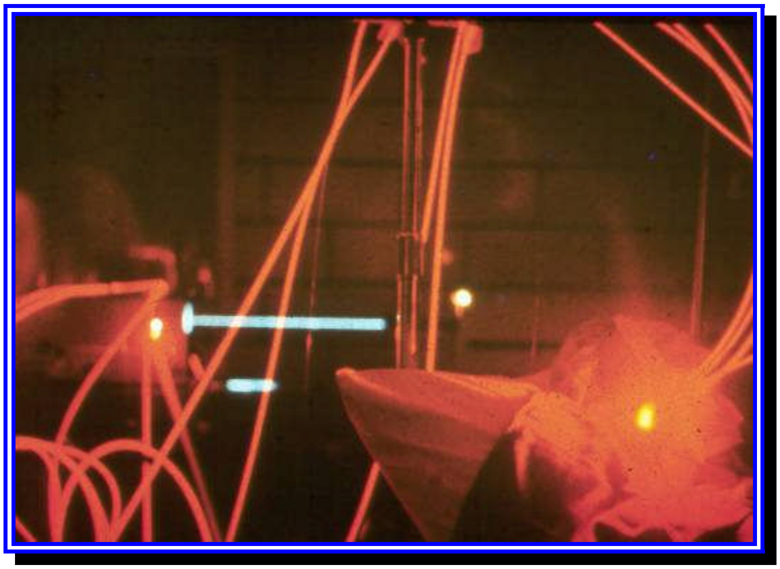
LASER MEDICINE and SURGERY

…Fundamentals for Operating Rooms, Clinics & Offices



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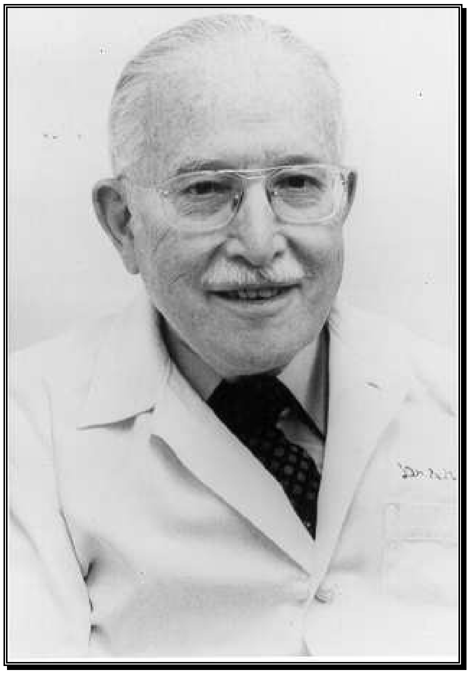
Dedicated to the Memory of Doctor Leon Goldman

1905-1997



Doctor Goldman was my Laser "Guru". He sponsored me as an ASLMS Fellow when he still practiced in Cincinnati, Ohio and I was affiliated with the University of Cincinnati – way back at the ASLMS 2nd meeting in Hilton Head.

Many great things can be said about Doctor Goldman. I'm not eloquent enough to do justice for him in this regard, and won't restate the many well deserved eulogies that have already been dedicated to him.

I do find it particularly appropriate to dedicate this manual on "Laser Biophysics and Safety" to Doctor Goldman. He was the original course director for this program of the ASLMS. It was the first formal course I ever took on the "Biomedical Laser" and his first or second time to ever teach it.

I am *extremely* honored to have followed in Doctor Goldman's footsteps as the Course Director for this ASLMS' program for a number of years.

It is his spirit that I will remember the most. He was really a child at heart, and he *loved* anything and everything about lasers and light. This showed through his enthusiasm for laser "art", and the ASLMS has sponsored several such exhibits at his prompting. He was truly excited about any new research in laser medicine, and stayed abreast of new developments in almost every specialty – better than anyone I've ever known who could keep up with such a diversity of information. He truly loved what he did. He is a significant factor that laser medicine is so far reaching today.

Christian scripture mentions "Children of Light". Doctor Goldman is truly one, and I wish him the best in his ongoing explorations and growth.

Gregory T. Absten -

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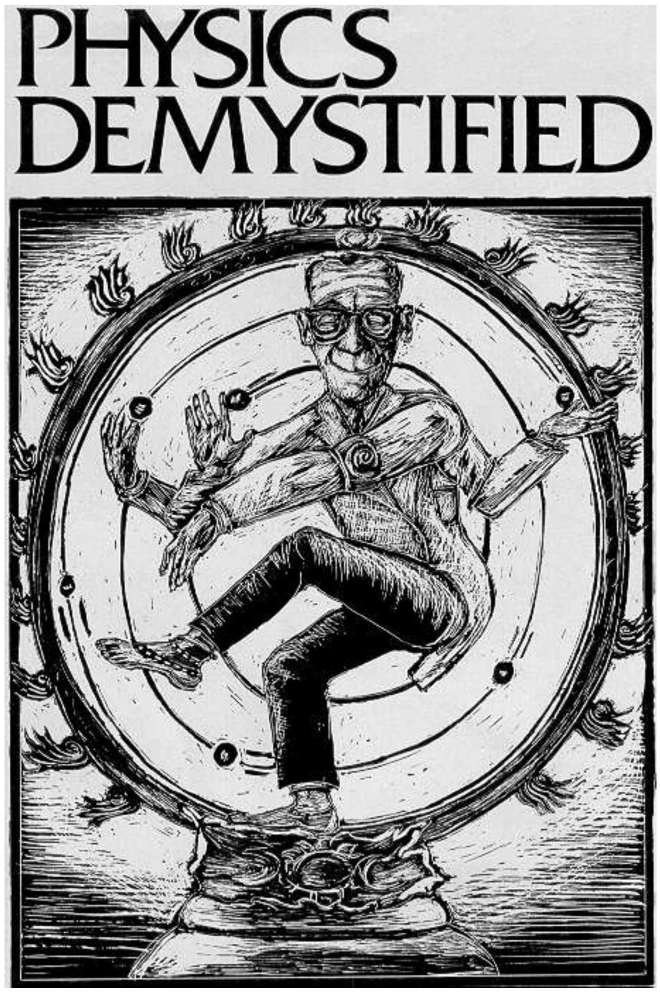
LASER BIOPHYSICS



Quantum Physics – the dreams that "stuff" is made from.
Where Science and Religion share common ground.

Gregory T. Absten B.Sc., MBA, CLRT
Contributions by Dan Little CBET, CLSO/M

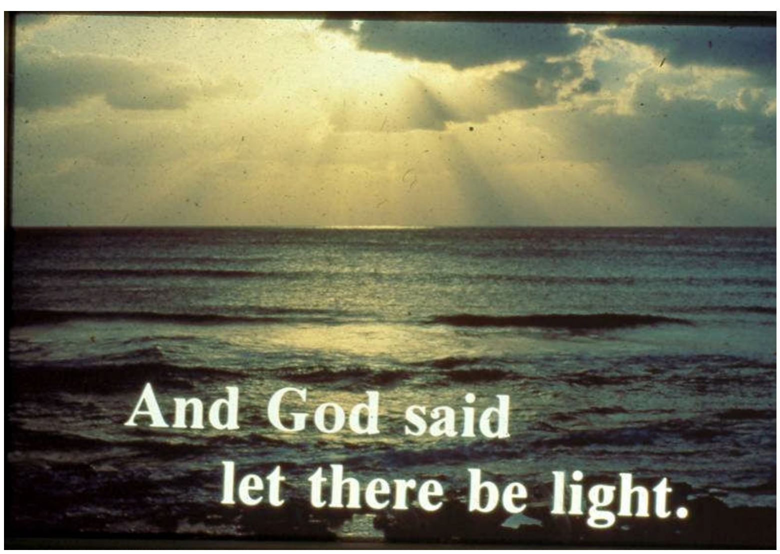
Revisions 1990, 1993, 1995, 1996, 1997, 1998, 1999, 2002, 2007, 2011, 2020

WHAT IS A LASER?

LASER is a device that converts some form of energy, usually electrical, into optical energy. LASERS generate intense beams of light. LASER is an acronym for:

L ight
A mplification by the
S timulated
E mission of
R adiation

LASER, therefore, is a process of amplification, not merely a device. LASER radiation in this context simply means light, any of several different colors. LASER radiation is not associated with the hazards of ionizing radiation such as X-ray.



… And there was light

Click on the Graphic to see a short Laser Light Show and Intro to Lasers in Medicine

PHYSICS OF LIGHT:

Although the actual physics of laser action are somewhat more involved than what we will discuss here, we can gain a great deal of insight by simplifying and generalizing these mechanisms.

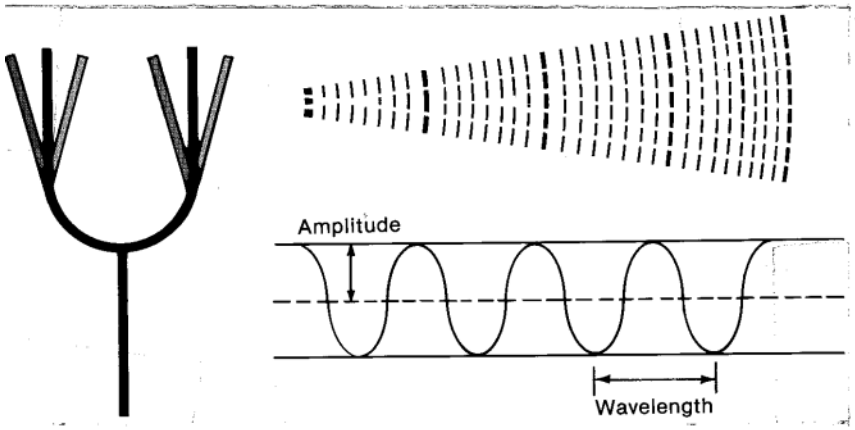
Physical matter can be thought of as light in its solid form. Light is locked up in matter and this is the source we use for either conventional For LASER light. The energy of matter can be tapped in an uncontrolled manner, such as a nuclear explosion, or its energy may be finessed out as does a LASER.

Different materials produce characteristic colors of light. Different types of LASERS are able to produce their own characteristic colors because of these materials.

Although the exact nature of light is still not understood, it does exhibit characteristics of both discrete particles, or photons, and waves. For purposes of understanding lasers we will primarily look at light in terms of its wave characteristics. A light wave may be compared to a sound wave for purposes of understanding these characteristics.

A wave is characterized by four quantities: (Figure 1)

1. Wavelength
2. Frequency
3. Velocity
4. Amplitude



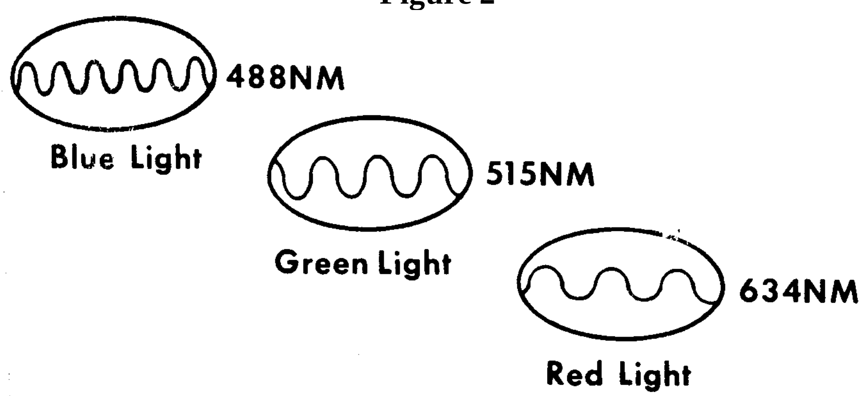
LIGHT WAVES HAVE BRIGHTNESS (AMPLITUDE) AND COLOR (WAVELENGTH) - much like a sound wave

Figure 1

The wavelength is the distance between two successive crests. Wavelength determines the color of light. The terms Color, Energy, and Wavelength all are synonymous. The shorter the wavelength the bluer the color and the more energy in the photon. (Figure 2)

LIGHT COMES IN PACKAGES CALLED PHOTONS

Figure 2



Another way to think of wavelength is as the vibrational energy or resonance of the photon. This perspective of vibrational energy is helpful in understanding why some laser wavelengths are not transmitted by standard fibers, which will be discussed later.

When we speak of wavelengths of light (λ) we usually work on the level of nanometers or microns (micrometers). Laser fibers are also usually measured in microns, such as 300, 400, 600 and 1000u (1mm) fibers.

The example here shows the 532nm λ of the KTP Laser

.532u	**1 Micron(u)** = 1/1000 mm = 1000 nm = 10000 Angstroms (A)
532nm	**1 Nanometer (nm)** = 1/1,000,000 mm = 1/1000 u = 10 A
5,320A	**1 Angstrom (A)** = 1/10,000,000 mm = 1/10000 u = 1/10 nm

Electromagnetic Wavelengths (otherwise known as light and electrical energy) cover a broad spectrum from long electrical waves to short cosmic rays. They are all light. Our eyes have been designed so that we can see only one note on this entire keyboard, visible light. Visible light ranges from about 385 nm in the violet to 760 nm in the deep red. (400-700nm in the textbooks)
(Figure 3)

ELECTROMAGNETIC WAVELENGTHS

ELECTROMAGNETIC RADIATION CONSISTS OF FREQUENCIES OF ENERGY SPANNING THE RANGE FROM ELECTRICITY AND RADIO WAVES, UP THROUGH HIGH ENERGY GAMMA AND COSMIC RAYS. LIGHT IS A PORTION OF THIS SPECTRUM.

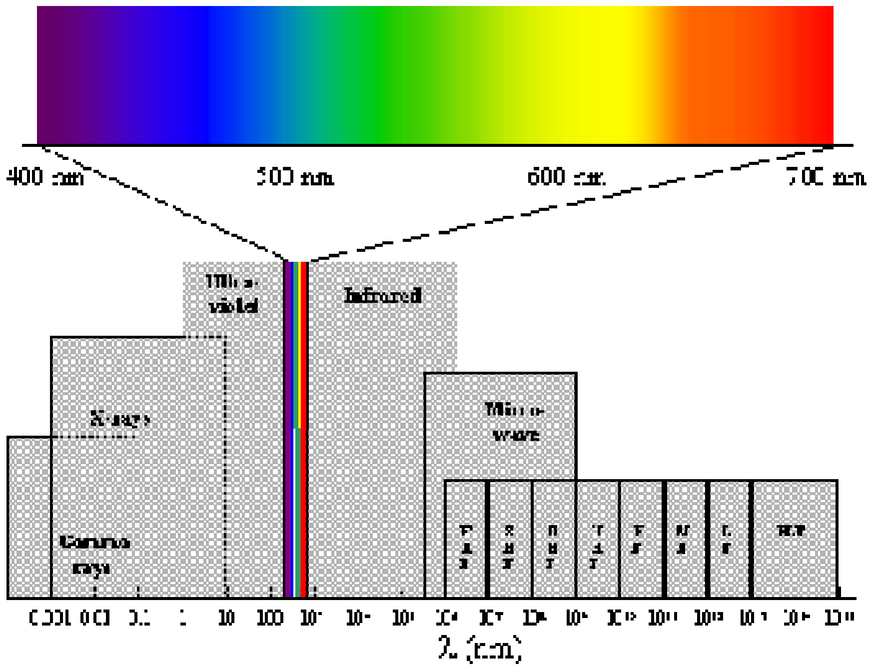


Figure 3

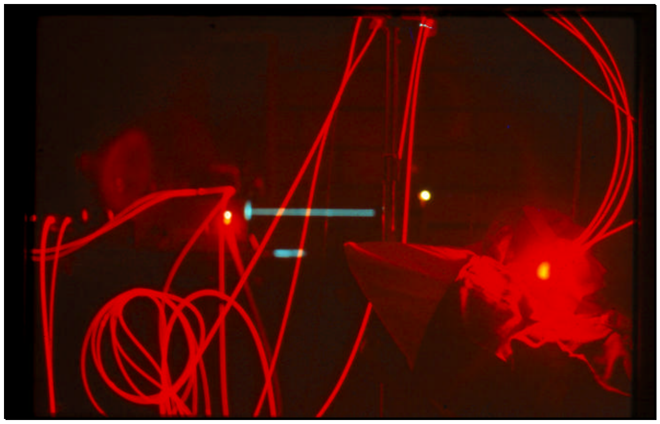
The frequency of a wave is the number of waves passing a given point per second and is usually expressed as cycles per second, or hertz. Because the velocity (speed) of light is constant[1] at just over 186,000 miles per second, frequency and wavelength are inversely proportional. The shorter the wavelength, at a constant speed, the higher will be the frequency. Another way to think of this is that the deeper red the light becomes the lower will be the frequency (vibrational energy) it generates. Shorter wavelengths contain more energy since they are of a higher frequency. This is evidenced by the fact that the shorter wavelength ultraviolet light causes sunburns. This does not imply however that one would use a shorter wavelength laser for more intense surgical effects, since those are determined by a combination of other parameters.

---

[1] The speed of light is a constant in any given material (air, glass, etc.) but is different from one material to another. When light enters glass (optics) from the air it experiences a change in its speed of propagation. The difference in the speed of light in a vacuum to the speed of light in a material is called the refractive index. This change of refractive index as the light enters a glass optic is what causes the light to bend, or refract, and is the basis of all optics. You can see this if you put a straight stick in water. By looking at it from different angles it appears that the stick bends as it enters the water. This is the change in refractive index.

The amplitude of the wave is shown as its vertical height. The higher the wave, the more power it contains. (Figure1).

How do LASERS generate light?



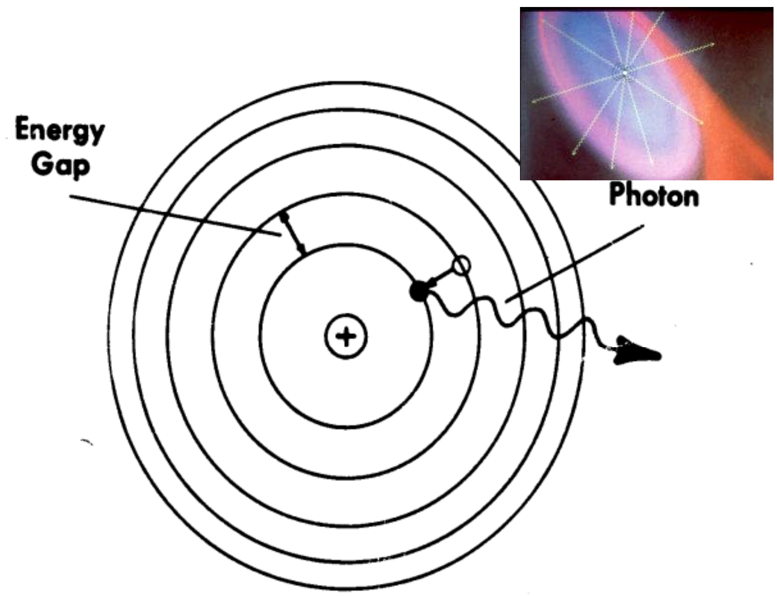
Argon Pumped Dye Laser for Photodynamic Therapy of Cancer
Courtesy of Jim McCaughan, MD

We have already seen that all matter contains light. A look at a simple atom will help illustrate the source of light. In the atom, electrons are found to occupy certain discrete orbital levels, or shells. The higher the energy level of the atom the further out will be the orbits of its electrons. These electrons are not free to occupy levels between discrete orbits, so that when the energy level of an atom is changed the electron must pop up or down to the next level. The atom absorbs energy to make this transition upward and emits energy when the transition is downward. [2]

Whenever the motion of an electron is changed, it will emit energy. (Figure 4) In the case of LASERS this emitted energy is in the form of light, usually in the infrared, visible, or ultraviolet regions. This is precisely how Argon and Nd:Yag lasers function since they consist of atoms rather than molecules. Later we will see how a molecular laser such as the Carbon Dioxide works.

---

[2] According to quantum mechanics, the atom interacts (absorbs or emits) light of a certain frequency. Frequency is related to wavelength and color), this frequency being determined by the equation n = TE/h, where h is Planck's constant, equal to 6.62 X 10^{-34} joule - seconds. In effect, this makes atoms and molecules electronic "instruments" that may be tuned to "play" certain colors of light on demand.



ELECTRONS OCCUPY CERTAIN ORBITAL LEVELS IN AN ATOM. WHEN AN ELECTON MAKES A TRANSITION TO A LOWER LEVER, ENERGY IS GIVEN OFF IN THE FORM OF A PHOTON.

Figure 4

The LASER medium is the substance used by the laser to produce light. The LASER is usually named after its active medium. The following is a partial list of LASERS and the respective colors they produce:

TABLE 1: SURGICAL LASERS

Carbon Dioxide	Far-infrared	10600 nm
The best laser for cervical / vulvar / vaginal use in colposcopy, best for microlaryngoscopy in ENT and for Neurosurgery. Used in super or ultrapulse mode for skin resurfacing. Best bulk vaporizing instrument for soft tissues. One of the mainstay lasers for veterinary general laser work.		
Erbium:Yag (Er:Yag)	Mid-infrared	2940 nm
Bone cutting and drilling - dental hard tissue - skin resurfacing . Finer effects than the CO2.		
Hydrogen:fluoride	Mid-infrared	2940 nm
investigational- bone cutting and drilling, investigational ophthalmology		
Yttrium-Scandium-Gallium Garnet YSGG	Mid-infrared	2790nm
Used for skin resurfacing – effects in between CO2 and Er:Yag lasers		
Holmium:Yag (Ho:Yag)	Mid-infrared	2100 nm
Primary use in orthopedic surgery, lithotripsy in URO, ophthalmology, dentistry		
Erbium:Glass (Er:Glass)	Mid-infrared	1540nm
Used in skin resurfacing treatments by a method known as fractional ablation		
Neodymium:Yap	Mid-infrared	1340nm
fiberoptically delivered for dentistry, ENT, Neuro, GYN, etc.		
Neodymium:Yag(harmonic) (Nd:Yag)	Mid-infrared	1318 nm
investigational tissue welding (fusion), skin rejuvenation		
Neodymium:Yag (Nd:Yag)	Near-infrared	1064 nm
General laparoscopic use with contact tips, hysteroscopy, flexible endoscopies, Q-switched types used in ophthalmology and dermatology. Pulsed Nd:Yags used for laser hair removal. CW Nd:Yags used with contact tips in veterinary medicine.		
Diode lasers	Variable with system	<530-1600>nm
Low power versions used for “photomodulation”(LLLT) and PDT, higher powered units used in dermatology for laser hair removal and general endoscopic use in urology, and endovascular laser therapy (evlt). Lower powered units also used for skin rejuvenation. A common unit for laser hair removal is at 810nm		
ALEXANDRITE LASER	Deep Red	755nm
Used in dermatology, primarily for hair removal.		
Ruby	Deep Red	694 nm
This was the original laser in 1960. Now used in dermatology in both Q-switched and long-pulsed modes for tattoo removal and hair removal		
Krypton - ion laser	Red	647 nm
	Yellow	568 nm
	Green	531 nm
Primarily used by retinal specialists in Ophthalmology. May also be used in dermatology but this has largely been supplanted by newer aesthetic lasers.		
Helium Neon **(HeNe)**	Red	632 nm
Used as the guide light in most infrared surgical lasers, and is also used in biostimulation (LLLT). Very low power in the milliwatts. (laser pointer) Note that many laser pointers are red diodes instead of HeNe’s.		
Tunable Dye Laser	variable with dyes:	
	Red	632 nm
	(For Photodynamic Therapy)	
	Yellow	585-595 nm
	Green	504 nm

The continuous wave lasers are used for PDT (red) and retinal specialists in ophthalmology (multicolored). Pulsed dye lasers are used in dermatology for vascular lesions (yellow) and dermatology and general surgery for lithotripsy.

<u>Copper Bromide Laser (CuBr)</u>	Yellow	577 nm
	Green	510 nm

Used in dermatology for fine capillary lesions and pigmented lesions. Much slower than the pulsed dye, but much more precise with the ability to trace individual capillaries (Yellow). Green used for pigmented lesions. Also used for skin rejuvenation and Acne treatments.

<u>KTP</u>	green	532 nm

This is a frequency doubled Nd:Yag laser, and some machines may allow both the green and Nd:Yag infrared outputs. Used in general laparoscopy, ENT, dermatology and is used to pump the Dye laser for PDT.

<u>Argon</u>	blue	488 nm
	green	515 nm

Used primarily in general ophthalmology (PRP), also used to pump the Dye laser for PDT.

<u>EXCIMERS</u>: Ultraviolet

Used in Ophthalmology for corneal reshaping, cardiovascular for laser angioplasty, to treat psoriasis in dermatology and investigationally in dentistry. These are (fast) pulsed lasers.

ArF	(corneal reshaping)	193 nm
KrCl		222 nm
KrF		248 nm
XeCl	(dermatology & cardiovascular)	308 nm
XeF		351 nm

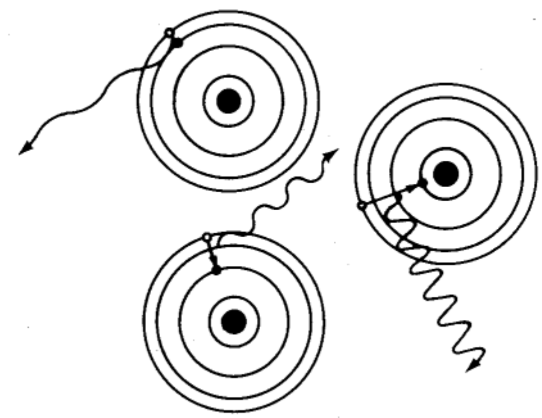
The number of companies manufacturing or selling medical laser equipment is just too prolific to list in this one manual, and would soon be out of date anyway. Go to our website at http://www.LaserTraining.org ,and then choose the “Resources & Free Material” menu button at the top of the page, then “Laser Links” to go to listings of almost all medical laser manufacturers.

One of the first requirements for a medium to possess lasing action is to have more atoms (or molecules) in the high energy state than in the resting level state. This situation is referred to as POPULATION INVERSION of the medium.

Spontaneous versus Stimulated Emission

Ordinarily an electron's orbit will spontaneously decay from its high energy state back to its resting base state. This process causes a photon to be spontaneously emitted. When many atoms in a medium undergo spontaneous orbital decay, the emission of photons is out of phase with one another. This process is entirely random, emits lights of many different colors (which combine to form white light) and shines in many directions. A popcorn popper effect is created, throwing kernels of light out in all directions in an uncontrolled fashion. This is incoherent light, the type of light to which we are all accustomed from the sun, light bulbs and fire. (Figure 5)

A photon can serve as the source of energy to pump up the atom to a higher energy level.



SPONTANEOUS EMISSION IS A RANDOM PROCESS, WHICH PRODUCES INCOHERENT LIGHT

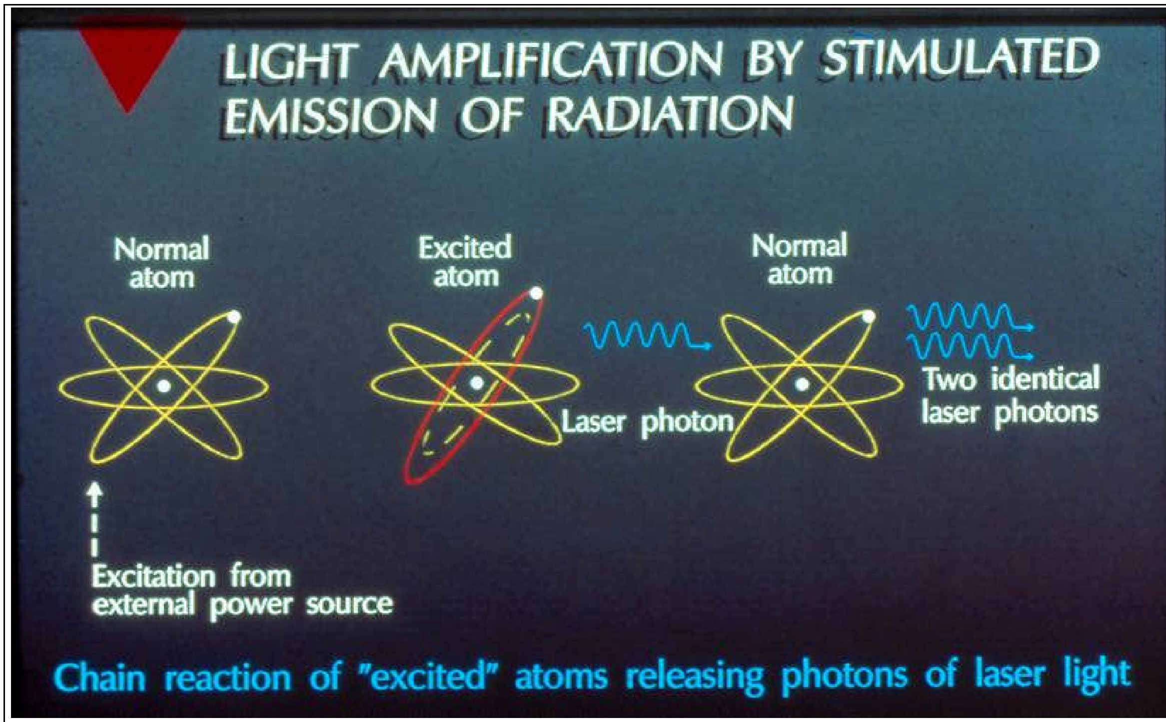
Figure 5

Optical excitation this way is done in the Nd:Yag laser with Flashlamps (and other solid state lasers such as Ruby, Alexandrite, Ho:Yag and KTP). Excitement of the atom will not occur if the color of the photon (energy) does not match the energy difference in the orbital levels.

In the same manner, an electron in an excited state can be "stimulated" by another photon of precisely the correct color to undergo orbital decay and emit an identical photon that was stored in this energy gap. The atom must be stimulated before it emits its stored light.

This process may be visualized as the vibrational energy of the stimulating photon vibrating in resonance with the affected energy band and resulting in destabilization of the electron from its excited state. Various "pump energy" sources are used to accomplish this. In CO2 lasers, a high voltage power supply passes High Voltage, direct current, through the laser tube. Some CO_2 lasers utilize an "RF" power supply to generate the Radio Frequency electricity which excites the gas. Dye lasers sometimes use a very bright flashlamp as an energy source, or alternately may use the beam from another laser (i.e.: argon pumped dye laser).

"Stimulated Emission" has occurred, in effect, by the stimulating photon knocking out from the atom an identical photon stored in its elevated energy bands. The end result of Stimulated Emission is that multiple photons of precisely the same color, whose wave patterns are perfectly in phase, stream out of the material as a special kind of coherent light. (Figure 6)



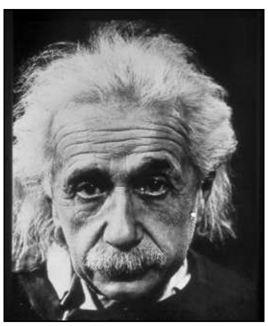
STIMULATED EMISSION IS A VERY ORGANIZED PROCESS WHICH PRODUCES A COHERENT WAVE PATTERN OF LIGHT - THE BEGINNING OF A LASER

Figure 6

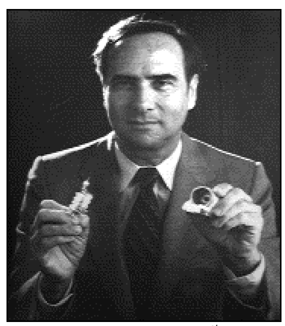
HISTORY: HOW IT ALL GOT STARTED . . .

This process of stimulated emission was originally described by ***Albert Einstein*** in the early 1900's as the mechanism whereby photovoltaic materials produced electrical current from light. It was not until the 1950's that ***Arthur Schawlow*** and ***Charles Townes*** wrote a paper on optical emission based on Einstein's theories[3]. ***Theodore Maiman*** created the first laser in 1960 from a small ruby rod. ***Leon Goldman M.D.*** should be considered the father of Lasers in Medicine for his pioneering work in bringing laser technology to medicine and acting as an early catalyst to promote development of medical laser applications. It should be pointed out as well that at the time Schawlow and Townes were developing their theory for "Optical Masers", that two Russian scientists were independently pursuing the same theory and published their results in parallel at about the same time.

