, another fiber must be obtained.
5) Do not use clamps or other instruments to secure fiber in the operative site.
6) Always use coaxial cooling that is appropriate to the procedure.
7) **NEVER USE CAS TO PURGE A FIBER IN THE INTRAUTERINE CAVITY!!!**
8) Never operate the laser unless you see the aiming beam (if used) and the tip of the fiber beyond the end of the endoscope.
9) Monitor the fiber for distortion or the beam, decreased power transmission, and accumulation of debris on the tip.
10) Never reuse a disposable fiber without manufacturer’s directions.
11) Always put the laser in standby mode when not aimed at a target.

APPROVED: _________________

DATE: _____________________ DATE REVIEWED: ________________
A hospital policy may look something like this:

<table>
<thead>
<tr>
<th>Facility Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title of policy</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Scope: This policy pertains to “what”</td>
</tr>
<tr>
<td>Department(s):</td>
</tr>
<tr>
<td>Group of policies or manual:</td>
</tr>
<tr>
<td>Operating Room</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

1) **Purpose:**
   A) Physicians operating the laser during a surgical intervention must be granted laser privileges through the Medical Center Credentialing Process.
   B) Personnel assisting with the technical aspects of the surgical intervention, utilizing laser technology, must attend a laser safety course.
   C) All personnel present and caring for patient during laser use must have received instruction in laser safety.

2) **Policy:**
   A) The patient will receive safe and reliable laser intervention.
   B) The policy should include the use of the types of lasers and instrumentation to be used; examples might be Argon, CO₂,
Holmium/Yag, KTP, Laser smoke plume, Laser Fibers, Nd: Yag and Green Light.

3) **Hospital:**

4) **Definition:** if applicable

5) **Procedure:** These standards should be the minimum patient care required by the state, and may include registered nurses and other members of the multidisciplinary teams input.

A) The circulating nurse or other qualified personnel will check the laser prior to use. The responsible room staff will checkout the laser key. These items may include checking the cord and plug, accessories, posting laser signs, and covering windows for all laser procedures except CO₂ lasers (per manufactures recommendations).

B) Fire extinguisher will be available in the laser room or treatment room.

C) Eye protection will be used on the patient.
   - Appropriate eye wear will be used if the patient is awake. This may include using a laser mask.
   - If the patient is anesthetized, moist sponges will be placed on the patient’s eyes.

D) Laser endotracheal tubes will be used if possibly apart of the surgical field. A countable moist sponge can also be used around the ET tube in necessary. Have a Tracheostomy instrument tray available for Head and neck surgeries including laser laryngeal procedures and all such cases.

E) A basin of sterile water or saline will be on the sterile field before beginning operation of the laser. Have a water filled
Acepto, syringe, or other delivery system available to extinguish the fire.

F) Flammable agents should not be used on patient prior to laser use e.g. tinctures, alcohol including alcohol based preps, etc.

G) All preps will be blotted dry before starting the laser procedure.

H) If laser surgery is performed around the rectum or anal orifice, the rectum will be packed off with moist countable sponges. A moist towel will be placed over the rectum for laser surgery of the vagina.

I) Instruments that are used should not be etched or scratched. They should be dulled or blackened. Large instruments or retractors should be covered with moist lap sponges or moist towels to reduce the risk of laser beam reflection.

J) A ridged endoscope with a non-reflective surface or a flexible fiber optic bronchoscopy with a non-reflective sheath must be delivering laser energy via endoscope near the endotracheal tube.

K) An area adjacent to the operative field will have a moistened towel or similar item throughout the entire procedure.

L) When placing the laser foot pedal identify the pedal and only place where the surgeon can operate only. All other pedals should be placed away from the laser foot pedal.

M) The Surgeon is responsible for and will select the proper setting and test fire the laser prior to use.

N) The laser plume will be controlled and evacuated by the appropriate smoke evacuator system. This system should be checked and monitored.
O) When the laser is not in immediate use, it will be placed in the “stand-by” mode. If not used for an extended period of time, it will be turned off.

P) Immediately following the laser procedure, the laser will be shut off and the key removed returned to locked container. This is to prevent accidental activation.

6) **SPECIAL CONSIDERATIONS:**

A) The CO₂, Argon, Nd:Yag, and KTP lasers require wave specific eye protection for patients and staff.

B) If a reusable laser fiber is used (as in the Nd:YAG or KTP) the fiber will be calibrated before use and test fired by the nurse or laser technician.

C) Reusable laser fibers will be sterilized as per manufacturer’s instructions.

D) The Holmium laser fiber will be inspected and the tip will be cleaned and stripped to ensure a clean tip and a well-defined circular pattern of the laser light.

7) **Documentation:**

A) Documentation will be appropriate to each facility. If computer charting is used make sure to fill in all fields appropriately.

Information will include:

1. Date of procedure
2. Procedure performed
3. Operating Surgeon
4. All staff and surgeons present
5. Safety checks performed
6. Laser settings
7. Jewels and watts in some facilities
8. Patient care performed
9. Any problems and subsequent follow-up

8) References:
   A) AORN Standards, Recommended Practices, and Guidelines
      2009 pp. 367-372

9) Implementation:
   A) Effective Date
      1. This procedure becomes effective upon approval by the approving authorities.
   B) Distribution
      1. Upon approval, this policy and/or procedures shall be distributed to all process stakeholders and the affected entities and departments.
      2. Uniform implementation to all affected entities, departments, and individuals may prepare and implement procedures consistent with this policy and as necessary conduct appropriate education to assure proper implementation.
      3. Where this policy may be located.

10) Appendix/ces:
    A) If applicable

11) Responsibilities:
    A) Policy Committee is responsible for ensuring that this procedure is accurate, relevant and current.
    B) Who facility contact persons are.
A smoke evacuation policy may look like this.

<table>
<thead>
<tr>
<th>Facility Name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title:</strong> Laser Smoke Plume Evacuation</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Scope: This policy pertains to “what”</td>
</tr>
<tr>
<td><strong>Department(s):</strong></td>
</tr>
<tr>
<td>Group of policies or manual:</td>
</tr>
<tr>
<td>Operating Room</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
</tbody>
</table>

1) **PURPOSE:**
   
   To provide a safer environment for patients and surgical staff by establishing a procedure to minimize the hazards that are inherent in laser smoke plume.

2) **POLICY:**

   A) The system of evacuation will thoroughly remove the plume from the treatment area. The evacuation systems available at “this Institution” are:
   
   • Examples are Neptune suction with smoke evacuation, Megadyne Mega vac, Valleylab Optimumn, and Medline.
   • In-line disposable smoke filters that filter to 0.3 microns are acceptable.
B) The appropriate evacuation system will be chosen primarily by the amount of plume being evacuated and if a known virus is being vaporized. The recommendation is:

- Large amounts of plume or known contagious viruses should be evacuated by the appropriate smoke evacuation system with heap filter (e.g., GYN vaginal cases, condylomata, human papilloma virus, etc.)
- In-line filters are generally effective for smaller amounts of plume (e.g., laryngoscopy, laser laparoscopy, neuro cases, etc.)

C) Other recommendations for protection include:

- The suction device (laser wand, suction tip) should be held 1 cm from the laser treatment area.
- Team members should wear laser masks that filter to 0.1 microns.

D) Filters will be disposed of in the red bio hazardous waste bags.

3) **SCOPE:**
   A) Facility Name

4) **DEFINITIONS:** If appropriate

5) **REFERENCES:** If appropriate

6) **IMPLEMENTATION:**
   A) Effective date becomes effective upon approval by the approving authorities.

   B) Distribution

   - Upon approval, this policy and/or procedure shall be distributed to all process stakeholders and the affected entities and departments.
• As applicable, affected entities, departments, and individuals may prepare and implement procedures consistent with this policy and as necessary conduct appropriate education to assure consistent and uniform implementation.
• This may also apply to the facilities intranet.

7) APPENDIX/CES: if applicable

8) RESPONSIBILITIES:
   A) Policy Committee is responsible for ensuring that this procedure is accurate, relevant and current.
   B) Who facility contact persons are.

Laser Safety Policies and Procedures should be reviewed annually to include laser technology and safety issues as they evolve. The laser team members and physicians are responsible for not only following, but enforcing P & P safety measures. These practices should always be documented.
This is an example of a laser safety checklist with major items to address for laser procedures. Additional items may be added to address the procedures that may be specific to a facility.

**Laser Safety Checklist**

A laser safety checklist is designed for the use of all perioperative personnel when using laser technology. Checklists are to provide guidance for any personnel who work with a laser to ensure a safe environment for patients and all health care workers during a procedure. Always update the checklist with the ever changing laser environment, to represent the most up-to-date safety measures available.

### Preoperative checklist:

- [ ] Move laser into the room, making sure to protect the articulated arm from bumping into walls or overhead lights. Make sure the appropriate smoke evacuation system is available for use.
- [ ] Laser warning signs are posted at all entrances to procedure room. Make sure the appropriate glasses or goggles are available at each entrance.
- [ ] Electrical cords, integrity (e.g., fraying, breaks in the insulation) is inspected.
- [ ] Procedure room has the appropriate outlet is available for laser to be used.
- [ ] Circuit breakers switch in correct position.
- [ ] If system is a free flowing CO<sub>2</sub> laser make sure the valves are open on the laser gas tank and purge the tank. Note the amount available in the tank, replace if low.
- [ ] Attach articulated arm to the appropriate lens or coupler that will be connected to a hand piece, waveguide, CO<sub>2</sub> laparoscope, or microscope.
- [ ] Respiratory protection is available (i.e., fit tested N95, high filtration face mask.
- [ ] Window are covered if applicable at all entrances to procedure room.
Delivery system including Handpiece or Micromanipulator is available for the procedure.

- CO₂ laser test fired to check for alignment.
- Laser self-tested and calibrated if needed.
- Check laser for proper functioning (e.g., Standby, high / low power)
- Smoke evacuator is operational and has a clean filter.
- Room is free of flammables.
- Correct Patient for surgical procedure and patient is free of flammables including hairspray or clothing.

**Surgical (intra-op) checklist:**

- Laser console and all cords are out of the traffic mainstream.
- Flammable prep solutions are dry before the laser is used.
- Operator should remove all watches, rings and / or any reflective surfaces from body.
- Appropriate eye protection is inspected and worn during laser use (including patient).
- Wet towels or drapes and sponges are in place at the procedural site, when possible.
- Basin of water is at procedural site.
- Anodized, dull, non-reflective, or matte finished instruments are used near laser site.
- Do not leave laser while in use.
- Only the laser foot pedal is accessible when laser is in use, verbalize placement of pedal to Physician / Surgeon.
- Activate the laser at the physician's verbal request. Make sure that the laser plume is being evacuated properly.
- Laser is placed on standby when not in use.
- Maintain communication with surgeon while operating the laser.
- Lowest possible oxygen concentration that maintains the patient’s oxygen saturation is used.
- Laser – resistant endotracheal tubes are used for airway or
aerodigestive tract procedures.

☐ Laser – resistant endotracheal tube cuffs are inflated with saline and dye.

☐ Endoscopy T – Piece is ready for use.

☐ Pleurovac assembled and ready for use, and second ET tube ready for use, including reintubation equipment.

Postoperative:

☐ Document information from the laser to charting.

☐ Laser key returned to secure storage when procedure is finished.

☐ Laser, smoke evacuator, and accessories are cleaned and stored appropriately.

☐ Protective eyewear is cleaned and inspected for scratches.

This checklist is based on Alliance and AORN checklist recommendation and includes additional items.

Do not forget proper documentation set by each facilities Policy and Procedures. Items usually charted are type of laser used, pulse frequency, power setting, watts used, joules used, total time and any addition requirement by a facility.

Charting may include obtain laser key prior to use, warning signs, windows covered, protective eye wear for staff, smoke hazard protection, patient protection, fire extinguisher available, and laser turned off and key returned. Make sure to chart this information correctly, if it’s not charted it did not happen.

During the procedure, the laser power, spot size, and other settings may be changed, continual calculations to determine the NHZ must be performed throughout the procedure. In a clinical or surgical procedure room the Nominal Hazard Zone (NHZ) is considered to be within the procedural or surgical room. Even continual low-power exposure can
promote cataract formation in the lens of the eye and also can damage the retina. Retinal cones detect color and are usually the first structure of the eye to be affected. A new onset of difficulty distinguishing between the colors blue and green may indicate early retinal damage.

**EYE PROTECTION:**

We have a natural blink and aversion response. These are our two self-defense mechanisms.

- The blink response our eyelids temporary close for less than 0.25 seconds during which no light can enter.
- The aversion response is closing the eyelid or movement of the head to avoid exposure to bright light. This response may provide protection from low power lasers less than 0.25 sec, but not the higher powered lasers.

Protective eyewear according to ANZI Z136.1 eyewear is required for Class 3B and Class 4 lasers. Surgical lasers fall within these classifications; therefore we are required to use eye protection during laser use.

In general the eye protection chosen must be selected on the basis of providing the protection required against the maximum exposure anticipated while still permitting the greatest amount of light to enter the eye for the purpose of seeing.

Factors considering in choosing eyewear:
1. Laser wavelength
2. Mode of operation – pulsed or continuous
3. Optical density (OD) at the spectral wavelength (amount of laser light energy protection it gives at a certain wavelength)
4. Maximum beam power which the eyewear provides protection for at least 5 – 10 seconds.
5. Visual Light Transmission – amount of all light allowed to enter thru to one’s eye.
6. Field of vision
7. Comfort and fit
8. Side protection
9. Impact resistance
10. Cost

Manufactures offer a wide range of wavelength selections and frame types. Manufacturers are responsible for marking protection identification information on the eyewear. Whenever assisting in a laser procedure one should choose the appropriate eyewear. Check to ensure that the wavelength(s) listed on the eyewear corresponds to the wavelength(s) of the laser being used.

When considering purchasing laser eye protection, keep the laser classification in mind.

Class 1 laser is safe under all conditions of normal use. This means the maximum amount of permissible exposure (MPE) cannot be exceeded.

Class 1M laser is safe for all conditions of use except when passed through the magnifying optics examples being a microscope or telescopes.

Class 2 lasers are safe because the exposure is no more than 0.25 seconds allowing the blink reflex to limit the exposure.
Class 2M laser is safe since at this level the blink reflex if not viewed through an optical instrument is adequate.

Class 3R laser is considered safe is handled carefully, with restricted beam viewing. The MPE can be exceeded, but with a low risk of injury.

Class 3B laser is hazardous if the eye is exposed directly; however diffuse reflections from matte surfaces or paper type surfaces are not harmful.

Class 4 laser include all lasers with beam power greater than class 3B. This level poses significant eye hazards, with possible devastating and permanent eye damage from the direct beam viewing. Diffuse reflections are also harmful to the eye within the Nominal Hazard Zone (NHZ). These lasers can also burn or cut skin. They can also ignite combustible materials presenting a fire risk.

Care of Laser eyewear and protective filters:

The integrity of the eyewear or filter should be maintained in order to actually provide optimum protection. They should be handled with care and kept protected from damage. Eye cases are recommended for storage or goggles when not in use. Never modify a product including laser protective equipment in anyway.

Routinely inspect eyewear for the following:

- Pitting
- Cracking
- Discoloration
- Coating damage
Light leaks
Mechanical integrity of the frame

If any integrity issues are found, the issues should be remedied or the item removed from service.