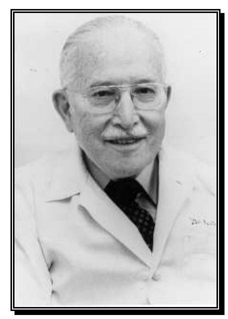
Gordon Gould actually takes credit for inventing the word Laser. As a student of Townes he proposed and drew up plans for such a device long before Maiman, but procrastinated on his patent application. Years later he went back and gained legal rights to the patent on the Laser. Ted Maiman has the patent on the Ruby Laser.



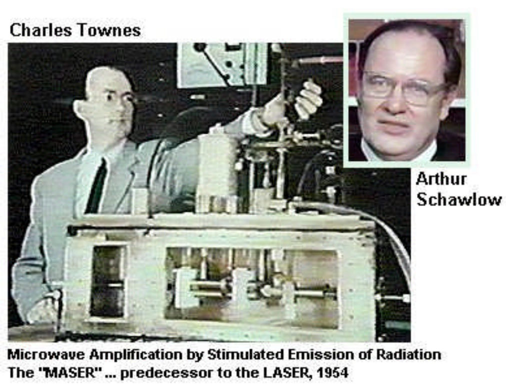
Albert Einstein



Theodore Maiman holding 1st Ruby Laser



Leon Goldman MD



[3] MASERS, or Microwave amplifiers, were developed in 1954 by Schawlow & Townes for the output of coherent microwave radiation. The paper that they subsequently wrote was a theoretical one to see if this process could be extended into visible light wavelengths, or "Optical Masers" as the Laser was first called.

LASER LIGHT IS UNIQUE

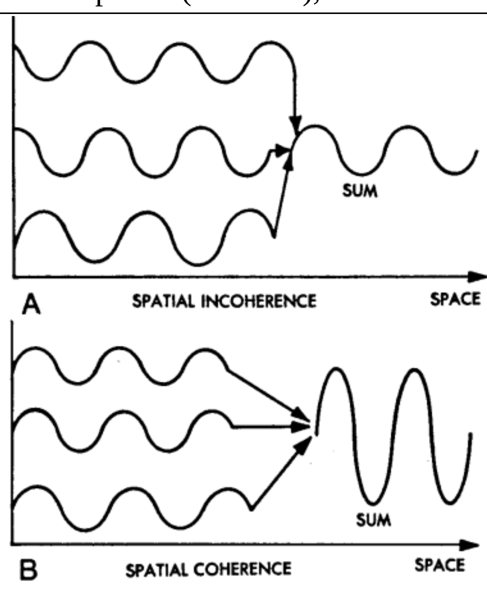
The process of Stimulated Emission gives rise to three properties of laser light that is unique from ordinary light. Not all of these parameters are utilized to create surgical effects. For the most part surgical laser systems are utilized only on a crude level (in terms of physics) for their heat producing effects, even though the resulting surgical effects may be exceptionally precise. Tapping these unique characteristics of laser will give rise to a myriad of diagnostic and therapeutic applications.

Laser light is unique in that it is:

1. **Coherent** (wave patterns are Locked in phase)
2. **Collimated** (stays together as A tight beam of light)
3. **Monochromatic** (produces Pure colors of light)

Coherence describes the phasing of the wave patterns of light. Coherent waves are analogous to the surf riding into the beach in powerful, orderly rows. The chop produced on the surface of a lake by a menagerie of water-skiers is incoherent. If you could hear incoherent light it would sound like the noise of pots and pans falling from a high cupboard onto the floor.

When all the waves are in phase (coherent), the effect is amplification and orderliness.

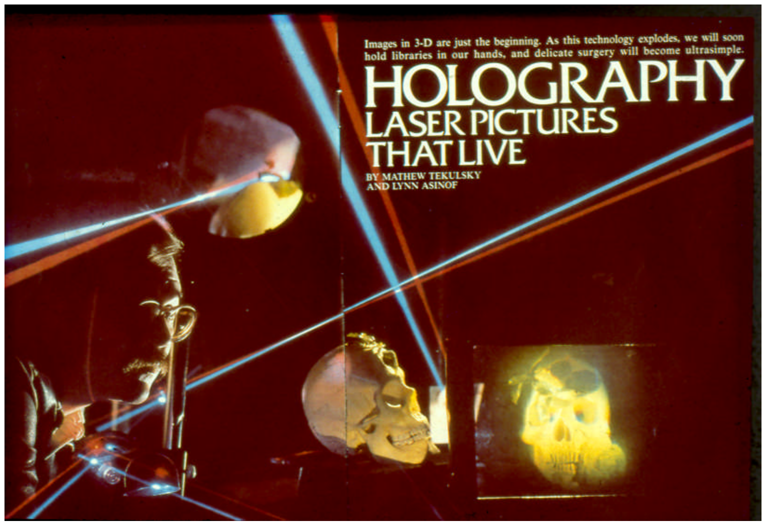


COHERENCE DESCRIBES THE PHASING OF PEAKS AND TROUGHS OF THE LIGHT WAVES. ORDERLY WAVES ARE CREATED WHICH INCREASES THE BRIGHTNESS OF THE LIGHT AND PROVIDES MATHEMATICAL ORDER TO THE PATTERN.

Figure 7

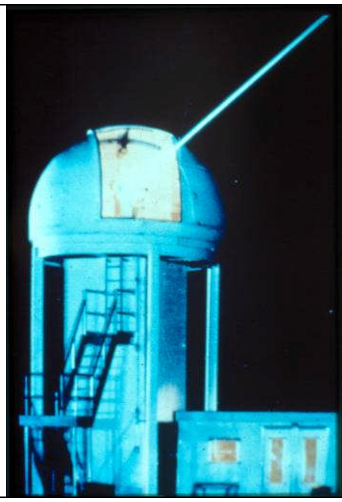
This is the beginning of the light amplification process. (Figure 7)

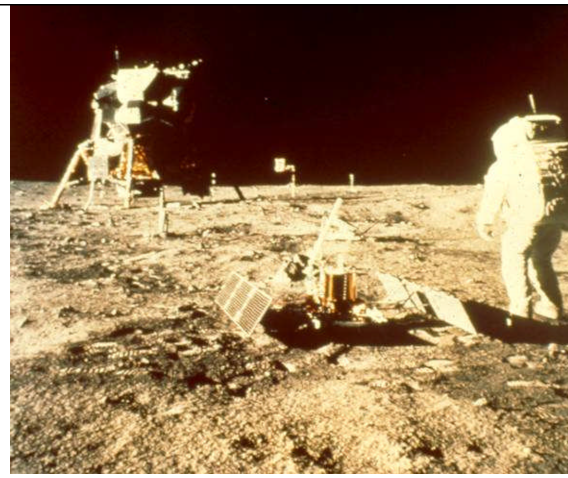
Another interesting phenomenon produced by the combination of the light's coherence and identical wavelengths is holography. Three dimensional images may be produced by taking a picture of an object in a special way with a laser.



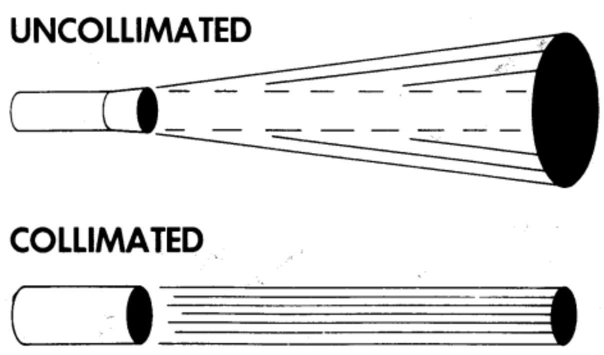
Holograms are fascinating in both their theory and actual mechanisms. They are reproductions of three dimensional figures that contain information as small as the wavelength of light used to make the picture. In other words, you can look at a hologram through a microscope and see the actual microscopic structure! If a hologram is broken into a thousand pieces, each individual piece will contain the whole picture! - it will simply be "fuzzier" the more pieces it is broken into. Endoscopic holographic pathology is a technique that has been explored. A very small catheter with a capsule at the end is inserted into the patient. A fiber inside the catheter allows a holographic "snapshot" on a small piece of microfilm within the capsule. When it is retrieved and developed, the pathologist may read the hologram microscopically, in three dimensions. Laser interferometry uses holographic principles to make precise measurements of target geometry. This is commercially useful now and will eventually see several applications in medicine.

Collimation means that the laser creates a light beam that stays together tightly over long distances. (Figure 8) This is partly due to the photons being merged in time and space, and partly due to the fact that the resonator is configured as a long slender tube (we'll see more about that later). The low divergence angle of a laser beam is illustrated by the laser moon ranging that was started with the Apollo program. NASA placed reflectors on the surface of the moon to fire lasers into and time the return trip of the light. This measures the earth-moon distance to the inch. A high power Nd:Glass laser fires into the moon and by the time this rod of light arrives at the surface its spot is about two miles in diameter. Considering the 240,000 mile distance to the moon, this divergence is insignificant.





The beam does spread somewhat however, and the rate at which it spreads as an angle is called the **divergence**. This angle is measured in radians and is very small for lasers compared with other light sources.



LASER BEAMS ARE COLLIMATED AND DO NOT APPRECIABLY DIVERGE WITH DISTANCE.

Figure 8

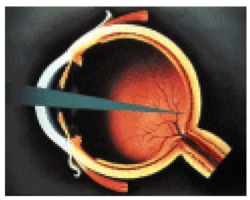
For reference purposes, a **radian** is an angular measurement. It is the ratio of the arc length described on the circumference of a circle by an angle, divided by the radius of the circle. Typical laser divergence is from 0.5 to 10 milliradians. A divergence of 1 milliradian is typical for a laser. At 1 milliradian the spot would increase 1 foot in diameter for every 1000 feet distance.

Divergence will importantly relate to the intensity of light as it reaches a surface. Light from any point source will spread to cover larger areas as the distance increases from the light source. The area covered by the beam spot will increase as the square of the distance from the source. If the distance is doubled, then the surface area covered increases four times. This is the **Inverse Square Law of Light.**

For surgical purposes, collimation and low divergence are important for both power retention and generating small spot sizes. Collimation allows the power to be retained wholly within the beam and does not fade with distance as with conventional light sources. The low divergence also allows the beam to be focused to very small spots, increasing the intensity and producing cutting, vaporizing and coagulating effects, or allowing the laser energy to be delivered through tiny fibers. Such a collimated beam with photons traveling in parallel acts as a "point source" of light and allows optics to focus to a very small "diffraction limited" spot size if configured correctly.

Monochromaticity means that the laser produces pure colors of light. Contrary to popular conception this does not necessarily mean that only one color is produced. An argon laser for instance will generate about 10 different wavelengths of light from blue to green. Lasers like this can produce multiple colors in a narrow band, each being a pure color by itself. If needed, just the desired color may be tuned from the laser. Ordinary light sources produce white light that consists of all colors with no definite separation and with broad bandwidths - like a rainbow from sunlight shining through a prism.

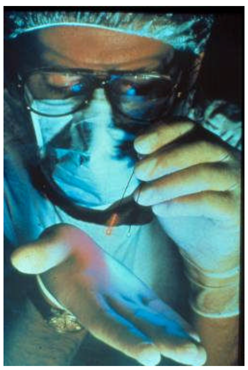
Lasers may be tuned to emit only one of the pure colors. Usually surgical lasers are used for their thermal effects and color is only grossly important because it determines how well the energy of the light is coupled as heat into the tissue. This determines the gross effect such as vaporization versus coagulation. The range of color is important. Blue-green is vastly different than infrared, but absolute spectral purity is usually superfluous when using the laser to cut or vaporize tissue. Pure color is much more important in physics and chemistry research.



<u>Ophthalmology</u> is one area in which fine tuning the color can be important. Macular work, and positioning laser damage at various levels of the retina, involves fine tuning from blues to greens to yellows and reds in order to spare sensitive portions of the retina.

<u>Dermatology</u> is another area where color specificity for aesthetics is becoming more important in the treatment of portwine stains, and other vascular lesions. The yellow light from dye and copper bromide lasers is much more selective, and sparing to skin, than previously used blue-green argon lasers. Wavelength range also becomes important in laser hair removal, in considering both skin and hair color and trying to prevent damage to dark skin. Longer wavelengths aren't as effective but are safer for dark skin.

Another medical area where the spectral purity of the light is critical is the area of Photodynamic Therapy. It is currently approved for treatment of esophageal and pulmonary tumors, and has widespread applications besides these. One of the largest and most diverse clinical series is by the Laser Medical Research Foundation in Columbus Ohio by Dr. James McCaughan, now retired. They have been clinically performing PDT since 1982 in a wide range of applications. In PDT a type of DiHematoporphyrin Ether (Photofrin by Sanofi currently) is administered systemically. In about 72 hours significant differences in residual drug levels exist between normal and malignant cells. By itself the drug is latent until activated by specific colors of light that the laser provides. This type of laser light produces no thermal effects and is used solely to initiate phototoxic processes in the cell via a photochemical reaction with the drug. The red wavelength is used because it penetrates farthest in tissue rather than because it has the best absorption peak for the Photfrin.



This technique was developed by Thomas Dougherty, Ph.D., and his group at Roswell Park in Buffalo New York. Porfimer sodium (Photofrin) is the primary drug now used for this work, but other drugs are coming. Other photosensitizing drugs and light sources are being examined for the work which has application in diagnosis and treatment of cancer, atherosclerosis, viral infections such as HPV and some dermatological conditions. This is an area of clinical photochemistry which utilizes the monochromaticity of the laser and has tremendous potential.

More recently PDT is seeing use in dermatological aesthetic applications such as skin rejuvenation, ACNE treatment and treatment of actinic keratosis.

Of anecdotal interest, this is Dr Dougherty's original Argon Laser used in the development of PDT in the late 70's and early 80's. It's now held by our technical director, Dan Little of Buffalo NY.

HOW DOES A LASER WORK?[4]

Any laser consists of four primary components:

1. Active Medium (what makes the laser)
2. Excitation Mechanism (Power supply)
3. Feedback Mechanism (Laser power mirrors)
4. Output Coupler (The front, partially transmissive mirror)

Active mediums (listed in Table I) may be either solid (crystal rods), liquid, gas or electronic. Examples of these materials include:

1. Solid:	Nd:Yag Ho:Yag Er:Yag Er:Glass YSGG Ruby Alexandrite
2. Gas:	Carbon Dioxide Argon / Krypton Excimers (Excited Dimers – various types) Helium Neon Copper Bromide (a salt that volatilizes into a gas)
3. Liquid:	Dyes (various kinds)
4. Electronic:	Semiconductors - Diode Lasers

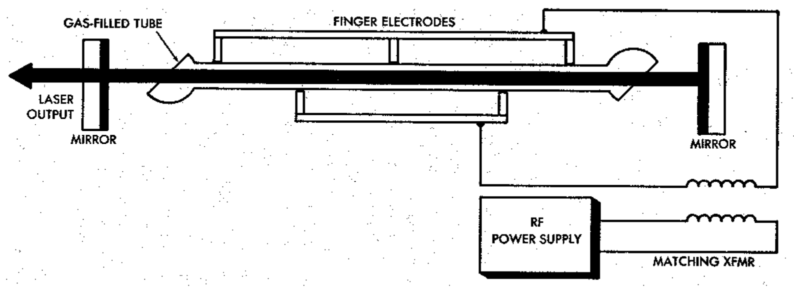
An excitation mechanism (energy source) is now needed to "pump" the active medium to achieve population inversion. Different mediums may be pumped differently.

[4] The material included here is not intended to be technical, but just generally informative. Our Laser Training Institute™ division does provide **Laser Repair training** for biomedical and other engineers, and information is available on the website at http://www.LaserTraining.org.

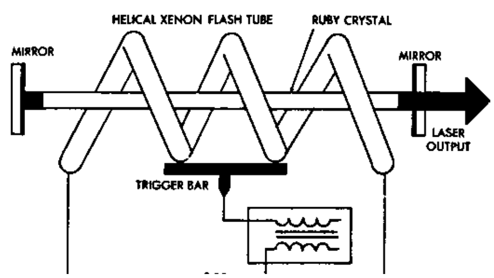
Surgical lasers use three primary methods to energize the active medium:

1. Direct Current (DC):
Most Gas Lasers including Carbon Dioxide and ion lasers

2. Radio Frequency (RF):
Carbon Dioxide (and some ion lasers outside medicine)



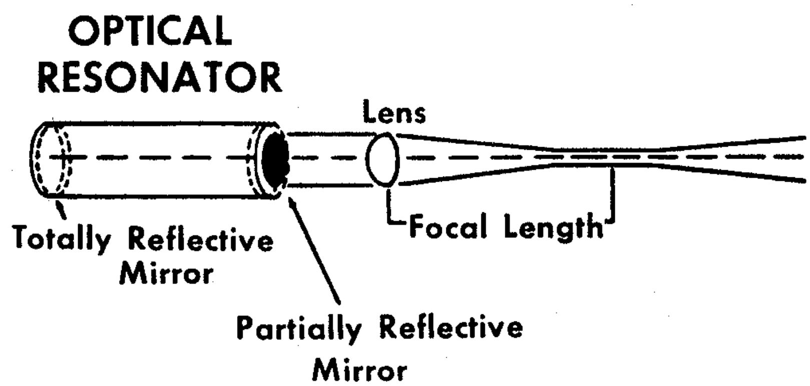
3. Optical:
Nd:Yag, Nd:Yap, Alexandrite, YSGG, Er:Glass,Ruby, Ho:Yag, Er:Yag, KTP (flash lamps): Dye Lasers (flash lamps or other lasers)



Most gas lasers such as CO2, Argon, Krypton and Helium Neon are excited by direct electrical current passing through the laser tube. Liquid and Solid state lasers such as the dye, KTP, or Ho:Yag are not electrical conductors so they must be pumped by another light source such as a flashlamp or another laser.

The feedback mechanism - the OPTICAL RESONATOR - is the key to amplifying the light produced from stimulated emission. This is the laser tube, or a chamber that allows reflection of the light waves back and forth at 186,000 miles per second between the two ends. This resonance builds in intensity and the light begins flowing out one end through a partially transmissive front mirror. Mirrors are used at each end of a tube to form this resonator. If you have ever created an infinity tunnel by facing two mirrors toward each other you have witnessed an example of this type of optical feedback.

This is the true laser amplifier used for optical gain. The process of stimulated emission does begin amplification but the resonator does most of the work to get the intensity up to high levels.



GENERATION OF THE LASER LIGHT OCCURS WITHIN THE RESONATOR. LIGHT GENERATED THROUGH STIMULATED EMISSION BOUNCES BACK AND FORTH BETWEEN THE TWO END MIRRORS, CREATING MORE INTENSE LASER LIGHT WITH EACH PASS OF A WAVE OF LIGHT.

Figure 9

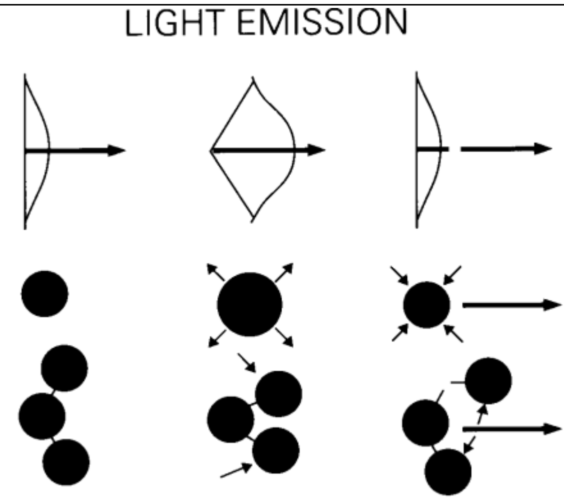
WHAT ARE SEALED TUBE LASERS?

These are systems which require no external gas sources attached to the laser. It is all self-contained within the Laser resonator, and possibly a small reservoir which is attached and integral to the tube. Ion lasers such as argon and krypton may utilize an attached reservoir from which the tube must be periodically recharged manually. Carbon Dioxide lasers have evolved from flowing gas systems (external gas tanks attached) to several types of sealed systems as follows:

FREE SPACE, FLOWING GAS SYSTEMS (CO2) are open glass tubes (hence the name free space) with the mirrors at each end. Electrical excitation comes from converting wall current into high voltage, DC electricity. This electricity energizes the gas in the tube via electrodes that are placed inside.

Because there is a disassociation of the Carbon Dioxide molecule after it has emitted light, and contaminants formed at the electrodes, new gas must continuously replenish this to keep up the lasing action. (Figure 10)

Gas is continuously pumped through the tube by a vacuum system, which incidentally can add noise to the room. Gas is supplied from tanks that may last a few hours and is relatively expensive as gas mixtures go. Since gas is pumped through, they are not a sealed tube type of system. Newer flowing gas systems have evolved into "microflow" systems which minimize gas consumption and noise from the unit. There are certain advantages to a flowing system in that the tube will operate indefinitely given a fresh supply of gas. You can find many of these systems that work as well now as they did when manufactured 25 years ago. Cleaning or replacing simple optics every few years, plus normal preventative maintenance, is all that is required to keep them functioning.



THE CARBON DIOXIDE MOLECULE EMITS ITS LIGHT MUCH AS A BOW FLINGS AN ARROW. HOWEVER, THE ENERGY OF THIS RELEASE BREAKS APART THE MOLECULE, REQUIRING EITHER A FRESH FLOWING GAS SOURCE, OR CATALYSTS IN A SEALED SYSTEM WITH A LARGE RESERVOIR OF GAS

Figure 10

RADIO FREQUENCY (RF) WAVEGUIDE lasers (CO_2) were the next step toward a more efficient type of Carbon Dioxide laser. These are sealed tube lasers that do not require external gas tanks. They are very quiet to operate.

These lasers do not use direct electrical excitation as do the free space lasers. Instead, the resonator itself is actually a radio frequency transmitter (High frequency electricity) that sends its signal transversely across the tube and excites the gas.

Newer technology, particularly with "Z" folded tubes has allowed the development of reliable 100 watt units. These are efficient, reliable lasers. Their advantages are the same as with all sealed tube lasers. They are inexpensive to operate, small, quiet and easy to operate. The gas in the tube will need to be recharged every five years or so.

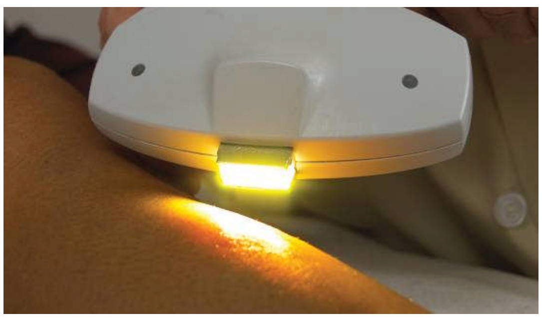
One of the advantages of a high powered RF system is that high energy pulses may be developed in the superpulse mode on the laser - much higher than that attainable by direct electrical excitation. This produces pulses which are of higher energy, provide higher average powers, and exceptionally clean tissue effects. The "trade name" for this type of pulsing is the ULTRAPULSE.

FREE SPACE, SEALED TUBE LASERS are the other type of Carbon Dioxide Laser. They have the advantages of low operating costs (due to no external gas), and quiet operation as the RF units. These lasers use DC excitation just as the flowing systems do. The difference is that they have a gas reservoir built right in to the tube and use a special gas mixture. The large reservoir and catalysts re-associate the Carbon Dioxide molecule after it breaks apart so that it is continuously usable. These tubes will also have to be recharged after several thousand hours or three to five years or so.

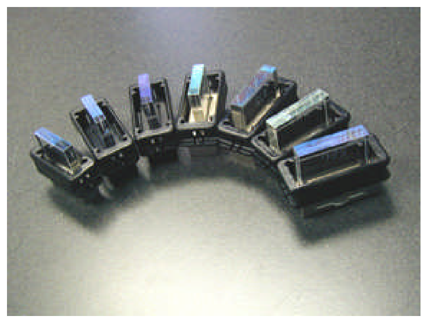
OTHER LIGHT SOURCES

Light Sources other than laser are also used for medical / surgical / aesthetic procedures. We won't go into those in detail here, but will at least explain them to differentiate them from lasers.

BROAD BAND LIGHT SOURCES:
IPL'S (Intense Pulsed Light) aka AFT (Auto Fluorescent Technology) aka BBL (Broad Band Light)



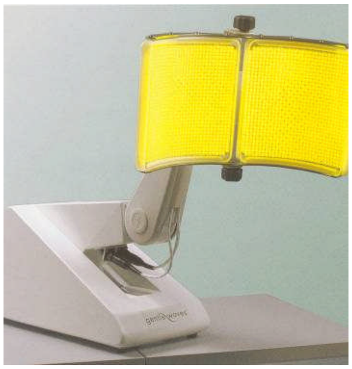
Syneron's IPL



Various filters used to select certain wavelength bands

These broadband light sources utilize a high powered lamp in the head of the unit to put out bright white (broad spectrum) light. Filters are then placed in the head of the unit to limit the output to various wavelength bands. These filters must be kept clean and scratch free. Such broadband light sources are used primarily for aesthetic procedures such as skin rejuvenation, vein removal and hair removal. Though they do have widespread use, they cannot be compared with the intensity and effects of lasers. However, in cosmetic practices they have become quite popular because they can be more profitable than lasers, since their purchase price is significantly lower. They make take a few more treatments than the more effective lasers, but it may be worth it because of the cost savings. Some IPL's have filters that float in cool gel on the skin, while others have recessed openings that do not allow direct skin contact and therefore don't require the cooling gels.

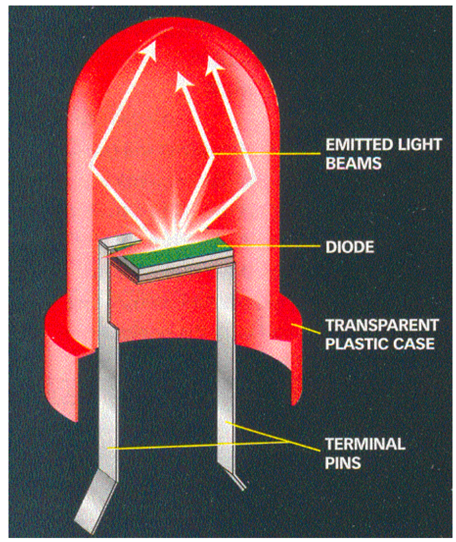
LED's – Light Emitting Diodes
Though there are some diodes that are actual lasers, these types of LED's fall short of that and are simply a solid state electronic light source. They have been promoted for low level light therapy and a term call "photomodulation".



Light Bioscience's "Gentlewave",
LED photomodulation device for skin rejuvenation

An LED is a light emitting diode. The diode lets current flow in one direction. To get a diode to emit light it is made from two semiconductor materials. One has too many free electrons, the other not enough. The electrical current forces the excess electrons across a barrier and light is produced. Incandescent bulbs in contrast generate light and heat by electrical resistance that makes the filament glow. LED's are more expensive now than light bulbs but use less power so are less expensive to run. They have no additional heat output like a light bulb. They have a lifespan measured in the tens of thousands of hours and are very small for their output.

Besides medicine, their most prolific use may be in automobiles and trucks. Within just a few years all automotive lights (except headlights) will be LED's.



ENERGY CONCEPTS

(See Appendix A for Radiometric Concepts & Definitions)

POWER in WATTS, is simply a measure of the ***RATE*** of energy delivery in Joules/second. To determine peak power of a laser pulse, divide the energy delivered by the time required. 200 millijoules delivered in 200 microseconds is equal to 1000 watts peak power. (.2J / .0002 sec = 1000 watts). Most Continuous Wave (CW) laser settings are in Watts.

POWER DENSITY is the most important factor in the effective operation of any laser. It determines the laser's ability to vaporize, excise, and coagulate various tissues of the body.

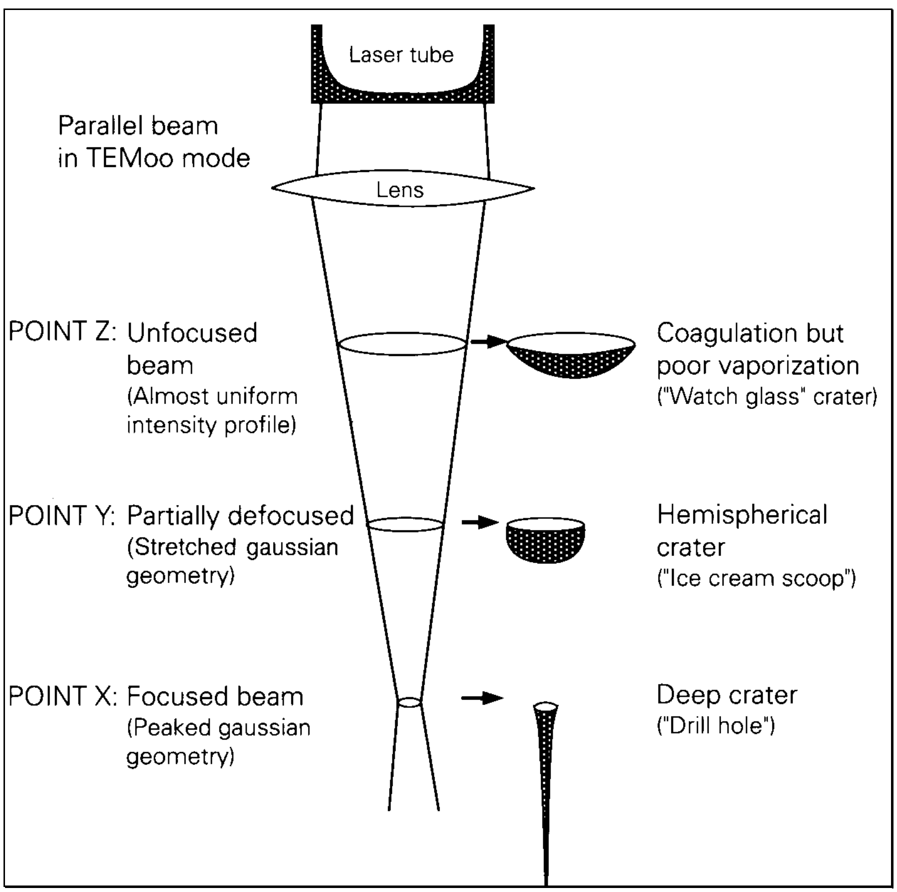
Power density is correctly called **IRRADIANCE**. It is a concept that describes the intensity of the light in terms of power incident upon the surface per unit area. This is expressed in watts/cm^2. The surface area of the spot (spot size controlled by the surgeon in the field), and the total power in watts of the laser (set at the laser by the technician) determine power density as follows:

$$\frac{\text{Watts x .86 x 100}}{\pi R^2} = \text{Watts/cm}^2$$

R = spot radius in millimeters

Power Density is what determines rate of tissue removal and creates the perception of eye-hand coordination of the physician. A common misconception is that the power alone determines the coordination required to avoid perforations or shredding of tissue with the laser. Power Density over a spot determines the rate of tissue removal within that spot. One can effectively change the size of the "paintbrush" (spot size) with which you are working without changing the overall rate of tissue removal (power density) within the spot by varying spot size and power. The larger the spot, the greater the power required to maintain the same power density (IRRADIANCE), shown as follows:

	0.6 mm spot	2.0 mm spot
1900 watts/cm^2 =	10 watts	60 watts



An example of a focusing laser lens for surgical excisions and ablations.
Aesthetic laser lenses and handpieces don't focus quite this way.

At extremes, a very low power density is very easy to control by the surgeon, but excessively burns tissue. A very high power density produces very clean tissue effects, but is hard to control by the surgeon. When vaporizing or debulking tissue, larger spot sizes are frequently easier to work with and reduce the total time required to "paint" the tissue.

High vs Low Power Density 1

CO2 Laser impacts on a grapefruit show the characteristic beam geometry's associated with high (left) and low (right) power densities. Too high a power density produces a thermally "clean" vaporization but is hard to control and apt to result in perforations. Too low a power density is very easy to control and results in slow hand motions, but can produce extreme heat and unseen burning of tissues - resulting in third degree burns and scars. A clinically acceptable power density (at any given power) lies somewhere in between these two, and its shape would ideally appear as half of a sphere -

Laser Plume: Power Density (IRRADIANCE), since it determines rate of tissue removal within a spot, is also the single most important determinant in how much Laser Plume, or smoke, is produced during a case. According to the ANSI standards, whenever laser plume is produced a Smoke Evacuator (Local Exhaust Ventilation) is the first line of defense against the noxious plumes. This laser plume, called Laser Generated Airborne Contaminants (LGAC) by ANSI, contain such offensive components such as formaldehyde, carbon or even viral DNA fragments (no one has ever shown a functioning intact virion from the plume however).

JOULE is the term used to describe the total energy the light delivers. Laser pulses are properly measured in joules output. 1 Joule = 1 watt for 1 second. You see then that the longer the light is delivered, or the higher the power, the more total energy will be delivered. Surgical Nd:Yag and ophthalmic lasers will usually have a joules (or millijoules) readout. Carbon dioxide lasers usually do not. Joules describes the total energy delivered but does not by itself indicate how concentrated this dose of light is. Most "Pulsed" laser settings are in Joules.

1 Joules = 1 Watt x 1 Second (One Joule = One Watt/Second)
1 Watt = 1 Joule/ 1 Second (1 joule delivered in 1 second)
1 Second = 1 Joule / 1 Watt (1 joule delivered at the rate of 1 watt)

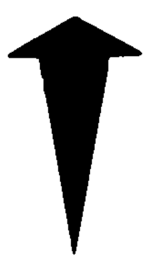
Flux describes the rate of energy delivery. For instance; 100 joules could be delivered in 1 second by 100 watts; or in 100 seconds by 1 watt. 100 watts per second is a higher flux.

RADIANT EXPOSURE: Combining this concept of rate of delivery (or pulse time) with that of power density leads to the concept of **FLUENCE** expressed as **Joules/CM²** – correctly called **Radiant Exposure**[5]. It is sometimes also called "Energy Density". As a general rule, the higher flux will be more precise thermally in its tissue effects. (Figure 11) This is very important as it relates to pulsing of laser energy. By pulsing the energy to very high peak powers, but for very short periods of time, any unwanted heat conduction to adjacent tissue is minimized or eliminated. This is what gives superpulsing on CO_2 lasers such a clean cutting effect, and why using pulsed dye lasers for birthmarks and similar lesions minimize any unwanted "burning" effects of the laser.

Pulsing the laser energy to very high energies creates non-linear effects. These are generally acoustical shock waves not associated with direct tissue heating. A Nd:Yag laser pulsed to tens of millions of watts within a few nanoseconds can create the cold-cutting "sparks" used inside the eye to cut membranes (posterior capsulotomy). At somewhat lower but still high fluences, a pulsed dye laser can create shock waves where the fiber abuts a kidney stone, causing concussive fragmentation of the stone.

This critical concept of high flux (more power in shorter time) for precision is easily understood intuitively. Suppose one has an electric hot-plate and wants to determine whether or not the surface is hot. If one "taps" the surface quickly with their finger they will not be burned if it is hot. However, if they leave their finger in contact with the surface for a few seconds a burn may result. The temperature of the hot-plate did not change, only the time of application which allowed for a conduction heat burn. (Technically this is not a perfect analogy but the general idea is conveyed)

The longer the laser is left in place, even at low power, the more extensive is the thermal conduction to adjacent tissues. It is very important to visualize this spread of heat during any laser procedure.



F 100 Joules = 100 watts x 1 second ("bolus")
L
U
X 100 Joules = 50 watts x 2 second

100 Joules = 1 watt x 100 seconds ("drip")

An increasing "bolus" of the dosage of light is actually an increase in FLUX.

[5] Please see the encyclopedic glossary for a more accurate technical definition of these terms. This definition is general, but describes its common medical usage.

Excess tissue damage is proportional to the time the beam is applied, not to the total power. This is one reason the surgeon should choose the highest power density that he can control, in order to do the job quickly and limit the spread of damage. This can frequently be accomplished by using the control panel “pulse” setting (not a true laser pulse but a timer to deliver short bursts of CW or pulsed energy).

Do not be misled however in thinking that sufficiently high power densities, achieved by using very small spots with low power lasers, will achieve satisfactory surgical results for vaporization. In order to debulk and vaporize larger volumes of tissue the spot must be broadened to perhaps the size of a pencil eraser. This allows for more uniform, smooth vaporization of tissue but requires higher total power to compensate for the dilution of power density. If one tries to debulk a mass with pinpoint spot sizes and high power densities it will create uneven ridges, furrows, bleeding and is generally unsatisfactory. An elegant technical solution to this problem is to use a random electronic scanner with these focused beams. The speed of the scan eliminates the problems of high power density spots while retaining the clean tissue effects. This is a way of achieving high fluence (meaning char free clean tissue vaporization) with an otherwise continuous wave beam.

Power density is the single most important factor when choosing laser apparatus. Therefore, the higher the power capabilities of the laser, the greater are its applications and future flexibility. On Carbon Dioxide Lasers, a power range of 50-60 watts is the "fence" to straddle in order to keep it versatile for all surgical specialties. Higher powers are desirable, but not absolutely necessary. The question whether to buy power over 50-60 watts boils down to money and not applications. One aspect of 50-60 watts is the potential limitation this may pose on pulsed average powers, such as superpulse - discussed in the next section. The other advantage of high power (80-100 watts) CO_2 lasers is that the average power of the superpulsing is also in a more useful range.

On other lasers, such as for hair removal in dermatology and other nonablative procedures, we usually substitute the concepts of high fluence for power density, but we run into the same limitations. If you use a very large spot (desirable), then you must have a laser that will generate sufficient power to “feed” this large spot and keep the treatment effective – and the laser needs to be “sturdy” enough to run reliably at these high settings.

RATE OF ENERGY DELIVERY, AND PULSING CONCEPTS

Most medical lasers offer a choice of operating modes to include continuous and pulsed modes. Some lasers deliver their energy solely as pulsed energy and many CO_2 lasers additionally offer a superpulse mode. It is important to remember that these terms such as "pulsing" are used loosely and often do not fit the correct technical definition. A brief summary of these modes and relative time scales will help present a clearer picture of how lasers may be manipulated to achieve different effects.

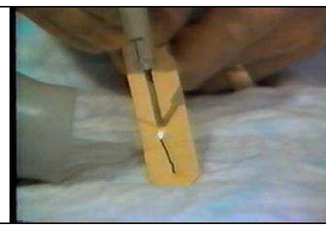
RELATIVE TIME SCALES AS THEY RELATE TO PULSING OF LASER ENERGY

Term	Time (sec)	Fraction	Exponent
Seconds	1.0	Full Second	
Millisecond	.001	Thousandths	10 -3
(Gated pulse - still primarily in a CW mode, just timed)			
Microsecond	.000001	Millionths	10 -6
(Pulsed, frequently causing induced shock wave effects such as for laser lithotripsy)			
Nanosecond	.000000001	Billionths	10 -9
(This is the range in which the Q-Switched Nd:Yag lasers for ophthalmology work)			
Picosecond	.000000000001	Trillionths	10-12

Continuous Wave (CW) refers to a steady state power output from the laser. Most medical laser systems work in this CW mode, even when set to a "pulse" of around .1 second. This term also sometimes refers to a mode in which the laser beam is emitted the entire time the foot pedal is depressed. Technically the latter is incorrect since a series of true pulses may also be emitted in this manner, but it is a common expression printed on control panels by manufacturers for laser operation and should be noted.

CLICK ON THE PICTURE AT THE RIGHT TO SEE A CO2 LASER OPERATE IN CW MODES. THIS EXAMPLE IS A CW MODE, BUT IS ALSO AN INSTANCE WHERE IT MEANS THE BEAM IS CONTINUOUSLY EMITTED AS THE FOOT PEDAL IS DEPRESSED.

CLICK HERE to see the CO2 Laser in the pulsed (gated) mode.



Gated Pulse (timer on a CW beam) is most commonly referred to as simply "pulse" on the control panel. This is merely a timer for a CW beam and is seen most often on CO_2 lasers. True laser pulses, which are different, may also be emitted in this timed fashion. The differentiating characteristic on a gated pulse is that the peak power output of the “pulses” is no higher than they would be if the laser were emitted in a continuous fashion. Most of the CO_2 lasers offer an option for a repeat pulse. This is simply the gated pulse that continues to be emitted repetitively as long as the foot pedal is depressed. This is a very useful feature on CO_2 lasers and models that allow for varying the speed of the repeat rate are the best. These timed pulses are good for maintaining surgical control.

PULSE - A true laser pulse is able to compress the power output of the laser tube and deliver very high peak powers of energy during the pulse but cannot maintain these high powers in a steady state. It delivers peak powers which are generally not attainable when operating with a CW beam. A 504 nm dye laser may be pulsed in microseconds to deliver 40 kilowatts of peak power to fragment kidney stones in laser lithotripsy. Even though the peak power is very high, it is not sustained and the total delivered energy will only amount to 10-60 millijoules. Pulsing includes Q-switching, mode-locking, superpulsing, ultrapulsing, and flashlamp pulsing techniques. With the exception of superpulse, most pulsing is designed into the laser and is not a selection made on a control panel.

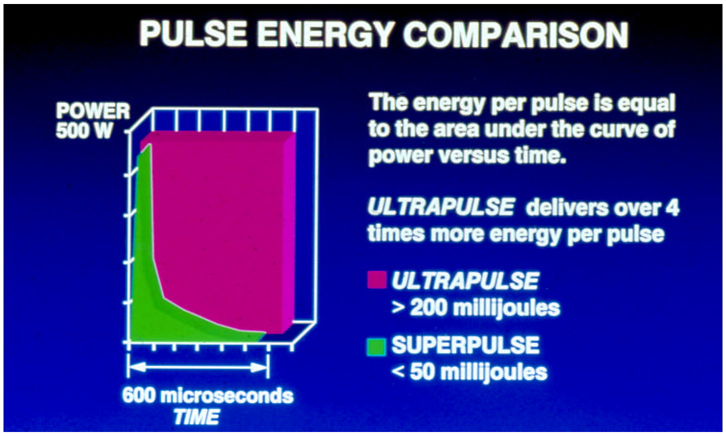
Q-switching and mode-locking are terms used to describe pulsing techniques that produce peak powers on the order of tens of millions of watts, for pulse duration's of only a few nanoseconds (very short pulse). Total delivered energy is again very low, 3-10 millijoules, because of the short pulse width. This is commonly employed in the ophthalmic Nd:Yag laser to achieve the "cold cutting" sonic effect. If the Q-switching occurs rapidly for emission of multiple pulses, the peak power of each pulse is less than would occur on single pulses or lower frequencies, but is still much higher than a gated pulse. For instance the KTP crystal in that laser will Q-switch the beam at over 25,000 times per second. Because of this very high frequency and lower peak powers it is referred to as "quasi-continuous".

Q-Switched Ophthalmic Nd:Yag Laser

SUPERPULSE is found on many CO_2 lasers and called various names by manufacturers such as superpulse, varipulse, megapulse, etc.. this is a true pulse on CO_2 lasers, usually producing a train of pulses from 250 to 500 watts maximum peak power per pulse at a rate of 300-1000 times per second (hertz). This rate is so fast that it looks continuous but the pulsing may be picked up as an audible "buzz" as the focused beam hits its target. Again, the total delivered energy is not as high as the 500 watt pulses might imply - perhaps only 75 millijoules per pulse. On CO_2 lasers this will be read out as the "average power" of the beam rather than joules energy and the maximum average power in superpulse will always be substantially lower than the maximum power available in continuous mode. Superpulse allows for cleaner cutting of tissues with less resulting charring.

Superpulse always works well for nice incisions because of the small spots and resulting high power densities. The limitation in the use of superpulsing comes from the relatively low, maximum average powers and energy per pulse attainable in this mode. Most lasers produce no more than one third the average power in superpulse than they do in a continuous wave mode. High power lasers, such as 80-100 watt units, allow for superpulsing of 25-35 watts average power. Lower power lasers often produce maximum superpulsing of only 10-20 watts average power. These lower energies per pulse and average powers, though useful for cutting, are usually insufficient for vaporizing larger areas using broader spots. Here the higher powers of a continuous wave mode may be more useful.

An exception is the superpulse mode on the Coherent (Lumenis) RF excited CO_2 laser, which is commercially called an Ultrapulse. These produce such high energies per pulse that average power is not sacrificed at all, and in fact can produce average Ultrapulse powers as high as the maximum CW power on the laser. Unlike the regular superpulses of around 75mj, the Ultrapulse can produce 500mj pulses.



LONG AND SHORT PULSED LASERS:

The terms "Long" and "Short" pulse can get very confusing in aesthetic laser applications because there really is not a technical definition of what long or short means. It can be used as a comparison however. The very short pulse of a q-switched Nd:Yag laser (nanoseconds) used in tattoo removal is a different animal than the longer pulse (40-100 milliseconds) used for laser hair removal. This is especially seen in hair removal. Shorter pulses are associated with more patient discomfort (assume same dose) but are more effective at creating elevated temperatures in hair follicles to destroy them. However, these shorter pulses also significantly heat darkly pigmented skin and can be very destructive to it. Longer pulse widths will be more sparing to dark skin, and this is usually coupled with a longer wavelength (like Nd:Yag or diode) for laser hair removal. In addition to this small structures such as fine hair or capillaries require very short pulses to be effective, while coarser hair or vessels require longer pulses.

NOMENCLATURE for Pulsing & Continuous Wave.

The amount of time the laser beam is on is called the PULSE DURATION for pulsed laser systems, but is called the EXPOSURE TIME for continuous wave lasers.

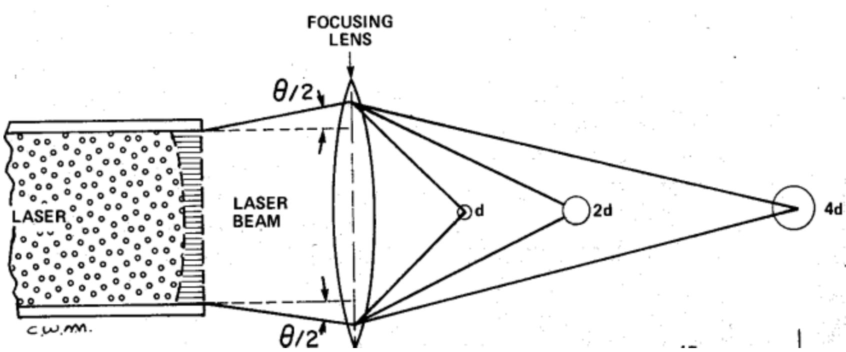
OPTICAL CONCEPTS:
IMPACT SIZE AND SPOT SIZE
FOCAL LENGTH & SPOT SIZE
FOCAL LENGTH & DEPTH OF FIELD

This discussion is primarily for lenses that focus down to small spots. This includes most of the non-fiber delivery devices for surgical ablations or excisions. Aesthetic procedures in dermatology only use these focusing lenses for surgical intervention. Most Aesthetic laser handpieces are collimated to a larger consistent spot and don't' focus this way, but the optical concepts are still important.

Spot size of the laser is one of the two factors controlling power density (either for a focusing lens or an aesthetic collimated one). The spot size in turn is affected by 5 parameters:

1. Lens Focal Length - shorter focal lengths produce smaller spots.
2. Diameter of incident beam into lens - the larger the beam, the smaller the spot. This is inherent in the laser design.
3. Wavelength of the light - the shorter the wavelength, the smaller the spot that can be produced, but medical systems don't usually push this to these small levels.
4. TEM of the beam (Transverse Electromagnetic Mode) - TEMoo produces the smallest spots. Sometimes though you want a "flat" beam for big spots and uniform effects, like dermatology procedures.
5. Delivery System - Fibers control spot sizes differently than focused beams. Spot diverges continuously from the fiber. Dermatology systems that are delivered by fiber usually do have handpiece that allows for a consistent spot size.

Lenses are interchangeable so this is something that can be controlled. The smaller the focal length of the laser lens, the smaller will be the spot and hence higher power density.



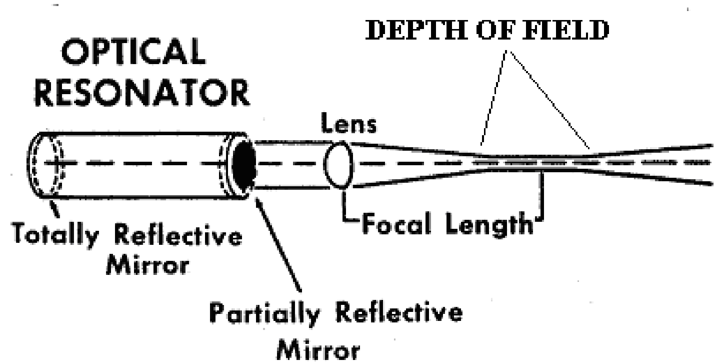
The longer the focal length of the lens, the larger the focused spot diameter will be as illustrated above.

The following are representative spot sizes from a Surgical Carbon Dioxide Laser:

400 mm lens = 0.8 mm
300 mm lens = 0.6 mm
200 mm lens = 0.4 mm
125 mm lens = 0.2 mm

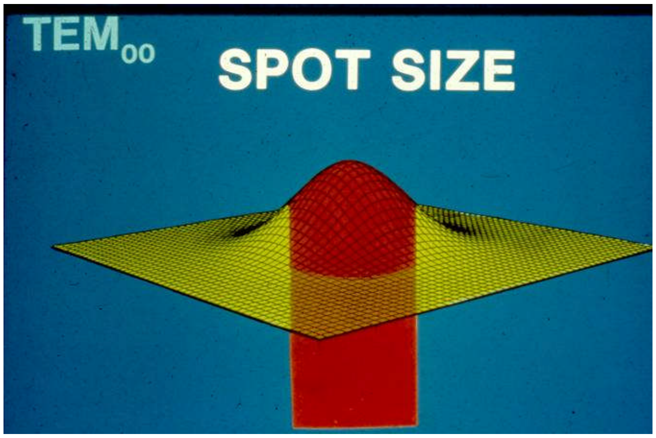
The spot size of a focused beam (beams emitted from the output end of fibers are somewhat different) is determined by the size, shape and color of the beam as it enters a lens. Spot size of a laser is an entirely different thing from the impact size the laser leaves behind. Spot size is a mathematical measurement whereas the impact size relates to the actual size of the crater (or incision width) left by the laser. Keeping spot size the same, the impact size will increase when the beam is applied longer to the site. (The edges of the beam have longer to create an effect and therefore increase its width)

Remember that small spots are useful for cutting and ablation techniques. Most of the dermatological procedures though use as large a spot size as the power of the laser will allow, providing uniformity and better light penetration into the dermis.



<u>DEPTH OF FIELD</u> – of a focused laser beam, is the space surrounding the focal point where the spot size is essentially unchanged. It's like a "waist" around the focal point. Once you're past this depth of field then spot size can change rapidly with distance. This can be important because changes in spot size radically change the power density and tissue effect (i.e. a focusing handpiece used to ablate tissues). Collimated aesthetic handpieces don't exhibit this characteristic. The longer the focal length of the lens, the longer will be the depth of field, and the shorter the focal length, the shorter the depth of field.

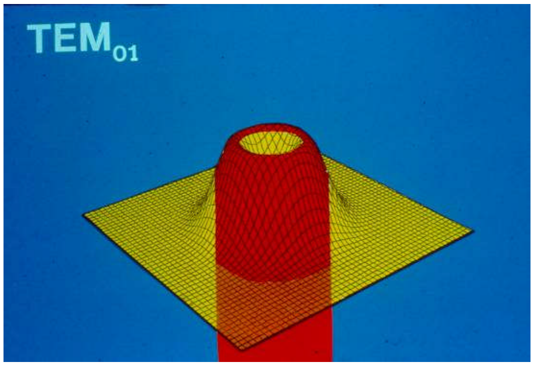
The wavelength (color) of the light also determines how small the spot may be focused. All other things equal, the smaller the wavelength the smaller the spot. An argon laser produces a much smaller spot than can the Carbon Dioxide laser. The type of laser you work with however is chosen for its specific effects on tissue and delivery mechanism rather than for its spot size abilities, and almost no medical system pushes these spot sizes down to their limits anyway. The Mode refers to the distribution of power over the spot area and determines the precision of the operative spot. The term used to describe this is TEM which means Transverse Electromagnetic Mode. The most fundamental mode, TEM00, shows an even power distribution over the spot so that most of the power is at the center and there are no hot or cold spots. A look at this power distribution reveals a cone shaped pattern. (Figure 12) The spot is brightest in the center and fades toward the edges. This mode can produce very fine spots, however it is not uniform so would not be the preferred beam shape to get uniform effects in most dermatological procedures. Aesthetic laser handpieces usually use a nonfocusing beam that is more uniform across its spot size, and usually come in larger spots such as 5-15mm.



A TEM00 MODE IS THE "CLEANEST" SHAPE OF A FOCUSED LASER BEAM, AND CAN PRODUCE THE SMALLEST FOCUSED SPOT SIZES. THIS IS DESIRABLE ON MOST SURGICAL SYSTEMS.

Figure 12

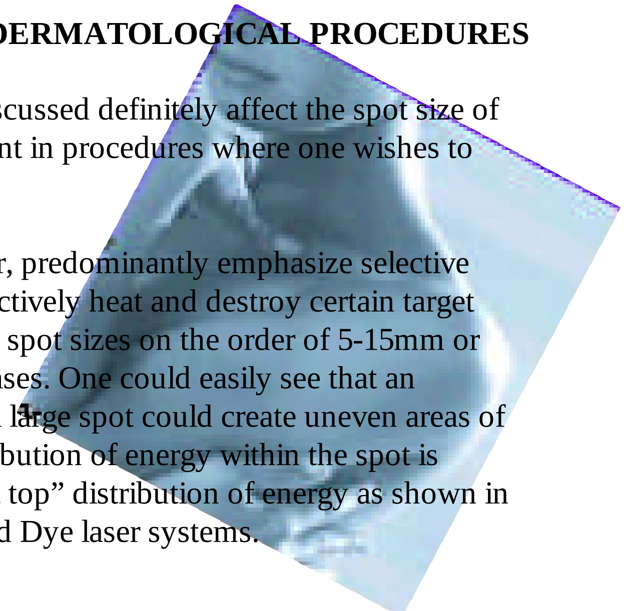
Because the impact size of the beam on tissue is a function of tissue heating, time is just as important as spot size in determining the actual impact size. The longer the beam is on, the more the heat builds up around the "fuzzy" edges of the spot, and the wider the impact. When the light is not distributed in this fundamental manner it is said to be in multimode distribution. This can occur in many different patterns but common mode in some older surgical lasers is the TEM 01 (a cold spot in the center) also called a doughnut mode. This mode is unable to be focused to as fine a spot as the TEM 00. (Figure 13) A 400mm lens and TEM 00 beam would focus to 0.8mm. A 400mm lens and TEM 01 would focus to 2.0mm. High power output of a CO_2 laser changes the mode structure at the beginning of lasing. A high power setting (i.e.: 80-100 watts) used in timed pulses of around 0.1 seconds tends to create a multimode beam and one can frequently see the resulting "doughnut" burn in a tongue blade when applied this way.



DIFFERENT DISTRIBUTIONS OF ENERGY WITHIN THE BEAM CAN OCCUR, BUT A TEM01 MODE IS COMMON AMOUNG OLDER CO2 LASERS, AND EVEN IN THE FIRST 1/10TH OF A SECOND OF AN OTHERWISE TEM00 BEAM. TEM01 MODES CANNOT BE FOCUSED TO AS SMALL A SPOT AS A TEM00 BEAM.

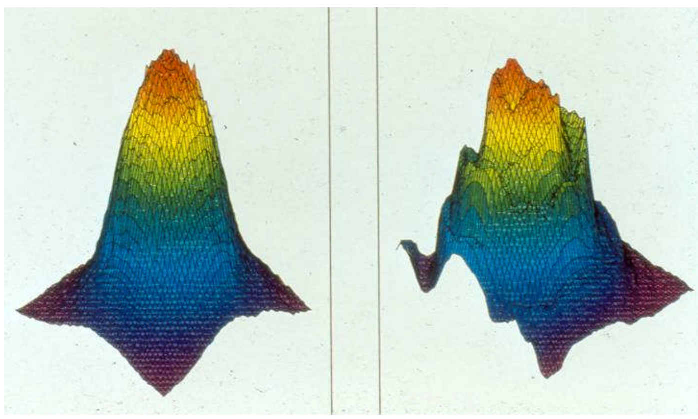
Figure 13

BEAM SHAPES WITH "HOT SPOTS" IN DERMATOLOGICAL PROCEDURES

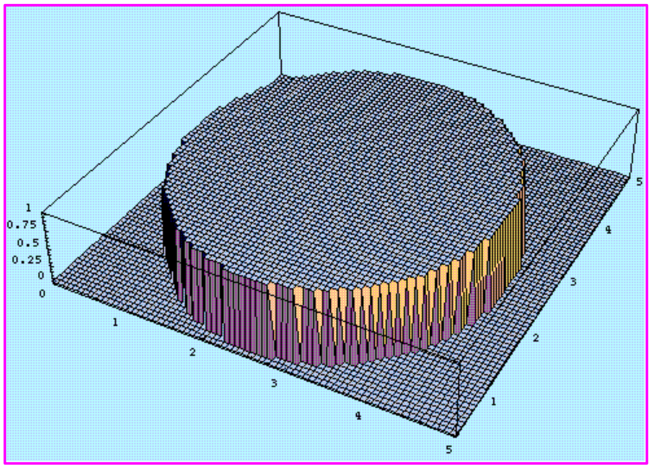


The TEM00 and TEM01 modes we have just discussed definitely affect the spot size of the focused beams. This becomes most important in procedures where one wishes to incise, cut or otherwise create very small spots.

Dermatology and Aesthetic procedures however, predominantly emphasize selective photothermolysis where the laser is used to selectively heat and destroy certain target tissues, rather than surgically dissect. Very large spot sizes on the order of 5-15mm or higher are generally desired for these types of cases. One could easily see that an inconsistent distribution of energy within such a large spot could create uneven areas of treatment, and for that reason a more even distribution of energy within the spot is desired. These are referred to generally as a "flat top" distribution of energy as shown in the following illustrations of two different Pulsed Dye laser systems.



The beam shape at the right is "flatter" than that on the left and would provide more consistent treatment and less chance of pinpoint "pricks" and bleeding at the center of the spot. This would apply to skin resurfacing, hair removal, pigmented lesion treatment or anywhere else the general technique of photothermolysis is employed with larger spot sizes.



Beam shape from Sciton's laser shows a very uniform distribution of energy within the spot, producing very uniform and consistent effects. (Used for Skin resurfacing)

Appendix A to "LASER BIOPHYSICS"
RADIOMETRIC QUANTITIES AND UNITS

Two principal CIE Systems - *Radiometric* and *Photometric*

Photometric Quantities and Units - Used for illumination engineering; basic unit of lumen (based upon CIE spectral dependence of the human visual response); normally not used in laser safety.

Radiometric Quantities and Units - Absolute units for power in watts (W) and for energy in joules (Q).

- **Irradiance**: Exposure dose rate incident upon a surface (W/cm^2).
  In medicine you'll hear this mostly expressed as ***power density***

- **Fluence Rate:** Exposure dose rate from all directions through a unit surface area (including backscatter) in W/cm^2.

- **Radiant Exposure:** Exposure dose incident upon a surface (J/cm^2).
  In medicine you'll hear this mostly expressed as ***Fluence***, even though it is technically incorrect.

- **Fluence**: Exposure dose from all directions through a unit surface area (including backscatter) in J/cm2.

- **Radiance** - radiometric unit of brightness in J/ (cm^2-sr)

- **Radiant Intensity** - beam power per solid angle (J/sr); seldom used in laser safety.

THE LASER TRAINING INSTITUTE™

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LASER COURSE POST TEST
- Laser Biophysics Module -
LASER AND ENERGY CONCEPTS

Name___________________________________Date______________________

1. **What is the difference between Spontaneous and Stimulated Emission of Light?**
   a. Stimulated emission gives rise to an organized coherent output, while spontaneous does not.
   b. Spontaneous emission produces more powerful beams of light than Stimulated
   c. Stimulated emissions must always use electricity, but spontaneous uses another light source
   d. The individual photons emitted through Stimulation are much brighter than spontaneous

2. **What are three unique characteristics of laser light?**
   a. Monochromatic, Powerful and Collimated
   b. Collimated, Coherent and Monochromatic
   c. Coherent, Collimated and Powerful
   d. Laser light always burns, always blinds, and is very bright

3. **Pick <u>two</u> individuals who contributed toward development of the laser**
   a. Leo Geovanni
   b. Leon Goldman
   c. Arthur Anderson
   d. Arthur Schawlow
   e. Joseph Marconi
   f. Theodore Maimon

4. **Why are lasers called "monochromatic" even though they may emit multiple lines of colors.**
   a. The statement is false; they do only emit one color of light
   b. They do emit different colors, but each color is a pure, narrow bandwidth
   c. Monochromatic only means it emits one beam of light, even if it's multi-colored
   d. The statement is false; it is monochromatic but lasers are infrared so colors don't apply

5. **Pick <u>one</u> area of medical application where the pure color of light is very important to its use.**
   a. General Surgery
   b. Urology – bladder tumors
   c. Ophthalmology
   d. Photodynamic Therapy

6. **What is the difference between a collimated beam of light and a divergent one.**

a. there is no difference, both divergent and collimated beams spread out
b. the beam spread from collimated beams is minimized compared to divergent ones
c. the beam spread from divergent beams is minimized compared to collimated ones
d. Collimated beams of light are always from laser, and divergent ones always from other light sources.

7. **Match the following laser(s) with the appropriate wavelength & color:**

____Carbon Dioxide	A.	488 & 515nm Blue Green
____Neodymium:Yag	B.	10,600 nm Far Infrared
____Argon	C.	1064 nm near infrared
____Holmium:Yag	D.	532 nm Green
____KTP	E.	2,100 mid infrared

8. **Why can laser beams be more highly focused (small spots) than regular light sources.**

a. The lenses used by lasers are more powerful than other lenses
b. The laser is a very fine beam anyway so may be focused to smaller spots
c. Collimated beams from lasers have parallel rays of light so focus to smaller spots
d. The high power outputs allow more light to be focused into a smaller area.