Laser eyewear should be cleaned according to the manufactures instructions in order to avoid damage to the absorption filter or reflecting surfaces. Usually a soft cloth and a mild non–abrasive detergent are acceptable for cleaning. No abrasive products such as alcohol, ammonia, alkaline cleaners or cold disinfectant solutions should be used. Eyewear should be checked for scratches and cracks after use.

Protection for both staff and patients:

The OR/Procedure (laser) Room staff will use Laser glasses. If during the procedure the patient is awake, they are also given appropriate protective glasses to wear. If the laser procedure is being done while the patient is under general anesthesia, the eyes are also protected even though the eye lids are closed. Moistened eye pads placed over the eyes for the use of CO₂ lasers and appropriate glasses for other lasers are placed on the patient face also over the eyes. If available, laser shield eye pads can also be used. These pads provide protection according to the wavelengths listed on the supply box.

Eye wear selection is based on the specific laser wavelength:

A. CO₂ Laser Procedures:
   - Clear goggles to cover prescription glasses.
   - Clear glasses with side shields.
   - Contact lenses are not acceptable.
B. Argon Laser Procedures:

- Special eyewear that it is for the argon laser and states optical densities (OD > 5 < 0.52 um).
- Amber filtered goggles.
- Amber filtered glasses with side shields.

C. Nd:YAG laser procedures:

- Special eyewear states that it is for the Nd:YAG laser and states optical densities (OD 4.5 at 1.06 um).
- Green filtered goggles.
- Green filtered glasses with side shields.

D. Diode Laser Procedures:

- Special eyewear states that it is for optical densities (OD 4 at 0.840 um).

**How to read the labeling on a pair of Laser Safety Glasses:**

To be legally certified as laser protective eyewear, the eyewear must be labeled. Eyewear may have duplicate labeling reflecting both the ANSI and the European Norm Standards. In either standard, all laser safety glasses eyewear is marked for specific wavelengths.

**Under ANSI STANDARDS: Optical Density (OD)**

Laser glasses are required to be labeled with two parameters:

1) The wavelength the eyewear is capable of providing protection
2) The Optical Density (OD) or the amount of laser light that will be filtered or allowed to pass thru the glasses. The optical density is calculated to reflect the highest laser power and/or pulse energy
for which the protection is required along with the wavelength of the laser and the exposure time.

Optical Density is abbreviated as: OD. The Optical Density is listed on a scale ...i.e. OD 1, OD 2, OD 3 ...etc. The higher the OD rating, the more laser light energy is filtered. Most surgical lasers require a minimum OD rating of 4. The usual range is from 4 – 7.

Under The European Standards (EIN): Damage Threshold (L)

European standards also require that the eyewear be labeled as to their level of damage threshold for the eyewear material. The damage threshold is calculated by a test of the laser to the eyewear during a 10 second direct hit of continuous wave or 100 pulses. The protection level is rating is abbreviated as: L. the Level scale is listed on the scale of: 1 – 10 (i.e. L1 or L3). The OD rating may be equivalent to the L rating. (i.e. OD5 may be equivalent to L5)

ADDITIONAL MARKING THAT MAY BE ON THE GLASSES – not required by ANSI or EIN:

1. The serial number of the pair of glasses may be listed.
2. The reorder part number of the glasses may be listed.
3. Visible light transmission percentage of VTL% may be listed. This is the percent of light that will pass thru the glasses. A lower percent indicates a decreased visibility making it hard for the wearer to see thru the glasses. Similar to a “darker” sunglasses effect. A lower amount of VLT% may affect the ability to perform task while wearing the eyewear creating a situation where the room
lights may need to be turned up, the computer monitor brightness may need to be turned up in those facilities that have computer charting.

4. Lasers operating at different modes have different density characteristics and often require different eye protective requirements; therefore modes may be listed also. The following abbreviations may be listed:
   - D = Continuous wave mode
   - I = Pulsed mode
   - R = Giant, Q switched or Super Pulsed mode
   - M = Mode locked or micro pulsed.

Examples of glasses are:

Universal Medical Argon Alignment Laser Glasses:
Universal Medical Yag Laser Glasses:

Figure 23

Universal Medial CO₂ Eximer Laser Glasses:

Figure 24

Universal Medical: Dye Diode and HeNe Ruby Laser Filter Safety Glasses - Model 300

Figure 25
Injuries To The Eye:

The major danger of laser radiation is hazards from beams entering the eye. The eye is the organ most sensitive to light. Light enters first thru the clear cornea and then thru the pupil. Light is converged by the lens and the image becomes inverted. Then it travels thru the vitreous humor and focuses back to the fovea / macula on the retina. In the retina, light impulses are changed into electrical signals that are sent along the optic nerve to the brain, which interprets the electrical signals as visual images.

If a laser light enters the eye, exposure can cause biological changes in the eye tissue and proteins. Even low power lasers can be hazardous to a person’s eyesight. The coherence and the low divergence of a laser light can be focused by the eye into an extremely small spot on the retina, resulting in localized burning and permanent damage in seconds. Even the intensity is moderate when it enters the eye, the laser radiation when focused by the lens can cause serious damage within fractions of a second.
The Cornea is a transparent layer of tissue covering the eye. Damage to the outer surface may be uncomfortable, but will heal. Damage to the deeper layers may cause permanent injury.

Certain wavelengths of laser light can cause cataracts or even boiling of vitreous humor according to Science Buddies. Infrared and ultraviolet lasers are particularly dangerous, since the body’s “blink reflex”, which can protect the eye from excessively bright light, works only if the light is visible.

Ultraviolet lasers can cause corneal flash burns, a painful condition of the cornea. The UV radiation can also cause photokeratitis (or ultraviolet keratitis is a painful eye condition) and cataracts in the eye’s lens. Excimer laser was nicknamed the cataract machine.

Mid – infared lasers with certain wavelengths with very strong absorption in the cornea can cause painful corneal injuries.

The fovea or macula is within the retina and it provides details and acute vision along with color perception. The balance of the retina can perceive light and movement. Laser damage to the macula can cause vision to be lost. If it occurs in the periphery, it may produce little or no effect on vision.

Damage can result from both thermal and photochemical effects, not always noticed immediately.

Signs of eye injury include:

- Headache
- Excessive watering of eye
- Sudden appearance of floaters
- Burning pain – Corneal / Scleral tissue – gritty feeling like sand in the eye.
- Blurry vision
- Retina – lacks pain sensory nerves – may not be apparent until damage has occurred
- Loss of vision or holes in vision
- Difficulty in detecting colors (due to damage of rods and cones)
- Hemorrhage and pigments of the retina may be seen during exam

Laser effects are influenced by the power, the spot size and the duration of exposure to the laser beam.

A high power, focused spot with a long exposure can cause more damage. Effects are also wavelength dependent upon the absorption characteristics of the eye tissue.

<table>
<thead>
<tr>
<th>Wavelengths</th>
<th>Primary Absorption Tissue</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 – 1400 nm</td>
<td>Retina</td>
<td>Retina contains melanin in the pigment epithelium. Focusing ability of lens and cornea increase the beam concentration and beam hazards to the retina.</td>
</tr>
<tr>
<td>Cont.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1400 and &gt;</td>
<td>Cornea</td>
<td>Layers contain water and tears. Permanent denaturization of protein in the corneal surface.</td>
</tr>
<tr>
<td>100 – 315 nm</td>
<td>Surface of Cornea</td>
<td>Temporary denaturization of the proteins in the corneal surface heals</td>
</tr>
</tbody>
</table>
Once all of these Policy and Procedures are in place a facility may hire a Laser Safety Officer (LSO). A Laser Safety Officer (LSO) has the authority to monitor and enforce the control of laser hazard and effect the knowledgeable evaluation and control of laser hazards. The LSO administers the overall laser safety program and the duties include, but are not limited to confirming the classification of lasers, doing the NHZ evaluation, assuring that the proper control measures are in place and approving substitute controls, approving standard operating procedures (SOP’s), recommending and/or approving eye wear and other protective equipment, specifying appropriate signs and labels, approving overall facility controls, providing the proper laser safety training as needed, conducting medical surveillance, and designating the laser and incidental personnel categories.

The LSO should receive detailed training including laser fundamentals, laser bioeffects, exposure limits, classifications, NHZ computations, control measures (including area controls, eye wear, barriers, etc.), and medical surveillance requirements.

The most conservative exposure dose would be an 8 – hour (occupational) time limit.
## OPTICAL DENSITIES FOR PROTECTIVE EYEWEAR FOR VARIOUS LASER TYPES

<table>
<thead>
<tr>
<th>LASER TYPE AND POWER</th>
<th>WAVELENGTH (mm)</th>
<th>OPTICAL DENSITY FOR EXPOSURE DURATIONS:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.25§</td>
</tr>
<tr>
<td>XeCl 50 Watts</td>
<td>0.308</td>
<td>--</td>
</tr>
<tr>
<td>XeFl 50 Watts</td>
<td>0.351</td>
<td>--</td>
</tr>
<tr>
<td>ARGON 1.0 Watts</td>
<td>0.0514</td>
<td>3.0</td>
</tr>
<tr>
<td>Krypton 1.0 Watt</td>
<td>0.530</td>
<td>3.0</td>
</tr>
<tr>
<td>Krypton 1.0 Watt</td>
<td>0.568</td>
<td>3.0</td>
</tr>
<tr>
<td>HeNe 0.005 Watt</td>
<td>0.633</td>
<td>0.7</td>
</tr>
<tr>
<td>Krypton 1 Watt</td>
<td>0.647</td>
<td>3.0</td>
</tr>
<tr>
<td>GaAs 50 mW</td>
<td>0.840</td>
<td>--</td>
</tr>
<tr>
<td>Nd: YAG 100 Watt</td>
<td>1.064</td>
<td>--</td>
</tr>
<tr>
<td>Nd: YAG (Q-switch)²</td>
<td>1.064</td>
<td>--</td>
</tr>
<tr>
<td>Nd: YAG² 50 Watts</td>
<td>1.33</td>
<td>--</td>
</tr>
<tr>
<td>CO² 1000 Watts</td>
<td>1.33</td>
<td>--</td>
</tr>
</tbody>
</table>

- a. Repetitively pulsed at 11 Hertz, 12 – nanosecond pulses, 20 mJ/pulse.
- b. OD for UV and FIR beams computed using a 1 – mm limiting aperture, this would represent a “worse case” scenario. All visible and NIR computations assume a 7 – mm limiting aperture.
- c. Nd:YAG operating at a less – common 1.33 μm wavelength.

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

### Control Measures and Safety Programs:

The specific control measure is specified in ANSI Z 136.1 standard and are summarized in this table.
<table>
<thead>
<tr>
<th>Control Measures</th>
<th>Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Protective housing</td>
<td>X</td>
</tr>
<tr>
<td>Without protective housing</td>
<td>LSO shall establish alternate controls</td>
</tr>
<tr>
<td>Interlocks on protective housing</td>
<td>a a a X X X</td>
</tr>
<tr>
<td>Service access panel</td>
<td>b b b b b X</td>
</tr>
<tr>
<td>Key switch master</td>
<td>- - - - - · X</td>
</tr>
<tr>
<td>Viewing portals</td>
<td>- - ◊ ◊ ◊ ◊ ◊</td>
</tr>
<tr>
<td>Collecting optics</td>
<td>- - ◊ ◊ ◊ ◊ ◊</td>
</tr>
<tr>
<td>Totally open beam path</td>
<td>- - - - - X X</td>
</tr>
<tr>
<td>Limited open beam path</td>
<td>- - - - - X X</td>
</tr>
<tr>
<td>Remote interlock connector</td>
<td>- - - - - · X</td>
</tr>
<tr>
<td>Beam stop or attenuator</td>
<td>- - - · · X</td>
</tr>
<tr>
<td>Activation warning system</td>
<td>- - - · · X</td>
</tr>
<tr>
<td>Emission delay</td>
<td>- - - - - ·</td>
</tr>
<tr>
<td>Class IIIB laser controlled area</td>
<td>- - - - X -</td>
</tr>
<tr>
<td>Class IV laser controlled area</td>
<td>- - - - - X</td>
</tr>
<tr>
<td>Laser outdoor controls</td>
<td>- - - - - X</td>
</tr>
<tr>
<td>Temporary laser controlled area</td>
<td>b b b b X X</td>
</tr>
<tr>
<td>Remote firing and monitoring</td>
<td>- - - - - -</td>
</tr>
<tr>
<td>Labels</td>
<td>- X X X X X</td>
</tr>
<tr>
<td>Area posting</td>
<td>- - · · X X</td>
</tr>
<tr>
<td>Administration and procedural controls</td>
<td>- X X X X</td>
</tr>
<tr>
<td>Standard operating procedures</td>
<td>- - - - · X</td>
</tr>
<tr>
<td>Output emission limitations</td>
<td>- - - LSO Determines</td>
</tr>
<tr>
<td>Education and training</td>
<td>- - - X X X</td>
</tr>
<tr>
<td>Authorized personnel</td>
<td>- - - - X X</td>
</tr>
<tr>
<td>Alignment procedures</td>
<td>- - X X X X</td>
</tr>
<tr>
<td>Eye protection</td>
<td>- - - - · X</td>
</tr>
<tr>
<td>Spector control</td>
<td>- - - · · X</td>
</tr>
<tr>
<td>Service personnel</td>
<td>b b b b X X</td>
</tr>
<tr>
<td>Laser Demonstration</td>
<td>- - X X X X</td>
</tr>
</tbody>
</table>
Control of smoke from Laser Procedures:

When performing surgical procedures with LASERS a smoke byproduct called smoke plume is created. This Plume is created when energy is put to intact cells of tissue and is then heated and cellular fluid is vaporized. Plume is a wisp or puff of smoke that may rise from the surgical field after a cell membrane bursts. All personnel who work in ORs are exposed to surgical smoke to some degree. The extent of exposure can be highly variable.

LASER is used to cut, coagulate or destroy tissue and from this process Plumes are created. Thermal Lasers vaporize tissue rapidly, causing an explosive effect. This explosive tissue response causes rapid generation of odors and thick plumes of smoke. Surgical Plumes may contain carbon monoxide, benzene, hydrogen cyanide, and formaldehyde, acetaldehyde, aldehydes, Toluene, Bioaerosols, and among other potentially toxic gases or vapors.

Along with these dangerous gases, Plume can also contain Viral DNA (viruses) including intact human papilloma virus, bacteria including Bacillus subtilis and Staphylococcus aureus, Mycobacteria including Mycobacterium tuberculosis, Human immunodeficiency virus (HIV)
proviral DNA, carcinogens, live and dead cellular material (including blood fragments) and irritants.

Chemical by-products have also been found including various volatile organic compounds, polycyclic aromatic compounds, phenol, hydrogen cyanide, and cresols. The charring of cells releases material such as carbonized cell fragments and hydrocarbons. At high concentrations the smoke causes ocular and upper respiratory tract irritation in health care professionals. According to The National Institute for Occupational Safety and Health (NIOSH) even low concentrations of compounds found in surgical smoke may be sufficient to cause irritative effects on the eyes and mucous membranes, especially in sensitive individuals.

Plume can also create visual problems for the surgeon. Not only can smoke have unpleasant odors, it has been shown to have mutagenic potential according to the CDC. A mutagen is any agent that causes genetic mutation. A Genetic Mutation caused by this external source and the effects can be negative for the person undergoing the mutation. This mutation occurs when the gene properties to not copy properly to the new cells. Changes to the genetic structure can also prevent the gene from functioning properly.