9. **What does L-A-S-E-R stand for?**

a. **L**aser **A**nd **S**timulated **E**mission of **R**adiation
b. **L**ight **A**nd **S**ound **E**mittors of **R**adiation
c. **L**aser **A**mplification by **S**olid-State **E**lectronic **R**emissions
d. **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation

10. **Pick the laser which is customarily delivered through an articulated arm**

a. Nd:Yag
b. CO2
c. Alexandrite
d. Argon

11. **What is the primary difference between the control of the spot size with bare fiber delivery (free beam applications) compared to the focusing lens of a CO2 laser.**

a. Both use focusing lenses to achieve the small spots for surgical cutting & ablation
b. The CO2 laser uses a handpiece lens while the fiber uses a microlens on its tip
c. Both are focused to small spots at the focal points of the lens
d. The CO2 laser has a focal point, the bare fiber's spot keeps getting bigger with distance

12. **Depth of field of a focused (CO2) laser beam is defined as:**

a. the distance from the laser lens to the smallest spot
b. the distance around the focal point, where the spot size remains essentially unchanged.
c. the distance the laser beam will travel through tissue
d. the focal point of the laser lens

13. **What are factors that determine power density of any laser beam**

a. TEM structure of the beam and peak power delivered
b. Spot size & Power
c. Power and Pulse duration
d. Wavelength and Power

14. **Where is the smallest spot of laser beam from a transmitting fiber.**

a. at the focal point of the fiber - usually 1 cm from the tip
b. just at the tip of the fiber itself, since it diverges and does not focus
c. the spot stays pretty much the same small spot since the beam is collimated

15. **Which best defines a true laser pulse?**

a. an automatic timer or shutter which emits light consistently in controlled intervals, like 0.1 second pulses.
b. a compression of laser energy which momentarily emits power at a higher rate than the laser otherwise could in the continuous wave mode.
c. a burst of laser energy which creates shock waves
d. high power outputs of any type

16. **Which factor changes power density more rapidly?**

a. spot size changes
b. laser power changes
c. Pulse width changes
d. wavelength changes

17. **Name two instruments (devices or attachments) through which the CO2 laser is commonly delivered to tissue.**

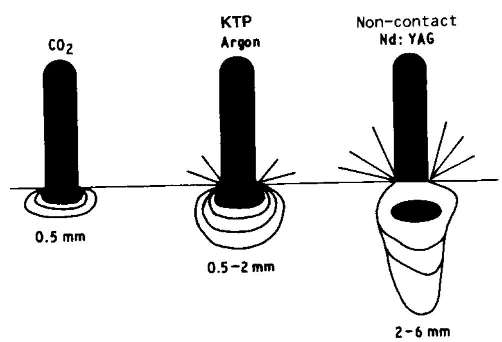
a. Flexible bronchoscope
b. Micromanipulator
c. Laparoscopic Coupler
d. Otoscope

18. **The depth of field of a focused laser beam is greatest with the use of:**

a. a 125 mm focusing handpiece
b. a 280 mm laser laparoscope coupler
c. a 400 mm laser lens used on an operating microscope
d. a 50mm handpiece lens

Each type of laser exhibits differing biological effects and is, therefore, useful for different applications. The primary laser systems used in medicine are the Carbon Dioxide, Er:Yag, Er:Glass, YSGG, Nd:Yag, Ho:Yag, Argon, KTP, Dye, Alexandrite, Ruby, and Diode Lasers. The difference in tissue effects of these lasers depends on their degree of absorption in target tissue, and how the energy is delivered. Even though we may achieve precise surgical effects, we are taking advantage of only the crude, thermal effects of the laser. Light has the ability to achieve more subtle physiological effects such as cellular stimulation or suppression which has tremendous applications in wound healing (and prevention of wounds), skin rejuvenation and treatment of chronic pain. These are the Low Level Laser Treatments (LLLT).

Surgical effects of the primary laser systems rely on heat transfer from the beam into tissue. The color of the beam is grossly important because it determines how efficiently this thermal transfer takes place, because of the degree of absorption of the beam in tissue.(Figure 14) However, it is probably more important as to how rapidly the energy is delivered, than the precise color itself.



SIMPLIFIED TISSUE REACTION

This is meant to indicate that various wavelengths will "reach" into tissues to different depths, but the illustration is too oversimplified here to draw conclusions about the clinical use of the dozen or more wavelengths currently on the market. In addition, the way the energy is delivered in terms of its peak power, pulse duration and spot size become even more important than wavelength in the clinical choice of any particular laser system. They are all related.

Figure 14

The energy of a blue-green argon laser beam will be absorbed much differently in tissue than infrared will. Some lasers, such as the argon, produce more than one color. The krypton may produce up to 16 spectral lines. The differences in tissue effect become much more subtle as the color variation narrows, and fine tuning a spectrally pure color from a surgical laser is usually insignificant. An example is the differences between the KTP and argon lasers. For the most part their clinical effects are identical, with some subtle differences in ophthalmology and dermatology.

It is the gross color that determines its surgical effect. Exceptions would be retinal work in the macular area, fine tuning dermatological procedures, and photodynamic therapy. All of these require fine tuning the color of the light.

As tissue begins to heat above 40-60 degrees C, it begins to desiccate, blanch white and shrink as proteins denature, and flash boil at just over 100 degrees C. Different lasers can take you to different points on this scale because of the way they transfer their "heat" (energy) into the cell.(figure 15)

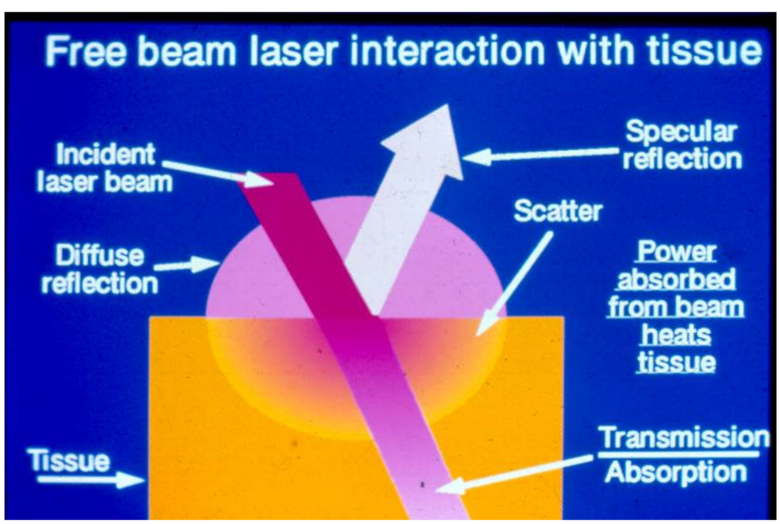
ABSORPTIVE HEATING

	Visual Change	Biological Change
100°C	Smoke Plume	Vaporization,Carbonization
90-100°C	Puckering	Drying
65-90°C	White/Grey	Protein Denaturization
60-65°C	Blanching	Coagulation
37-60°C	None	Warming,Welding

Figure 15

The nature of interaction of all laser light with biological tissue can be described in terms of:

1. **REFLECTION**
2. **TRANSMISSION**
3. **SCATTERING**
4. **ABSORPTION**



In order for any of these lasers to exert their effect upon tissue the beam has to be absorbed. If it is reflected from or transmitted through tissue, no effect will occur. If the light is scattered, it will be absorbed over a broader area so that its effects are more diffuse. A thorough understanding of these four characteristics of light with tissue is necessary before the physician may most appropriately select the correct laser system for a particular application.

Regardless of the laser system used for a surgical application, its effects may be broadly classified as follows:

A. TISSUE HEATING (to a non-destructive level)

1. Skin rejuvenation, nonablative
2. Tissue welding

B. COAGULATION (destructive heating)

occurs at or above 45 degrees centigrade

1. Hemostasis, cautery
2. Protein - with attendant necrosis

The coagulation would include examples of selective photothermolysis – coagulative levels of heat generated in specific structures via selective absorption of the color of light.

C. VAPORIZATION

occurs at or above 100 degrees centigrade

1. Cutting (Ablating along a fine line with traction)
2. Debulking (Ablating volumes of tissues)

D. NON-LINEAR EFFECTS -- PHOTOACOUSTIC

1. "Cold Cutting" - ophthalmic Nd:Yag
2. Photoacoustical "Lithotripsy"
3. Fragmentation of tattoo pigment via Q-switched lasers.

These are the "shock wave" effects that rip and tear tissues. The ophthalmic system creates tiny sparks in thin air that tear apart the clouded membrane behind the lens, while the urological system for lithotripsy "jack-hammers" the stones apart. These acoustic effects are generally considered to start in the nano-second pulse range (i.e. Q-Switched lasers), but it is also true that clinical acoustical effects can be seen to begin in the microsecond range as well (i.e. lithotripsy, or purpura in microsecond pulsed dye lasers)

E. PHOTOCHEMISTRY

1. Photodynamic Therapy (PDT)

The use of photosensitizing drugs and specific wavelengths of light to activate them.

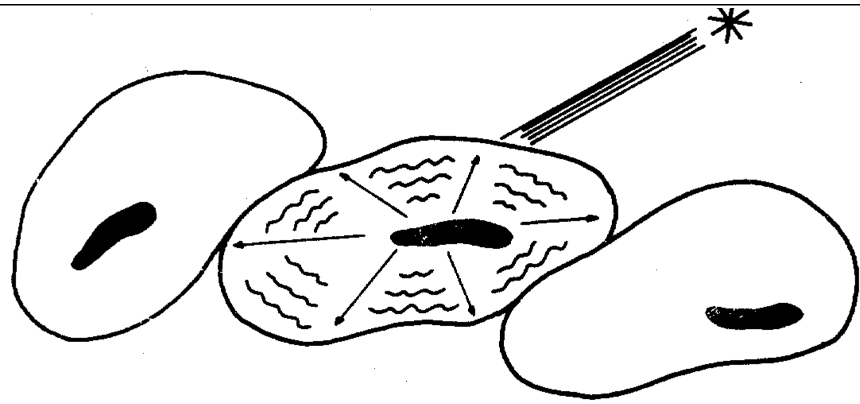
F. PHOTODISASSOCIATION

1. Nonthermal ablation of the Cornea in ophthalmology

This is the vision correction laser. An electro-chemical reaction occurs between the specific 193nm wavelength of the laser and the bonds that hold organic tissues together. It removes tissue without heat generation.

When used to cut or debulk tissue, the laser is actually vaporizing cells. This is a sublimation like process where the cells "flash boil" The mechanism relies on rapid transfer of energy from the light, absorbed in the tissue to generate heat.

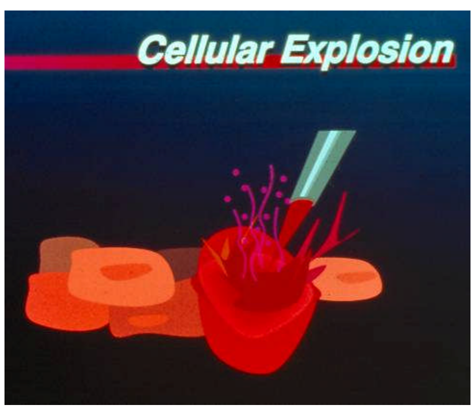
First the cellular water is superheated to past the boiling point of water at the vaporization point. The bottom of the incision or crater will be about 100 degrees C in soft tissue. In fat this will be much higher because of the higher boiling point. In bone it will be significantly higher still because of the carbon and calcium. The target determines the temperatures reached, not the laser. The temperature causes both complete destruction of all cellular proteins and an immediate pressure build-up within a cell. (Figure 16)



ABSORPTIVE HEATING OF THE CELL CAUSES A RISE IN TEMPERATURE AND PRESSURE OF THE INTRACELLULAR FLUID

Figure 16

The rapid rise in intracellular temperature and pressure causes an explosion of the cells, throwing off steam and cellular debris which looks like smoke. (Figure 17)



THE INCREASING TEMPERATURE AND PRESSURE CAUSES THE CELL WALL TO BURST, RELEASING SUPERHEATED STEAM AND DEBRIS SEEN AS THE LASER PLUME

Figure 17

The smoke-like steam rising from the impact site is seen as the laser plume. The plume remains in the path of the laser beam and the particle fragments flash white hot as theyare carbonized. (Figure 18)

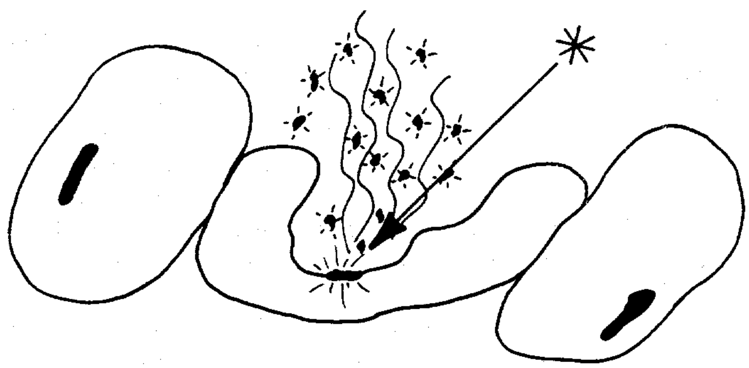


Figure 18

The Laser Plume which is generated by vaporization MUST be evacuated with a specialized smoke evacuation system – mandated by the ANSI Laser Safety Guidelines.

<u>Heat and Heat Transfer</u>

Whether created by electrosurgical electrodes or laser devices, cutting, ablation and photocoagulation (including selective photothermolysis) are caused by heat. The advantages of these high energy modalities lie in their ability to effectively create and localize this heat enough to produce desired surgical effects with associated hemostasis. Laser effects may be more highly localized than can electrosurgery. Laparoscopic dissection of a ureter, for instance, may be performed with more control with a laser than with electrosurgery. On the other hand, electrosurgery is usually very convenient to use in areas where such precision is not required, such as when taking down thin filmy adhesions.

Understanding and control of heat generation is critical in the aesthetic applications of lasers. Skin is terribly thermally sensitive. Structures that one wants to eradicate (hair follicles, capillaries, pigmented lesions, etc) must be heated to the point of destruction without damaging surrounding structures. This is selective photothermolysis.

Heat was once thought to be a substance. It was believed that when a hot object was placed in contact with a cooler object, an invisible entity called phlogiston entered the cooler object to make it hotter. Now we know that heat is the result of continuous motion and vibration of the atoms and molecules that constitute all matter. The transfer of heat between objects of different temperatures involves a reduction in the average motion of the particles of the hotter object and an increase in the average motion of the particles of the cooler object. The concept of heat therefore, is not really energy in itself, but is the transfer of energy between objects.

Heat may be measured quantitatively as either calories or British Thermal Units (BTU). Temperature is not heat. Temperature is a measurement of the intensity of heat, although an object at high temperature does not necessarily have more heat than an object at lower temperature. Larger or heavier objects can contain more heat, at the same temperature, than smaller objects. This is why larger diameter laser fibers which are used in contact with tissue, or contact probes can contain more heat, and accomplish more work, than smaller diameter devices at the same temperatures. A 55 gallon drum of water at body temperature contains significantly more heat than a thimbleful of boiling water. The temperature of the boiling water is higher (intensity) but the total heat content of the large drum is higher because of size.

Concentration of heat as calories is affected by power density of the applied laser beam. One calorie is the amount of heat required to heat 1 cubic centimeter of water 1 degree centigrade. If a certain laser energy is distributed over 1 cm^3 of tissue, then a 6 degree Centigrade temperature rise results. If the same energy is concentrated to 0.1 cm^3 of tissue, a 60 degree Centigrade temperature rise results (tissue temperature of over 100 degrees). The concentration of energy, as power density, is therefore VERY important and is exactly analogous to the electrode size with electrosurgery, and how it is manipulated on tissue. (You don’t need to know all of this in order to adequately use medical lasers, but it’s nice to have at least heard the concept).

The transfer of heat from one object to another occurs through one or more of three basic mechanisms: *conduction, convection and radiation*. Lasers are used in one of two ways to generate heat - either "non-contact" methods which rely on radiation transfer, or contact methods which rely on conduction transfer. Electrosurgery relies on radiation transfer only, when used correctly.

<u>Conduction heat transfer</u> is the flow of heat energy in matter as a result of molecular collisions. In other words if you touch a hot object to tissue it can burn it through direct conduction of heat. This is the mechanism of the classic "cautery" of tissue by hot objects - not to be confused with electrosurgery, which is not cautery. "Cautery" applies to simple hot objects that touch tissue.

"Contact" laser fibers and sapphire probes typically used on Nd:Yag lasers are another type of "cautery" which work by direct conduction of heat from an object into tissue by direct contact. These might be truly termed "photocautery" since the laser supplies the energy required to heat the tip of the fiber or sapphire. This is much more effective than electrical methods of heating and results in significantly smaller devices - less than 1.0 mm. Laser light does transmit through these fiber and sapphire devices and even though there may be some focusing of the energy right at the tip, the major mechanism of action is conduction heating from the crystal material to tissue directly through contact. The crystal, or contact laser fiber tip, gets very hot.

An area where conduction heating can become a problem is when laser is left in contact with tissue for excessive periods of time because of low power (power density) applications. Unwanted heat conducts from the target tissue into adjacent tissues and may cause excessive thermal injury by heat conduction. The illustration at the left shows the progressive heat spread.

Adequate powers (power density) minimizes this thermal conduction by allowing vaporization to proceed immediately. The excess heat is carried away in the laser plume to prevent conduction. Since adequate power densities generally involve quicker vaporization times, the time allowed for conduction also decreases.

The power density on the upper portion of this ablation on chicken meat was lower than that of the bottom portion of the ablation (CO2 Laser Ablation). The higher power density ablation is significantly “cleaner” that the other. In this case control was maintained over the higher power density beam by using a laser scanner to automatically control it. This is the way that skin resurfacing is performed with some lasers. If the power density had gone even lower than shown here, a very black carbonized layer would have formed which is VERY undesirable.

Another problem with conduction is that irrigating fluid makes an excellent conductor - a kind of heat sink. This means that contact type laser devices, although useful under fluid, are subject to significant diminution of heat intensity at the tip because of the conductive cooling qualities of the fluid. During laparoscopy in fact, irrigating an already hot laser fiber contact tip can cause cracking of the tip.

Non-contact lasers, such as the Carbon Dioxide, Excimer, Alexandrite, Ruby, Pulsed Dye, or Ho:Yag, do not operate in the "cautery" mode since the beams of light themselves are not hot. This doesn’t imply however that excessive tissue heating won’t occur of the laser is used improperly.

The green light KTP laser, or the argon laser, function as a contact or non-contact type of system depending on which fiber is selected and how it is used. The Nd:Yag laser is the most commonly used with contact tips and fibers for laparoscopy. The Nd:Yag could technically be used in a non-contact fashion, but this is fraught with potential hazards for laparoscopy so that contact techniques predominate with this laser.

In dermatological applications of the laser the time frame for excess heat conduction can be measured in milliseconds. For general surgical procedures on other structures it's not that time sensitive, but the principle still applies. You know this intuitively if you pick up a too-hot coffee cup. You have to let go right away. If you keep holding it you're liable to be burned.

<u>Convection is the second method of heat transfer</u> and involves larger scale quantities of matter than conduction, such as seen in heating of gases and liquids in boiling a pan of water. It becomes important to laser and electrosurgery, because convection is what carries away the excess heat from the incision site through generation of steam (laser or electrosurgical plume). If either device is used to dissect in a manner which is too slow to allow ANY generation of steam (it doesn't need to be copious amounts, just enough to carry away heat), then heat will build up in the tissue and conduct into lateral tissues. This usually occurs when the laser or electrode is used at such painfully low powers that vaporization cannot immediately proceed, and the device just "wallows" and burns in tissue. Adequate power levels for clean vaporization will generate the required "steam envelope" around the device and carry away excess heat.

<u>Radiation heat transfer</u> is the primary mechanism of heat transfer for electrosurgical and non-contact laser modalities. This involves the transfer of thermal energy by electromagnetic waves. Materials don't have to touch to transfer heat this way. Heat may even be transmitted across a vacuum by radiation since it does not depend on the presence of matter. This is the essential mechanism of the non-contact lasers mentioned above. If a laser fiber is used "away" from the tissue, so that a high power density spot creates the vaporization, then it is said to be non-contact. If a laser fiber or contact tip is actually stroked through the tissue, in contact with it, then the heat of the fiber tip itself does the work and this is said to be a contact technique.

Radiation transfer means that laser beams contain no inherent heat in the light itself! They transmit only radiant energy. Heat is created only when the tissue absorbs the transmitted radiation and converts it to motion in its atoms and molecules. This is exactly the way a microwave oven works - only at different frequencies. Those lasers which rely on the "cautery" effect of a hot tip create the heat there when the laser radiation (semantics for light) is inefficiently transmitted from the tip - this inefficiency generates heat in the quartz or ceramic material of the tip. It can be a very effective and hemostatic cutting instrument.

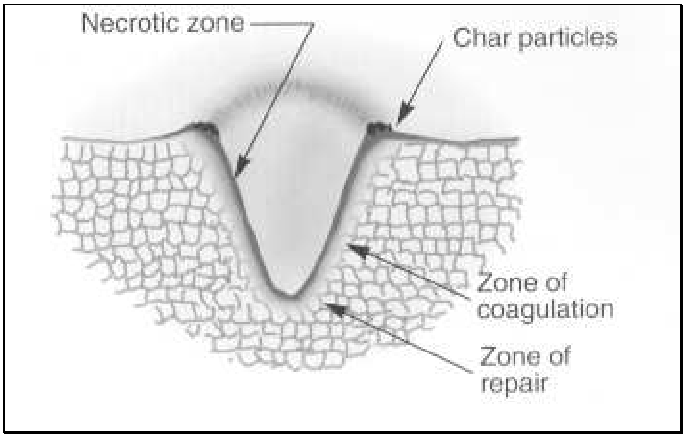
The last pertinent concept of heat and heat transfer is that of the heat capacity of an object. Heat capacity and specific heats of objects are closely related and have to do with how much heat is required to produce a certain temperature change. In other words biological objects of high heat capacity require much more heat to effect any given surgical effect. Highly vascular tissues have a higher heat capacity than other tissues, and consequently require higher laser powers, or larger contact tips, to effect the same surgical effects.

In Dermatology and Aesthetic procedures we talk about the “Thermal Relaxation Time” or TRT of tissues. This is explained more fully in our Aesthetic Laser Procedures home study course but basically means that smaller structures heat up more quickly and lose their heat more quickly than larger structures. For laser hair removal for instance, very fine hairs will require much shorter pulses at the same fluence in order to effectively beat the TRT of the hair and kill the follicle.

Now that we've seen what heat actually is and how it may be transferred, we can look at specific tissue effect characteristics of lasers.

CARBON DIOXIDE LASER - The Carbon Dioxide laser is absorbed highly by soft tissue independent of its color. The fluid absorbs the energy into a very small volume which heats rapidly to well above boiling. The effect is one of intense, localized heat that cuts or vaporizes tissue. At broader spots and lower power densities it may also be used to superficially blanch or coagulate tissue. At lower power densities still, so that tissue temperature is about 55-58 degrees C, it will "weld" thin walled tissues together such as small arteries and nerves. The weld is immediate and nondestructive. Other lasers are now being used more commonly to "weld" tissues. The 1.3u Nd:Yag laser has been commercially developed for this explicit purpose. It includes a computer database which presets the laser for various types of tissues. The argon laser is also being used to weld together tissue such as in arteriotomies on an investigational basis. The 2.06u Ho:Yag laser is another that has been used to "weld". It has even been shown that water, heated accurately to between 55-58 degrees C, will "weld" together thin-walled types of structures.

The CO_2 laser is considered a precision surgical laser because of its high degree of absorption in soft tissue with limited lateral damage. It is associated with cutting and vaporizing of tissue. It does provide some hemostasis but only against small vessels and capillary type oozing. Electrosurgical units are still required in most types of laser surgery.



The CO_2 laser produces an infrared beam of light of 10,600nm wavelength, and commercial units range up to 100 watts output. Depth of an incision is determined by both power density and time of application (how fast the stroke). Laser incisions are significantly less bloody than cold steel incisions. Even though a gray char may form at the edges of the incision, it is entirely superficial and can be irrigated away (Heavy black char indicates incorrect technique and applying the laser for too long. When cutting with the smallest spot attainable and using a superpulse type of beam, the char may be totally nonexistent). The lateral zone of damage extends less than 0.5mm from the incision compared with inconsistent streaks of 5mm to 1cm with electrocautery. Because of the precise localization of the CO_2 laser beam effect, as well as the sealing effects of the beam, surrounding tissue exhibits minimal edema, scarring or stenosis.

CLICK HERE to see a short video demonstration of the CO2 Laser

Technique is important in achieving these results. Cutting means using the smallest spot size attainable (beam in focus). Power densities will be reasonably high now at most any power so that the quality of the cut is not in question with a change in power (contrasted to vaporization). Power is now simply the speed of the incision. If you want to go faster - turn the power up. To go slower - turn the power down.

Whether used with a handpiece or through the microscope, when used for cutting, the focused beam is swept across the incision line. The depth of cut depends on how hot the spot (power density) and fast the stroke (time). The feel for this control of depth of incision is developed by practice - not much different than learning to use a sharp blade. It is important to maintain slight tension across the incision line when cutting with any laser. Even though the depth of incision can be seen, once the beam has penetrated the tissue or membrane, it instantaneously travels on to whatever tissue is behind it. For this reason, some type of backstop is used to prevent damage to adjacent tissue. Most commonly used are wet sponges or cottonoids for general packing and protection, and titanium rods or backstops for dissection.
The three parameters the surgeon controls are:

1. Power in Watts (set by the laser nurse)
2. Time of exposure (or how quickly the beam is moved)
3. Spot size (controlled by the surgeon in the field)

The CO_2 laser performs with the following order of suitability:

1. Cutting
2. Debulking (ablating)
3. Coagulate

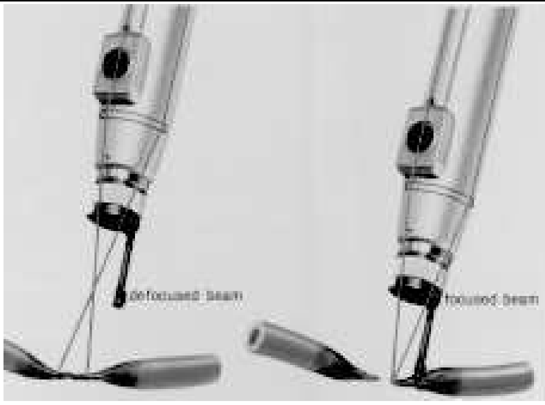
When used to cut or ablate tissue, the technique of using the highest power densities one can safely control is best. This usually means that high powers are used with 2-3mm spot sizes to debulk. This localizes the thermal damage at the impact site to its minimal level. Rather than using the laser on continuous at low powers, one can use significantly higher powers and a pulsed setting to provide better hand control. Superpulsing and Ultrapulsing provide such "clean" vaporizing beams, as do the computer scanning devices used with the highly focused beam. Ultrapulsing and/or scanning are also used in procedures such as the laser "skin resurfacting" for renewal of skin.

There are therefore no specific power levels to use for any given procedure, though there are some general indications of power levels used by different specialties. When the CO_2 laser is used to debulk tissue the spot is broadened and power increased to compensate.

CHANGING TISSUE EFFECTS OF THE CO_2 LASER

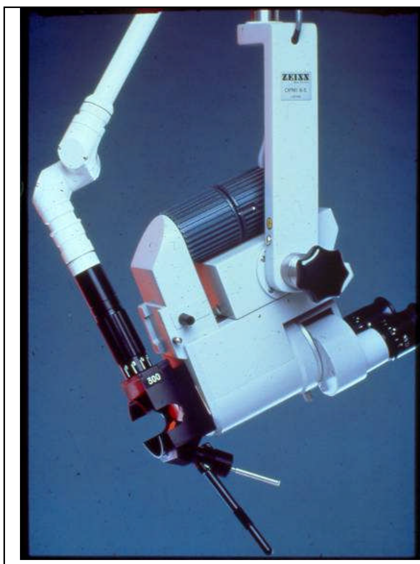
Cutting - When used to incise tissue, the smallest focal spot of the laser is chosen. Power from the laser then directly controls power density. One chooses a power setting that will result in a comfortable rate of incision. To go faster simply turn up the power, and turn it down to go slower. Since power density will still be relatively high with the small spot, the high or low power does not make much difference in the quality of the cut, only the speed and eye-hand coordination required to keep up. Traction and counter traction are very important to obtain a precise, clean incision.

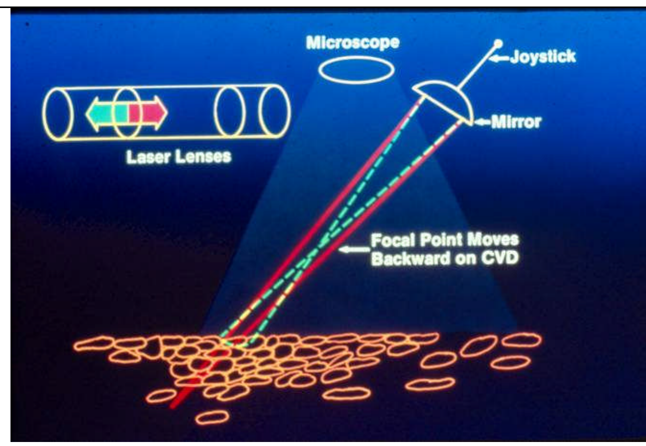
Vaporization - When used to vaporize or debulk tissue using broader spot sizes, the power no longer becomes the direct control over power density. Power density is the characteristic which the surgeon perceives as determining eye-hand coordination - not the power output as is frequently believed. When able to use spot sizes as large as 2-3 millimeters, the preferred technique is to set the laser to its maximum power output, then adjust the spot to obtain a controllable power density. This gives the best tissue effect. It is analogous to "painting" with a laser. When covering a broad area one would prefer a broad brush or roller. When painting a small area a very tiny brush is used. The broad spot makes it easier to maintain uniformity in tissue vaporization and reduces the total time of the procedure, resulting in less heat spread.



Larger defocused spots are associated with lower power densities and "cooking" or shrinkage of tissues. Smaller focused spots are associated with higher power densities and cutting of tissues

A quick and easy way to properly adjust the spot to this maximum power is done with a 0.1 second test shot in a tongue blade at the laser's maximum power. A micromanipulator on the microscope or colposcope gives the best control over the spot. As the laser is test fired the spot is gradually changed to give a scoop shaped crater in the tongue blade. Ideally it will look like a golf ball cut in half, with no pointed bottom to the crater. The point means the power density is still too high and will result in ridges, furrows and bleeding. On the other hand, too shallow a scoop will indicates too low a power density which allows for excessive time spent on the tissue and possibly char formation. This 0.1 second test shot will give a good, controllable "ballpark" setting which may then have to be slightly adjusted once the beam is on tissue.





The Micromanipulator provides superior control over spot size and power density. Moving the lens setting changes the spot sizes. At left, a CO2 Laser Micromanipulator is mounted to a Zeiss Surgical Microscope. These are used in procedures in ENT, GYN, NEURO and others.

If the surgeon still feels somewhat uncomfortable at the rate they must move their hands to keep up with the vaporization, the preferred control technique is to place the laser in a repeated gated pulse, or to pump the foot pedal. This is better than reducing the power of the laser. The preceding discussion of vaporization makes the assumption that spot size may be adjusted to achieve a controllable power density. In some applications, such as CO_2 laser laparoscopy, the spot size of the beam may be fixed by the lens in use. In this case the power of the laser becomes the only control over changing the power density, and one would not use maximum laser powers here.

When performing procedures like skin ablation for rejuvenation, many of these procedures are highly automated, with superpulse and ultrapulse settings providing the high peak power pulses, and scanners or pattern generators controlling the geometry.

MIDINFRARED LASERS:

Erbium:Yttrium Aluminum Garnet (Er:Yag), and Hydrogen Fluoride (HF) Lasers - The Erbium:Yag laser is now used in dermatology for facial resurfacing, and in dentistry. The HF laser has not yet seen much clinical use, but will in the future. These lasers produce an infrared output of light at approximately 2.94u. This wavelength is even more highly absorbed by water than is the CO_2 laser. Therefore the Er:Yag laser is more precise in soft tissue than the CO_2. For facial resurfacing it produces a much finer effect than the CO_2 laser, but doesn't handle deeper wrinkles like the CO_2.

An exceptional characteristic of these lasers is their ability to precisely cut through bone and other mineralized tissue such as tooth enamel. It makes an excellent bone saw with no lateral heat damage. However, this wavelength will not pass through standard quartz fibers. Other types of fibers are available but are still plagued by practical problems. It should be noted that although these specific lasers have these beneficial characteristics, in practice they are not used at all for these applications.

Yttrium-Scandium-Gallium Garnet (YSGG) – 2790 nm (2.7u) light is currently used for skin resurfacing. It's effects are in between that of the CO2 and Er:Yag lasers also used for resurfacing. As of 2007 only one company markets this type of laser, and it is under the trade name of the "Pearl" laser.

Holmium:Yttrium Aluminum Garnet (Ho:Yag) – (Please note that there is a "slight" variant of this in the Thulium:Yag Laser. Essentially they are the same thing and the difference in promotions is mostly marketing). The Ho:Yag produces light at approximately 2.06u which does transmit through standard quartz fibers, making it an easily usable medical laser system. The tissue effects are somewhat less precise than the CO2 laser, but not nearly as diffuse as the Nd:Yag laser. It allows for endoscopic access with a wavelength that is suitable for cutting and vaporization with reasonable hemostasis. Technically this wavelength will not transmit through fluid, yet its greatest use is in orthopedics for arthroscopy in a fluid filled joint. The Ho:Yag is a pulsed laser, typically providing 1-2 joules of energy per pulse from 10 to 20 times per second. This creates a tiny steam bubble at the end of the fiber tip under fluid in the millisecond time range. It is impossible to see with the unaided eye. This creates its own "space" where tissue cutting and vaporization can occur. It is excellent for cutting and shaping cartilaginous tissues hemostatically. The high fluence pulsed nature of the light creates a very clean vaporization and is effective on all cartilage - no matter how tough.