What are these agents? They are;

Aldehydes:

Acetaldehyde is an irritant of the eyes and mucous membranes. Sensitive subjects complained of mild upper respiratory irritation even after 15 minutes exposure. The International Agency for Research on Cancer (IARC) has concluded that “There is sufficient evidence for the carcinogenicity of acetaldehyde of acetaldehyde to experimental
animals” but not in humans. This places Acetaldehyde by the OSHA Hazard Communications Standard as a category 2B carcinogen. The Environmental Protection Agency (EPA) considers acetaldehyde as a probable human carcinogen. NIOSH considers acetaldehyde a potential occupational carcinogen and recommends keeping levels to the lowest feasible concentration.

Acrylaldehyde (Acrolein) is a severe eye and respiratory system irritant. The principal site of chemical effects is the mucous membranes of the upper respiratory tract. Acrolein has a vasopressor effect which causes a rise in blood pressure. The unsaturated nature of the compound results in an eye irritancy potential 2.5 time greater than that of formaldehyde. Acrolein is a major contributor to the irritant properties of cigarette smoke.

Formaldehyde, a colorless gas with a strong odor, is a constituent of tobacco smoke and of combustion gases. Formaldehyde levels in ambient air can result from diverse sources such as automobile exhaust, combustion processes, and may also be released from foam plastics, carbonless copy paper, particle board, and plywood. Exposure can occur through inhalation and skin absorption. Symptoms of exposure to low concentrations of formaldehyde may include irritation of the eyes, throat, and nose; headaches; nausea; nasal congestion; asthma; and skin rashes. It is often difficult to ascribe specific health effects to specific concentrations of formaldehyde because people vary in their subjective responses and complaints.

NIOSH has identified formaldehyde as a suspected human carcinogen. Worker exposure by all routes should be carefully controlled to levels as low as possible.
Benzene is an aromatic organic hydrocarbon containing a six-carbon ring with alternating double bonds. Acute inhalation exposure to high concentrations of benzene can cause drowsiness, fatigue, nausea, vertigo, narcosis, and other symptoms of central nervous system (CNS) depression as noted with excessive exposure to other aromatic hydrocarbons. The health effects associated with benzene exposure are chronic effects to repeated exposure to low concentrations over many years.

Benzene is classified by the International Agency for Research on Cancer (IARC) as known human carcinogen and has been associated with irreversible bone marrow injury and development of hematopoietic toxicity, including aplastic anemia and leukemia in humans. NIOSH classifies benzene as a human carcinogen and recommends controlling occupational exposures to prevent employees from being exposed to concentrations greater than 0.1 ppm determined as a TWA concentration for up to a 10 hour work shift in a 40 hour work week. NIOSH urges reducing the exposures to the “lowest feasible concentration”.

Carbon Monoxide (CO) is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials. CO combines with hemoglobin and interferes with the oxygen-carrying capacity of blood. Symptoms include headache, drowsiness, dizziness, nausea, vomiting, collapse, myocardial ischemia, and death.

Cresol occurs in three isomers, all of which can cause CNS disorders; gastroenteric disturbances; dermatitis; and damage to the liver, kidneys, or lungs. Exposure occurs through skin contact, ingestion and inhalation. In addition, inhalation of particulate cresol as an aerosol is
possible. Toxic manifestations that may develop within 20 to 30 minutes after absorption include eye irritation, conjunctivitis, headache, dizziness, dimness of vision, tinnitus (ringing in the ears), irregular and rapid respirations, weak pulse, dyspnea (shortness of breath), and profound muscle weakness, occasionally followed by mental confusion. Repeated or prolonged exposure may cause gastrointestinal disturbances (vomiting, loss of appetite), nervous disorders, headache, dizziness, and dermatitis.

Hydrogen Cyanide: The general population may be exposed to cyanides form a variety of sources, including inhalation of contaminated air, ingestion of contaminated drinking water or cyanide containing food, and the metabolism of certain drugs. Cyanide is found in low levels in the tissues of healthy people as a result of normal metabolism, eating of cyanide-containing foods, and cigarette smoking. Smokers are known to have higher levels of cyanide in nervous system effects.

The single largest source of airborne cyanides in the ambient environment is vehicle exhaust. Other atmospheric sources include emissions from chemical processing industries, iron and steel mills, metal surgical industries, metal plating and finishing industries, petroleum refineries, municipal waste incinerators.

Particulates health problems are associated with various particulate exposures are influenced by four critical factors: the type of particulate involved, the length of exposure, the concentration of airborne particulates in the breathing zone of the workers, and the size of the particulates present in the breathing zone. Particulates size is the main factor that influences deposition in the respiratory system. Large particles are likely to lodge in the walls of the nasal cavity or pharynx.
during inspiration; Medium particles are likely to settle out in the trachea, bronchi or bronchioles as the air velocity decreases in the smaller passageways; and small particles typically move by diffusion into the alveoli.

Phenol is and irritant of the eyes, mucous membranes, and skin. The skin is a route of entry for the vapor and liquid phases. Symptoms of chronic phenol poisoning may include difficulty in swallowing, diarrhea, vomiting, and lack of appetite, headache, fainting, dizziness, dark urine, mental disturbances, and possibly a skin rash.

Polycyclic Aromatic Compounds (PACs) refer to a set of cyclic organic compounds that includes polynuclear aromatic hydrocarbons (PAHs), and also compounds that may have sulfur, nitrogen, or oxygen in the ring structure, and alkyl-substituted cyclics. NIOSH investigators have hypothesized that PACs with 2 to 3 rings may be associated with more irritative effects, while the 4 to 7 ring PACs (termed high-molecular weight PACs) may have more carcinogenic and/or mutagenic effects.

Toluene is a colorless, aromatic organic liquid containing a six-carbon ring (a benzene ring) with a methyl group (CH₃) substitution. Inhalation and skin absorption are the major occupational routes of entry. Toluene can cause irritation of the eyes, respiratory tract and skin. The main effects reported with excessive (inhalation) exposure to toluene are CNS depression, and neurotoxicity. Exposure of 100 ppm for 6 has led to eye and nose irritation, and in some cases, headache, dizziness, and a feeling of intoxication (narcosis).

Volatile Organic Compounds (VOCs) describe a large class of chemicals that are organic (i.e., contain carbon) and have a sufficiently high vapor pressure to allow some of the compound to exist in the gaseous state.
at room temperature. These compounds are emitted in varying concentrations from numerous indoor sources including, but not limited to carpeting, fabrics, adhesives, solvents, paints, cleaners, waxes, cigarettes, and combustion sources.

Xylene is a colorless, flammable organic liquid with a molecular structure consisting of a benzene ring with two methyl group (CH₃) substitutions. The vapor of xylene has irritant effects on the skin and mucous membranes, including the eyes and respiratory tract. This irritation may cause itching, redness, inflammation, and discomfort. Acute Xylene inhalation exposure may cause headache, dizziness, uncoordination, drowsiness, and unconsciousness. Concentrations from 60 to 350 ppm may cause giddiness, anorexia, vomiting. High concentrations of xylene have a narcotic type effect on the CNS and minor reversible effects on the liver and kidneys.

Bacterial and viruses would include:

Bacteria have three principle forms spherical (ovoid), rod-shaped or spiral. Bacteria mutates, like all living things. The environment determines the beneficial mutations which have the survival value.

Staphylococcus Aureus is a common cause of healthcare associated infections reported to the National Healthcare Safety Network (NHSN). The percentages reported are Coagulase-negative staphylococci the leading infection is 15%, while Staphylococcus aureus is 14%. Staphylococcus Aureus is the most common cause of surgical site infections at 30% and causing ventilator associated pneumonia at 24%. Of all the healthcare associated S. Aureus infections, it is suggested that 49-65% are caused by Methicillin resistant strains.
MRSA: Methicillin Resistant Staphylococcus Aureus is a type of “staph” bacteria that does not react to certain beta-lactam antibiotics called antimicrobial-resistant and will normally cause skin infections. Bacteria are a one-celled organism without a true nucleus or cell organelles, belonging to the kingdom of procaryotae (Monera). Millions of non-pathogenic bacteria live on human skin and mucous membranes; these are called normal flora. Bacteria that cause disease are called pathogens. Bacteria, like all living things, undergo mutations. It is the environment that determines which mutations are beneficial to bacteria. Mutations may be Beneficial to bacteria and may not be to humans, because mutation provides resistance to the potentially lethal effects of antibiotics against bacteria.

Mycobacterium Tuberculosis:

Tuberculosis (TB) is a bacteria that could have a class of its own, however, this lesion will just hit on some important points related to drug resistance. TB is a bacteria that attacks not only the lungs, but also kidneys, spine and brain. TB is spread through the air from one person to another. It is usually passed when an infected person coughs, sneezes, speaks or sings. According to the CDC, It cannot be spread by kissing or sharing a toothbrush.

Not every patient infected with TB becomes sick; in fact most people are able to fight off the TB bacteria from growing. This is called Latent TB Infection (LTBI). Patients about 5 to 10% with (LTBI), who do not receive treatment, will develop TB. TB sometimes is discovered through the tuberculin skin test or special TB blood test. You could have the disease for years before it becomes active. If the TB bacteria is able to
become active, possibly because of a weakened immune system, and then begins to multiply, eventually the patient will become sick.

Extensively drug-resistant tuberculosis (XDR-TB) is caused by Mycobacterium Tuberculosis. XDR TB is a rare type of multidrug resistant tuberculosis (MDR TB). The first line of medication used to treat TB is Isoniazid and Rifampin, now are no longer effective against MDR TB. XDR TB is also resistant to the best second line medications including Fluroquinolones and at least three of the unjectable drugs being Amikacin, Kanamycin, and Capreomycin. At this time, patients have bad outcomes due to less effective treatments.

Today, patients with weak immune systems are at higher risk of death once infected with TB. Symptoms of a patient with TB may be not feeling well with a bad cough that they may have had for more than three weeks. A patient may experience chest pain, weakness, fatigue, weight loss due to suppressed appetite, with possible chills and fever. Some patients may complain of night sweating. A patient may complain of coughing up phlegm possibly with blood. Symptoms will vary when a patient is affected in a different part of the body.

Persons that have these conditions including babies and young children who are also at greater risk are:

1. HIV infected
2. Substance abuse
3. Silicosis: a form of pneumonoconiosis which are inhaled.
4. Diabetes mellitus
5. Severe kidney disease
6. Low body weight
7. Organ transplants
8. Head and neck cancer
9. Patients on corticosteroids or taking rheumatoid arthritis.

The CDC has a tremendous amount of information about TB, if more information is needed.

Human immunodeficiency Virus (HIV) is a retrovirus of the subfamily lentivirus that causes acquired immunodeficiency syndrome (AIDS). This causes a loss of immune function and the subsequent development of opportunist infections identical to those associated with HIV.

NIOSH research has shown airborne contaminants generated by these surgical devises can be effectively controlled. Two methods are recommended by the NIOSH and CDC they are Ventilation and Work Practices.

**Ventilation techniques** include a combination of general room and local exhaust ventilation (LEV). General room ventilation is not sufficient to capture contaminants generated at the source. Two major LEV approaches used to reduce surgical smoke levels are room suction systems and portable smoke evacuators.

Smoke evacuators contain a suction (vacuum) pump, filter hose and an inlet nozzle.

Smoke evacuators should have a high efficiency in airborne particle reduction and should be used in accordance with manufacturer’s recommendations to achieve maximum efficiency. The capture velocity should be 100 to 150 feet per minute at the inlet nozzle is generally recommended by NIOSH. A high efficiency particulate air (HEPA) filter or equivalent is recommended for trapping particulates.
Room suction systems can pull at a much lower rate and were designed primarily to capture liquids rather than particulate or gases. If these systems are used to capture generated smoke, users must install appropriate filters in the line, insure line is cleared and filters are disposed of properly. This system in not generally as effective to control generated smoke properly from the surgical field.

**Work Practices:** the smoke evacuator or room suction hose nozzle inlet must be kept within 2 inches of the surgical site to effectively capture airborne contaminants generated by these surgical devices. There are many commercially available smoke evacuators system to select from and all of these LEV systems must be inspected and maintained correctly to prevent possible leaks. Users must utilize control measures such as “universal precautions”, as required by OSHA Blood-Borne Pathogen standard.

Additional respiratory protection from particulate exposure could be the N95 respirator. The amount of control of exposure reduction is much greater with an N95 face mask than in a surgical mask. Surgical masks are very loose fitting and protect the wearer mainly from splashes and spray.

Smoke evacuators come in different sizes now to accommodate the different types of surgical settings. These setting include Operating Rooms, labor and delivery surgery rooms, same day surgery rooms, Doctor’s offices, procedure rooms and where ever LASER may be used.

Smoke evacuators should be on (activated) at all times when airborne particles are produced during all surgical or other procedures. Is smoke evacuation mandatory? No, but it is recommended by several organizations including NIOSH, AORN, and ECRI (health Devices). Staff
education can change the notion that you must “put up with the smoke” to work in the OR, it is not part of the territory.

Remember per NIOSH and the CDC the various filters and absorbers used in smoke evacuators require monitoring and replacement on a regular basis and are considered a possible biohazard requiring proper disposal.

The CDC created a smoke evacuation module that anyone can take online at their web site.

Laser Masks:

The smoke evacuator must be the first line of defense. Masks are worn to protect staff from potential contaminants. They have been shown not to really provide adequate protection, however they filter more than a regular mask.

This is an example from Medline Industries:

These types of laser masks have a special filter which block laser plume as small as 0.1 microns.
An N95 respirator would look something like this, this particular model is also from Medline.com.

These masks do provide some protection from airborne particles and are worn for “TB” cases. These masks must be properly size fitted in order for them to work properly.

A PAPR can also be worn and this is a battery operated respiratory system that filters the air of the wearer. This unit is a disposable hood.

With all of these safety elements in place there are several ways lasers are used for medical application. Several surgical applications can be applied.

Other safety measures could include:

Backstops which have been developed that can stop a laser beam from striking normal tissue. Quartz rods and titanium are effective backstops for the CO₂ laser and can be reprocessed. The Nd:YAG and argon
wavelengths can be transmitted through clear rods in this case titanium rods are preferred.

Mirrors may be used during laser surgery to reflect the beam where it is hard to reach. The mirrors usually are made of rhodium or stainless steel. When using a mirror it is important to aim the laser at the image in the mirror. Always inspect the mirrors prior to use for damage, including cracks.

Large retractors that are not ebonized, but required for a surgical procedure should be completely wrapped in a sponge(s) to decrease the chance of laser reflection.

During oral procedures in which a dental protector is needed, make sure this product can withstand inadvertent contact from the laser.

**Abdominal Aortic Aneurysm (AAA):**

An abdominal aortic aneurysm is when the large blood vessel (aorta) that supplies blood to the abdomen, pelvis, and legs becomes abnormally large or balloons outward. An aneurysm involves the stretching, widening or ballooning of the aorta according to PubMed health. The most common cause of an abdominal aortic aneurysm is atherosclerotic disease.
Causes of an abdominal Aortic Aneurysm (AAA) are not always known, and can develop in anyone. However a male between the ages of 60 to 80 and with a history of smoking the risk factor is eight time more likely to develop an aneurysm. A patient with one or more of these risk factors has a greater chance of developing an Abdominal Aortic Aneurysm (AAA). Risk factors are:

- Emphysema
- Genetic factors (family history)
- High blood pressure
- High cholesterol
- Heart disease
- Male gender
- Obesity
- Smoking

Symptoms of an abdominal aneurysm may not always be immediately present because they usually develop slowly over several years. Aneurysms that develop and expand quickly, tear and rupture, or blood leaks along the wall of the vessel (aortic dissection), symptoms may develop more quickly. For patients who are at the point of rupture those symptoms may be:

- Pain in the abdomen or back – severe, sudden, persistent or constant. The pain may spread to the groin, buttocks, or legs.
- Clammy skin
- Dizziness
- Nausea and vomiting
- Rapid heart rate
- Shock
This is a medical emergency and Surgery must be done right away. Less than 80% of patients survive a ruptured abdominal aneurysm.

Signs of the slow growing AAA may include:

- A lump or mass in the abdomen
- Pulsating sensation in the abdomen
- Stiff or rigid abdomen

For the patient with no symptoms, an aneurysm may be discovered with an:

- Angiogram
- CT scan of the abdomen, this may also be confirmed with this test if an aneurysm was suspected.
- Ultrasound of the abdomen – this also may be used if an aneurysm was suspected.

When a patient is having symptoms any of these tests can be done.

When the results of these tests are completed assessment of the aneurysm less than 2 inches or 5.5 cm across may be watched by the physician. This is usually checked every 6 months by ultrasound to see if it is getting bigger.

Any aneurysm above this size will be addressed based on the speed of growth of the aneurysm. If it is a fast growing aneurysm traditional surgery may be recommended for an open repair with a graft of man – made material. The outcome is usually good, if the aneurysm is repaired before it ruptures by a vascular surgeon.

Another approach is called endovascular surgery. This approach is less invasive and may promote faster recovery with less pain.
Unfortunately if the aneurysm is leaking or bleeding, it may not be able to be performed endovascularly in this situation.

A newer surgical concept is Interventional radiology (IR or VIR) for vascular and Interventional radiology. It may also be referred to as Surgical Radiology. This medical sub–specialty of radiology uses minimally invasive image guided procedures to diagnose and treat nearly every organ system of the body. Interventional radiologists pioneered modern minimally invasive medicine and the inventors of angioplasty and catheter delivered stents improved. The procedures now can be performed through small incisions while using these needles and small catheters. All this is completed while using x-rays, MRIs, CT scans and Ultrasound.

Conditions that were once treated surgically can now be treated non–surgically with minimal physical trauma to the patient, creating an easier recovery (less time in the hospital) with a reduced infection rate.

In 1969 the development of stents began slowly, Charles Dotter developed the idea of expandable stents with an intra–arterial coil spring.

In 1978 Charles Dotter, MD, is known as the “Father of Interventional Radiology” for pioneering this technique, was nominated for the Nobel Prize in Physiology or Medicine. Charles Dotter had close ties with Bill Cook who as an innovative device manufacturer spurred the growth of interventional radiology.

Alexander Margulis coined the term “interventional” for the new minimally invasive techniques.
Angioplasty and stenting lead the way for more known applications of coronary artery angioplasty and stenting enhancing the practice of cardiology.

In 1991 the use of abdominal aortic stent grafts now were used in IR. By using the Interventional radiology method including angiography and stenting to occlude the AAA and prevent its continued growth. This can also be used for thoracic aortic aneurysms (TAA) and aortic dissection. Causes of a thoracic Aneurysm may include artherosclerosis, syphilis, trauma or multiple other conditions.

In 1999 the development of endovenous laser ablation procedure to treat varicose veins and venous disease.

In the present time laser artherectomy is a minimally invasive procedure for the treatment of peripheral artery disease (PAD) and Critical Limb ischemia (CLI). The procedure usually takes a few hours, only a few minutes of this procedure could be actual laser time.

The laser is introduced in the same manner as a conventional balloon angioplasty. Through a narrow, flexible tube, the laser catheter is inserted into an artery. The laser catheter contains a bundle of optical fibers that transmit untraviolet laser light. Once the laser reaches the obstruction, and pulsed laser energy is used, called photoablation, it vaporizes the plaque into particles easily absorbed into the bloodstream.

Abdominal Aortic Aneurysms can be repaired with an Endovascular Aneurysm repair (EVAR) method; this may be in combination with the use of laser. A stent graft is placed within the aneurysm to provide a permanent conduit for blood flow.
There are always complications for any procedure and for these types of procedures dissection, malpositioning, renal failure, thromboembolization, ischemic colitis, groin hematoma, wound infection. Systemic complications would include myocardial infarction, congestive heart failure, arrhythmias, respiratory failure and renal failure. Devise related complications would include, migration, detachment, rupture, stenosis, and kinking.

There are 5 types of endoleaks associated with these types of procedures, they are:

- Type I – perigraft leakage at proximal or distal graft attachment sites (near the renal and iliac arteries).
- Type II – Retrograde flow from collateral branches such as the lumbar, testicular and inferior mesenteric arteries.
- Type III – Leakage between different parts of the stent (at the anastomosis between components).
- Type IV – Leakage through the graft wall due to the quality of graft material.
- Type V – Leakage from unknown origin.

Overall this is still a safer procedure than having to open a patient the traditional way.

**Diabetic Retinopathy:**

It is estimated that in the United States more than 14 million people have diabetes mellitus. Of this group of people about half do not even know they have the disease. There are two types of diabetes Type I diabetes which is usually a juvenile onset that requires insulin injections
to regulate blood sugars. And Type II adult onset, which in some cases can be controlled with adjustments in diet.

Diabetic retinopathy is seen in both, although type II is at greater risk for developing this complication. 25% of type I diabetics after five years have retinopathy. Those with diabetes also have 25 times the chance of blindness. There are new medications to slow or hopefully prevent diabetic retinopathy, and the use of laser also decreases the damage done from other coagulation procedures.

Diabetic retinopathy is classified into two categories: Proliferative diabetic retinopathy or Background diabetic retinopathy which includes macular edema. To stop the stimulation of hypoxic retinal pigment cells from forming fragile blood vessels, laser photocoagulation is performed. The laser energy impacts the ischemic areas by debriding the retinal layer and destroying the ischemic retina that produces the factor responsible for the growth of fragile blood vessels. This allows more oxygenation from the choroid layer to enhance retinal profusion.

The Argon laser has been the laser of choice for retinal photocoagulation. With laser evolution, the lasers used more today is the highly focused green, yellow, red, diode, and infrared laser light have become popular for this procedure. Energy from the laser can be applied to one spot or all around the retina to seal new blood vessels or debride the retina to stabilize or improve the patient’s vision. The goal in treating diabetic macular edema is to stop damaged blood vessels from leaking and causing the retina to swell and stabilize the vision. Laser in these cases stabilizes vision instead of improving it.
Retinal detachment:

Retinal Detachment (retinal tear) is the separation of the inner sensory layer of the retina from the outer pigment epithelium this is called Rhegmatogeous retinal detachment. This layer peels away from its underlying layer and may be localized in the initial detachment. Rapid treatment is required, before the entire retina detaches leading to vision loss or even blindness. This is considered a medical emergency. This can be a result of trauma, penetrating trauma, or blunt blows to the orbit and concussions to the head. The gradual onset is can happen in most cases when trauma is not involved.

The retina is a light sensitive thin layer of tissue against the back wall of the eye. The retina translates that focused image into neural impulses and sends them to the brain thru the optic nerve. The posterior vitreous may also detach due to Injury or trauma to the head or eye may also cause a small tear in the retina. This tear in the retina allows vitreous fluid under the retina. This may have the appearance of a bubble.

Retinal tears can be placed into three types:

A. Holes – Due to retinal atrophy
B. Tears – Due to vitreoretinal traction
C. Dialyses – are very peripheral and circumferential and can be due to tractional or atrophic.

Exudative retinal detachment occurs due to inflammation, injury, or vascular abnormalities and is a result of fluid accumulation underneath the retina without the presence of a hole, tear or break. Exudative retinal detachment although rare can happen due to a growth of a tumor on the layers of tissue beneath the retina, usually the choroid (choroidal melanoma).

Tractional retinal detachment happens when fibrous or fibrovascular tissue, caused by an injury, neovascularization or inflammation, pulls the sensory retina from the retinal pigment epithelium.

Signs and symptoms of a retinal detachment happen commonly in conjunction with a posterior vitreous detachment. It is not unusual for the Posterior vitreous detachment to precede a retinal detachment and the symptoms are:

- Flashes of light (photopsia) – very brief in the extreme peripheral (outside of the center) part of vision.
- Blurred vision
- A sudden increase in the number of floaters which can be dramatic.
- A ring of floaters or hairs just to the temporal side of the central vision.
- A slight feeling of heaviness in the eye.

When it progresses to a retinal detachment this situation may include these symptoms:
A dense shadow or blindness that starts in the peripheral vision and slowly progresses towards the central vision.

The impression that a veil or curtain was drawn over the field of vision.

Straight lines (edge of the wall, road, etc.) that suddenly appear curved (positive Amsler grid test).

Central vision loss.

Risk factors for retinal detachment include severe myopia, family history, trauma, retinal tears, and complications of cataract surgery.

High impact sports such as American football, boxing, karate, kickboxing, even in high speed action including automobile racing, sledding. Intraocular pressure spikes caused by activity including weightlifting, heavy manual lifting can be associated with increased risk.

To diagnose a retinal detachment a patient may be examined using a fundus photography or ophthalmography. Photo documentation for future reference is also a benefit to this type of examination. Other tests that can be used are:

- Flourecein angionography
- Electroretinogram
- Intraocular pressure measurement
- Retinal photography
- Slit – lamp examination
- Ultrasound of the eye

Although there are several treatments for a retinal detachment we will focus on the laser treatment.
Patients scheduled for a Vitrectomy is the growing treatment of choice for retinal detachment. This procedure involves removal of the vitreous gel and is usually combined with filling the eye with either a \( \text{SF}_6 \) or \( \text{C}_3\text{F}_8 \) gas or silicon oil. The advantage of the gas is no myopic shift after the surgery is completed and the gas is absorbed by the body in several weeks. The silicon oil requires the patient to return to surgery after a period of up to 8 months to have the silicon removed. This silicon oil is used in cases of proliferative vitreo – retinopathy (PVR).

Once a patient has had a vitrectomy it usually leads to a rapid progression to a cataract in the eye that had surgery. The good news is that 85% of the cases will be successful with one surgery; the 15% however will usually 2 or more surgeries.

Vitrectomy is a surgery to remove some or all of the vitreous humor from the eye. Anterior vitrectomy usually entails removing a small portion of vitreous from the front part of the eye while Pars plana vitrectomy is in the deeper part of the eye and involves removing some or all of the vitreous.

A vitrectomy may include many steps several being a Membranectomy, fluid – air exchange, air – gas exchange, silicone oil injection, scleral buckling, lensectomy and Photocoagulation.

Photocoagulation is the laser treatment to seal off holes in the retina or to shrink unhealthy tissue, damaging blood vessels which can grow in some diseases including diabetes. Condensation of protein material by the controlled use of an intense beam of light (e.g. argon laser) used especially in the treatment of retinal detachment and destruction of abnormal retinal vessels or intraocular tumors. This procedure can
result in the return of 20 / 20 vision; this depends on the underlying reason of the condition that prompted the surgery in the beginning.

Since Ophthalmology started using laser in the 1960’s it has expanded to include other eye treatments. Other diseases that laser treatment may be used are retinal ischemia, neovascularization of the choroid or retina, glaucoma and complications form cataract surgery know as posterior capsular opacification.

The laser has become a standard tool for ophthalmologists and continually is being developed to advance its applications.

**Neurosurgery:**

Neurosurgeons have been using CO\textsubscript{2} lasers to fight and destroy brain tumors for quite some time now. This science is changing and growing every day. It is the advancement of the delivery systems that has made a huge difference in laser resection of brain, spinal cord and nerve tumors. Washington University has successfully used MRI to guide a laser through a burr hole into a non-operable brain tumor and “cook” the tumor. More types of these lasers are being designed to try and conquer these types of tumors with less invasive technology. Surgeons are able to treat these tumors with laser by heating and coagulating tissue, obliterate vascular malformations and aneurysms and fuse tissues for vascular and nerve repair and anastomosis.

Brain tumors have also been treated with PDT using metal vapor, diode and dye lasers to induce photochemical reactions. Current use is for microsurgical removal of tumors and production of precise brain and spinal cord lesions for treatment of functional disorders.
What is the brain? The brain is a soft large mass of nerve tissue that is contained within the cranium. The brain is the crainial portion of the central nervous system. The brain is also known for its grey and white matter. The grey matter is mainly composed of neuron cell bodies and is concentrated in the cerebral cortex. It is also in the basal ganglia and nuclei. White matter is composed of axons, which form tracts connecting parts of the brain with each other and the spinal cord.

**Brain Tumors:**

A brain tumor is an intercranial mass or solid growth of abnormal cells that occurs with in the brain, central spinal canal and the tissues including structures around it. Lymphatic tissue, in the blood vessels, cranial nerves, in the brain envelopes (meninges), skull, pituitary gland, or the pineal gland are other areas tumors can grow. Cells of the brain may also become tumors; these may come from neurons or glial cells. These cells become astrocytes, oligodendrocytes, and ependymal cells.

Tumors that start in the brain are called primary tumors. Tumors that start somewhere else in the body and then spread to the brain are called metastatic or secondary brain tumors. Brain tumors are described in two main categories:

1. Non-cancerous or benign tumors.
2. Cancerous these are malignant tumors.

Any brain tumor can be a serious life threatening depending on the size, due to the limited space in the cranium. Treatment depends on the type, size, the location and the level of development. Most common treatments include surgery, radiation and chemotherapy. Unfortunately brain tumors are often discovered in the advanced
stages when unexplained symptoms appear. Even in cases of malignant
tumors this does not always have a fatal ending. Tumors are discovered
because the patient has symptoms, others show up during an MRI or
other type of scan, or unfortunately during an autopsy.

The two main factors that affect the visibility of a tumor are the size of
the tumor (volume) and Location. Symptoms usually become apparent
to the person or to the people around them. There is always the
possibility of a benign tumor becoming more malignant. Benign tumors
are often slower growing and malignant tumors become fast growing
tumors.

Symptoms of a solid neoplasm origin being a primary or secondary alike
of the brain can be divided into 3 main categories. These symptoms are
true for all types of brain tumors including secondary tumors.

1. Consequences of intracranial hypertension: This usually results
from increased intracranial pressure. Large tumors or tumors with
extensive perifocal swelling also called edema will lead to
elevated intracranial pressure. This increased pressure leads to
headaches, vomiting (this could be without nausea), altered state
of consciousness (somnolence, coma), dilation of the pupil on the
side of the lesion (ansisocoria), papilledema (prominent optic disc
at the funduscopic eye exam). Small tumor can become
obstructive in nature. These tumors can block passages of
cerebrospinal fluid (CSF) which also causes increased intracranial
pressure. Increased intracranial pressure could result in herniation
of certain parts of the brain, such as cerebellar tonsils or temporal
uncus, resulting in brainstem compression. In the very young
pediatric population this elevated pressure could cause an increased diameter of the skull and bulging of the fontanelles.

2. Dysfunction depends on the tumor location and the damage of the surrounding brain tissue or structures. This could happen either through compression or infiltration, any type of focal neurologic symptom such as cognitive and behavioral impairment. This impairment may include impaired judgment, memory loss, lack of recognition, spatial orientation disorders, personality or emotional changes, hemiparesis, hypoesthesia, aphasia, ataxia, visual impairment, impaired sense of smell, impaired hearing, facial paralysis, double vision, and dizziness. More severe symptoms may include paralysis on one side of the body hemiplegia, or impairment to swallow. These symptoms however are not limited to brain tumors, could have been caused by stroke or traumatic brain injury. Pituitary tumors could lead to bilateral temporal visual field defect because of compression to the optic chiasm.