Erbium Glass (Er:Glass) – 1540 nm. This laser is used for a slightly different type of skin resurfacing treatment called “fractional ablation”. Unlike the CO2, Er:Yag or YSGG lasers, this does not ablate the entire surface. It creates thousands of little “pinhole” zones of coagulation called microthermal zones (MTZ) in the skin, when then heal from these small “pixels” outward. This wavelength does not transmit into the eye so is a corneal hazard rather than retinal one. Wavelengths small than this become retinal hazards.

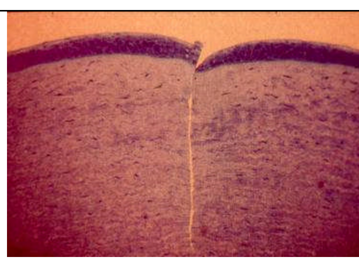
Nd:YAP Laser (Yttrium Aluminum Perovskite) 1340nm. A pulsed system from 5-30Hz (as of 2011). Can have thermal effects into photoacoustical (mechanical effects). Fiberoptically delivered.

EXCIMER LASERS:

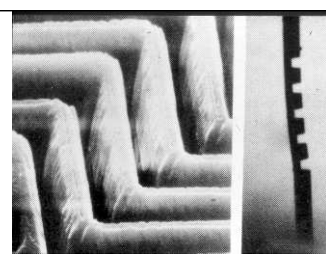
These lasers produce various wavelengths of ultraviolet light. Their primary use is currently in ophthalmology for reshaping of the cornea, but they will also see more use in cardiovascular catheterizations. A brief discussion of their general characteristics helps to summarize their potential tissue effects.

Excimers are high frequency pulsed laser systems. Many of the tissue effects attributed to wavelength are actually from the high peak power nature of the pulses. The resulting high fluence at the ends of fibers allows for a very precise, limited-thermal type of effect.

The short wavelength of the Argon Fluoride at 193 nm produces a cutting effect in biological tissue on a non-thermal, photochemical basis. It is theorized that the high energies in the ultraviolet photons cause organic molecular bonds in biological tissue to simply fly apart. This is a non-thermal cut that ophthalmologists may use to cut or sculpt corneal tissue with no heat damage or "puckering" of corneal tissue. This wavelength will not pass through conventional quartz fibers and is therefore not useful in current endoscopic procedures.



ArFl Excimer incision in human cornea. Note the lack of any thermal shrinkage or “puckering” at the wound edges.



ArFl Excimer sculpting of a human hair at right – note the square edges. Developed in 1984 at IBM to etch microchips in organic substrates

The 308 nm wavelength of the Xenon Chloride laser does pass through conventional quartz fibers and is being used in cardiovascular applications requiring catheter access. Though technically not as thermally precise as the 193 nm, the small spots at the tip of the fibers and high peak power pulses result in very precise removal of tissue.

The 308 nm excimer (ultraviolet) is also used in dermatology for the treatment of psoriasis, acne and other applications.

DIODE LASER SYSTEMS:

Diode lasers are semiconductor electronic devices, somewhat like a transistor. This type of laser produces laser light intrinsically and does not require the internal systems of gas or crystal types of lasers. They are very simple. Diode lasers may produce light of various colors, depending on the particular diode, but most produce infrared light of very low power - measured in milliwatts, or now up to a watt or so per diode. The development that is occurring is in the expansion of wavelengths to the visible light spectrum and power increase of up to several watts. Already, arrays of diodes have been joined together to produce infrared surgical units of up to 100 watts in power. These are used in conjunction with contact type fibers for hemostatic dissections or urologic procedures. Other low powered units are used as ophthalmic photocoagulators, or for Low Level Laser Therapy (LLLT), and in hair removal procedures.

The low power diodes are sufficient for ophthalmic use. The trend will be to replace the complicated and expensive ophthalmic laser systems with these portable (in a briefcase or smaller) lasers. Until a full range of colors are available however, they will not totally replace ion lasers for ophthalmology. They will also see use in photodynamic therapy as a light source to activate photosensitizing drugs.

Higher powered pulsed diodes are used in dermatology for hair removal.

GENERAL FIBEROPTIC SURGICAL LASER SYSTEMS:

ARGON - KTP - ND:YAG - HO:YAG

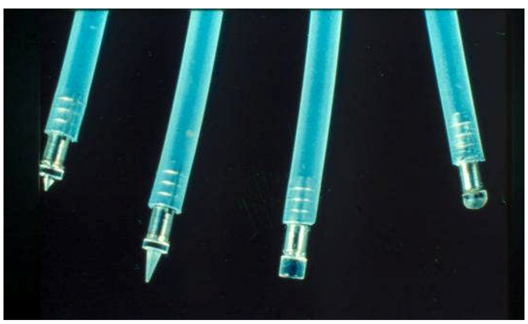
These lasers are delivered fiberoptically through standard quartz fibers (with the exception of Q-switched ophthalmic and dermatological systems), and medical units are available from about 15-100 watts of power. The fibers are from 0.2 mm to 1.0 mm in diameter with 0.6 mm (600 micron) being the standard size. When used at powers much above 20 watts, or with sapphire probes, they must be either gas or liquid cooled which requires a surrounding catheter of 1-2mm in diameter.

The laser beam diverges rapidly (10-15 degrees) from the end of the fiber on all of these lasers. This causes spot sizes to increase rapidly with the distance from the fiber and power densities to fall quickly. In effect, all tissue effects will occur within only 1-2 inches from the fiber tip. The spot is too large past this point to cause any noticeable effect. Cutting results from the high power densities just at the tip, vaporization within just a few millimeters of the tip, and photocoagulation from 1-2 centimeters from the tip. This is the advantage of a fiberoptically delivered system using non-contact type fibers. Many different effects are possible with a simple distance change of the fiber to the tissue. The small quartz fiber also allows easy endoscopic access for the laser.

Neodymium:Yttrium Aluminum Garnet Laser (Nd:Yag) - When used on tissue with a regular fiber, rather than a contact device, a deep tissue coagulation may be created of 4-6 mm in depth with the Nd:Yag laser. Limiting the delivered energy to about 20 watts for 1-3 seconds produces only 1 or 2 mm of coagulation. It is highly absorbed by dark tissue and may also be transmitted through fluid.

Sapphire tips or other contact fibers add to the versatility of a Nd:Yag laser. They convert the laser energy into direct heat energy of the sapphire allowing a direct "contact" type of procedure for cutting and vaporizing with limited later heat damage, unlike the effect from a bare transmitting fiber on the Nd:Yag.

At right is the type of widespread and deep coagulation one can get with the noncontact Nd:Yag laser, shown here on a piece of grocery store liver. Compare this with the short video segment of its use with a contact tip below.



CLICK HERE FOR A LAB TAPE DEMONSTRATION OF THESE CONTACT TIPS

Some controversy exists about whether the tissue effects of contact tips are due to pure heating of the element or to high power density laser light exiting the tip of the probes. Several characteristics of the sapphire tips seem to point to the direct heating effect and are briefly described:

<u>Sapphire "Contact" Tip Characteristics - Direct Heating:</u>

1. A lag time exists between the beginning of lasing and the onset of tissue effects. This allows for the heat to build in the probe.

2. "Virgin" clean probes must develop a slight blackening or discoloration of the material before the probe will work. The high power density theory would point to a better effect with a clean probe (like a clean lens). "Dirty" lenses absorb energy and become hot.

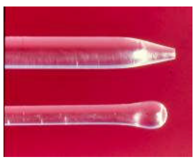
3. The lateral extent of damage is not determined by the power of the laser. Power determines only how quickly the probe works.

4. Probes burn up quickly when they are not in contact with tissue when fired. The excess heat has no tissue heat-sink to dissipate it and melts as a consequence.

5. Cutting occurs more quickly if the laser continues to fire while the probe is momentarily lifted from tissue. Upon contact, the rate of cutting is slightly higher than after its temperature stabilizes in tissue.

6. The probes may actually be seen to glow with heat as they are used. The Nd:Yag light is invisible.

Regardless of the mechanism of action, the results are the same. Sapphire tips, and shaped fibers in general, greatly expand the conventional uses of the Nd:Yag laser by enabling fine cutting and tissue vaporization in addition to the deep coagulation possible with a bare fiber.



Other types of fibers mimic this same cutting by the heating effect of the sapphire probes. These fibers have shaped tips - either sharpened or rounded. The transmission of light is from the fiber tip is severely impeded, resulting in high temperatures at the tip. They are used in contact with tissue, but don't burn up quickly like sapphires if fired off tissue. They cut with very limited lateral damage just as the sapphires.

Other uses of the Nd:Yag lasers include Q-switching to high peak power pulses for ophthalmology and dermatology. In ophthalmic applications, the laser pulse is at a tremendous peak power, which induces the small "spark" and cold cutting effect on membranes within the eye. In dermatology, the pulse is not at such a high peak power, but is still high enough to cause disruption and fragmentation of dye pigments within a tattoo. In Dermatology, the Nd:Yag laser is also sometimes frequency doubled to 532 nm green light (like a KTP laser) to go after vascular lesions.

ARGON, KTP LASERS & Copper Bromide - The argon (488 and 515 nm) and KTP (532 nm) lasers, though producing slightly different wavelengths and pulsing characteristics, create clinically identical effects for most practical applications. They are generally considered superficial photo coagulators (0.5 to 2.0 mm) but will vaporize tissue at sufficient power densities and may be used to cut if the tip of the fiber is drawn along the tissue. They do not require sapphire tips like the Nd:Yag laser since they will already cut and vaporize nicely without the extensive damage of the Nd:Yag. There are some technical differences in the absorption of the wavelengths by hemoglobin (KTP absorbs more strongly in hemoglobin). The Argon is a continuous wave laser whereas the KTP is a high-frequency pulsed system. Clinical effects are fairly identical. Power outputs of both units are about 15-18 watts maximum, and for this reason bare fibers are used with no external cooling gas required.

CLICK HERE to see the argon laser as used in ophthalmology

The KTP (Potassium Titanyl Phosphate) laser is technically a frequency doubled Nd:Yag laser. It directs the 1064 nm output of the Yag through a KTP crystal which changes the wavelength to 532 nm green light. The tissue effects from a transmitting fiber are hemostatic cutting and some vaporization. It shares no clinical characteristics with the Nd:Yag laser. Because the KTP has a Nd:Yag at its heart, it is possible to buy units that allow use of both wavelengths from the same laser.

The argon and the KTP laser are both used to "pump" tunable dye lasers used for photodynamic therapy. The Copper Bromide Laser (CuBr) emits both green at 511nm and Yellow light at 577nm. It is used primarily for aesthetic vascular and pigmented lesions.

HO:YAG LASERS - At around 2100nm wavelength, this is wavelength is the last of the medical infrared systems that will pass through a conventional fiber. Though they don't technically transmit through fluid, they may be used under fluid during procedures such as arthroscopy because the high energy pulse creates a momentary bubble of several millimeters through which the energy can work. They are used for arthroscopy, urology (lithotripsy & prostate ablation) dentistry and ophthalmology (lower power units).

AESTHETIC LASER & LIGHT BASED PROCEDURES

The discussion in this manual is general in nature, to discuss medical/surgical manipulation of tissues by lasers. We do have specific manuals available for Aesthetic Laser Applications including Laser Hair Removal, that discusses aesthetic tissue effects in more detail. Visit our website at http://www.LaserTraining.org .

THE LASER TRAINING INSTITUTE™

Professional Medical Education Assn., Inc

P.O. Box 522379 Marathon Shores, FL 33052

LASER COURSE POST TEST
- Laser-Tissue Interactions Module -
BIOLOGICAL EFFECTS

Name____________________________________Date_______________________

1. **The laser wavelength which is most highly absorbed by water is:**
   a. The Ho:Yag (Holmium Yag)
   b. The Nd:Yag (Neodymium Yag)
   c. The CO_2 (Carbon Dioxide)
   d. The He:Ne (Helium Neon)

2. **The laser wavelength which scatters most through tissue and causes the most diffuse coagulation injury is the:**
   a. The Ho:Yag (Holmium Yag)
   b. The continuous wave Nd:Yag (Neodymium Yag)
   c. The continuous wave CO_2 (Carbon Dioxide)
   d. The HeNe (Helium Neon)

3. **Which laser is a non-thermal instrument:**
   a. 308nm Excimer laser for cardiology
   b. 193nm Excimer laser for ophthalmology
   c. 2.9u Er:Yag laser for dermatology
   d. CO2 laser for skin resurfacing

4. **How does light from a free beam laser heat tissue?**
   a. light creates a "photo-effect" within cells to vaporize them
   b. light is absorbed by the tissues, which generates heat
   c. the laser beam is hot and heats tissues when it shines on them
   d. lasers all use cold-cutting capabilities with no heat generation

5. **The primary advantage of using pulsed laser energy on tissue is:**
   a. The procedure takes less time
   b. The procedure is better tolerated by the patient
   c. Thermal damage from the laser impact is more highly limited
   d. Reimbursement rates are better for higher pulse powers

6. **Sapphire or contact tips, when added to the Nd:Yag laser, change the otherwise widespread coagulation created by that laser to very precise effects, by**:

a. Acting as fine focusing lenses to increase power density

b. Acting as a thermal knife to convert laser energy absorbed by the tip, to conduction heat of the sapphire tip - a hot knife.

c. slowing down the procedure so that very low powers may be used

d. changing the wavelength so that laser now cuts

7. **The primary way to surgically change the tissue effect of any fiberoptically delivered laser (free beam) is:**

a. to move the handpiece faster or slower

b. to repeatedly have the laser nurse alter the power output of the unit

c. to keep changing the wavelengths of light emitted

d. to alter the distance of the fiber tip from tissue, thereby changing power density

8. **Identify the laser below which relies on acoustical shock wave formation to create its tissue effects:**

a. yellow light pulsed dye laser for dermatology, vascular lesions

b. Q-switch pulsed Nd:Yag laser for ophthalmology, "secondary" cataracts

c. CW Nd:Yag laser for urology,

d. Argon laser for ophthalmology, retinal photocoagulation

9. **Which laser application involves photochemical reactions, but does not involve either heat or shock wave generation from the laser:**

a. laser assisted prostate resection in urology

b. photodynamic therapy to treat cancer

c. yellow light pulsed dye laser use in dermatology

d. fragmentation of kidney stones by pulsed dye laser, green light

10. **Which of the following laser pulses exhibit the highest flux? (assume same spot sizes)**

a. 1.5 joules delivered in 400 microseconds - .0004 seconds

b. 1.5 joules delivered in 1/20 of a second - .05 seconds

11. **The use of low laser power, when combined with larger spot sizes, can create unseen excessive burning of adjacent tissues, especially if char is allowed to form.**

a. True

b. False

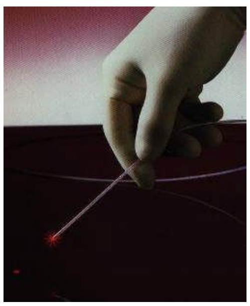
c. Irrelevant question, power & spot size do not contribute to burning

Medical Laser Safety
and
Credentialing Guidelines

GREGORY T. ABSTEN

(MR. ABSTEN HAS SERVED AS THE LASER SAFETY MEMBER OF THE BOARD OF DIRECTORS FOR THE AMERICAN SOCIETY FOR LASER MEDICINE & SURGERY, AND SAT ON BOTH THE CREDENTIALING AND SAFETY COMMITTEES, AND THE ANSI 136.3 LASER STANDARDS COMMITTEE).

BACKGROUND - STANDARDS OF PRACTICE FOR MEDICAL LASER USE



Medical laser systems provide a very useful modality of diagnostic, therapeutic and surgical use in medicine. Medical laser systems are almost all classified as Class IV devices which means they may be a fire hazard, produce skin or eye burns, or cause retinal damage from direct or reflected beams.

Operational and safety policies and procedures should be developed by each medical institution based upon general guidelines suggested by federal agencies and professional societies (ANSI, AORN & ASLMS). Lasers are not particularly hazardous provided that common sense and some easy to follow policies are practiced.

Few legal requirements exist which statutorily regulate laser "credentialing" or safety policies and procedures. However, prudence and legal precedents in litigation dictate that a formal approach be taken toward the establishment of these policies and procedures to ensure safe and effective use of these instruments. The specifics of the policies may then be tailored to each individual institution according to need.

There is a move from State to State to regulate nonphysician use of lasers for the increasingly popular aesthetic procedures. This varies with each state and is ultimately determined by the State Legislature and State Medical Board. Some states are setting up standards and mandated licensing of aestheticians, cosmetologists and Electrologists who become laser operators – primarily for laser hair removal, but other cosmetic use too.

There is only one cross-industry board that provides standards and proctored examinations for voluntary certification of laser operators, nurses and technicians. That is the **National Council for Laser Excellence** (NCLE), of which our nonprofit organization is a part. You may review the standards for laser certification at www.LaserCertification.org .

The basis for a formalized program of laser safety rests in the ANSI Z136.3 standards for safe use of lasers in health care facilities. ANSI does NOT have the force of law however, and is therefore not a legal requirement - they are voluntary standards. Practical concerns however dictate that these ANSI standards be implemented in hospitals because of the reliance of other enforcement agencies, such as OSHA or JCAHO, on these standards.

From a liability perspective, **it is more important that a formalized and documented approach to laser safety be taken, than the specifics of those policies.** It is our recommendation that the hospital safety policies be adopted around the ANSI standards as closely as possible, but do not hesitate to vary from these standards if informed judgment dictates.

Physicians are not legally "credentialed" by these policies to practice laser surgery, yet it is important that some credentialing guidelines be followed - for both physicians and the laser operators (nurses / technicians)

ORGANIZATIONS WHICH PROVIDE GUIDELINES AND/OR ENFORCEMENT

Several organizations provide guidelines that may be utilized to develop generally accepted standards for laser training and use.

O.S.H.A. (Occupational and Safety Health Administration) does have legal enforcement capability governing safety in the work place. Most of these are general in nature with the intent that every employer provide a work environment for its employees that is reasonably safe from hazards and provides appropriate protection and/or training to reduce any potential hazards. OSHA usually uses recommendations from groups such as ANSI or professional societies such as ASLMS to determine whether a safe work place has been provided for medical laser use. One problem which hospitals face is that OSHA enforcement may be brought about by disgruntled employees, and the OSHA officers may have very little knowledge of either laser or surgical practice. This presents situations where potential OSHA actions have little logical rhyme nor reason behind them, and the only thing the hospital can do is simply be diligent in having implemented a structured set of safety policies/procedures. The hospital's first obligation is to make sure that the measures instituted are in fact protective of patient/employee health in their own specific circumstance at that hospital. This may result in slightly different measures being taken at different hospitals.

OSHA enforces based upon ANSI standards, but their own handbook that is used to list these requirements is the OSHA Publication 8.1-7. This is an instructional handbook used to evaluate safe laser practices.

Three general levels of control are utilized by O.S.H.A., as recommended by ANSI to ensure employee protection.

1. Administrative control deals with items such as written policies and procedures for safe laser use. Make sure you have them. The details are not quite as important as the fact that you have a well thought out and written plan.
2. Environmental/Operational control deals with items such as selection of appropriate instrumentation, safety eyewear, placement of danger signs, etc..
3. Exposure controls, which are more appropriate to areas such as ionizing radiation or loud noise exposure on a chronic basis, deal with maximum permissible exposure (MPE's) limits to the light. Long time frame MPE's for laser light do exist for the work environment, but primarily deal with industrial units or long term chronic exposure - much more so than the intermittent use found in surgery. Even the class IV medical lasers in current use do not pose a practical chronic exposure problem provided appropriate eyewear is worn. It is critical however, that the MPE's for such class IV lasers NOT be exceeded, and that is the reason for protective eyewear.

Manufacturers of protective filters and eyewear take into account these MPE's when developing the appropriate level of protection into their filter materials. Detailed graphs of exposure limits and protection level are generally provided by these manufacturers and are ANSI required, though most medical applications are already well within the safety limits.

ANSI (American National Standards Institute), though having no legal authority, provides recommendations for safe use of laser systems, including medical applications. ANSI originally developed recommendations for safe laser use that primarily governed high powered industrial applications.

ANSI is a U.S. clearinghouse and coordinating body for voluntary standards on a national level. It is made up of trade groups, technical societies, professional groups and consumer organizations. ANSI has approved more than 10,000 standards, of which safe laser use is only one. These standards are widely used by governmental agencies, and by industry and commerce.

By nature of their significantly lower power outputs, and the degree of controlled access and education that already exists in most surgery departments, plus the requirements which medical laser manufacturers must meet, medical laser systems are inherently safer than their industrial counterparts. The ANSI Z136.3 standard for the safe use of lasers in health care facilities are revised periodically. ANSI Laser standards are available from the "Laser Institute of America (LIA)" who serves as the secretariat and publisher for these laser safety standards, or from Rockwell Laser Industries at www.RLI.com. The ANSI Z136.1 standard is the parent document to the ".3" health care facility one. The ".1" is the more detailed and technical document useful to physicists and engineers and generally applied in an industrial or scientific setting.

It is important to remember that these guidelines are still voluntary and do not have the force of law. However, some agencies such as OSHA do have the force of law and may rely upon these standards as their reference. Because of this and JCAHO's reliance upon these "voluntary" standards, they have essentially become the defacto force of law for hospitals, clinics and medical offices.

The **I.E.C**. (International Electro-Technical Commission) is a European based standards organization much like the American based ANSI, but this group is International in Scope. It has no authority over either users or manufacturers of lasers within the United States. From a perspective point of view it should be noted that standards that are adopted in this International Commission (including Laser Safety) are frequently incorporated into subsequent ANSI Laser Safety Standards.

The **I.A.L.A**. (International Aesthetic and Laser Association) was developed to pull together aesthetic/cosmetic laser providers of all types and sizes. They provide a unified voice for standardized training and credentialing, and actively work with lobbying efforts in U.S. States to ensure safe, consistent and fair licensing requirements. www.internationallaserassociation.org.

The **A.S.L.M.S.** (American Society for Laser Medicine and Surgery) is a professional society dedicated to the enhancement of scientific research, education and promotion of effective and safe laser modalities to medicine. Membership in this society is a definite asset to anyone in the medical profession with an interest in lasers. The ASLMS conducts an annual scientific meeting which presents papers on laser related work in all fields of clinical and research medicine. Preconference courses for the ASLMS are conducted in Laser Biophysics and Safety, Nursing, and various medical disciplines.

The ASLMS provides recommendations on appropriate laser training for physicians concerning credentialling issues. It provides the best medically specific recommendations governing laser credentialling and training. Membership includes a subscription to the professional journal "Lasers in Medicine and Surgery". Membership is available in the ASLMS to physicians, nurses, scientists and commercial members. Contact the ASLMS at 715-845-9283 for more information. http://www.ASLMS.org

The AORN (Association of Operating Room Nurses) publishes a "Practical Resources" guidebook on lasers for the perioperative nurse. While it is a worthwhile resource, we do not recommend using this as the sole source of laser safety information. It contains several recommended practices for the safe use of lasers, and an anecdotal collection of various sample forms and AORN articles on laser procedures.

The Joint Commission. (Joint Commission on Accreditation of Hospitals) is primarily concerned with quality assurance procedures. The specific items which they review upon onsite inspections may vary depending on the individuals comprising the onsite team. When reviewing documentation for surgical laser programs, they generally review the written policies and procedures, documentation of training and/or "credentialling", and documentation of periodic maintenance on equipment. Adherence to the ANSI standards should also meet all the requirements of JCAHO. One could previously count on announcement of inspections and reviews every 3 years or so. JCAHO now performs “surprise” inspections with no previous announcement, and they evaluate the facilities laser safety program based upon ANSI 136.3 .

The FDA (Food and Drug Administration), specifically the Bureau of Medical Devices and Radiological Health, is involved with enforcement of laser safety guidelines as it relates to the manufacture and sale of these devices in interstate commerce. The FDA also approves laser devices for marketing for specific medical applications. It is important for medical institutions and physicians to recognize that this control extends to laser manufacturers and not to hospitals or physicians. The Institutional Review Board (IRB) of a hospital, or its equivalent, reviews and approves internal proposals for medical/surgical procedures that are not in common practice and therefore considered investigational. Manufacturers also participate in an investigational program with the FDA in order to gain marketing approval on the laser for specific applications.

The FDA is therefore NOT involved with overseeing operational policies and procedures of the hospital's laser practices.

State and Local Regulations vary from one state to another. Users should become familiar with regulations, if any, in their state. Some of the states which have developed some type of laser regulation include California, Illinois, Massachusetts, New York, Georgia, Alaska, Virginia, Vermont, Alaska, Texas, Florida and Arizona. Most states simply enforce the ANSI Z136.3 standards. Also be aware that the question of medical licensure and permission to perform various laser procedures is an issue that is separate and distinct from general laser regulatory requirements.

CONTACT INFORMATION:

Laser Institute of America (LIA)
12424 Research Parkway
Suite 130
Orlando, FL 32826
407-380-1553
(Sells the ANSI standards, Z136.1 & Z136.3)

American Society for Laser Medicine and Surgery (ASLMS)
2404 Stewart Square
Wausau, WI 54401
715-845-9283
(Professional Medical Society for Laser Applications)

American National Standards Institute (ANSI)
1430 Broadway
New York, New York 10018
212-354-3300
(develops the ANSI laser safety standards)

Association of Operating Room Nurses (AORN)
2170 S. Parker Road
Denver, CO 80231-5711
303-755-6300
(publishes the LASER practical resources booklet)

FDA Center for Devices and Radiological Health (CDRH)
5600 Fishers Lane
Rockville, MD 20857
301-443-3403
(regulates medical laser manufacturers / sales)

Occupational Safety and Health Administration (OSHA)
Bureau of National Affairs
1231 25th St NW
Washington DC 20037
202-452-4200
(has enforcement capability to enforce ANSI standards as they desire)

The Laser Training Institute™ ,
a division of
Professional Medical Education Assn, Inc.
PO Box 997
Grove City, OH 43123
800-435-3131, 305-851-8081
www.LaserTraining.org
(this nonprofit group provides laser training for nurses, physicians, and technical programs for clinical engineers)

National Council on Laser Excellence
C/O Professional Medical Education Assn
PO Box 997
Grove City, OHY 43123
www.LaserCertification.org
Comprised of hospitals, laser manufacturers, service groups and nursing. Laser Certification for Laser nurses, Aesthetic Operators and Repair Technicians.

PHYSICIAN CREDENTIALLING AND LASER PRIVILEGES

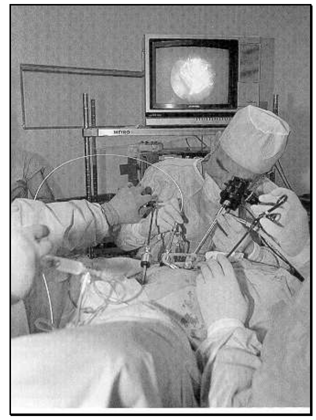
The most serious safety concerns of laser are not due to inherent hazards of the lasers themselves. They are due to inappropriate medical/surgical technique and errors in medical judgment in their application. An example would be the use of very low power densities with the CO_2 laser which would create charring and extensive lateral conductive thermal damage.

Quality hands-on training for the surgeon is the single most important factor in the safe use of laser instrumentation. A skilled and knowledgeable surgeon achieves good results safely with whatever tool they choose to use.

Acknowledging that there is no specific legal requirement for laser Credentialing of physicians, it is a standard practice to grant laser privileges within a hospital, based on evidence of proper training by the submitting physician. To not do so would breach any legal defense should litigation arise.

Most generally a laser committee is formed to review applications for laser privileges, among their other functions. This might be an ad-hoc committee which reviews the applications and makes recommendations for approval to respective department chairman, the surgical committee, or the hospital executive committee.

The complicating factors in granting laser privileges is that so many types of lasers are now available, and being used for procedures which should themselves be the subject of internal credentialing (ie: extensive pelviscopic surgery). The hospital should then develop a mechanism whereby privileges for procedures themselves are granted, and privileges for wavelengths of lasers added to these privileges.



For example, even though a physician may be "laser credentialed", they would not be performing laser procedures for which they were otherwise not credentialed to perform. A physician should not be granted privileges for pelviscopic surgery based solely on laser training, unless that training is coupled with instruction in pelviscopy and they meet any other hospital requirements for performing pelviscopy.

As an example in gynecology, many institutions stage the level of laser credentialing to progress from colposcopic and external application, to basic operative laparoscopy, to more advanced laparoscopic procedures.

Basically, a physician should have received an 8+ hour course in the use of the wavelength of laser for which they are applying for privileges. This basic laser training course is broken down into three primary components, and committees should review the application to determine whether these components have been addressed in the course or by self study.

The first component of a course is didactic presentations on principles of laser use and safety. This covers basic theory, surgical techniques of laser control, and a comparison of the tissue effects of various lasers.

The second component is clinical presentations in the physicians own specialty, and taught by another physician in that specialty. In other words a gynecologist should not be credentialed solely on the basis of attending a laser course that was designed for general surgeons. The clinical material should include indications, contra-indications, techniques and case presentations.

The third component of a laser course is a hands-on session with the specific types of laser(s) to be used. Very few courses actually teach laboratory sessions which include all of the available laser types. The credentialing is granted for one or more initial laser types, with additional types added as physicians receive incremental training in those units.

The labs consist of practice on inanimate materials, and many programs may also include live animal laboratories where appropriate. The laboratories should be designed such that each participant receives adequate hands-on time with the laser.

For those wishing to conduct on-site laser training programs for physician staff, our nonprofit organization can provide such training in any specialty.

Physicians are licensed to practice medicine by virtue of their medical licensure, and hospital privileges to practice surgery are extended by the executive committee of the hospital. The hospital's board of trustees ultimately assumes the responsibility for extension of these privileges including those of laser use. In this sense, laser is no different than any other surgical tool that the physician may wish to utilize. No statutory legal requirement dictates that they be so credentialed. Lack of such internal credentialing standards however may lead to serious deficits in any medical-legal defense if such situations should arise.

The reviewing committee should allow for a course length that suits the intended objectives. A course in general surgery and cholecystectomy might require a minimum of two days, while a specific course on the Ho:Yag laser for arthroscopy can be easily accomplished in one eight hour or less course. Hair removal experience could be gained in shorter sessions but over several days with many patients.

After initial laser credentialing, physicians should be allowed to add other types of lasers to their privileges simply with evidence of some additional training on that wavelength, and not have to repeat extensive courses for each laser they wish to use. This assumes however that they are not also performing additional types of procedures. A laparoscopist, already credentialed and proficient in the use of the CO_2 laser intra-abdominally, should be allowed to use a Nd:Yag laser laparoscopically with evidence of only some incremental training on that unit. The same would not be true for a colposcopist, trained and credentialed in the use of the CO_2 laser, but not currently performing laparoscopies. They would require more extensive work with the Nd:Yag laser AND in laparoscopy.

After formal laser training has been received and evidence submitted to the committee, a preceptorship for a minimum number of cases is usually required before full laser privileges are extended. This might be done with another physician in the hospital, already laser credentialed, for a couple of cases. More useful, though not required in most institutions, is for the physician to scrub in with another experienced physician for the types of cases they wish to perform. This would occur over a couple days or more and is actually more like a post-graduate mini-residency program.

Sometimes there are circumstances which should allow for special considerations in granting laser privileges. These mechanisms should be designed into the credentialing policies. Applicants for laser privileges who have not met the formal training requirements should still be granted privileges if they can show that they otherwise are knowledgeable in the proficient use of the concerned laser(s). There are several possible mechanisms for this.