3. Irritation including abnormal fatigue, weariness, absences and tremors possibly including epileptic seizures.

It is not unusual for a person to have a primary benign brain tumor for years and have not signs or symptoms. A tumor presentation could be vague and intermittent symptoms like headaches and occasional vomiting or weariness; this could easily be mistaken for gastritis or gastroenteritis. Pressure on the brain may not create pain. The brain has not nerve sensors in the meninges (outer surface), this is one reason some of the procedures on the brain can be performed while the patient is awake.
The Dutch GP Association created a list of causes for headaches that should alert general practitioners to dig a little deeper with their diagnosis. Here is the list:

<table>
<thead>
<tr>
<th>Cause of Headaches</th>
<th>Potential Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>First headache complaint for person over 50 years old</td>
<td>Brain tumor, arteritis temporalis</td>
</tr>
<tr>
<td>First migraine attack in a person over 40 years old</td>
<td>Brain tumor</td>
</tr>
<tr>
<td>Headache in person under 6 years old</td>
<td>Brain tumor, hydrocephalus</td>
</tr>
<tr>
<td>Person over 50 years old with pain at temples</td>
<td>arteritis temporalis</td>
</tr>
<tr>
<td>Pregnancy with unknown headache</td>
<td>Pre-eclampsia</td>
</tr>
<tr>
<td>Increased headaches after trauma</td>
<td>Sub/epidural hematoma</td>
</tr>
<tr>
<td>Severe headaches and very high blood pressure</td>
<td>Malignant hypertention</td>
</tr>
<tr>
<td>Acute severe headache</td>
<td>Meningitis, CVA (cerebrovascular accident or stroke), subarachnoidal hemorrhage</td>
</tr>
<tr>
<td>Headache and fever (with reduced consciousness)</td>
<td>Meningitis</td>
</tr>
<tr>
<td>Stiffness of the neck / neurological dysfunction</td>
<td>Meningitis, brain tumor</td>
</tr>
<tr>
<td>Headache with signs of elevated intracranial pressure</td>
<td>Brain tumor</td>
</tr>
<tr>
<td>Focal neurological dysfunction</td>
<td>Brain tumor</td>
</tr>
<tr>
<td>Early morning vomiting or vomiting unrelated to headache or illness</td>
<td>Brain tumor</td>
</tr>
<tr>
<td>Behavioral changes or rapid decline in school results</td>
<td>Brain tumor</td>
</tr>
</tbody>
</table>

Exposures to vinyl chloride or ionizing radiation are the only environmental factors associated with brain tumors. Mutation and deletions of tumor suppressor genes may be the cause of some forms of brain tumors. Patients with Von Hippel - Lindau syndrome, multiple endocrine neoplasia, neurofibromatosis type 2 are at a higher risk of developing brain tumors.
Types of tumors are:

- Gliomas (50.4 %)
- Meningiomas (20.8 %)
- Pituitary Ademonas (15 %)
- Nerve sheath tumors (8 %)
- Other (5.8 %)

Tumors have characteristic that allow determination of its malignancy, how it will evolve and this will assist the medical team in deciding the plan of action.

Anaplasia: or dedifferentiation; A characteristic of anaplastic tumor tissue is the loss of cell differentiation and their orientation to one another including blood vessels. These cells will have lost total control of normal functions and have deteriorated cell structures. Cells can become anaplastic in two ways:

1. Neoplastic tumor cells can dedifferentiate to become anaplasias (the dedifferentiation) and causes the cells to lose all of their normal structure and function.
2. Cancer stem cells can increase their ability to multiply and create a situation of uncontrollable growth due to failure of differentiation.

Atypia: This is an indication of abnormality of a cell, which may be indicative of malignancy.

Neoplasia: is the uncontrolled division of cells and the neoplasia is not problematic but the consequences of the cell division is. The uncontrolled division of cells leads to an increased size of the mass and increased intracranial pressure with destruction of brain parenchyma.
Necrosis: is the premature death of cell which is cause by external factors. These factors are infections, toxin or trauma. Necrotic cells send the wrong chemical signals which prevent phagocytes from disposing of the dead cells. This leads to a build up of dead tissue.

Arterial and venous hypoxia, or the deprivation of adequate oxygen supply to certain areas of the brain happen when the tumor takes the nutrients from the blood supply. This leaves the normal tissue without any means of nutrition and the tissue fails to thrive.

**Treatment:**

Surgery, in most cases is the most desired course of action and the tumor is removal by craniotomy. The purpose of surgery is to remove as much of the tumor as possible. If it is possible to remove the whole tumor this is the best result. If the whole tumor cannot be removed it is still best to debulk as much of the tumor as possible. Radiation and Chemotherapy will also be used to kill tumor cells that are left behind.

Many meningiomas can be successfully removed, except for some tumors at the base of the skull. Pituitary tumors can often be successfully removed.

Lasers work great for those tumors that are hard to resect and are a very valuable tool in neurosurgery. They are able to “cook” the tumors in areas that are hard work with conventional surgical methods. Laser can be used in situations where it is a lot less invasive and patients do not need to go to ICU and are able to go home much faster.

Potential advantages of laser ablation treatment are:
• With guided MRI images, can be more precise that conventional surgery.
• Recovery time, hospital stay (1 day) and complications are reduced and do not interfere with other treatments.
• The small size of the lasers enables safer access to deep seated and surgically inoperable tumors.
• Destroys only the target tissue, leaving surrounding tissue unharmed which is important in the brain and spinal cord area.
• Can be performed with the patient awake.
• May not need a bone flap.
• Causes little pain during and after surgery.
• Does not limit the use of other treatment options.

Glioblastoma multiforme is the deadliest and most common form of malignant brain tumor. Even with aggressive surgical excision, radiotherapy and chemotherapy the average survival rate is a little over one year. Experimental treatments include the gamma – knife radiosurgery, boron neutron capture and gene transfer.

Astrocytomas are primary brain tumors that arise from astrocytes. Astrocytomas are star – shaped glial cells and account for about 60% of all malignant primary brain tumors. Astrocytoma tumors types are put into grades and these include:

• Grade I: Pilocytic astrocytoma is one of the most common types of glioma in children.
• Grade II: Diffuse astrocytoma is a low grade tumor usually in men and occurs in women between the ages of 20 - 60.
• Grade III anaplastic astrocytoma is more common in adult men and appears between the ages of 30 – 60.
• Grade IV Glioblastoma multiforme (GBM) is also a glioblastoma and accounts for almost 50% of all astrocytomatas. This is one of the fastest growing and deadliest types of brain tumor. Only 10% of pediatric brain tumors are glioblastomas.

Oligodendrogliomas develop from oligodendrocyte glial cells, and they form the protective coatings around the nerve cells. These are classified as a low – grade tumor (II) or anaplastic (III). A pure oligodendroglioma is rare; they are usually mixed with gliomas and occur in young to middle aged adults.

Ependymomas are derived from ependymal cells, which line the ventricles of the lower part of the brain and central canal of the spinal cord. Ependymomas are the most common type of brain tumor in children and adults around the 40 -50 age range. These tumors are divided into four categories:

1. Grade I: Myxopapillary ependymomas
2. Grade I: Subependymomas
3. Grade II: Ependymomas
4. Grade III and IV: Anaplastic ependymomas.

There are over 100 types of brain tumors.
**General Surgery:**

General surgery at present has fewer applications for lasers than several years ago. There is possibly a benefit from laser use in a more localized and precise zone. Some plastic and proctologic procedures are done with laser; examples are hemorrhoid excision and condylomata removal.

**Urology:**

Urology physicians have used Holmium: YAG and pulse – dye lasers to fragment urinary calculi through miniaturized rigid and flexible endoscopes. These stones will either be fragmented or even vaporized. The laser fibers can be used in either of the endoscopes for easier access to the stones. Lasers have made this procedure more efficient and less time for the patient to be under anesthesia.

One complication is the possibility of the YAG laser is to cut the ureteral wall if contact was to occur. The pulse – dye laser is virtually thermal risk free.

When delivering the Nd:Yag, KTP, Holmium or Thulium beam in fluid filled media, e.g. bladder tumor ablation or ureteral lithotripsy, vaporized tissue is not aerosolized. The vaporized particulate stays in the fluid and is taken to the suction machine for disposal.

**Otolaryngology:**

Indication and uses have changed over the last decade due to laser technology and the laser delivery systems have improved so much over this time frame. Laser applications have included laryngology, head and
neck surgeries, cancer surgeries, rhinology, otology, pediatric otolaryngology, and facial plastic surgery. Uvulopalatoplasty, ablation of respiratory papillomatosis, stapedotomy, and transoral laser microsurgery for malignancies of the pharynx and larynx. These applications may occur in otolaryngologist’s hospitals, ambulatory surgery centers and office-based settings.

Lasers that are used in these types of cases are the: Co₂ laser (10,600 nm), Nd:yag (1064), Erbium:YAG (2940 nm), Argon (488 and 514 nm), KTP (532 nm), Copper Vapor (578 nm), Continuous Yellow Dye (577 nm), Flashlamp – Excited Dye (585 nm), Ruby (694 nm), Alexandrite (755 nm) and diode lasers of varying wavelengths.

Delivery systems can include using a rigid bronchoscope to deliver laser output to the trachea. When using a laser to do resurfacing a handheld delivery system may be used. Flexible CO₂ optical delivery system has been developed to reach inaccessible placed.

**Anesthesiology:**

Anesthesiology department plays a big part in laser safety. They have even set up a task force: American Society of Anesthesiologists Task Force on Operating Room Fires, and produced the “*Practice Advisory for the Prevention and Management of Operating Room Fires,*” *Anesthesiology, vol. 108, no. 5, May 2008.* In most cases surgical lasers used in procedures requiring anesthesia are usually class 4. When laser safety is not used correctly in these cases the end result could be significant skin and fire hazards, and the patients eyes being especially vulnerable.
The elimination of flammable gasses and reflective surfaces while protecting the patient is the main goal for anesthesia. It is important to eliminate oxygen when possible to remove this source of ignition. It is important to remember all the components are available for a fire when using a laser heat, flammable material and oxygen. Anesthesia will take into consideration the use of total intravenous anesthesia when possible. If the patient only receives amnestic and anesthetic drugs it will be extremely important to keep the patient as still as possible during the firing of the laser.

Control of the firing of the laser is provided by an accurate alignment of the visible aligning beam and active laser beam. An accurate aim at the target tissue in order to keep the laser as far away from the endotracheal tube as possible is required. A special laser endotracheal tube should always be used on all laser cases where there is a possibility of the tube being hit by a laser beam. Anesthesia should also take extreme care to make sure the patients eyes have been protected with wet eye pads, protective shields, and tape has been placed if needed to secure these items.

If possible, fire retardant drapes and wet towels should be placed as close to the area around the lesion when appropriate. Consideration of these wet drapes should give special notice to the patient not to cause hypothermia, temperature should be monitored closely.

Complications for anesthesia for of the ventilator process may become complicated when the surgeon and anesthesia are sharing the same airway. The exposure of the glottis or a tumor during laryngeal procedures may become more difficult.
Cosmetic Laser Procedures

The skin is one of the most accessible organs for laser effect and consequently has the widest range of laser applications. Cosmetic lasers are monochromatic and use different laser single-wavelengths (colors of light) which target different skin issues. This creates a need for a variety of lasers to treat different types of skin conditions. A combination of several different lasers may be recommended by your Physician or surgeon due to the skin issues one might have.

Lasers work through a process called “selective photothermolysis”. This means it modulates the frequency of light (photo) to produce heat (thermo) in a specific area targeted to destroy (lysis). The wavelength of a light beam must be in sync with the color of the target to be addressed, such as brown spots, unsightly red broken capillaries or some other undesirable skin condition.

There are two basic types of lasers used for cosmetic purposes: Ablative and nonablative. Ablative lasers vaporize the top layers of damaged skin. Nonablative lasers work deeper in the skin without removing or damaging the top layers. Nonablative laser technology does not create downtime for the patient.

Different issues might be:

- Fine lines and wrinkles which may require a combination of skin resurfacing and skin-tightening procedures accomplished with a more aggressive ablative laser, such as a Erbium Yag laser or a CO2 (carbon Dioxide) laser. The CO2 is also used for cutting skin in laser assisted surgery and removal of skin tags. If using the CO2 laser to remove warts, make sure to use a smoke evacuator with a
hepa filter for the plume. Pulsed Dye Lasers have shown some success, along with other less aggressive nonlaser, light-based treatments, such as IPL and LED photofacials.

- Skin Tightening is accomplished with most cosmetic laser procedures. Laser is a controlled injury of the skin, which encourages increased collagen production and provides some level of superficial tightening. If more significant tightening is requested, CO2 lasers are the laser most used. There has been success using nonlaser, light-based treatments, using titan infrared devices and Thermage radio-frequency based systems.

- Pigmentated lesions, such as sun spots, age spots (melasma) and other forms of hyperpigmentation are treated with lasers. The most common lasers used are the pulsed dye, Nd:Yag and Fractional (fraxel) lasers, along with nonlaser, light-based treatments, such as IPL.

- Precancerous lesions should be removed by surgical means to ensure the boarders of the cancers are removed as well. Actinic Keratoses should be removed before they can become malignant. Lasers are now being used as a preventative measure, and the ablative lasers used are CO2 and erbium: yag.

- Vascular lesions include broken blood vessels on the face, unsightly veins on the legs, spider nevi, hemangiomas and certain birth marks including port wine stains. IPL is the main choice for minimally invasive removal of these lesions.

- Tattoos are usually removed by a CO2 and ND: Yag laser, there has been some success with the IPL.

- Hair Removal is highly dependent on the patient’s pigment and skin type. For darker-skinned patients the ND: Yag and diode
lasers work better and for lighter patients IPL has been more effective.

- Acne and Acne scars, the CO2 laser works on the deeper acne scars. Work has been done with the erbium: Yag, fractional laser and certain nonablative lasers for the superficial acne scarring. For active acne, LED technology is working quite well.

In the world today, many different types of light-based technology is being used. Even though these methods are referred to as “laser” devices they are not true lasers. These technologies include the LED treatments, IPL, Titan and similar infrared energy based technologies and radio-frequency procedures such as thermage.

Let us go into a deeper understanding of some of the problems that can be addressed by laser treatments.

Melanin is a class of pigment responsible for producing color in the body in places such as the eyes, skin, and hair.

**Melasma** is a very common patchy brown, tan or blue-gray facial skin discoloration, usually seen in women in the reproductive years. The exact cause is unknown, but does seem to develop typically in the summer months. Melasma is associated with sun exposure, external hormones related to birth control pills, and internal hormones related to pregnancy (more so in Latin and Asian descent). Antiseizure medication and other medication can make the skin more prone to pigmentation after ultra violet (uv) light. The usual areas this appears can be the lip, upper cheeks, forehead, and chin for women in the age range of 20-50 years old. This occurs more in Olive or darker skin
people with Hispanic, Asian or Middle Eastern descent. Melasma is uncommon in men. According to Medicinenet.com Six Million women are living in the U.S. with melasma and 45-50 million women worldwide live with melasma; over 90% of all cases are women. Sunscreen aids in prevention through protection along with sun avoidance.

Three types of common facial patterns have been identified in melasma, they are:

- Centrofacial pattern- (center of the face) is the most prevalent form of melasma.
- Malar pattern- cheekbones and includes the upper cheeks.
- Mandibular pattern- jawbone only.

The types of pigmentation patterns which are diagnosed in melasma: are: epidermal, dermal, mixed, and an unnamed type found in dark-complexioned individuals.

- Epidermal type is identified by the presence of excess melanin in the superficial layers of the skin.
- Dermal melasma means the presence of melanophages (cells that ingest melanin) through the dermis.
- The mixed type has both Dermal and epidermal types.
- Excess melanocytes are present in dark-skinned individuals.

Melasma may clear spontaneously without treatment; sunscreen and sun avoidance may help in clearing up this problem.

Treatments include over the counter creams such as %2 hydroquinone (HQ) creams, Esoterica and Porcelana. Concentrations above 2% require Prescriptions; concentrations at 4% are creams that include Odagi clear, Glyquin, Tri-luma, and Solaquin. These creams lighten the
skin. Sunscreen should be applied over the creams. Bleach has also been used.

When these treatments do not work then lasers may be the treatment choice. This is not a primary choice because there may be little to no improvement. In fact it may temporarily worsen some types of melasma. Always treat laser treatment with caution. Multiple laser treatments may be required in most cases to be effective.

**Hyperpigmentation** is the darkening of an area of skin caused by increased melanin. It may be caused by sun damage (ultra violet rays), inflammation, or other skin injuries including acne vulgaris. Acne is caused when oil glands block pores and create pimples. This later leaves dark spots. Usage of chemicals on skin may cause hyperpigmentation. Hyperpigmentation is associated with a number of diseases or conditions, including:

- Addison’s disease and other sources of adrenal insufficiency in which hormones that stimulate melanin synthesis, (i.e., melanocyte-stimulating hormone MSH), are frequently elevated.
- Cushing’s disease or other excessive adrenocorticotropic hormone (ACTH) production disorders. This is because MSH production is a byproduct of ACTH synthesis from proopiomelanocortin (POMC).
- Acanthosis Nigicans-hyperpigmentation of intertriginous areas associated with insulin resistance.
- Melasma, also known as “Chloasma”-patchy hyperpigmentation often found in pregnant women.
- Linea Nigra – A hyperpigmentation line found on the abdomen during pregnancy.
• Peutz-Jeghers syndrome – an autosomal dominant disorder characterized by hyperpigmented macules on the lips and oral mucosa and gastrointestinal polyps.
• Certain chemicals such as salicylic acid, bleomycin and cisplatin.
• Smoker’s Melanosis.
• Celiac Disease
• Cronkite-Canada syndrome
• Porphyria
• Tinea fungal infections such as ringworm.
• Haemochromatosis – a common and debilitating genetic disorder characterized by the chronic accumulation of iron in the body.
• Powered jet injections.

Hyperpigmentation can sometimes be induced by dermatological laser procedures.

**Actinic Keratosis** (AK) Solar Keratosis is a 2-6 millimeter small rough spot occurring on the skin when chronically exposed to the sun. They are usually red in color with a rough texture with the appearance of a white or yellowish scale on the top. In addition to being rough, it may feel sore or painful when something rubs against it. Specialized forms may include cutaneous horns in which the skin protrudes in a thick, hornlike manner and actinic cheilitis, which refers to scaling and roughness of the lower lip and blurring of the boarder of the lip and adjacent skin. Common location include the cheeks, bridge of nose, scalp, back of neck, upper chest, as well as the tops of the hands and forarms. Men are more likely to develop AKs on the top of ears. Actinic Keratoses are precancerous (premalignant), and can develop in to skin cancer. This process can take years and few actually convert to cancer.
The Cancer is called squamous cell carcinoma, and it has a potential for metastasis, though this is rare and only occurs when the lesions are deeper into the tissues. These are usually diagnosed by doctors examining the AK, and a biopsy might be recommended.

Seborrheic keratosis is raised brown lesions that may appear on any area of the skin, and they can run in families.

Treatments are:

- **Cryosurgery:** freezing AKs with liquid nitrogen causes them to fall off.
- **Surgery:** cutting away or burning off AKs
- **5-Flurouracil (5-FU):** These are creams that cause AKs to become red and inflamed before they fall off. This process is uncomfortable and takes weeks, it is also unsightly. This process is not one that patients like to use.
- **Aldara (Imiquimod):** This topical cream treats super fluid basal cell carcinoma; this minor form of skin cancer caused by too much skin exposure and does not require surgery. It also treats actinic keratosis. When used for genital warts, it changes the way the body’s immune system responds to the virus. This allows for removal of both genital and perinatal warts.
- **Photodynamic Therapy (PDT):** This process involves applying dye (aminolevulinic acid [Levulan] or ALA) that sensitizes the skin to light. By leaving this dye on the skin for about an hour, and then exposing the skin to light, the dye becomes activated. This light can come from a laser, or other light sources. A low power diode laser works well for this application. This works the best for
patients with AKs. Patients do need to avoid the sun for several days after this process.

Patients with AKs should have them examined annually. This is to make sure new lesions have not formed or older ones have not become thicker and more suspicious looking.

**Squamous cell carcinoma** is a cancer that begins in the squamous cells. These are thin, flat cells that look like fish scales under the microscope. These cells are found in the tissue that forms the surface of the skin, the lining of hollow organs of the body and passages of the respiratory and digestive tracts. Squamous cell carcinomas could possibly arise from any of these tissues.

**Inflammatory Linear Verrucous Epidermal Nervus** (ILVEN) is an uncommon type of epidermal nevus. The use of laser therapy is a new method of treatment; a carbon dioxide laser is used. With this new treatment all symptoms (erythema, excoriation, granulation and pruritus) disappeared. In its place a pale pigmentation was reported.

**Spider Angioma** (also known as nevus araneus, spider nevus, vascular spider and spider telangiectasia) is a type of telangiectasia (a vascular lesion formed by dilatation of a group of small blood vessels which may appear as a birthmark) found slightly below the skin surface. The cause is due to failure of the sphincteric muscle surrounding a cutaneous arteriole. This often contains a central red spot and has redish extensions like a spider’s web. They present in about 10-15% of healthy children and healthy adults. A sign of liver disease may be more than five spider naevi that present on a patient.
Spider angiomas are found only in the distribution of the superior vena cava, and are usually on the face, neck, upper part of the trunk and arms. They have been found on the backs of the hands and fingers of young children. If spider angiomas are on the face they may be treated with electrodesiccation and laser treatments can be used to remove the lesion. There is a small risk of a scar or recurrence after treatment.

**Hemangioma of infancy** is a benign tumor composed of dilated blood vessels usually encapsulated within a fibrous shell. It is usually a self-involuting tumor, (swelling or growth) of the endothelial cells that line blood vessels and is characterized by increased number of normal or abnormal vessels filled with blood. It can also be called “cavernous hemangioma.” Hemangiomas usually appear in the first weeks of life and usually resolve by age 10. More severe cases have permanency, if not treated by a physician. Laser surgery is the most proactive way of removal in cases where patients are older than 10 years of age. It is the most common tumor in infancy. It can be found on the skin or in an internal organ such as liver or the larynx. In the larynx, breathing could become compromised. If around an eye, it could cause occlusion amblyopia.

A very rare situation involving extremely large hemangiomas, which can cause high-output heart failure due to the amount of blood that must be pumped to excess in blood vessels which creates an ineffective blood volume and pressure. High-output (HF) is characterized by an elevated resting cardiac index beyond the normal range of 2.5 to 4.0 L/min per m2.
Hemangiomas may be present in bone structures including vertabra. They are detected with CT or MRI scans. Lesions adjacent to bone can also erode the bone.

Hemangiomas could break down on the surface which is called ulceration. If the ulceration is deep, significant bleeding may occur in rare occasions. Ulcerations involved with a deeper area can be painful and problematic.

Another type of hemangioma is a strawberry hemangioma, which presents as a dull, red, benign lesion and appears usually on the face or neck and is demarcated from the surrounding skin. It can grow rapidly and then regress. This type is usually caused by proliferation of immature capillary vessels in active stroma (foundation-supporting tissues of an organ). If the removal is necessary, surgical excision using the carbon dioxide, argon, or potassium titanium oxide phosphate laser is effective in ablating this lesion.

Port-wine stains (capillary vascular malformation) are examples of permanent malformations including masses of abnormal swollen veins (venous malformations). It is a vascular anomaly consisting of superficial and deep dilated capillaries in the skin producing reddish to purplish discoloration of the skin. One of the most famous Port-wine stains is Mikhail Gorbachev’s who has a prominent port-wine stain (PWS) on his forehead.

The cause of hemangiomas is unknown although several studies suggest estrogen signals in hemangioma proliferation. There is also a hypothesis presented by Harvard and the University of Arkansas that maternal placenta embolizes to the fetal dermis during gestation resulting in hemangiomagenesis. More research is needed to prove
this theory. Lasers have made the biggest impact on treatment, because of the method of destroying the cutaneous capillaries without significant damage to the overlying skin.

The term “naevus flammeus” is divided into two categories: port-wine stain and salmon patch. PWS may be a sign and symptom of a syndrome such as:

Sturge-Weber syndrome (A congenital neurocutaneous syndrome) - Marked by a port-wine nevi along the distribution of the trigeminal nerve, angiomas of leptomeninges and choroid, intracranial calcifications, mental retardation, seizures and glaucoma.

Klippel-Trenaunay-Weber syndrome- is a rare condition that is present at birth. The syndrome usually involves PWS, excess growth of bones and soft tissue, and varicose veins. Blood vessels and/or lymph vessels fail to form properly.

**Laser Dentistry:**

A Dental laser is a type of laser specifically designed for the use in dentistry or oral surgery. In the 1990’s the Food and Drug Administration approved the use of lasers on the gums. By 1996 they
had allowed the use of lasers on the harder tissue including teeth and the bone of the mandible.

The lasers that are used in dentistry are the diode lasers, carbon dioxide lasers and Yttrium aluminium garnet lasers because of the different wavelengths that are needed. Diode lasers in the 810 – 900 nm range are absorbed by red colored tissues such as in gingivae. They are used for not only gingivectomy but for tissue contouring as well. The biggest barrier for laser dentistry is the cost, even with the reduced need for anesthetics and less bleeding following soft tissue procedures. Swelling may even be controled also helping with little if any discomfort postoperatively.

Other laser in dentistry are used for enhancing tooth bleaching, enhancing the effect of bleaching agents. While others to remove tooth structure for elimination of disease and restoration. All dental lasers require eye protection, and that includes family and guests in the dental operatory during the laser treatment.

Lasers that remove decay are fast and seldom require anesthesia. Major benefits associated with laser dentistry are:

- Procedures performed using soft tissue dental lasers may not require sutures.
- Bacterial infections are minimized because of the high energy light beam sterilizes the area being worked on.
- Damage to the surrounding tissue is minimized.
- Wounds heal faster and tissues can regenerated.
Applications for hard tissue (Tooth) laser procedures include a cavity detector. Low intensity soft tissue dental lasers may be used for early detection. By reading the by–products produced by the tooth decay.

Tooth preparation for dental filling, lasers can be used in some cases instead of the traditional turbine dental drill. These lasers also kill the bacteria located in the cavity potentially improving the long term tooth restoration. Lasers can also be used in some cases to seal tubules located at the root of the tooth that are responsible for hot and cold sensitivity.

Applications for soft tissue (Gum) laser dentistry procedures include crown lengthening. Dental lasers can reshape gum tissue and bone to expose healthier tooth structure for a stronger foundation for the placement of restorations. Reshaping the gum tissue to expose healthy tooth structure and improve the appearance of a gummy smile.

For children who are tongue tied (restricted or tight frenulum) and babies unable to breast feed due to limited tongue movement a laser frenectomy may be the correct choice.

Soft tissue folds called Epulis may also be removed, to correct ill - fitting dentures. Benign tumors can also be removed from the gums, palate, sides of cheeks and lips usually pain and blood free.

Photobiomodulation can be used to regenerate damaged nerves, blood vessels, and scars. Low intensity dental lasers can also reduce pain associated with cold sores and minimize healing time.
Laser assisted uvuloplasty or uvula palatoplasty (LAUP) procedure can be performed to reshape the throat and relieve the correlating breathing problems associated with sleep apnea in most cases.

Dental lasers are also used to quickly reduce pain and inflammation of the temporomandibular jaw joint.

Technology in lasers changes and expands every day. It is important to stay up to date with the ever changing safety needs of these lasers.

Highlights to remember about laser safety:

- Lasers can be dangerous!
- Every laser operator should have laser training and understand the risks of working with a high powered laser.
- Know the safety guidelines and stay up – to – date with all changes of those guidelines.
- Always exercise caution when using a laser.
- Never expose yourself or others to the beam.
- Make sure warning signs and glasses are placed at all entrances to the room (nominal hazard zone).
- Evaluate the dangers in the room the laser will be used, including reflective surfaces.
- Wear eye protection whenever the laser is in use.
- Always put the laser in standby when it is not.

Please remember to always be safe especially when it comes to eyes.
Please remember to open the PDF at the top of the testing page, you can use it like an open book test and use it to follow the information.

Please also remember to take a survey at completion of this course, it is located at the end of the course choices on the test page. This will help us improve and let us know what classes you would like in the future.

If you like this course or others that we offer, please let your friends, family and co-workers know about us. We would greatly appreciate the support.

Hope you enjoyed this course! Thank you again for supporting Cutting Edge
LASER TERMS

Ablation: Tissue removal by laser action.

Absorb: To transform radiant energy to a different form, with a resultant rise in temperature.

Absorption: Transformation of radiant energy to a different form of energy by the interaction of matter, depending on temperature and wavelength.

Accessible Emission Level: The magnitude of accessible laser (or collateral) radiation of a specific wavelength or emission duration at a particular point as measured by appropriate methods and devices. Also means radiation to which human access is possible in accordance with the definitions of the laser’s hazard classification.

Accessible Emission Limit (AEL): The maximum accessible emission level permitted within a particular class. In ANSI Z 136.1, AEL is determined as the product of accessible emission Maximum Permissible Exposure limit (MPE) and the area of the limiting aperture (7 mm for visible and near – infrared lasers).

Accessible laser radiation: Laser radiation to which it is possible for the human eye or skin to be exposed in normal usage.

Active Medium: Substance within the laser head that is energized to produce photons and laser energy.
Administrative control measure: Control measures incorporating administrative means, e.g., training, safety approvals, LSO designation, and P & Ps, to mitigate the potential hazards associated with laser use.

Aiming beam: This is a visible guide light that is used together with an infrared or other invisible laser wavelength. This is often a He Ne Laser.

Air – gas exchange: Injection of gas, or more typically mixed gas and air, into the posterior segment of the globe. Typical gases used are perfluoropropane or sulfur hexafluoride. The gases are mixed with air to neutralize their expansive properties to provide for longer acting retinal tamponade.

Air – purifying respirator: A respirator with an air – purifying filter, cartridge, or canister that removes specific air contaminants by passing ambient air through the air – purifying element.

Alignment: To confirm and set the laser beam to a specific target point prior to laser treatments. Both aiming beam and treating beam must be precise in the same location.

Anodized: A surface application to metal surgical instruments which inhibits light reflection. This surface is often called a matte surface.

ANSI: American National Standards Institute – voluntary group that is nationally recognizes as establishing laser standards.