A letter from a department chairman during residency or fellowship which states that the applicant has received adequate training in the program, and recommends them for laser privileges, should be acceptable evidence. This scenario will become increasingly more common as residency programs integrate laser use in training without any separate and formalized laser programs.

Initially, physicians using lasers early on were self taught and spent dedicated laboratory time to develop these skills. This should still be an acceptable alternative, especially for newer wavelengths or procedures, as long as the committee can validate the dedicated laboratory time. It should also include a thorough review of the clinical literature and theory of laser use and application. An applicant for privileges should be specific about why they believe their actions have met the intent of the credentialling policy.

Some long term laser users are quite safe and proficient, but never received any formal laser training. At their own institution they might simply be grandfathered in as the credentialing policy is adopted. When trying to obtain privileges elsewhere it could become a problem. The committee should accept, as evidence of suitability, publications in accepted medical literature by the applicant which indicates laser knowledge and clinical experience.

LASER NURSE / TECHNICIAN AND LSO CREDENTIALLING AND CERTIFICATION

Like physician credentialling, no hard and fast legal requirements exist for laser credentialling of nurses and technicians, but the National Council for Laser Excellence (NCLE) does offer voluntary Certification standards for those with the experience and training prerequisites, and who take and pass a proctored examination. Details are found in the Laser Certification handbook at www.LaserCertification.org . ANSI does discuss the need for such "internal" credentialling, and OSHA and JCAHO will look for such certificates or letters as evidence of training. Some states such as Florida, as they begin to regulate aesthetic laser use, make mention of requiring some “national laser certification” as part of the licensing process, and these NCLE Laser Certifications will meet that requirement.

Recommendations for training of both laser nurses, safety officers and other perioperative personnel are outlined in the ANSI standards described later in this section. For laser nurses / LSO's they generally include didactic presentations on laser basics and safety, and hands-on work with the hospital's laser systems.

Because commercial medical lasers are already classified as to level of safety hazard (Laser classes I-IV), Laser Safety Officers (LSO) do not need the more lengthy training involved with technical measurement of safety hazards and resulting classification of systems. Since the systems are already classified, the LSO may dispense with the mathematics of such calculations and instead simply apply the standards as recommended by the manufacturer of the laser involved, or implement the policies as suggested in this section.

THE LASER SAFETY PROGRAM

It is notable to point out that most of the serious patient injuries or deaths resulting from laser related procedures (fortunately not common) are not due to malfunctions in equipment. Most are due to errors in use of equipment or surgical technique during the procedure. This reinforces the importance of quality training for physicians and nurses. From the actual laser hazard viewpoint, the emphasis on real world hazards lie in potential eye injuries and ignition of drapes or ET tubes. An exception is for the service technicians who work on the equipment. The electrical hazards are the greatest for them.

An excellent review article on Laser Safety, by David Sliney Ph.D., is published in the journal LASERS IN SURGERY AND MEDICINE, Vol. 16, Number 3, 1995 by Wiley-Liss publishers.

It is important to have a laser safety program from the very beginning. Your program should be established before the first laser is brought into the hospital.

The first step in the safety program is the establishment of the laser safety committee. Essentially the purpose of this committee is to oversee all the laser activity within the hospital. This will be the group responsible for establishing and enforcing the policies and procedures for laser use. They will monitor the safety aspects of the program and investigate any accidents should they occur. Credentialling of physicians will be one of their primary responsibilities as well as the assurance that ongoing training is provided health care personnel. The responsibility for administering the laser safety program is delegated to the appointed Laser Safety Officer. They are responsible for monitoring and overseeing the control of Hazards (See ANSI Z136.3, 1.3 and 5.1.1)

All institutions should address in writing the following areas of development of their policies and procedures for laser:

1. Establishment and function of the laser safety committee
2. Physician credentialling standards
3. Nursing / Technician / Laser Safety Officer Credentialling standards
4. Specific laser safety practices for patients and personnel (ANSI section 4)
5. Routine laser maintenance provisions, whether by the hospitals biomedical department, or by manufacturer or third party service agents.
6. Start up and shut down check lists for the lasers
7. Laser personnel job descriptions
8. Education and training for personnel (ANSI section 5)
9. Medical Surveillance of personnel (ANSI section 6)
   (eye exams are no longer a requirement of ANSI)
10. Emergency procedures
11. Appointment of the LASER SAFETY OFFICER by the Administration

Whether developed as separate policies or incorporated into the ones listed above, the following additional areas should be addressed for smooth operation of the program:

1. Documentation
2. Patient Education
3. Consent forms, where special ones are indicated
4. Scheduling of the equipment for surgeries
5. Quality assurance

Though not an exhaustive list, this should be a catalyst for the hospital's own ideas. Existing policies should be reviewed periodically and updated according to need. The most important aspect of this is that laser policies should be consistent throughout the hospital and from department to department. Policies should be as comprehensive as possible so that they may accommodate a wide variety of lasers and applications as they develop, without being unnecessarily restrictive. They should be reviewed for compliance with ANSI recommended standards, but may vary when indicated by informed judgment.

Safety guidelines are not meant to blindly replace informed judgment. Though specific details may be inserted into the policies, blind adherence to policy in a "cookbook" type of approach is not recommended in lieu of an understanding of actual laser risks and hazards. This is one of the reasons that a limited number of nurses or technicians should be selected to receive thorough training in lasers and operation of the equipment, and the reason for a dedicated Laser Safety Officer. Rotation of laser duties among all of O.R. personnel is not recommended.

The Laser Safety Officer is THE key position in the safety program. This person will have the responsibility of ensuring that the safety policies are enforced in every procedure. The laser nurses and/or technicians operate as extensions of this safety officer and under their authority. This person will be the functional interface between the laser safety committee and the real world application of the laser equipment. It is generally assigned to one of the more senior, or better trained, Laser Nurses, but more frequently now may include a clinical engineer, technician or sometimes even a physician.

Though physicians or administrators may assume this position, it is recommended that a laser nurse or biomedical engineer be assigned the responsibility of Laser Safety Officer. Under their authority, the laser operators must be assertive enough to turn off a laser if unsafe practices are occurring, and be backed by the safety committee and/or hospital administration – although the only authority provided by ANSI in this regard is to inform the operating physician of an imminent safety hazard.

ANSI Z136.3 SAFE USE OF LASERS IN HEALTH CARE FACILITIES

The following is a synopsis as of March 2005 of the 2005 ANSI Z136.3 guidelines for the safe use of lasers in health care facilities. Readers are encouraged to purchase current copies of the ANSI standards (Z136.1 and Z136.3) from the American National Standards Institute. New 136.3 standards are being released in 2011 as this manual is revised.

The content included here is in the form of ***editorial comment and synopsis*** and does not purport to review or reproduce this ANSI document. It summarizes it in a nutshell. You need an original copy though. This highlights some of the points which the author judges appropriate, and discusses the pertinent changes from its previous 1996 edition. The interpretation of the ANSI standards is based on the professional opinion and experiences of the author from over twenty five years experience in the medical laser field, and is not represented as formally portraying the opinions (if any) of the ANSI committee. ANSI section and paragraph numbers are noted in parenthesis for reference when appropriate. You MUST have a copy of the pertinent ANSI standards if you are a health care facility utilizing lasers.

It is important to note the nomenclature used in the ANSI document. Where the word *SHOULD* is used, the standard is recommended but not required to be in compliance with the standards. Where the word *SHALL* is used, adherence to the standard is required.

In this review we have highlighted changes from the previous versions of Z136.3 by indicating a "*CHANGE: or ADDITION:" in bold letters outside the margin, and/or *italicized* the wording which has changed.

Several abbreviations are useful to note up front. These include:

- HCLS - Health Care Laser System
- HCF - Health Care Facility
- JCAHO - Joint Commission on Accreditation of Healthcare Organizations
- LSO - Laser Safety Officer
- MPE - Maximum Permissible Exposure
- NHZ - Nominal Hazard Zone
- OSHA - Occupational Safety and Health Administration
- SOP - Standard Operating Procedure(s)

ANSI Z136.3 - 2005:
American National Standard for the Safe Use of Lasers in Health Care Facilities.

General Note about the 2005 Revision: There has been some rewording of sections, shifting of material from one section to another, and renumbering of sections. These have not really affected the content and won’t be highlighted here much. Our emphasis is on a synopsis of each section and notation where there has been a change in substance from the last revision.

SECTION 1. GENERAL

This sets out the scope of the ANSI standards, talks about hazard classifications and delineates the responsibilities of the Laser Safety Officer.

1.1 Scope. It does indicate that the measures outlined in these standards are in no way intended to limit or restrict any type of medical/dental laser use which is under the direction of qualified health care professionals. The ultimate responsibility for the safe use of laser systems is left with these individuals. This provides the authority for any variance from these standards which health care personnel determine through informed judgment.

***CHANGE**: 1.1 Scope: A couple changes in wording were added in order to clarify the fact that these standards apply in ANY health care setting – even aesthetic, as follows: *"… or any HCF where the laser is being used to treat people. The control measures of this standard apply to all facilities where laser radiation is applied to individuals for recognized health care procedures or for claimed salutary or aesthetic beneficial effect."*

Additional wording was also added that operating manuals must contain adequate instructions for Calibration of Class 3 & 4 lasers (from Code of Federal Regulations).

1.2 Hazard Classification Scheme. Laser Hazard Classifications are discussed, and reference made to ANSI Z136.1 as the parent document to ANSI Z136.3 for health care facilities. This classification scheme is based primarily upon the laser's ability to cause damage to eye and skin. A small change in wording was made to reflect that it's the human access to radiation during operation that determines class.

1.2.1 Laser Hazard Classification. The manufacturer's labeling of the laser class of their product (all medical lasers have this if they are in routine commerce) will meet all of the classification requirements of the ANSI standard. This eliminates the need for detailed measurement and mathematics by the Laser Safety Officer (LSO).

Should the classification level change because of engineering or service changes to the equipment, the LSO is responsible for determining the resulting new class. This is a rather uncommon occurrence and would generally be involved with intentional modifications of the equipment. If so, other sections of the standard describe the basis for classification.

***CHANGE & ADDITION:** The Classes of Laser Systems were slightly changed in the previous revision of the 136.1 document. For this reason ANSI added a very lengthy paragraph to this section that describes the differences in the new classes.

Most medical lasers are classified as Class 4 systems, and as such will be subject to both control measures (operational safety policies & procedures) because of eye & skin burn hazards.

1.2.2 Federal Regulations, and;

1.2.3 Non-governmental Controls

Talks about the roles of the FDA, CDRH, OSHA and JCAHO.

***ADDITION:** An addition was made to point out that there may be other State & Federal requirements (Many states are starting to license non-physicians for cosmetic laser procedures)

1.3 Laser Safety Officer (LSO).

1.3.1 General.

This section is a general job description for the LSO: *"The LSO shall effect the knowledgeable evaluation and control of laser hazards by utilizing, when necessary, the most appropriate clinical and technical support staff and other resources."*

***ADDITION:** Stronger wording was utilized to state that the LSO manages the laser program: *"The LSO is authorized by the HCF administration and is responsible for monitoring and overseeing the control of laser hazards."* It also added wording to clarify that the duties described by ANSI will be carried out by the LSO either directly or just ensuring that the task is accomplished.

1.3.2 LSO Specific Responsibilities. Very importantly, the duties of the Laser Safety Officer are spelled out here. These include all of the following items:

- Hazard Classification: Ensure that is labeled according to its class by the manufacturer or the LSO will have to determine the class. They added wording to ensure that the LSO affixes the proper label to the laser if it was not done by the manufacturer.

- Evaluation of Hazards: This includes an overall assessment of the designated treatment areas and the people who work in them. The additions to the wording relax the LSO's assessment of the environment a bit by allowing them to use recommendations of the manufacturer and considering where the laser is used and by whom.

- The LSO is to notify the user of imminent hazards.

- Ensure that control measures are implemented (safety policies and procedures). This includes the authority for deviating from the ANSI guidelines where informed judgment and the specific circumstances of the hospital may dictate. It also provides for periodic review (a safety audit) of the control measures.

Wording was added to give the LSO more flexibility in determining control measures by asking the manufacturer "*or as determined by the LSO*".

- Ensure that all of the approved administrative and procedural control measures are actually followed in practice. This may include all of the standard safety policies and procedures, and other procedures such as documentation of routine laser maintenance or use of laser checklists.

- Ensure that protective equipment (glasses, smoke evacuators, barriers, special ET tubes, etc.) is provided and properly used. This may include recommendation or approval of all such equipment. We believe this to be one of the more important "police" functions of the LSO.

- Ensure that the proper laser warning signs are in place prior to laser use, and make sure that the laser equipment is properly labeled.

- Ensure that periodic maintenance SHALL be carried out by qualified technicians, and approve the facilities (laser room) and lasers prior to use.

***ADDITION:** 1.3.2.8 Facilities and Equipment. Wording has been added regarding the LSO ensuring service, *"and assure that the records of this maintenance and service are maintained."*

- Ensure that Laser Safety Education and Training is provided to ALL personnel. These requirements are further delineated in section 5.

- Establish the staff categories for medical surveillance (eye exams) of personnel, which are now OPTIONAL and NOT REQUIRED.

***CHANGE:**

1.3.2.10 Medical Surveillance. Adds the qualification about the LSO determining the personnel categories for eye exams *"IF the HCF requires medical surveillance of health care personnel."* This is now a major change in that these eye exams are no longer a requirement of 136.3 .

1.4 – CHANGE IN TITLE:

Changed from "Small Medical Clinic" to "Non-Hospital Environment".

Further clarifies that these standards apply to ANY health care type use of equipment on people whether it's argued it's a small clinic or not.

***CHANGE:**

1.4 Non-Hospital Environmnent. Previously ANSI recommended that the professional user assume the role of LSO, but now they call them the "user" and *"This user SHALL assume the administrative responsibilities of the LSO."*

1.5 DIAGNOSTIC HEALTH CARE LASER SYSTEMS

This discusses the fact that many pieces of Health Care Equipment may have lower classes of lasers in them that do not require any additional controls.

SECTION 2: DEFINITIONS.

Please see the accompanying "Encyclopedic Glossary of Laser Terms" in this "Lasers in Medicine & Surgery" manual for a more comprehensive glossary than that found in ANSI. However, ANSI did make some additions to their Definitions which are worth pointing out:

***ADDITIONS:**

Laser Assistant – a person responsible for setting up the laser prior to use or who operates the console to control the laser parameters under supervision of the user. See also laser operator

Laser Operator – A term with more than one meaning within the medical laser community. 1) The person controlling the application of laser energy to the patient, for the intended purposed of the HCLS, and within the scope of their practice, training, and experience. This is the common meaning of the term "laser operator" when the laser operation is entirely under the control of the surgeon and no assistance is required, and is usually assumed by mfgs, when the HCLS operator manual is written. See laser user. 2) The person who operates the laser console to control the laser parameters under the supervision of the laser user. "Laser operator" is commonly used in this sense in an operating room environment, especially by nursing, and allied health care staff. See laser assistant. The term "laser operator" is not used in this standard because of the potential for confusion with the terms "laser assistant" and "Laser user".

Laser Treatment Controlled Area (LTCA) – an important addition was made to this definition as follows: *"In a large room, a limited LTCA can be designated if clearly marked and controlled"*. This is the first time that ANSI has acknowledge that an LTCA does not have to be established in some circumstances for an entire room. (Not to be confused with the NHZ either, which also does not have to be designated the entire room.

Laser User – a person who is using the laser for its intended purposes within the user's scope of practice, training and experience. Also termed *laser surgeon* when appropriate.

SECTION 3: HAZARD EVALUATION AND CLASSIFICATION

This is a general section which discusses the overall determination of whether a laser hazard exists. It includes the laser class (1-4). Significant wording was added to this revision that reviews the classes of lasers as revised in the 2000 136.1 revision. It does talk about modifications of equipment and the need for the LSO to assess the hazard with a possible reclassification of equipment.

There were additions here give the LSO greater flexibility in creating a small NHZ within the room in contrast to making the entire room a NHZ as follows:

***ADDITION:**

3.4.1 The Nominal Hazard Zone

"The Nominal Hazard Zone of the HCLS shall be provided (for free space) by the HCLS manufacturer. The HCLS may be equipped by the manufacturer with alternative delivery systems, each of which will have its own NHZ. Thus, the LSO shall assure the NHZ for each and every alternative delivery system is known."

***ADDITION:**

3.4.2 The Laser Treatment Controlled Area (LTCA)

I won't quote the entire section but this new definition makes it clear that the LSO may choose to make the NHZ a very small area and not the entire room as shown in these excerpts:

"The extent of the NHZ shall be indicated by the LSO if the entire LTCA is not declared as the NHZ …"

"… generally arise from the use of lasers with very small NHZ's such as ophthalmic "

"If the NHZ is very small it may be possible to define the LTCA as a region of a large room … "

This is the very first time that a provision is made for making the LTCA an area of a larger room, rather than the entire room in which the NHZ is contained.

3.5 Personnel who may be exposed.

Essentially says that the presence of people can alter how the LSO assesses the hazard and can act accordingly.

SECTION 4: CONTROL MEASURES

This discusses the procedures (safety policies and procedures) to minimize laser related hazards. This is the practical "heart" of the ANSI document for perioperative personnel. It reviews the various types of control measures (such as administrative, equipment, treatment areas, etc.). It talks more about the Nominal Hazard Zone (NHZ) and the "bread & butter" safety aspects such as protective eyewear and control of the laser room.

Many of these specific concerns are addressed in the accompanying section on Sample Policies and Procedures (Lasers in Medicine & Surgery manual). Because of the importance of this section we will also review some of the key points here.

Ancillary hazards are stressed. These include potential dangers in areas such as electrical servicing, gas embolism, ET tube fires, laser plume (airborne contaminants). Section 7 addresses these non beam hazards in more detail.

***CHANGE:**

<u>4.1.1 HCLS Used in Research.</u>

This discusses the fact that research labs shall comply with 136.1 – 2000 and NOT these 136.3 standards. However, a big change in the wording was added to clarify the type of lab as *"In non-clinical research laboratories…"* Most hospital based labs ARE clinical research labs and would now still be under the 136.3 .

<u>4.2 Administrative Controls.</u>

Administrative controls: This includes the authority for the LSO to oversee safety measures, and provides for the establishment of standard operating procedures (sop). It also allows the LSO to delegate specific responsibilities. **The authority for the LSO is provided in this section where it says that "an LSO SHALL be appointed to effect administrative controls . . ."**

A clarification in wording was added to the revision to indicate that the facility *"shall"* establish SOP's, and they went on to recommend that they *"should"* include things like perioperative checklists.

***CHANGE**:

<u>4.2.1 Standard Operating Procedures</u>

The previous standard required that all the SOP's (and much other paperwork) be maintained directly with the laser. The rewording says "*These operating and maintenance SOP's shall be maintained and readily available."*

It also goes on to talk about the LSO requiring safety SOP's for servicing of the lasers.

<u>4.2.2 Manufacturer's Procedures.</u> This section indicates that *"the LSO SHALL require written operating and maintenance procedures from the manufacturer or distributor of the HCLS."* These are to be updated and maintained by the LSO for reference. Author's note - - the Code of Federal Regulations also require that manufacturer's provide the service manual to anyone "upon request", at the reasonable cost of production.

***CHANGE:** The previous wording to require Service manuals from the manufacturer was deleted, as well as the reference of keeping these manuals directly with the laser.

<u>4.2.3 Authorized Personnel-Laser Operators.</u> This is the authority to ensure that the laser is operated by a specially trained, laser operator. It states that *"the HCLS SHALL be operated by facility authorized personnel appropriately trained in laser safety."* Section 5 on training is referenced.

4.2.4 Maintenance and Service. This requires that the LSO provide for such maintenance and ensure that it is provided only by technicians trained in such service. This might be provided by the laser manufacturer, third party service agents, or the hospitals' own clinical engineers if properly trained. (The Laser Training Institute - our laser training division, provides such training for clinical engineers that meet ANSI recommendations – www.LaserTraining.org)

4.2.5 Procedural and Equipment Controls.

Procedural controls (such as dedicated operators, use of anodized instruments, etc.) are to be determined by the LSO and SHALL be used. The standard lists some of these controls which are now to be used unless specifically stated that it's optional. -- See the accompanying section in the "Lasers in Medicine & Surgery" manual on Sample Policies & Procedures.

***CHANGE:** The previous version said the controls "may" include, but the 2005 version simply states "These include controls).

***CHANGE** – An entirely new section 4.3 on EQUIPMENT CONTROLS was added. Most of this material had been incorporated elsewhere in the previous standards, but they've now been made their own stand alone section.

4.3.1 Guarded Switch.

Requires that a guarded foot/finger switch be used with the lasers. When multiple guarded foot pedals are used with other instruments this standard requires that precautions be taken to prevent accidental firing of the laser. Though they are no more specific than this, it is generally held that the laser foot pedal will be kept separate from the others (microscope & ESU usually), and that only the operating surgeon have control over this laser foot pedal.

4.3.2 Accessory Equipment

Requires that accessories be compatible with the lasers and retain the required degree of laser safety. This addresses scanners, handpieces, micromanipulators, endoscopic safety filters, etc.. It also addresses the use of filters on certain scopes such as operating microscopes, lending further support to the LSO allowing the operating physician to forego safety eyewear, in lieu of protective filters on scopes.

4.3.3 HCLS Warning Labels.

Requires that the medical lasers be properly labeled. This is a requirement of the manufacturer and their required labeling (such as output apertures, wavelength, etc.) will satisfy this requirement. However, the LSO should ensure that this manufacturer provided labeling is not removed or covered on the lasers.

4.3.4 Service and Repair of Laser Systems (all classes)

Laser Maintenance & Repair: The LSO will determine whether any changes in the control measures are required after servicing of the equipment. Under ordinary circumstances no change will be required -- if the laser was simply repaired or serviced back to its original configuration and operation. Service calls are typically accompanied by a service report and acceptance back into service, which should satisfy the documentation requirements to show that no change in control measures are required. If the laser must be temporarily modified or altered (sometimes this is done to make a laser functional while waiting on a special part or repair), then the LSO should confer with the service technician to determine what, if any, changes in control measures may be required to ensure the safe operation of the unit.

***ADDITION:** 4.3.5 Equipment Modifications

Wording was added to include *"software"* changes from the manufacturer that may require changes in safe operating procedure. Further strong wording was included to reinforce the fact that modifications to the equipment, including delivery systems, may make it difficult to anticipate changes in a safe environment, and the LSO must consider this.

4.3.6 Facility and Equipment Safety Audits.

Safety Audits: The LSO shall supervise a safety audit of the facility and equipment. An audit of once per year is recommended. The wording of "supervise" leaves open the option of using outside consultants to conduct such safety audits, or to delegate the function to someone else internally. It will assess items such as eye protection, barriers, smoke evacuation, warning signs, room control, laser interlocks, labeling, safety policies, medical surveillance (if done), etc..

***Change:**

Title change in 4.4 from LTCA and NHC, to Laser Use Environment.

4.4 Laser Use Environment.

The Nominal Hazard Zone (NHZ) and Laser Treatment Controlled Area: The NHZ is that area where the laser is intense enough to create hazards to personnel (it is assumed that the patient is ALWAYS in the NHZ). This section was significantly expanded in the revision to give the LSO more flexibility in determining the size of the NHZ and any control measures required.

Some of the added wording includes " *… environment influences the choice of the most appropriate control measures …. LSO may require additional control measures … may determine that some control measures in Section 4 are not required .*"

4.4.1. NHZ

The LSO will determine the NHZ by info supplied in the manufacturers labeling, measurement, an appropriate analysis, or equivalent assessment.

***CHANGE:** The wording has been changed somewhat to indicate that sometimes when the NHZ is very small – some of the safety practices might still be extended within the entire LTCA.

“Under some conditions, the LSO may determine that these safety practices may be required within the entire LTCA …. Such situations may arise when movement of personnel in and out of the NHZ may be anticipated.”

***ADDITION:** - in reference to service personnel and alignments:

“Service personnel and others involved in alignment, calibration or servicing of the NCLS should recognize that these activities may create a larger NHZ.”

4.4.2 Laser Treatment Controlled Area

The Laser Treatment Controlled Area (laser room) requires certain control measures be taken. These include the posting of the warning signs at the entrance, supervision by a laser trained individual, accessible to ONLY properly trained and authorized personnel (EVERYONE in the room must have had some basic laser safety training), and cover windows/doors to prevent laser transmission outside the room (for those wavelengths which pass through glass or plastic -- this eliminates the need for such coverings with CO2 lasers if the windows have glass in them).

***ADDITION:**

Wording was added to provide flexibility for the LSO to create a small NHZ, or even to create a small LTCA within the treatment room as follows:

“In those rare instances where the LTCA is a very limited area of a much larger space, the LSO shall carefully define the border of the LTCA.” ….

“The extent of the NHZ shall be indicated by the LSO if the entire LTCA is not declared as the NHZ. The need to describe the location of the NHZ will generally arise from the use of lasers with very small NHZs, such as an ophthalmic laser with a 40-cm NHZ. By contrast, the much larger NHZ associated with some high output surgical lasers will fill the LTCA. The LTCA shall be clearly delineated and shall:…”

4.4.2.1 Be posted with warning signs at the entry

4.4.2.2 Be supervised by HCP trained in laser safety

4.4.2.3 Be occupied only by patients and HCP appropriately trained / authorized. Supplied the appropriate eyewear upon entry (but don’t have to wear until the NHZ)

4.4.2.4 Cover all windows/openings (when in the NHZ) into the room. Discusses the wavelengths for which coverings are not required. (ArFl, CO2)

4.4.2.5 Use of blocking barriers when appropriate. Discusses that traditional interlocks are not usually appropriate during medical/surgical procedures.

4.4.2.6 Entry/Exit designed to be rapid.

4.4.3 Surgical Probes and Optical Fibers

Contact tips / sculptured fibers are explicitly recognized by ANSI but no specific recommendations are made for the controls required. They leave it up to the LSO to evaluate potential hazards and implement appropriate controls. This leaves open the option for the LSO to narrowly limit the NHZ (by proper assessment) with these devices and potentially exclude the use of safety eyewear for personnel in and out of the room.

***CHANGE:** ANSI has flip-flopped on their last two revisions here. At first they use the word hazardous, then they took it out on the last revision, and now they've added it again.

"The diffuse scattering produced by frosted probes attached to optical fiber optic delivery systems and used with class 4 lasers may be hazardous."

4.4.4 Patient Eye Protection

This section discusses the patients' eyes, glasses and other protective methods. Patient eye protection is required in ALL situations, but the method of protection is left up to the LSO. Options include wet pads, safety eyewear and corneal shields, among others

***CHANGE:**

In the previous edition of ANSI it was required with a SHALL, to use corneal shields whenever working around the patients eyelids. Now it has been softened some and says in these situations *"corneal shields are usually required"*.

4.5 Maintenance & Service Procedural Controls

4.5.1 Alignment Procedures (Class 2, Class 3R, Class 3B, or Class 4).

Beam alignment controls: This section of ANSI applies primarily to service personnel, but is written to include "routine" perioperative check out of the laser. The problem is that many eye injuries have occurred during beam alignment procedures. With current technology lasers, operators infrequently if ever, are involved with alignment procedures of the laser beam with the aiming beam or of calibrating the power meter. These are most frequently performed by service personnel and frequently involve the removal of panels from the laser.

4.5.1.1 Operation Alignment and Calibration

You're required to check the alignment of the aiming beam with the surgical laser on systems like a CO2 laser where they can separate. You're also required to "Verify" the power meter and calibration. This is a **CHANGE** in wording from the previous version which required you to "Calibrate" you laser every case. This is not physically possible for a medical laser operator in most situations, and the intent was to verify that the meter was working.

4.5.1.2 Safety During Alignment Procedures.

This section is talks about the hazards of alignments, requires that the manufacturer provided detailed alignment methods, and that the LSO approve them.

4.5.1.3 Temporary Laser Controlled Area.

This section does require that a temporary laser controlled area be established whenever service is performed, and that all personnel including the service technicians will adhere to control measures (eyeglasses, etc.) and post warning signs. This provision makes it inappropriate to perform laser service in open areas where personnel come wandering by. This also applies to circumstances such as training labs, demonstrations, etc.

4.5.2 Service Personnel.

This section requires that all service technicians shall have documented "education and training commensurate with the class of the . . . laser" on which they are working.

4.6 Protective Equipment

4.6.1 General

Protective equipment for personnel: This section discusses the various forms of protective equipment such as eyewear, shields, barriers, windows, gloves, clothing, etc. It goes into some detail on the rationale for selecting and using appropriate eyewear.

4.6.2 Protective Eyewear

The wording was changed in this section just for clarification:

"Eyewear shall be accompanied by the following information:

1. Optical density at appropriate wavelength

2. Manufacturer's recommendations on shelf life, storage conditions, and appropriate cleaning methods. "

4.6.2.1 Eye Protection

***ADDITION:** An addition to the wording makes it clear that eyewear SHALL be worn inside the NHZ, but also specifically eliminates this requirement OUTSIDE the NHZ. This reinforces the capability of the LSO to designate smaller NHZs where appropriate, reducing the requirements for protective eyewear on personnel where appropriate.

"Their use shall be enforced within the NHZ, but not required outside the NHZ."

It also adds a requirement that is common sense, but had not been included in the standard:

"Damaged or faded protective eyewear shall be removed from service."

4.6.2.1.1 Selecting Appropriate Eyewear

***ADDITION:** They've added wording to be more specific – it says *"the manufacturer or the LSO shall specify the … eyewear by make and model or performance specifications and the locations and conditions of the use of the eyewear."*

4.6.2.1.2 Eyewear for Fiberoptic Procedures.

This section discusses possible hazards from possible fiber breakage. It leaves the designation of the NHZ entirely up to the discretion of the LSO. This section provides the explicit option to the LSO of designating the entire room as the controlled area (glasses required) but does not require it. Conversely, it specifically leaves open the option for the LSO at their discretion to designate a smaller NHZ and eliminate glasses requirements during enclosed endoscopic procedures. The new wording includes:

"All personnel within the NHZ shall wear laser protective eyewear."

"LSO may determine that the use of protective eyewear during an endoscopic procedure is not required."

Further wording in the new revision differentiates types of fibers and discusses armored fibers on ophthalmic slit lamps so that making the entire room does not need to be declared the LTCA, let alone the NHZ.

***ADDITION of new section**

4.6.2.1.3 Microscopes and Other Optical Viewing Instruments

This content was partly contained in the previous version, but its put in its own section here and made clear that appropriate filters must be used on different types of viewing

4.6.2.2 Optical Density (OD).

All of the safety eyewear shall be labeled with the optical density and wavelength(s) for which protection is provided. This labeling requirement precludes the use of one's own eyeglasses, or shop safety glasses, with CO2 lasers -- which would otherwise be quite adequate for protection. This section on optical density is significantly simplified from previous versions of Z136.3 , and references the Z136.1, sections 4.6.2.4 for more detailed discussions.

This section also contains wording which acknowledges indirect viewing (i.e. Video Monitors) as acceptable indirect viewing methods (compared to the use of protective eyewear). It is directed toward the problem areas of broadly tunable systems, but shows the acceptability of such alternative monitoring viewing.

4.6.2.1.3

4.6.2.4 Cleaning and Inspection.

The eyewear will be cleaned and inspected periodically. This responsibility will fall to the LSO, even if delegated to other individuals. Cracks, breaks, wear of coatings, etc., should all be looked for when inspecting eyewear. Cleaning methods should be gentle on the filter material, remembering that some materials have protective coatings which can be rubbed off by too vigorous cleaning.

***CHANGE:** Added Section on Barriers and Curtains

4.6.3 Laser Protective Barriers and Curtains (Class 3b or 4)

- Doorway/Window screens (any blocking material) is suggested to be of nonflammable material (use of word "should"). It requires that these windows be provided with an appropriate barrier or filter. The previous section 4.4.2.1 (4) allows the normal glass in these windows to be used for CO2 and some other lasers, with no additional materials required.