Aperture: An opening through which radiation can pass.

Argon: A gas used as a laser medium. It emits blue – green light primarily at 448 and 515 nm.
Argon Laser: 480 – 521 visible intense light laser. This light is highly absorbed in pigment, hemoglobin and melanin.

Assigned Protection Factor (APF): the workplace level of respiratory protection that a respirator or class of respirators is expected to provide to employees when the employer implements a continuing, effective respiratory protection program.

Astrocytoma: Is a tumor of the brain or spinal cord composed of astrocytes.

Attenuation: The decrease in energy (or power) as a beam passes through an absorbing or scattering medium. This is the opposite of amplification.

Atmosphere - supplying respirator: A respirator that supplies the respirator user with breathing air from a source independent of the ambient atmosphere, and includes supplied – air respirators (SARs) and self – contained breathing apparatus (SCBA) units.

Average power: The total energy imparted during exposure divided by the exposure duration.

Aversion Response: Closure of the eyelid, eye movement, pupillary constriction, or movement of the head to avoid an exposure to a noxious stimulant or bright light stimulant. In this standard, the aversion response to an exposure from a bright, visible, laser source is assumed to limit the exposure of a specific retinal area to 0.25 s or less and it includes the blink reflex time.
Background diabetic retinopathy: is thought to be caused by chronic damage to small retinal blood vessels produced by the diabetic condition, thus leading to macular edema.

Beam: A collection of rays (waves) that may be parallel, convergent, or divergent.

Beam Diameter: The distance between diametrically opposed points in the cross section of circular beam where the intensity is reduced by a factor of $e^{-1}$ (0.368) of the peak level (for safety standards). The value is normally chosen at $e^{-2}$ (0.135) of the peak level for manufacturing specifications.

Beam Divergence: Angle of beam spread measured in radians or milliradians (1 milliradian = 3.4 minutes of arc or approximately 1 mil). For small angles where the cord is approximately equal to the arc, the beam divergence can be closely approximated by the ration of the cord length (beam diameter) divided by the distance (range) from the laser aperture.

Blink reflex: The blink reflex is lid closure associated with the involuntary upward movement of the eye, triggered by an external event such as an irritation of the cornea or conjunctiva, a bright flash, the rapid approach of an object, an auditory stimulus, or with facial movements. The ocular aversion response may include a blink reflex.

Brightness: The visual sensation of the luminous intensity of a light source. The brightness of a laser beam is most closely associated with the radiometric concept.
Canister or Cartridge: A container with a filter, sorbent, or catalyst, or combination of these items, which removes specific contaminants from the air passed through the container.

Carbon Dioxide: Molecule used as a laser medium. Emits far energy at 10,600 nm (10.6 μm).

Central Nervous System Lymphomas: A malignant neoplasm of the CNS.

Closed Installation: Any location where lasers are used which will be closed to unprotected personnel during laser operation.

Coagulation: Heating the tissue to a temperature below which vaporization effects occur, approximately 60 – 65°C, to stop bleeding. This is a process of clotting.

CO₂ Laser: A widely used laser in which the primary lasing medium is carbon dioxide gas. The output wavelength is 10.6 μm (10,600 nm) in the TIR infrared spectrum. It can be operated in either CW or pulsed. Highly absorbed by water.

Coherence: a term describing light as waves which are in phase in both time and space. Monochromaticity and low divergence are two properties of coherent light.

Collateral radiation: Any electromagnetic radiation, except laser radiation, emitted by a laser or laser system, which is physically necessary for its operation.

Collimated: All waves are parallel to each other.

Collimated beam: Effectively, a “Parallel” beam of light with very low divergence or convergence.
Collimate light: Light ray that are parallel. Collimated light is emitted by many lasers. Diverging light may be collimated by a lens or other device.

Collimation: Ability of the laser beam to not spread significantly (low divergence) with distance.

Computed tomography (CT): uses a sophisticated x-ray machine and a computer to create a detailed picture of the body’s tissues and structures. It is not as sensitive as an MRI in detecting small tumors, brain stem tumors and low – grade tumors. When contrast is used it makes it easier to see abnormal tissue and locate the tumor. In some cases it can help to determine its type.

Continuous Wave (CW): The output of a laser which is operated in a continuous rather than a pulsed mode. In this standard, a laser operating with a continuous output for a period ≥ 0.25 s is regarded as a CW laser.

Continuous Mode: The duration of laser exposure is controlled by the user (by foot or hand switch).

Continuous Wave (CW): Constant, steady – state delivery of laser power.

Controlled Area: Any locale where the activity of those within are subject to control and supervision for the purpose of laser radiation hazard protection.

Cooling system: System of circulating water or air to keep the laser head form overheating.
Corticosteroids (steroids): Are used to treat inflammatory illness. Side effects include high blood pressure, mood swings, increased risk of infection, stronger appetite, facial swelling and fluid retention.

Craniotomy: Is the incision through the cranium to gain access to the brain during neurosurgical procedures.

Delivery system: Method used to deliver the light energy from the laser to the target area.

Demand Respirator: An atmosphere – supplying respirator that admints breathing air to the facepiece only when a negative pressure is created inside the facepiece by inhalation.

Deputy laser safety officer (DLSO): The person authorized and responsible for managing the laser safety program, in the absence of an opaque obstacle.

Diabetic retinopathy: May damage sight by either a non-proliferative or proliferative retinopathy. The proliferative type is characterized by formation of new unhealthy, freely bleeding blood vessels within the eye (called vitreal hemorrhage) and / or causing thick fibrous scar tissue to grow on the retina detaching it. When bleeding or retinal detachment occur, vitrectomy is employed to clear the blood, membranectomy removes the scar tissue, and injection of gas or silicon with scleral buckle may be needed to return sight.

Diffraction: Deviation of part of a beam, determined by the wave nature of radiation and occurring when the radiation passes the edge of an opaque obstacle.
Diffuse reflection: Takes place when different parts of a beam incident on a surface are reflected over a wide range of angles in accordance with Lambert’s law. The intensity will fall off as the inverse of the square of the distance away from the surface and also obey a cosine law of reflection. Also change of the spatial distribution of a beam of radiation when it is reflected in many directions by a surface or by a medium.

Diode: A form of crystal laser often with a semiconductor. Diode laser produce several wavelengths between 375 – 1800 nm.

Divergence: The increase in the diameter of the laser beam with propagation distance from the exit aperture. This is sometimes referred to as beam spread.

Ebonized: An application of a coating, which produces a blackened appearance to decrease reflections of laser beams.

Embedded laser: A laser with an assignment of a hazard classification higher than the classification (capacity) of the laser system in which it is incorporated; the system’s lower classification is the result of engineering features which limit the accessible emission.

Emission: Act of giving off radiant energy by an atom or molecule.

Employee exposure: Exposure to a concentration of an airborne contaminates that would occur if the employee were not using respiratory protection.

Enclosed Laser Device: Any laser or laser system located within an enclosure which does not permit hazardous optical radiation emission from the enclosure. The laser inside is termed an “embedded laser.”
End – of – Service – Life Indicator (ESLI): A system that warns the respirator user of the approach of the end of adequate respirator protection, for example, that the sorbent is approaching saturation or is no longer effective.

Energy (Q): The capacity for doing work. Energy content is commonly used to characterize the output from pulsed lasers, and is generally expressed in joules (J). The product of power (watts) and duration in (seconds), One watt second = one joule. Total energy (joules) = watts x time.

Engineering control measure: Control measures designed or incorporated into the laser or laser system, e.g., interlocks, shutters, watch-dog timer circuits, etc., or its application.

Ependymoma: A tumor arising from fetal inclusion of ependymal elements.

European Laser Safety Standards: (EN) European safety regulations. This agency is similar to the US agency – ANSI. Require eyewear to be labeled with protection levels that detail their damage thresholds.

Excimer “Excited Dimer”: A gas mixture used as the active medium in a family of lasers emitting ultraviolet light.

Excitation: The addition of energy to a particle or system of particles to produce an excited state.

Excited state: An atom with an electron in its high – energy state.

Exposure time: The period of time that the treatment power is applied during a treatment exposure.
Extended source: A source of radiation, that can be resolved by the eye into a geometrical image. In contrast to a point source of radiation that cannot be resolved into a geometrical image.

External power source: A system outside the laser chamber which hyper excites the atoms.

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

Fiber: A system of flexible quartz glass fibers with internal reflective surfaces that pass wavelengths through thousands of reflections.

Fiberoptic: Fibers used for conducting light.

Filter or air purifying element: A component used in respirators to remove solid or liquid aerosols from the inspired air.

Filtering facepiece (dust mask): A negative pressure particulate respirator with a filter as an integral part of the facepiece or with the entire facepiece or with the entire facepiece composed of the filtering medium.

Fit factor: A quantitative estimates of the fit of a particular respirator to a specific individual and typically estimated the ratio of the concentration of a substance in ambient air to its concentration inside the respirator when worn.

Fit test: The use of a protocol to qualitatively or quantitatively evaluate the fit of a respirator on an individual.
Fire retardant: A material that does not support combustion without an external source of heat such as a laser.

Flashback: Reflections of a laser radiation back through a fiber optic endoscope. Often a protective filter is built into the endoscope to prevent this.

Fluid – air exchange: Injection of air into the eye to remove the intraocular fluid form the posterior segment of the globe while maintaining intraocular pressure to temporarily hold the retina in place or seal off holes in the retina.

Focal length: The distance from the secondary nodal point of a lens to the primary focal point. In a thin lens, the focal length is the distance between the lens and the focal point.

Focal point: The point toward which radiation converges or from which radiation diverges or appears to diverge.

Gas Discharge Laser: A laser containing a gaseous lasing medium in a glass tube in which a constant flow of gas replenishes the molecules depleted by the electricity or chemicals used for excitation.

Gas Laser: A type of laser in which the laser action takes place in a gas medium.

Half-power point: The value on either the leading or trailing edge of a laser pulse at which the poser is one-half of its maximum value.

Health care application: Use of a laser device on a patient (human or animal) by or under the supervision of a licensed practitioner, physician, dentist, veterinarian, within their scope of practice for diagnostic, preventative, aesthetic, or therapeutic purposes, where
bodily structure or function is altered or symptoms are relieved. These include prescription use of the medical laser device and over the counter indications of use.

Health care personnel (HCP): An individual directly involved in application and use of a laser for health care applications.

Helium – Neon (HeNe) laser: A laser in which the active medium is a mixture of helium and neon. Its wavelength is usually in the visible range. Used widely for alignment, recording, printing, and measuring.

Helmet: A rigid respiratory inlet covering that also provides head protection against impact and penetration.

Hertz (HZ): The unit which expresses the frequency of a periodic oscillation in cycles or pulses per second. 1 Hz=1 cycle per second.

High efficiency particulate air (HEPA) filter: a filter that is at least 99.9% efficient in removing monodispers paricles of 0.3 micrometers in diameter. The equivalent NIOSH 42 CFR 84 particulate filters are the N100, R100, and P100 filters.

Hood: a respirator inlet covering that completely covers the head and neck and may also cover portions of the shoulders and torso.

Hydrogen Chloride: (HCL) a gaseous compound which is a source of the excimer laser chlorine atom.

Immediately dangerous to life or health (IDLH): An atmosphere that poses an immediate threat to life, would cause irreversible adverse health effects, or would impair an individual’s ability to escape from a dangerous atmosphere.
Infrared radiation (IR): Invisible electromagnetic radiation with wavelengths which lie within the range of 700nm to 1mm (0.70 to 1000 µm). These wavelengths are often broken up into regions: IR - A (0.7 – 1.4 µm), IR – B (1.4 – 3.0 µm) and IR – C (3.0 – 1000 µm).

Installation: The procedure for supplying and connecting electrical power and other utilities to an HCLS.

Interlock: A device on the laser that turn off the laser and make it inoperable. Interlocks can be attached to entryways so that if the door is opened the unit will not operate.

Intrabeam viewing: The viewing condition whereby the eye is exposed to all or part of a direct laser beam or specular reflection.

Ionizing radiation: Electromagnetic radiation having a sufficiently large photon energy to directly ionize atomic or molecular systems with a single quantum event.

Irradiance (E): Radiant flux (radiant power) incident per unit area incident upon a given surface. The SI unit of irradiance is watts-per-square-meter (W·m⁻²), or for convenience, watt-per-square-centimeter (W·cm⁻²). Symbol: E.

Joule: a unit of energy. 1 joule = 1 watt· second.

KTP: Potassium Titanyl Phoshate – A crystal used to change the wavelength of the Nd:laser from 1060 nm (infrared 0) to 532 (green).

Label: for the purposes of this standard, a display of written, printed, or graphic matter upon the protective housing of a laser product. See; Medical device labeling.
Labeling: A term used in two senses in this standard. First, Medial device regulations, 21 CFR 801, use “Labeling” to indicate the intended and approved use of the HCLS. Second, a term used to describe the physical label attached to the HCLS equipment.

Laser: A laser is a cavity with mirrors at the ends, filled with material such as crystal, glass, liquid, gas or dye. A laser device produces an intense, coherent, directional beam of light by stimulating electronic or molecular transitions to lower energy levels. Lasers have a unique property of coherency, collimation, and monochromaticity. Laser is an acronym for Light Amplification by Stimulated Emission of Radiation.

Laser Accessories: The hardware and options available for lasers, such as secondary gases, Brewster windows, Q-switches and electronic shutters.

Laser Beam: The beam of light that is emanating from the laser chamber.

Laser Device: Either a laser or a laser system.

Laser energy: Laser energy is coherent, monochromatic and collimated, posing both skin and eye hazards, depending on the wavelength and power.

Laser generated airborne contaminants (LGAC): Airborne contaminants are generated when a laser beam interacts with target material. The materials may include, but are not limited to, plastics, metals, ceramics, glasses, wood, and tissue. LGAC may be in the form of gases, vapors, organic or inorganic particulates, or aerosols, and often are a complex mixture of substances in all three states. (Plume)
Laser Indirect Ophthalmoscope (LIO): An optional headset accessory that can be used as a laser delivery device for ophthalmic applications. Used with a hand held focusing lens (i.e., volk lens sizes 20 &28 are available.)

Laser Medium (Active Medium): Material used to emit the laser light and for which the laser is named.

Laser operator: A person who handles the laser equipment and is responsible for setting up the laser prior to use or who operates the console to control the laser parameters under supervision of the user. The operator may also be the laser user.

Laser protective eyewear (LPE): Equipment such as eyecups, face shields, goggles, eye shields, spectacles and visors, intended to protect the eyes from overexposure to laser radiation, LPE does not include laser protective windows.

Laser radiation: Coherent optical (non-ionizing) radiation emitted by a laser. This should not be confused with ionizing radiation.

Laser Rod: A solid – state, rod – shaped lasing medium in which ion excitation is caused by a source of intense light, such as a flash lamp. Various materials are used for the rod, the earliest of which was synthetic ruby crystal.

Laser safety officer (LSO): The LSO is the person (Physician, Nurse or Technician) authorized and responsible for the laser safety program. This individual has the training and experience to administer a laser safety program and has responsibility for oversight and control of laser hazards. The LSO is authorized by the administration and is responsible for monitoring and overseeing the control of laser hazards.
Laser safety site contact (LSSC): In diverse practice areas, such as large facilities or corporations, a LSSC serves under the supervision of the LSO, and is the person responsible for all aspects of laser safety in each site where lasers are used.