***CHANGE:** Added Section on Drapes

4.6.3.1 Drapes.

- Drapes in the surgical field should be wet or of fire retardant material during laser use. One should remember that the drapes need not be soaked in their entirety, but only wetted in the immediate vicinity of laser use. This conservative application of wetting fluids will preclude "wicking" which would otherwise occur and compromise the sterility of the field. It should also be remembered that blood soaked sponges or towels are just as nonflammable as fluid soaked.

4.6.4 Skin Protection (Class 3b or Class 4)

- Skin protection: Though not routinely required for most lasers, the ultraviolet excimer lasers may produce some long term harmful effects from chronic exposure (such as in eye clinics for corneal reshaping). Gloves and long sleeved jackets can provide suitable protection. Sun block is considered inadequate.

***CHANGE:** This section expands the discussion of skin protection to include chronic exposure to UV from excimer lasers. It says that *"skin cover SHALL be used if repeated exposures are anticipated at or near the applicable MPE limits for the skin."*

It also changes the wording regarding sun blocks that they *"SHALL be considered inadequate for these UV lasers"*.

4.7 Warning Signs and Labels.

- Laser warning signs must be conspicuously posted to warn personnel of laser use. They should not be left posted on a permanent basis, since personnel will become accustomed to seeing the signs all the time and become complacent when the laser is actually in use. Some signs may be electrically lighted to flash when the laser room is active. Signs should conform to the standard warning format required by OSHA, and outlined in ANSI 4.7.2.2 .

***CHANGE:** The section was added to discuss the conspicuous posting of the signs on all doors, and importantly to indicate that these signs should be covered or removed when the laser is not in use.

4.7.2 Signal Words. (On Laser Signs)

***ADDITION:** Wording was added to recognize the new International Label for Laser Caution and Danger signs.

***ADDITION OF NEW SECTION:**

4.8 Exhibits, Demonstrations and Clinical Training.

Says that any medical laser used in a health care facility but not on human subjects SHALL be operated within the restrictions of ANSI 136.1-2000. It discusses that special beam enclosures can be constructed to greatly reduce the NHZ.

SECTION 5: LASER SAFETY AND TRAINING PROGRAMS

This section was substantially reworded for clarification. Most of the content was previously scattered throughout the standard, but is now brought together in this section in a more organized manner.

***CHANGE:** *Change in wording for emphasis that "The Health Care Facility SHALL establish and maintain an adequate safety program …"*

The LSO supervises and evaluates the control of laser hazards.

The section discusses delegation of authority to the LSO, and the establishment of the laser committee where there is a diversity of usage -- such as in hospitals. Private offices would not require the establishment of such a committee, but the practitioner would assume or delegate the authority and responsibility of the LSO.

***CHANGE:** Stronger wording was added about forming a laser committee – The dropped the phrase "May be formed" and instead says *"Should be formed"* (where diversity of usage warrants.

Certification and credentialing of personnel remain the responsibility of the individual facility, so that no one organization is actually authorized to "Certify" laser physicians or nurses by ANSI recommendations. Training standards are outlined by ANSI, and in-house credentialing or certification by the hospital would rely upon documentation of such training, and any additional in-house requirements such as hands-on work or preceptorships. One of the options the facility has however, is to recognize the voluntary Laser Certifications from groups such as from the National Council on Laser Excellence (NCLE – www.lasercertification.org) and explicitly recognize these as meeting the facilities requirements for credentialing of laser operators and safety officers. This process saves each institution from "re-inventing the wheel", so to speak, and provides a consistent basis for credentialing.

A method for accident and incident reporting is required, but ANSI acknowledges that existing quality control mechanisms at the facility will satisfy this requirement.

5.2 Training (Change in wording from "Education" to "Training")

Detailed training in Laser Safety SHALL be provided to personnel working in the presence of Class 3B and 4 Lasers. This training SHALL be documented and retained on file.

***ADDITION**: Additional wording was added for clarification that *"Required criteria for credentialing and certification shall include all applicable aspects of safety"*.

5.2.1 Personnel

***CHANGE: -** Change in wording just to further Clarify the training that applies to:

- LSO's
- Users
- Laser Technical Support Staff

- Nurses and Allied health personnel

Laser operators and others (all perioperative personnel) are REQUIRED to have training in the assessment and control of laser hazards. All training activities should be documented and on file with the institution. ANSI says training shall be provided to LSO's, Physicians, laser technicians or clinical engineers, service personnel including inhouse or contractor provided service, and all perioperative personnel such as anesthesiologists, nurses, dental hygienists, technicians, and others. Because of the regular turnover of personnel within operating rooms, this laser training will have to be provided periodically (presumed to be at least annually or greater) in order to maintain ongoing compliance with this training requirement.

5.2.2 Training Programs.

This is a section which indicates what type of training SHALL be provided. It indicates that it should provide a thorough understanding of all procedures (comprehensive) required for establishing and maintaining a safe environment during laser use. It should be specific to the HCLS in use and the procedures performed. It does indicate that the facility shall set the policy for content, and be in accordance with any other applicable regulations (presumably state regulations).

The appendices in ANSI (not an official part of ANSI) contain sample laser training programs.

SECTION 6: MEDICAL SURVEILLANCE OF HEALTH CARE PERSONNEL (HCP)

***CHANGE:** A major change is that EYE EXAMS ARE NO LONGER REQUIRED to be in compliance with ANSI – except in the case of a suspected accident.

Medical surveillance *“should be considered”* for all personnel who work around 3b or 4 lasers. The section *“recommends”* that such surveillance be performed upon initial employment but *“shall be required”* whenever a potential injury is suspected.

The LSO will determine which personnel fall within which category, “*IF*” the facility requires such exams, to determine who should be under medical surveillance.

For laser personnel, if the facility requires the exams, and provided that visual acuity is 20/20 for near and far vision, and the central field is normal when tested by pattern, no further examination is required. Deviations require fundus examinations or other tests to determine the underlying pathology as determined by the examiner. For incidental personnel only visual acuity testing is suggested unless an accident has occurred or is suspect.

Periodic examinations are NOT required in this section after the pre-employment exam. Exams *“SHALL”* be conducted after suspected accidents or specific eye complaints.

Records of the examinations must be kept on file. Provision is made for access to the records by the employee and all authorized medical personnel.

Though specifically NOT required by ANSI, the author suggests that POST-employment examinations be conducted on personnel if they've had these exams. Allowing personnel to leave employment without a subsequent examination leaves the employer open to potential liability should the employee suffer some type of injury post-employment, and then blame it on the lasers. Be advised however that ANSI specifically says that periodic exams and exams upon termination of employment are not required, but may be offered.

SECTION 7: NON-BEAM HAZARDS

Hazards unrelated to the actual laser beams themselves are discussed in this section. Many of these hazards are not unique to laser and apply in other situations as well. They include general items such as electrical hazards, laser plume and blood borne pathogens.

7.2 Electric Controls and Power Supplies

***CHANGE:** Change in title from "Electrical Hazards" to this more specific title. They also eliminated the" footpedal confusion" wording in this section from the previous version..

This section on Electric Controls point out seven common potential hazards in HCF.

7.3 Infection Control

***ADDITION –** This section is a new addition. Simply references 29 CFR 1910.30 to prevent spread of infection.

7.4 Laser Generated Airborne Contaminants (LGAC)

This section has been clarified in its wording.

Laser plume (airborne contaminants) is required to be controlled by the use of ventilation and respiratory protection. ANSI refers to smoke evacuators as "local exhaust ventilation" and indicates that it shall be the primary method of control. The associated filters are to be considered a biohazard and properly disposed of (red bagged with the use of gloves). It points out that Electrosurgery smoke creates the same pollutants as laser plume.

***ADDITION:**

7.4.1 Infection Control-LGAC Pathogens

This section just points out that LGAC can contain blood and blood by-products which are hazardous. However it ADDS the wording that the potentially hazardous area for the exposures often exceed the NHZ. This is a further acknowledgement by ANSI that the NHZ may often be made a small area within the laser room, but that if the laser plume is not adequately evacuated at the source that it will probably create smoke pollution outside of the small NHZ area within the rest of the room, or potentially outside of it.

7.4.2 Control Measures

Simply talks about the fact that local exhaust ventilation (smoke evacuators) shall be the primary method to control this laser smoke (LGAC). Smoke evacuators must be used as near to the site of smoke production as is practical (usually this means within a couple of inches).

***ADDITION**

The new version adds a section to discuss protection of the patient from laser smoke, especially when creating the smoke in or near respiratory passages. It says that the smoke evacuators SHALL be used to afford this protection. The author would like to remind the reader that care must be taken when using suction of any type in and near patient's airways because of deoxygenation of the patient. Pulse oxymeters provide one tool to monitor the patients saturation level, but this requires a medical judgment.

7.4.2.1 Local Exhaust Ventilation

This talks about both wall smoke and larger bore tubing smoke evacuation. Inline filters are discussed for wall suction methods, and either trapping all the smoke within the system or venting it out of the area.

***ADDITION**

For systems that exhaust the air back out into the room (most smoke evacuators) this new version has added a *should* recommendation for some way to know when to change the filter (an indicator, or preventative maintenance plan that spells out the criteria for changing the filter).

The section goes on to discuss of proper disposal of the filters and tubing because it is a biohazard, and they added more specific wording about the filters being classified as either ULPA or HEPA filters.

7.4.2.2 Respiratory Protection (the "Laser Masks" section)

This discusses the high filtration surgical masks that have been used as "Laser Masks" to protect the wearer from airborne viruses or particles in the laser smoke. The section essentially says that they don't work and the first line of protection SHALL be the smoke evacuation. However, they also don't say you can't use these masks as long as you're also adequately evacuating the smoke.

The author agrees that "laser masks" are unsuitable for protection from viral agents, but recommends having them available for optional use based upon the "psychological" benefit for those that choose to use them.

7.5 Collateral and Plasma Radiation

This is a general discussion of ultraviolet light and other wavelengths that might be emitted by internal components of the laser such as flashlamps, and the need to suitably shield these. Also discusses the bright light that can be generated when vaporizing bone and hard tissues, and the need to provide proper filters (this is not the same as safety filters for the laser light).

***CHANGE**: - They did eliminate the previous wording here that talked about lasers emitting Low Frequency and Radio Frequency energy.

7.6 Fire and Explosion Hazards.

Fire and Explosion hazards are discussed in terms of flammable materials and in terms of endotracheal tube fires -- which could be catastrophic.

***CHANGE:** Reference is now made that Drape fires can be causes by broken laser fibers or inadvertent impacts by the laser. An addition is also made to reference the NFPA (National Fire Protection Act) 115 on their Recommended Practice on Laser Fire Protection.

7.6.1 GENERAL

***CHANGE** – This is not really a change in substance from the previous version, but it was reorganized into this new section. It talks about flammable items, moistening sponges in the surgical field, fire extinguishers, water for dousing a fire, and breakage of fibers. It says that water for quenching a fire SHALL be immediately available when you're using a laser capable of causing a fire. It also adds a new paragraph that discusses common-sense items on avoiding fiber breakage such as not clamping or leaning on them.

The standards require that a portable fire extinguisher be made prominently available, as well as water for dousing of flames. During most surgical procedures irrigating solutions are generally on the backstand anyway. The standard does not require that the extinguisher be located in the room itself, and some authorities have actually recommended against this practice, since finding the extinguisher in the smoke filled room might be very difficult. A prominent location just outside the room might be more appropriate.

7.6.2 Endotracheal Tube Fires. (For Laser use in the airway)

Protection against endotracheal tube fires is discussed in some detail. Flammable PVC tubes SHALL not to be used under any circumstance, and instead several alternatives are available and SHALL be used which include specially wrapped tubes and commercially available laser resistant tubes.

***CHANGE**: The standard now requires that the cuff SHALL be inflated with fluid and externally protected with wet cottonoids. It also now mandates that the lowest concentration of oxygen SHALL be used in laryngeo-tracheal procedures.

This section also references flammable colonic gases (flatus) and suggests that adequate ventilation should be provided. The author points out that one common practice of packing the anus with sponges while doing procedures such as anal warts should only be done with the utmost caution. Ventilation (and suction or bowel preps) is an effective method of eliminating this flammability problem. A medical complication of packing the anus with sponges is that if the virus that causes the warts is external to the anal sphincter, and one then shoves a sponge up inside this sphincter, then they have iatrogenically potentially spread the virus even further and created more of a problem. ANSI recommendations on ignition of intestinal gases is expanded in a new section noted below.

***CHANGE**: This section now eliminates the previous mandate for use of noncombustible agents and localized ventilation, but it does go on to recommend (not require) IV versus inhalation anesthetic techniques to avoid buildup of gaseous concentrations that support combustion.

***ADDITION**: Added Section
7.6.3 Inhalation Gas Hazards
Discusses the fact that Nitrous Oxide and other anesthetic gases support combustion equally as well as oxygen and must be considered.

***ADDITION**: Added Section
7.6.4 Laser Ignition of Intestinal Gases
This talks about the presence of methane gas during perianal procedures such as in laser hair removal and various methods to control this hazard, including the use of wet sponges in the anal area. See the author's note above on the potential medical hazards if inserting these sponges up into the anal sphincter.

<u>7.7 Electromagnetic Interference and Susceptibility</u>
This section discusses possible interference with devices such as pacemakers, or interference from electrosurgical Units. Electromagnetic Interference (EMI) safety hazards are normally designated in the manufacturer's labeling. If they are not, then they shall be established by the LSO or consultant.

In the author's experience, this has not been a common practical problem for medical laser systems, but is certainly possible.

<u>7.8 Endoscopic Delivery Systems</u>
Care should be taken when using lasers through endoscopes to prevent damage to or flaming of the endoscope. Flexible scopes are flammable and the fibers should be advanced sufficiently to prevent burning of the scope. Rigid scopes are not flammable, but firing of the laser fiber too close to the end, or optics, of the scope can destroy the scope. Care should be taken to avoid heating the metallic tubes of rigid scopes, which could cause conduction burns in patients.

<u>7.8.1 Contaminants from Gas Containers Used in Endoscopy.</u>
This acknowledges that gas delivery systems on lasers (purge gas lines, fiber cooling, etc.) may be contaminated, and requires in-line filters to remove contaminants.

7.9 Waste Disposal.

This section acknowledges that filters / tubing and other laser related materials are contaminated and requires treatment as such according to hospital and regulatory guidelines for contaminated materials (i.e. red bagging).

7.10 Laser Gases and Dyes.

This section points out that some of the gases and dyes used with many lasers are hazardous substances.

7.11 Room Design

This section points out that many non-beam hazards could be reduced or eliminated by proper room design -- such as smoke evacuation, reflecting materials, windows, traffic patterns, etc.. The new version simplifies the discussion and eliminates the more detailed wording of the previous one.

SECTION 8: CRITERIA FOR EXPOSURE OF THE EYE AND SKIN

This section references tables A2 and A3 in the appendix for typical MPE's of lasers, and associated NHZ distances. It also cross references Section 8 of ANSI Z136.1 for more detailed information.

SECTION 9: MEASUREMENTS

ANSI acknowledges that the classification schemes which they use in Section 3 of the standards minimizes the need for measurements and calculations by the LSO, but encourage the LSO to obtain more precise data from the manufacturers in order to better define the NHZ.

***CHANGE**

Eliminates the previous section on Calibration of the laser and changes it to Beam Shape and Alignment.

9.1 Beam Shape and Alignment

***ADDITION** – They’ve now added wording that says that lasers *should* not be used without their aiming devices or if the beam quality appears compromised.

***CHANGE** – changed the title of this section and changed its content from aiming beams to that of measurements of output.

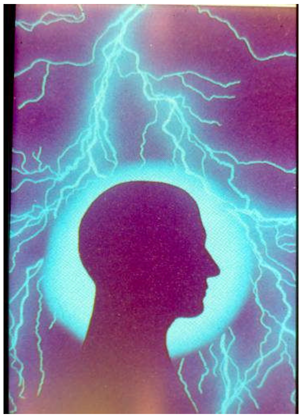
9.2 Other Beam Considerations

Says that measurements should be made at the output of the delivery system and talks about cleaning and maintaining the delivery optics. It talks about checking beam quality by burning on a tongue depressor (author’s note – not possible with all lasers).

Section 10. Revision of American National Standards Referred to in this Document.

Administrative comment about revisions of other standards referenced in this document applying when they are revised.

LASER & ELECTRICAL SAFETY FOR BIOMEDICAL ENGINEERING



Lasers present certain unique hazards to biomedical engineers because of the removal of covers and interlocks which otherwise afford a degree of protection for nurses and physicians to the electrical and optical hazards of these devices in normal medical use. The potential for electrocution or severe electrical burns present the greatest risks for injury to the engineer, moreso than the beam hazards. Of course one must always be careful to avoid direct intra-beam viewing whether or not safety glasses are worn. In fact, biomedical engineers are more at risk for eye injury when working on these lasers than the physicians and nurses who operate them.

The Biomedical Engineer needs to review all the ordinary safety hazards which laser presents and make sure they are thoroughly familiar with the required safety precautions. In addition to these ordinary hazards and precautions, the engineer should be aware that service situations accentuate these potential safety hazards.

In particular the engineer needs to be continuously aware of the potential path of the laser beam. When protective covers are removed the beam has the ability to be partially reflected off internal structures in the laser housing, causing burn or eye hazards in unusual directions from the ordinary beam pathway. The engineer needs to be alert to this potential. The infrared CO2 and Nd:Yag lasers pose a particular problem in this area because the invisible beam can be reflected off structures BEFORE it has been joined with the HeNe aiming beam. This creates an invisible burn / eye hazard around the beam pathway and many field service engineers have received burns from unseen reflections. The prudent engineer will carefully "test" the space around the beam pathway with their hands before exposing their face to these vulnerable areas. It is possible to receive burns on the hand in this fashion, but that is a better alternative to a burn on the face, eyes or hair – and in fact one usually just feels some heat to let you know the beam is there.

It is also easy to burn ones hair, or set it on fire, by being overly complacent around the output of the laser. One frequently needs to get up close to inspect the mechanisms while the laser is firing and it's easy for hair or clothing to fall into the pathway of the beam at these times.

Inadvertent direct viewing of the laser beam is the worst case scenario for the engineer. This is most likely to occur when checking alignments of output devices or the laser head and one needs to be especially careful in these situations. ***NOTE THAT LASER SAFETY EYEWEAR IS NOT DESIGNED TO PROTECT AGAINST DIRECT IMPACTS FROM THE LASER BEAM.***

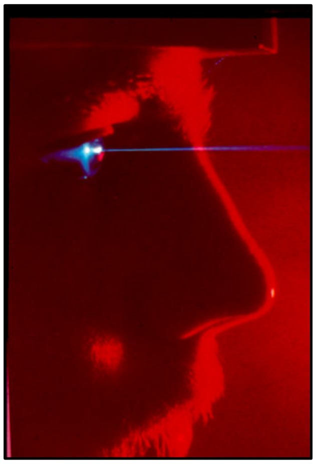
Electrical hazards far outweigh the eye hazards to service personnel. Certainly eye damage is nothing to be taken lightly, but there have been several deaths from electrocution during service of laser equipment. The electrical hazard is most pronounced on high amperage lasers such as Nd:Yag, Ion Laser, Metal Vapor and similar systems. These frequently employ power sources of 208v, 30 amps and greater. ***THESE ARE LETHAL CURRENTS - PRECAUTIONS REQUIRED.***

The engineer should be constantly conscious of their positioning around laser power supplies so that they don't inadvertently come in contact with them. This would include ordinary electrical precautions that all biomedical engineers should know before working on electrical equipment. These include such precautions as removing jewelry and rings which might present sources of electrical contact, avoiding grounding situations with other body parts or tools, and using ones right hand to work around high voltage/current while the left hand is held behind the back as a precaution against inadvertent grounding or closing the circuit.

CO2 lasers, while presenting definite electrical hazards, don't rank in the same lethal class (even though they could be lethal) as the above mentioned lasers. CO2 laser power supplies put out typical high voltages in excess of 15KV, but only in the range of 20 milliamps. If one were unfortunate enough to get "bitten" by this current, it would provide a "wallop" enough to knock one across the floor (and possibly more severe damage). The capacitors in these and other lasers retain a charge for a considerable period of time after unplugging the laser, so that one should intentionally ground out such capacitors (preferably with HV probes) after the laser is unplugged and before working around the power supplies.

Good judgment and generally recognized electrical precautions should be taken around all laser equipment.

LASER EYE HAZARDS



There are two fundamental types of injury that can occur to the Skin or Eye, and include Photothermal (burns) or PhotoChemical injury. The primary hazard with routine medical laser use is with the photothermal injury. Photochemical injury involves chronic exposure to UltraViolet laser light and would cause a degradation of tissue over time – such as cataract formation on the lens of the eye with chronic exposure, or skin cancer for chronic skin exposure. Due to the nature of medical laser treatments this type of photochemical injury is possible, but not very likely with the use of appropriate eyewear and skin cover. These PhotoChemical injuries occur with Ultraviolet light starting at around 351nm. As a generalization you might say that the shorter wavelengths of UV light from about 351nm are PhotoChemical effects while the longer wavelengths of the visible and infrared are PhotoThermal ones.

Potential PhotoThermal Eye Hazards come from either a painful burn to the surface of the eye (sclera or cornea), or to a coagulative burn to the retina itself. Some Q-switched lasers could create a “tearing” type of injury to internal eye structures, but these are very unlikely (but not impossible) in routine medical environments because one’s eye would have to be right at the output of the laser.

While one must be knowledgeable and careful to avoid eye injuries with all lasers, most of the precautions that are routinely taken with medical laser systems are far in excess of what is actually required to be safe, or what is required by ANSI recommendations. This section addresses lasers used in medical surgical procedures, and not lower classes of lasers that might be used in commerce and industry.

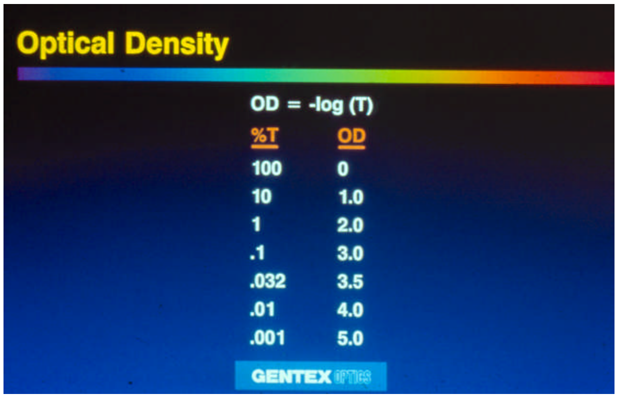
All surgical lasers are classified as **Class 4 Laser Systems** by ANSI and all of these systems have the potential to create serious eye damage or blindness, besides burns. The primary hazard is looking directly into the output of the laser beam itself – much like staring into the sun. Laser Safety Eyewear does not even provide protection against this “Intra-Beam” viewing. Laser Safety Glasses are meant to provide protection from less intense beams that diffusely reflect or scatter back from targets.

The **Nominal Hazard Zone (NHZ)** describes the physical boundaries of the area where one could be injured by the laser beam – either eye or skin burns. This references an exposure limit called the Maximum Permissible Exposure (MPE) which is the limit above which burns or damage occurs. Medical Laser Safety Officers don’t have to actually calculate MPE’s to determine the NHZ, but this is the typical way to determine it in an industrial setting. In hospitals the NHZ has been routinely taken to be the entire laser room but this is not necessary if the Laser Safety Officer (LSO) determines that the area of actual risk is much smaller than the entire room. The LSO may use their informed judgment and outside recommendations to determine the actual NHZ, without having to perform measurements and calculations. If the NHZ is more narrowly defined to the limited area where a burn could actually occur, then safety glasses would be required to be worn only inside this area. The entire room for the procedure is called the **Laser Treatment Controlled Area (LTCA).** The LTCA requires that warning signs be posted at the entrance, windows covered if needed, and glasses be *made available* at the entrance to the room. When the person then enters the NHZ they are required to wear the glasses. If the LSO sets the NHZ and LTCA as one and the same then the person must wear the glasses when they enter the room. **The NHZ is solely determined by the Laser Safety Officer.**

The Nominal Ocular Hazard Distance (N.O.H.D.) should not be confused with the NHZ. This refers to the distance from direct viewing into the laser beam, where an injury could occur, and can be quite a large distance, even with a relatively small NHZ. (The lesson here is to NOT shoot the laser beam directly into someone’s face). The NOHD from a collimated handpiece on a pulsed dye yellow light laser for instance might be several hundred yards. If someone were standing at the NOHD the chances of an injury would be very low.

When the laser is used within a confined cavity such as in laparoscopy or arthroscopy, and the laser is kept in standby whenever it is not inside the cavity ready to be used, one could legitimately define the NHZ as confined to that cavity. (This could most appropriately be done with laser such as the Ho:Yag laser when used inside the bladder by urology) No personnel would be required to wear safety glasses at all during these cases. It is perfectly safe to view laser procedures on a TV monitor without protective eyewear – you’re looking at the light from the screen’s tube – not the laser itself. There are pros and cons to each side of the question of conservatism in setting the NHZ.

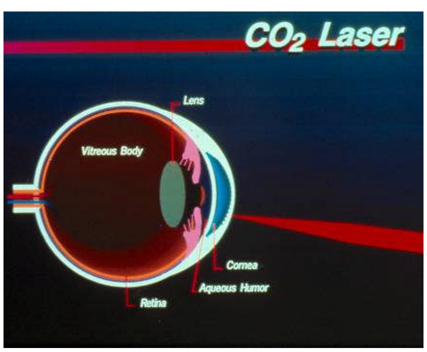
Laser Safety Eyewear provides protection against reflections and diffuse laser light – not the direct beam itself. They are specific to the wavelength of laser being used. Do not rely upon the color of the lens (ie green for Nd:Yag lasers) to determine which laser it is for. Safety eyewear can be made with colored filters, or with coatings placed over colorless lenses. This means that you can’t tell the wavelength(s) of protection just based upon color. All safety eyewear is required to be labeled with the wavelengths (or more likely a wavelength range – not just one wavelength) and the optical density of the material. Some manufacturers can custom design safety eyewear for institutions that use multiple wavelengths of light by coating the lenses for all applicable lasers. This is very convenient for multi-laser users. Sometimes the question is asked of whether eyewear could be made that would cover every wavelength of laser light. The answer is yes, however this would cover every wavelength of light and allow no light whatsoever to enter – Black Glasses that you can’t see through. -- Extremely safe from lasers, but hard to work in.



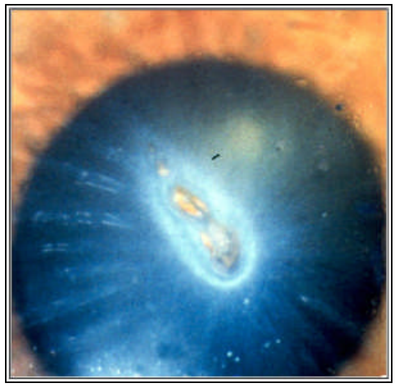
The optical density is an indication of how “strong” a laser light the lens will block. Think of it as the darkness of sunglasses. A higher number offers more protection. Medical Laser safety glasses are generally in the range of 2-10 O.D.. There is a logarithmic increase as seen in the table to the left. An increase of 1 in O.D. is a 10 fold increase in light blocking capability. Laser Safety Officers are permitted to rely upon the recommendations of the laser manufacturer in selecting the O.D. and this is generally in the range of 4-6 O.D. for medical use. Higher O.D.s make it more difficult to see and work through, while lower O.D.’s offer much less protection. Remember that it is protection from diffusely reflected and scattered light and NOT the direct beam.

Laser Safety Eyewear should be cleaned gently. It is possible to rub off the protective coatings on the surface with rigorous rubbing and you wouldn’t even know it unless you tested them. They should be inspected periodically for cracks or deep scratches in the material as well.

Different lasers will present either the corneal (surface) or retinal hazards depending on their wavelength. Lasers that are not transmitted through fluid, such as the CO2 , YSGG, Er:Yag lasers, Er:Glass and Ho:Yag, will present surface burn hazards. They cannot transmit through the membranes & fluid of the eye, so they stop at the surface. Power density determines whether an impact from these lasers will cause a burn, and this would be true if it were on the surface of the eye or the skin. The CO2 laser for instance is generally used with a focusing lens. This means that it defocuses quickly and power density drops rapidly – losing its ability to burn within just a few feet. A 60 watt CO2 laser used through a 125mm focusing handpiece lens will not burn one’s eye if further than 4-5 feet from the output of the laser.

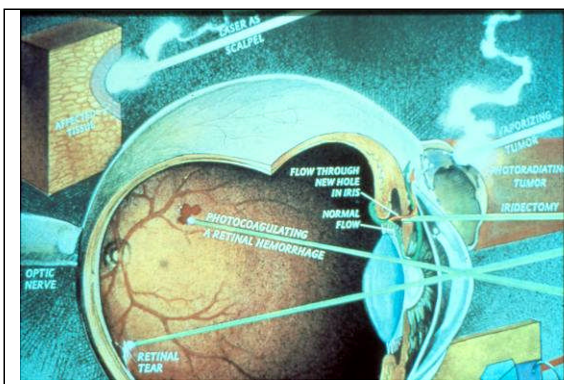


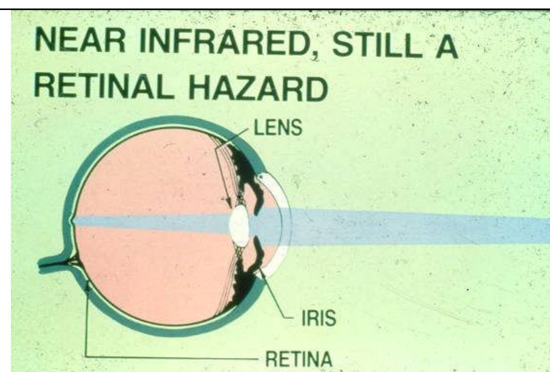
The CO2 laser presents a surface burn hazard, not a retinal one. If used through a conventional focusing lens it presents no hazard at all more than a few feet from the output. This means that one could safely work in a laser room with no safety glasses, provided they are more than a few feet from the output of the laser (and it would have to point right in their face). Ones own eyeglasses do offer protection against a CO2 laser impact, but these do not qualify under ANSI recommendations since they are not labeled with the wavelength and O.D., and have not been destructively tested for this purpose. The glass optics in surgical microscopes do offer protection to the viewer against a reflected beam in lieu of safety eyewear and ANSI does recognize this.



Corneal burn caused by a CO2 laser during a Blepharplasty (courtesy of Occuloplastik). The laser was dissecting soft tissue adjacent to the eye when it reflected off a metal skin retractor. There is really no reason for this type of injury, and special instruments would not have prevented it. Anytime the laser is used in such proximity to the eye protective shields or goggles should be used, and in this case the contact eye-shields that are placed under the eyelids should have been used but were not.

The Ho:Yag laser is “safer” than even the CO2 laser for normal use. The wavelength does not transmit to the retina, like the CO2, and more importantly has very low power densities just a few inches from the fiber tip because of the divergence. This means that a direct shot to the eye from across the room (from a fiber) will do no harm because it does not get to the retina and the spot size is too large to allow for any burns.



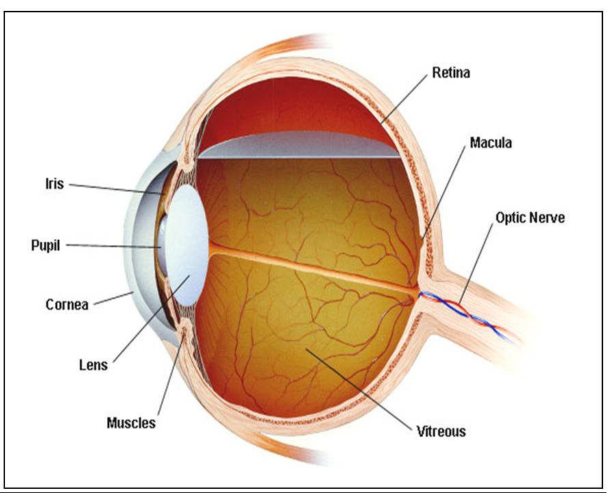


Visible and Infrared wavelengths (Argon, Krypton, KTP, Pusled Dye, Nd:Yag, Alexandrite, Diode, Ruby, etc.) present a retinal hazard to the eye rather than a burn on the surface of the eye. This means that the “real” NHZ is expanded with these lasers in comparison to the CO2, Ho:Yag and Er:Yag lasers. The latter systems don’t have enough power density at a distance to cause the surface eye burn, but the former visible and infrared systems can transmit into the eye from across the room. Most of these lasers are delivered via fibers so power densities drop very rapidly in a few inches from the tip. They won’t burn you at a distance but will get into your eye. Your own ocular lens then refocuses this light into a small spot on your retina, increasing the power density and creating a retinal burn. Wearing of safety eyewear becomes more important with these systems, but it will still not guarantee protection against a direct impact to the eye through the glasses.