Laser treatment controlled area (LTCA): The room within the HCLS is used, and the occupancy and activity of those within this area are subject to supervision for the purpose of protection against all hazards associated with the use of the HCLS. In a large room, a limited LTCA can be designated if clearly marked and controlled.

Laser user: A person who controls the application of the laser radiation at the working area and is applying the laser energy of the HCLS for its intended purpose within their scope of practice, license, training and experience. The laser user is the same person as defined as “laser operator” in many manuals provided by manufactures.

Lens: A curved piece of optically transparent material which, depending on its shape, is used to either converge or diverge light.

Lensectomy: Removal of the lens in the eye when it is cloudy (cataract) or if it is attached to scar tissue.

Light: The range of electromagnetic radiation frequencies detected by the eye, or the wavelength range from about 400 to 760 nm. The term is sometimes used loosely to include radiation and radiation beyond visible limits.
Limited aperture: The maximum diameter of a circle over which radiance and radiant exposure can be averaged when determining safety hazards.

Limited exposure duration: An exposure duration which is specifically limited by the design or intended use(s).

Macular holes: The normal shrinking of the vitreous with aging can occasionally tear the central retina causing a macular hole with a blind spot blocking sight.

Macular pucker: Formation of a patch of unhealthy tissue in the central retina (the macula) distorting vision. Also called epiretinal membrane. After vitrectomy to remove the vitreous gel, membranectomy is undertaken to peel away the tissue.

Maintenance: Performance of those adjustments or procedures specified in user information provided by the manufacturer with the laser or laser system, which is to be performed by the user to ensure the intended performance of the product. It does not include operation or service as defined in this section.

Maximum permissible exposure (MPE): The level of laser radiation to which a person, under normal circumstances, may be exposed without hazardous effects or adverse biological changes in the eye or skin. The criteria for MPE for the eye and skin are presented in ANSI z136.1-2007, section 8.

Medical device labeling: A term defined in the FDA Medical Device Regulations, 21 CFR 801, which includes all of the information required to appear in the device labeling including the intended use. Labeling for example is a user’s manual, is required to supply adequate directions
for use, which is defined to mean directions under which the layman can use a device safely and for the purposes for which it is intended. Exemptions from adequate directions for use may apply under specific circumstances for prescription devices.

Medulloblastoma: A malignant tumor of the roof of the fourth ventricle and cerebellum. This tumor is the most common malignant brain tumor in childhood.

Membranectomy: Removal of layers of unhealthy tissue from the retina with minute instruments such as forceps (tiny grasping tools), picks (miniature hooks), and visco–discection (separating layers or tissue with jets of fluid.)

Meningomas: A slow growing tumor that originates in the meninges.

Micromanipulator: A device attached to a microscope head. It controls the direction of the laser beam as it passes thru the microscope.

Misaligned Optics: The aiming beam falls in one location and the treating beam falls in another location. Not desired, because beams must be coaxial or on the same path.

Mode: The laser beam shape at its focal point. Pattern if radiation i.e. continuous or pulsed light.

Monochromatic: Having the property of only one wavelength or color.

MRI Angiography: Evaluates blood flow and is limited to planning surgical removal of a tumor suspected of having large blood supply.

Neon: A rare inert gas occurring in the atmosphere. It is colorless but glows reddish – orange in an electrical discharge.

Nd:Yag Laser Neodymium: Yttrium Aluminum Garnet. A synthetic crystal used as a laser medium to produce 1064 nm light.

Neodymium (Nd): The rare earth element that is the active element in Nd:Yag laser and Nd:Glass lasers.

Nm or Namometer: 1 billionth of a meter (10 to the minus 9 power) and is wavelength measurements.

Nominal hazard zone (NHZ): The space (near the laser tissue impact) within which the level of the direct, reflected or scattered radiation during normal operation exceeds the applicable MPE. Exposure levels beyond the boundary of the NHZ are below the appropriate MPE level. This is also referred to as the nominal ocular hazard area (NOHA). Special skin and eye precautions must be done.

Nominal ocular hazard distance (NOHD): The distance along the axis of the unobstructed beam from the laser to the human eye beyond which the irradiance or radiant exposure during normal operation is not expected to exceed the appropriate MPE.

Non-beam hazard: A class of hazards that result from factors other than direct exposure to a laser beam.

Note: Additional information to expand or clarify the meaning of a normative section of the standard. Notes do not include the term “shall.”
Oligodendrogliaomas: A malignant tumor of unknown etiology that consists mostly of oligodendrocytes and occurs primarily in the cerebrum.

Operation: The performance of the laser or laser system over the full range of its intended functions (normal operation). It does not include maintenance service as defined in this section.

Optical Cavity (Resonator): Space between the laser mirrors where lasing action occurs.

Optical density \([D(2) \text{ or } OD]\): A Logarithmic Expression for the attenuation produced by an attenuating medium, such as an eye protection filter. A value that defines the attenuation property of a filter and is equal to the logarithm to the base ten of the reciprocal of the transmittance at a particular wavelength, i.e., \(D(2)=\log_{10}[\tau(2)]\), where \(\tau(2)\), is transmittance at wavelength 2.

Optical Fiber: A filament of quartz or other optical material capable of transmitting light along its length by multiple internal reflection and emitting it at the end.

Optical Pumping: The excitation of the lasing medium by the application of light rather than electrical discharge.

Output Power: The energy per second measured in watts emitted from the laser in the form of coherent light.

Patient: For purposes of this standard a patient is the recipient of the laser health care application.
Perioperative: The period of time that extends from the setup to the completion of a surgical procedure, including the setup, testing and use of the health care laser system.

Peritumoral Edema: Some tumors, particularly medulloblastomas interfere with the flow of cerebrospinal fluid and cause hydrocephalus which is accumulation of fluid in the skull. This accumulation of fluid then builds up in the ventricles (the cavities) in the brain. Symptoms of peritumoral edema include nausea and vomiting, severe headaches, lethargy, difficulty staying awake, seizures, visual impairment, irritability, and tiredness.

Personnel: Those persons who are engaged in laser use for health care applications.

Personal Protective Equipment (PPE): Personal safety protective devices used to mitigate hazards associated with laser use, e.g., laser eye protection (LEP), and biological hazards for infection control, e.g., protective gowns, clothing, masks and gloves.

Photocoagulation: Use of laser beam to heat tissue below vaporization with the objective to stop bleeding and coagulate tissue.

Photodynamic Therapy (PDT): This application is one that combines light and a photosensitizing drug product. The HCLS, lamp systems or led devices are used to activate the photosensitizing agent within the target tissue to achieve the desired outcome. Current FDA approvals exist for the treatment of lung and esophageal obstructive cancer, endobronchial cancer, Barrett’s esophagus, actinic keratosis, psoriasis and wet macular degeneration. Clinical applications being investigated include treatment of breast, bladder, head and neck, prostate, biliary
tract and skin cancers as well as moderate inflammatory acne vulgaris and various skin pathologies.

Photon: Energy in the form of light given off by excited atoms.

Pituitary adenomas: A benign tumor of the epithelial cells, of the gland.

Plasma radiation: Black-body radiation generated by luminescence of matter in a laser generated plume.

Plume: Gases, vapors and aerosol created by vaporization of tissue or other materials and may contain viable bacteria, viruses, cellular debris or noxious fumes.

Point source: For purposes of this standard, a source with angular substance at the cornea equal to or less than alpha-min ($\alpha_{\text{MIN}}$), i.e., $\leq 1.5$ mrad.

Policies and procedures (P&P’s): Written policies and procedures that list administrative and procedural control safety measures.

Power: The rate which energy is emitted, transferred, or received. Power is expressed in watts (W). $1 \text{W} = 1$ Joule per second.

Power Density: A term used to denote the inherent in the power per unit are (watts/cm$^2$) propagating laser beam for incident on a given target area.

Proliferative diabetic retinopathy: Involves the development of new blood vessels on the retina because of the metabolic changes produces by diabetes. The proliferation of blood vessels is thought to be caused by hypoxic retinal pigment cells that produce a neovascular growth
factor that stimulates vessel growth. These vessels lead to retinal and vitreal hemorrhage, retinal traction, and detachment.

Pulse-repetition frequency (PRF): The number of pulses occurring per second, expressed in hertz. Symbol: F

Procedural control measure: See administrative control measure.

Protective filter: A high density optical device used to attenuate the laser beam.

Protective housing: An enclosure that surrounds a laser or laser system that prevents access to laser radiation above the applicable MPE. The aperture through which the useful beam is emitted is not part of the protective housing. The protective housing may enclose associated optics and a work station and limits access to other associated radiant energy emissions and to electrical hazards associated with components and terminals.

Pulse: A discontinuous burst of laser, light or energy, as opposed to a continuous beam. A true pulse achieves higher peak powers than that attainable in a CW output.

Pulse duration: The duration of a laser pulse; usually measured as the time interval between the half-power points on the leading and trailing edges of the pulse.

Pulsed laser: A laser that delivers its energy in the form of a single pulse or a train of pulses. In this standard, the duration of a pulse < 0.25s.

Pump: To excite the lasing medium.

Pumped Medium: Energized laser medium.
Pumping: Addition of energy (thermal, electrical, or optical) into the atomic population of the laser medium, necessary to produce a state of population inversion.

Radian (rad): A unit of angular measure equal to the angle subtended at the center of a circle by an arc whose length is equal to the radius of the circle. 1 radian ≈ 57.3 degrees; 2π radians = 360 degrees.

Radiance: Radiant flux or power output per unit solid angle per unit area expressed in units of watts per steradian per meter squared (W · sr⁻¹ · m⁻²).

Radiant Energy (Q): Energy emitted, transferred, or received in the form of radiation expressed in units of joules (J).

Radiant exposure (H): Surface density of the radiant energy. The SI unit of radiant exposure is joules per meter squared (J·m⁻²), or for convenience, joules per centimeter squared (J·cm⁻²). Symbol: H the terms energy density and fluence are sometimes used as synonyms for radiant exposure, although these terms have slightly different technical meanings.

Radiant flux: Power emitted, transferred, or received in the form of radiation expressed in units of watts (W).

Radiant intensity (of a source in a given direction): Quotient of the radiant flux leaving a source and propagated in an element of solid angle containing the given direction, by the element of solid angle expressed in units of watts per steradian (W·sr⁻¹).

Radiant power: Power emitted, transferred or received in the form of radiation.
“Ready” Status: The laser is on and will deliver a laser beam when the footswitch is depressed.

Reflection: The return of radiant energy (incident light) by a surface, with no change in wavelength.

Refraction: The change of direction of propagation of any wave, such as an electromagnetic wave, when it passes from one medium to another in which the wave velocity is different. The bending of incident rays as they pass from one medium to another (e.g., air to glass)

Repeat interval setting: The laser is set to stop treatment during a pulsed setting. Example – Interval settings of 0.4 seconds, the laser will repeat a set of pulses stop for 0.4 seconds and then repeat another set.

Repeat pulse mode: The laser delivers a continuous train of pulses separated by the set repeat interval. The pulse train continues until the footswitch is released.

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

Resonator: The mirrors (or reflectors) making up the laser cavity including the laser rod or tube. The mirrors reflect light back and forth to build up amplification.

Retinal detachment: A blinding condition where the lining of the eye peels loose and floats freely within the interior of the eye.

Retinal hazards: Retinal damage can occur from 400 nm - 1400 nm.

Ruby: The first laser type; a crystal of sapphire (aluminum oxide) containing trace amount of chromium oxide.
Scanning laser: A laser having a time – varying direction, origin or pattern on propagation with respect to a stationary frame of reference.

Scattering: A process in which a light beam is distributed to many different paths after striking a surface.

Scleral buckling: Placement of a support positioned like a belt around the walls of the eyeball to maintain the retina in a proper, attached position.

Secured Enclosure: An enclosure to which casual access is impeded by an appropriate means (e.g., door secured by lock, magnetically or electrically operated latch, or by screws).

Semiconductor laser: A type of laser which produces its output from semiconductor materials such as GaAs.

Service: The performance of those procedures or adjustments described in the manufacturer’s service instructions which may affect any aspect of the performance of the laser or laser system. These are usually performed by qualified technical personnel provided by the manufacturer or other service companies. Is does not include maintenance or operation.

Shall: Shall is to be understood as mandatory.

Should: Should is to be understood as advisory.

Silicone oil injection: Filling of the eye with liquid silicone to hold the retina in place.
Single Photon Emission Tomography (SPECT): is similar to a PET scan, however is not as effective in distinguishing tumor cells from destroyed tissue after treatments.

Single pulse mode: Laser delivers one laser treatment pulse each time the laser pedal is pressed.

Specular reflection: A mirror-like reflection.

Spontaneous Emission: Release or discharge of a photon absorbed energy from a hyper excited atom, occurring without aid.

Spot size: The diameter of a focused beam at the point of treatment 1 micron = 10 – 6 meters.

Solid Angle: The ratio of the area on the surface of a sphere to the square of the radius of that sphere. It is expressed I steradians (sr).

Source: The perm source means either laser or laser – illuminated reflecting surface, i.e., source of light.

“Stand by” Status: The laser is temporarily turned off. No laser beam will be emitted if the footswitch is depressed. This is a safety feature of laser units.

Stimulated Emission: Release of electromagnetic energy when an electron inverts energy from a higher state to a lower energy state in which the activity has been increased by an external source.

Super Pulse: An operating mode on a laser describing a fast pulsing output with peak powers.

Thermal Effect: CO₂ is absorbed in water and minimizes conductivity of heat.
Transmission: Passage of radiation through a medium.

Transmittance: The ratio of total transmitted radiant power to total incident radiant power.

Tunable Laser: A laser system that can be “tuned” to emit laser light over a continuous range of wavelengths or frequencies.

Tunable Dye Laser: A laser whose active medium is a liquid dye, pumped by another laser or flash lamps, to produce various colors of light. The Color of light may be tuned by adjusting optical tuning elements and/or changing the dye used.

Ultraviolet (UV) radiation: Electromagnetic radiation with wavelengths shorter than those of visible radiation; for the purpose of this standard, 180 to 400 nm.

Vaporization: A conversion of a solid or liquid into a vapor.

Ventricles: Of the brain are hollow chambers filled with cerebrospinal fluid (CSF), which supports the tissues of the brain.

Visible Light Transmission (VLT): Amount of light able to pass thru the protective eyewear. This is expressed in percentages. The amount of light transmission can affect the wearers’ visibility of his / her surrounding environment. A low VLT % may require an increase in the ambient lighting in the room.

Visible radiation (light): Electromagnetic radiation which can be detected by the human eye. This term is commonly used to describe wavelengths which lie in the range 400 to 700 nm.
Vitreous floaters: Deposits of various size, shape and consistency, refractive index, and motility within the eye’s normally transparent vitreous humor which can obstruct vision. Here pars plana vitrectomy has been shown to relieve symptoms. Because of the possible side effects, it is used only in severe cases.

Vitreous hemorrhage: Bleeding in the eye from injuries, retinal tears, subarachnoidal bleedings (as Terson syndrome), or blocked blood vessels. Once blood is removed, Photocoagulation with a laser can shrink unhealthy blood vessels or seal retinal holes.

Watt: The unit of power of radiant flux is 1 watt = 1 joule per second.

Wavelength: The distance between two successive points on a periodic wave which have the same phase.

Xenon: A noble gas.

Yag: An acronym for Yttrium Aluminum Garnet, a widely used solid – state crystal composed of yttrium and aluminum oxides and a small amount of the rare earth neodymium.
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