Even though both the visible and infrared lasers both present serious eye hazards, the visible wavelengths afford more of a chance of avoiding the injury than infrared such as from the Nd:Yag laser. Visible lasers can of course be seen while infrared can not. A person receiving a “hit” from a visible laser knows it immediately and has some chance to blink or jerk out of the way. This is called the aversion response and is a perfectly natural phenomena. This reduces the time of exposure to your eye for the “hit” and helps to limit damage. The lower class lasers, such as laser pointers, are considered eyesafe if the time it takes to exceed the MPE for retinal damage is more than .25 seconds. A normal aversion response is .25 seconds so this means that you can be hit in the eye with a laser pointer (brighter than sunlight) but suffer no eye damage because one’s normal physiology causes you to jerk out of the way before damage can occur. In fact the normal aversion response is probably closer to 0.1 seconds for a younger person but the published rate is .25 seconds. This provides a safety margin. The class 4 surgical systems will cause damage far quicker than the .25 seconds so are not considered eyesafe. However, receiving a reflected flash of laser light – not a direct impact – that might otherwise cause eye damage can possibly be avoided through a quick aversion response. This is at least helpful but no guarantee of protection. Infrared lasers provide no aversion response since they can’t be seen to begin with. This means that the exposure time is likely to be longer with these beams since you can’t see them to know you’re getting the hit.

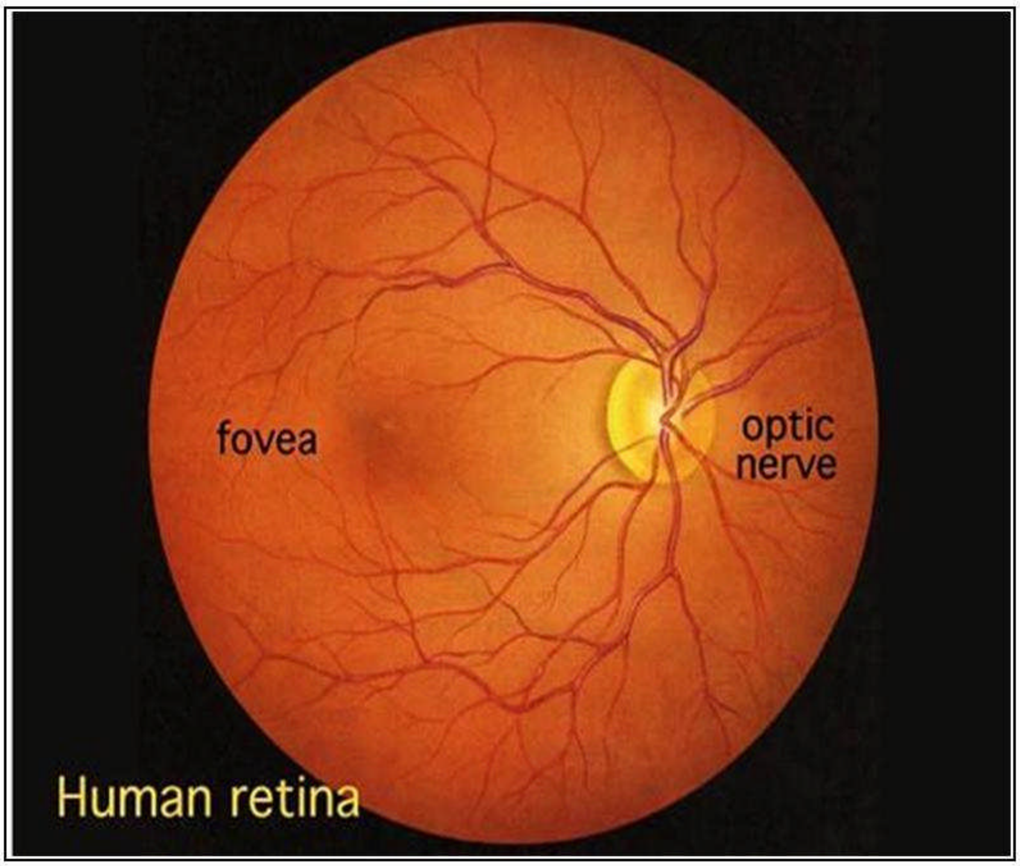
Eye Anatomy and areas of Laser Damage:

We’ve already discussed laser wavelengths that present Corneal (or Scleral) burn hazards, versus those that are retinal. The extent of damage which could occur to the retina is highly variable and depends on such factors as the incident energy, where it impacts the retina (where you were looking at the time), how long it was applied, whether or not your eye was moving at the time, etc..



The “anterior” portion of the eye is that portion from the lens (and it’s confining posterior capsule) forward to the Cornea. It contains a thin watery fluid called the aqueous humor. The Cornea is of course the transparent “window pane” that allows light to pass into the eye through the pupil, to be focused by the lens onto the retina. It is comprised of optically clear epithelial cells. The cornea and exposed sclera (white part of the eye) are the target for those wavelengths that do not pass through fluid (from roughly 1400 nm upward, and 400-300nm downward). Chronic exposure to UV light at around 351nm could cause photochemical injury and cataracts within the lens.

The posterior portion of the eye is filled with a gelatinous type fluid called the vitreous gel, and the retina surrounds the inside walls.



The Retina is a highly vascular neural network that drapes most of the interior back and sides of our eye. This contains the rods (black-white-gray) and cones (color) which allow us to see. Laser “hits” on the peripheral part of the retina and vision is far less damaging than impacts closer in to the central parts of vision in the fovea. The Macula is the central part of our vision and laser impacts in this area would be far more debilitating. The Fovea is the most sensitive part of the Macula, and the most sensitive part of the Fovea in turn is the Fovea Centralis - a small highly dense area of nerves only about 1-2mm in diameter. A laser impact here would be most devastating (looking directly down the barrel of the laser when it fired), but an impact anywhere within the Macula would be very debilitating to central vision. The optic disc is the place where the optic nerve and blood vessels enter into the eye. This is a natural “blind spot” and we can’t see from here. The retina is at risk from wavelengths that pass through fluid (and therefore through the lens and into the back of the eye) from roughly 300-400 nm up to around 1400nm. This is primarily visible and Near-Infrared (IR-A) light. The big problem with retinal hits is that these wavelength must pass through and be focused by the lens in the eye. This increases the intensity of the impact by 100,000 times from its entry into the eye to its focused spot on the retina. Window coverings must also be provided in the laser rooms for all the lasers that will transmit through glass (excluded are CO2, Er:Yag, YSGG and Ar:Fl excimer). However this applies only when the entire room has been designated as the NHZ (so that it incorporates the window). Such covers, when used, must be of flame retardant material.

LASER SAFETY OPERATIONAL GUIDELINES

SAMPLE POLICIES AND PROCEDURES
AND AORN RECOMMENDED PRACTICE CROSS REFERENCE

GREGORY T. ABSTEN

The following guidelines are offered as specific recommendations for a broad based laser safety program. The format should allow for incorporation of many types of lasers into the program as applications grow.

The previous section on ANSI Z136.3 standards has been incorporated into these sample policies and procedures where appropriate. They are not cross referenced within this section.

MEDICAL CENTER
SAMPLE LASER SAFETY PROGRAM POLICIES

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These are sample Laser Safety Policies for Hospitals and Medical Centers that may be used as a template for your own facilities policies. They are **based on ANSI 136.3, 2005 recommended standards**. ANSI provides many options for the Laser Safety Officer to initiate control measures and determine the Nominal Hazard Zone (where you have to wear safety glasses). These recommended policies serve simply as a template and your facility should decide how to change provisions of these policies to suit your own circumstances and evaluation of the hazard level. Further safety consulting, safety audits, and in-house training on your own equipment is available from our organization by contacting us through the website listed above, or calling 800-435-3131 in the U.S.

THESE ARE FREE SAMPLE POLICIES PROVIDED BY OUR NONPROFIT ORGANIZATION WHICH MAY BE COPIED AND SHARED WITHOUT LIMIT.

POLICY: To ensure the proper and safe use of this facilities medical laser equipment, and to credential physicians and staff for use of lasers in this facility.

PURPOSE: To provide for patient and personnel safety during laser procedures
To provide for optimum and effective use of the laser
To provide for the proper care of the laser and related equipment.

PROCEDURES:

I. Appointment and Responsibilities of the Laser Safety Officer (LSO)
An individual shall be appointed by the hospital administration to serve as the facility Laser Safety Officer, and to have cross-departmental authority throughout the facility to manage the Laser Safety Program, as described in A.N.S.I[6]. Z136.3 standards for the Safe Use of Lasers in

[6] American National Standards Institute

Health Care Facilities. They may enlist the advice or assistance of laser manufacturers, consultants or knowledgeable individuals to assist in the management of this safety program within the budgetary guidelines and policies of this facility.

a. Authority – The LSO shall have the authority to suspend, restrict or terminate the operation of the Health Care Laser System (HCLS) if they deem that a hazardous condition exists. They will additionally notify the operating physician of such hazard. The LSO may delegate this authority to the dedicated Laser Assistants operating the equipment.
b. Delegation of Authority – it is understood that the responsibilities of the LSO in enforcing the written laser safety policies and procedures, and monitoring the laser treatment controlled area for safety during procedures, are duly delegated to the dedicated Laser Assistants who may be operating the laser equipment while the LSO is not actually in the treatment room.
c. Appointment of an Ad-Hoc Laser Safety Committee – The LSO may, from time to time, on an as-needed basis, form a Laser Safety Committee comprised of members of the physician staff, departmental directors and hospital employees for the purpose of collaboratively addressing specific laser safety program issues. The LSO may also disband such temporary committees when its purpose has been met.
d. Laser Safety Officer Credentialing Standards.
    i. The LSO shall be an individual with the training, self study and resources deemed appropriate by the hospital administration to administer the Laser Safety Program. Their background may include, but should not be limited to, nurses, biomedical engineers, or environmental health and safety officers, who have obtained appropriate training to manage the Laser Safety Program.
    ii. Training shall include:
        1. general laser and energy concepts (physics), tissue interactions and laser safety.
        2. hands-on orientation to the hospitals specific lasers
        3. Laser Safety Program management including familiarity with A.N.S.I. Z136.3 recommended standards for the Safe Use of Lasers in Health Care Facilities.

    The facility will also recognize individuals certified by the National Council on Laser Excellence (and the administering Board of Laser Safety of the LIA) as Certified Medical Laser Safety Officer, as having met these requirements.
e. Duties of the LSO:
    i. The LSO shall manage and administer the overall laser safety program of this facility, based upon their informed judgment of the potential laser hazards and control measures which they choose to implement to protect against these hazards, utilizing the ANSI Z136.3 recommended standards as a guideline.
    ii. Establish written laser safety policies and procedures, working collaboratively with the physician staff and other departments where needed.
    iii. Approve the HCLS installation, use and operation, including the suitability of the facilities for safe operation.
    iv. The LSO has the authority to allow deviation from these written policies and procedures on a specific per case basis when circumstances indicate that this may better serve or facilitate the patient’s treatment without compromising safety, and to re-evaluate and modify safety policies and procedures as needed to effectively manage the laser safety program on an ongoing basis.
    v. Work collaboratively with the hospital physician credentialing mechanism to ensure that physicians are properly credentialed in the use of the facilities laser equipment, and to keep a current list of authorized physician users for the purpose of authorizing the scheduling of laser cases.
    vi. Ensure that proper safety training is provided to all staff working in the presence of the HCLS.
    vii. Ensure that proper safety and operational training is provided to the dedicated Laser Assistants, and to approve the credentialing of such assistants.

viii. Ensure that the proper protective safety equipment, such as laser warning signs, safety eyewear, smoke evacuation equipment, etc., is available, in good condition and appropriate for the laser procedure being performed.
ix. In collaboration with the operating physicians and anesthesia, approve patient eye protection measures such as safety eyewear, opaque metal eyeshields, corneal shields, moistened drapes or sponges as deemed appropriate.
x. Investigate all known or suspected accidents resulting from the operation of a laser, and initiate appropriate actions including compliance with the hospital's incident reporting policy.
xi. Ensure that the laser equipment is properly maintained by qualified individuals including the facility biomedical engineering department, third party service agents, or the laser manufacturer.
xii. Ensure that both Laser Operating Manuals and Laser Service Manuals (complete with specific alignment and calibration information) are obtained for each laser in use within the facility.
xiii. Ensure that laser rental groups or any similar contract laser service that operate within this facility has supplied to the LSO documentation of appropriate training of their personnel and periodic maintenance of their equipment. The LSO will also accept NCLE[7] Laser Safety Officer or Laser Operator certifications as evidence of appropriate training. The LSO will supply such rental/contract service operators a copy of the facilities written laser safety policies and procedures and require their compliance while operating within the facility.
xiv. Conduct a comprehensive Laser Safety Audit/Inspection of the facilities Laser Safety Program, including physical inspection of all HCLS and protective safety equipment, on an annual basis. This may be performed directly by the LSO or may be delegated to consultants or organizations providing such Laser Safety Audits/Inspections.
xv. Become a member of the American Society for Laser Medicine and Surgery (ASLMS), in order to stay abreast of developments in the medical laser field, and to distribute such communications to hospital physicians and staff as deemed appropriate.
xvi. Maintain continuing education on an annual basis in the area of medical/surgical laser use or safety, such as the annual scientific meeting of the American Society for Laser Medicine & Surgery or other laser related programs or meetings.

II. Physician Credentialing Standards

a. Physicians wishing to utilize the various lasers of this facility must be properly trained in the use of such equipment and submit their credentials for approval to their respective departments, through the Chief of Staff's office. The Chief of Staff's office will then forward an updated listing of approved physician users to the Laser Safety Officer and the Operating Room Coordinator on a monthly basis (unless no additional approvals have been granted within that time). Approval will be for each type of laser individually. Such training shall include:
  i. general laser and energy concepts (physics), tissue interactions and laser safety.
  ii. clinical considerations for the specific lasers and applications including indications, contraindications, procedural techniques, complications and management of complications.
  iii. hands-on training with the specific type of laser
  iv. orientation to the operation and user options on the hospital's specific laser system provided by the Laser Safety Officer or their designee.

[7] National Council on Laser Excellence, a credentialing board of the non-profit Professional Medical Education Association. – www.LaserCertification.org

Such training may be obtained through their residency program, formalized courses, or individualized study including individual review of the medical literature and work with the laser manufacturer or participation in a combination of study experiences that will meet these requirements. It may also be evidenced by current credentialing of the applicant by other hospitals or medical centers for the same type of lasers/applications.

b. Physicians will be approved for procedures only within their scope of medical practice.
c. The chief of their respective department will make the final recommendation on approval of the application.
d. A laser credentialed physician shall be present for the first 2 cases.
e. Evidence of laser credentialing at another accredited medical facility will be sufficient for granting of laser privileges at this facility.
f. Once an initial approval for privileges of one laser type is granted, privileges for additional types of lasers may obtained by making similar application and showing evidence of incremental training with the "new" type of laser. The extent of this incremental training will be determined by their department chief based on how similar the laser and/or procedure is to those already approved, but at a minimum will require a brief orientation to the specific laser equipment.

III. Scheduling Procedure
a. The current list of qualified physicians, supplied by the Chief of Staff's office to the Operating Room Coordinator shall serve as the basis for physician scheduling of laser use.
b. Scheduling will be on a first scheduled, first served basis.

IV. Presence of the responsible Physician – The physician who has been credentialed for the laser use must remain in the treatment room at all times during laser use. A resident, fellow or another staff physician being preceptored may utilize the laser under their direction, but the responsible physician must be present at all times.

V. Selection of Laser Treatment Parameters, Modes of Operation and Equipment Configurations – It is the sole responsibility of the operating physician to select the laser parameters and equipment configuration by which the patient is treated. The physician shall request these parameters from the dedicated Laser Assistant who shall configure and set the laser equipment as requested. Any suggestions or recommendations by the Laser Assistant are to be for informational purposes only and the sole responsibility for the settings shall be the operating physician's.

VI. Dedicated Laser Assistants
a. A dedicated laser assistant shall be assigned to set up and operate the laser equipment, and monitor the laser treatment controlled area for safety during the procedure. From the time the laser key switch is activated, to the time it is turned off, the laser assistant shall have no other duties except for direct operation of the laser control panel and to monitor the room for compliance with safety policies & procedures.

VII. Laser Assistant Credentialing Standards
a. Nurses/Technicians who have been selected to operate the laser equipment during surgical procedures shall be properly trained in laser safety, operation of the specific laser units and the facilities specific laser safety policies and procedures. Credentialing of such assistants is through approval of the Laser Safety Officer (LSO). Laser assistants may be RN's, LPN's, PA's, Surgical Technicians or other individuals deemed qualified by the LSO. The LSO shall maintain a current list of credentialed Laser Assistants with the Operating Room Coordinator for the purpose of coordinating schedules for laser cases.
b. Training shall include:
    i. general laser and energy concepts (physics), tissue interactions and laser safety.
    ii. hands-on training with the facilities specific laser(s)
    iii. Instruction in the hospital's written laser safety policies and procedures.

Such training may be obtained from the manufacturer or another credentialed laser assistant or the LSO, formalized courses, or individualized study including individual home study programs, in any combination that meets these three requirements. The facility will also recognize individuals certified by the National Council on Laser Excellence as Certified Laser Operators/Surgical or Certified Medical Laser Safety Officer as having met these requirements.

c. Another credentialed assistant, or the Laser Safety Officer, shall be present for the first 2 cases.
d. Once an initial approval for one laser type is granted, approval for additional types of lasers may obtained by incremental instruction in the operation of the additional Laser system(s) as determined by the LSO.

VIII. Maintenance of Laser Log for each case – The use of a laser log shall be at the sole discretion of the LSO as they may from time to time require. This laser log shall be maintained by the dedicated Laser Assistant according to the parameters on the printed form. The LSO may change, add or eliminate information or this log as they deem appropriate. The use of a laser log does not preclude or replace the need for patient charting as required by law, and such a Laser Log is not a requirement of ANSI 136.3.

IX. Laser Safety/Operational Checklists – An abbreviated checklist for proper laser setup, operation and safety shall be utilized by the dedicated laser assistant for each laser case. The checklist shall be as determined by the LSO, and may be altered by the LSO on an as needed basis.

X. Laser Treatment Controlled Area, Nominal Hazard Zones and use of Laser Safety Eyewear.

a. The Laser Treatment Controlled Area (LTCA) shall be the entire treatment room. Control measures to maintain laser safety shall include:
    i. Appropriate warning signs will be posted on each entrance to the room, and removed when the laser cases are not being conducted. These signs shall meet ANSI recommendations and include the appropriate laser wavelength(s) so that staff will know which eyewear is appropriate.
    ii. Be supervised by the dedicated Laser Assistant assigned to the case to monitor the room for compliance with laser safety policies and procedures. Such supervision is required only when the laser key is in the active “on” position.
    iii. Laser Safety Eyewear, appropriate for the laser in use, shall be made available to personnel upon entrance to the room, regardless of where the Nominal Hazard Zone is declared. All safety eyewear shall be labeled according to the wavelength and Optical Density (except patient metal eye shields, which provide protection against all laser wavelengths) The default policy will be for the entire room to be deemed the Nominal Hazard Zone (NHZ) for all laser cases, so that personnel will also need to wear their eyewear upon entry. The LSO does have flexibility in contracting this NHZ for certain cases as explained elsewhere in this safety policy, at which time the glasses will need to be worn only when in the NHZ and not the entire room.
    iv. Laser Safety Eyewear will be without defect, and will be removed from service if defects are noted in the frames, the filter material or optical coatings.
    v. The room will be occupied only by those personnel who have had documented training or orientation to laser safety. If a person who has not had such documented safety training is required to be in the room, then the laser assistant may provide a quick verbal orientation to laser safety and use of protective equipment such as eyewear appropriate to the laser case, and document this orientation in the laser log or in the patients chart.
    vi. All window openings into the laser treatment room (when the NHZ has been declared the entire room) shall be covered with opaque flame-retardant material to block viewing of the laser light from the outside. Such coverings will not be

necessary for the Carbon Dioxide Laser since that wavelength will not pass through the glass.

b. Nominal Hazard Zone shall by default include the entire Laser Treatment Controlled Area (laser treatment room) so that laser safety eyewear must be worn by all personnel within the room when the laser is active.

c. Nominal Hazard Zone may be made smaller than the entire treatment room[8], as determined by the LSO (and this authority delegated to the dedicated Laser Assistant) on a case by case basis utilizing the following criteria. The LSO or the dedicated laser assistant may convert the NHZ back to the entire treatment room at any time if they become uncomfortable with the situation or environment of the laser use.

   i. Carbon Dioxide Laser used in Laparoscopy. – The NHZ may be declared totally within the body cavity that is endoscopically accessed so that no personnel in the room are required to wear laser safety eyewear. This is contingent upon the dedicated Laser Assistant being present at the control panel of the laser at all times that the key is "on", and ensuring that the laser is placed in the standby mode when the laparoscopic laser delivery device is outside of the body cavity. If the physician is not utilizing video for viewing through the endoscope and is looking directly through the optics of the laparoscope, the glass in these optics provides sufficient eye protection and no further protective eyewear is required. The laser assistant and physician will require the use of glasses only when test firing the laser outside of the patient's body cavity in which case the NHZ will be considered three feet in the direction of laser output for the purposes of the test firing. (others in the room need not wear glasses)

   ii. Carbon Dioxide Laser used with the focusing handpiece (125mm or shorter focal length lens). – The NHZ may be declared the surgical table so that only those personnel standing at the surgical table are required to wear laser safety eyewear. Since the NHZ has been contracted to an area smaller than the entire room, an additional laser warning sign will be posted on an IV pole or other conspicuous manner at the table to remind personnel entering the field to wear their protective eyewear. This is contingent upon the dedicated Laser Assistant being present at the control panel of the laser at all times that the key is "on", and ensuring that the laser is placed in the standby mode when it is not actually being used, and to closely monitor personnel entering the field at the table to ensure that they are wearing the protective eyewear.

   iii. Holmium:Yag Laser – used endoscopically in urology or other endoscopic procedures. – The NHZ may be declared totally within the body cavity that is endoscopically accessed so that no personnel in the room are required to wear laser safety eyewear[9]. This is contingent upon the dedicated Laser Assistant being present at the control panel of the laser at all times that the key is "on", and ensuring that the laser is placed in the standby mode when the laser fiber is outside of the body cavity. If the physician is not utilizing video for viewing through the endoscope and is looking directly through the optics of the laparoscope, then Ho:Yag laser safety eyewear or endoscopic filter will be required for viewing. If the physician is viewing entirely through video attached to the endoscope, then no additional protective eyewear is required.

   iv. Diode Laser – used endoscopically in urology. – The NHZ may be declared totally within the body cavity that is endoscopically accessed so that no personnel

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[8] Reference ANSI Z136.3 Section 4.4 which states that the LSO may determine that some control measures in Section 4 are not required (cross references Section 1.3.2.4), particularly when a sterile field exists so that movement in and out of a confined NHZ is minimal or absent (Section 4.4.1).

[9] Reference ANSI Z136.3 Section 4.6.2.1.2, second paragraph "The LSO may determine that the use of protective eyewear during an endoscopic procedure is not required".

in the room are required to wear laser safety eyewear[10]. This is contingent upon the dedicated Laser Assistant being present at the control panel of the laser at all times that the key is “on”, and ensuring that the laser is placed in the standby mode when the laser fiber is outside of the body cavity. If the physician is not utilizing video for viewing through the endoscope and is looking directly through the optics of the laparoscope, then Diode laser safety eyewear or endoscopic filter will be required for viewing. If the physician is viewing entirely through video attached to the endoscope, then no additional protective eyewear is required.

v. 532nm and 810nm Opthalmic Diode lasers when used through the indirect laser ophthalmoscope, or intra-ocular probes for intraocular use – The NHZ may be declared the procedure table so that only those personnel working at or directly around the procedural table are required to wear laser safety eyewear. Since the NHZ has been contracted to an area smaller than the entire room, an additional laser warning sign will be posted on an IV pole or other conspicuous manner at the table to remind personnel entering the field to wear their protective eyewear. This is contingent upon the dedicated Laser Assistant being present at the control panel of the laser at all times that the key is “on”, and ensuring that the laser is placed in the standby mode when it is not actually being used, and to closely monitor personnel entering the field at the table to ensure that they are wearing the protective eyewear, and to closely monitor the physician user to ensure that the output of the indirect ophthalmoscope is directed solely towards the patient when the laser is in the ready mode, or similarly ensure that the laser is in the standby mode if an intra-ocular probe (fiber) is not contained within the eye.

d. Patient Eye Protection – patient’s eyes will be protected for all laser cases, as determined collaboratively by the LSO, operating physician and anesthesiologist. Such protection may take the form of laser safety eyewear, protective metal eye shields made for laser safety, or moistened sponges, drapes or towels as deemed appropriate. The method of eye protection shall be charted in the patient’s chart.
    i. Laser procedures performed within the bony orbit of the eye (i.e. blepharplasty) shall require the use of protective corneal shields specifically made for laser eye protection.
    ii. Laser safety eyewear, as used by personnel, may be used by the patient during cases involving only local anesthesia, if the laser use is not directly on or around the face, in which case more thorough protection should be provided.

e. Testing of automatic safety shutters – On equipment that incorporates automatic safety shutters to protect the operating physician’s eyes during laser use (i.e. certain diode and KTP lasers, or others), the Laser Assistant shall test the shutter mechanism for proper operation prior to use by the physician.

f. No person who is controlling the output end of the laser device shall point the device (even when the laser is in standby or not firing) in the direction of anyone’s face. This is to be rigidly enforced by the Laser Assistant, recognizing the fact that laser safety eyewear does not guarantee eye protection from a direct impact of the laser through the glasses.

g. Suspected Personnel Eye Injuries – in the event of a suspected eye injury a report will be made immediately to the Laser Safety Officer, and a hospital incident report completed per hospital policies. An eye examination will be required upon a suspected eye injury, although routine or baseline eye examinations are not required of any personnel.

XI. <u>Laser Safety Training for all peri-operative personnel</u> – All personnel who may have the occasion to work within a laser treatment room (LTCA) shall be provided with basic laser safety instruction. This will include at a minimum the knowledge of matching appropriate laser safety eyewear by wavelength with the posted laser warning signs, the types of hazards that

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[10] Reference ANSI Z136.3 Section 4.6.2.1.2, second paragraph “The LSO may determine that the use of protective eyewear during an endoscopic procedure is not required”.

laser may present, and awareness of the functions of the facilities Laser Safety Officer and dedicated laser assistants. Such basic safety training will be incorporated into employee orientation training. Sign-in sheets for laser inservices will be acceptable documentation of such training, or any formal certificate of laser training that includes safety.

XII. Secure storage of laser keys – The key to each laser shall be stored separately from the laser in a secure location, and only qualified personnel shall have access to this key.

XIII. Footpedal safety – because of the possibility of confusing footpedals between the laser and other surgical equipment during cases, the laser footpedal shall be kept on a separate side of the surgeon (either right or left from) from footpedals for other equipment such as electrosurgery or microscopes. Only the physician directing the output of the laser to the treatment site shall operate the laser footpedal.

XIV. Smoke Evacuation – whenever a laser plume[11] is generated from the use of the laser, adequate smoke evacuation will be utilized to capture the emitted laser plume. The evacuator collector tip will be held as close as practical so the site of plume emission – generally within about 2 inches – in order to collect all of the plume as it is generated. When the smoke generation is minimal or generated within a cavity such as vaginal speculum or microlaryngoscope, small bore suction may be provided in lieu of or in addition to the large bore suction.

a. When using the small bore suction tubing, from regular wall suction, a smoke filter shall be placed between the fluid collection bottle and the wall suction source to preclude damage to the suction system.
b. All suction tubing and filters are to be treated as contaminated material and disposed of properly.
c. Viral protection masks – Surgical masks that provide viral level filtration shall NOT be required during laser cases, and smoke evacuation will be utilized as the sole control measure for eliminating the laser plume. These viral masks will be made available on the laser supply cart for personnel who wish to use them.
d. Laser procedures performed under fluid do not generate a laser plume and smoke evacuation will not be necessary (i.e. Ho:Yag laser lithotripsy, Indigo diode cystoscopy, etc.)

XV. Aiming beam alignment – the aiming beam and the surgical beam from the carbon dioxide or Er:Yag lasers will be checked by the laser assistant prior to each case to ensure alignment by test firing of the laser onto a moistened tongue depressor. This alignment will be further confirmed by the operating physician prior to laser use on the patient. The laser will not be utilized if the aiming beam and surgical beams are not coincident. Testing of the alignment should occur with the delivery device used for the procedure where possible (i.e. laparoscope, microscope, etc).

XVI. Lack of Aiming beam on fiberoptically delivered lasers – When the aiming beam cannot be seen emitting from the fiber when the laser is placed in the ready mode (both lasers with separate aiming beam lasers and those that use low power versions of the same laser for aiming. This applies to Diode lasers, the Ho:Yag, Nd:Yag, KTP, and others) then the laser will not be test fired until the equipment has been checked by service personnel. This is to preclude damage to the laser from alignment problems.

XVII. Use of low reflectance instruments. Metal surgical instruments may be anodized to reduce their reflectance of laser light and should be considered when the operating physician deems appropriate. They are not a requirement for all laser use however and most surgical procedures

[11] Laser plume: also called Laser Generated Airborne Contaminants (LGAC), smoke, or laser smoke. It should be noted that plume generated from electrosurgical units contains the same contaminants and toxins as that produced by lasers.

may be safely performed with standard instruments. Care shall be taken to avoid directly firing onto metal instruments. Special low reflectance instruments shall be used during microlaryngoscopy cases with the CO2 laser.

XVIII. Protection of rigid and flexible endoscopes – Both rigid (i.e. cystoscopes, arthroscopes, hystersocopes) and flexible (i.e. bronchoscopes, gastroscopes, colonoscopes) endoscopes may be damaged by firing the laser fiber when it is within the channel of the endoscope or in close proximity to the optics of the endoscope.

a. Flexible endoscopies – the laser shall not be placed in the ready mode until the fiber is sufficiently advanced from the channel of the endoscope – approximately 1.5 cm. This is to be determined either by marking the proximal end of the fiber where it enters the endoscope with the correct positioning so that the laser assistant can see visually that the fiber tip is sufficiently advanced; or by looking at the video screen with the fiber tip sufficiently advanced prior to use in the patient, so that the fiber tip positioning may be visually determined by its position on the video screen.
b. Rigid endoscopies - the laser shall not be placed in the ready mode until the fiber is sufficiently advanced past the distal optic of the rigid endoscope by approximately 1.5 cm. This is to be determined either by marking the proximal end of the fiber where it enters the endoscope with the correct positioning so that the laser assistant can see visually that the fiber tip is sufficiently advanced; or by looking at the video screen with the fiber tip sufficiently advanced prior to use in the patient, so that the fiber tip positioning may be visually determined by its position on the video screen.
    i. Arthroscopies – the laser fiber is generally inserted separately from the rigid arthroscopic telescope. Care will be taken by the operating physician to avoid placing the laser fiber tip in close proximity to the telescope optic during the procedure, to avoid damage to the endoscope.

XIX. Fire Protection – the LSO will ensure that the following fire safety precautions are taken during laser cases:

a. Fire Extinguishers – the dedicated Laser Assistants will be made aware of the location of nearby fire extinguishers that are required by NFPA regulations.
b. A container of water (any non-flammable fluid) will be available during all laser cases for immediate dousing of flames if needed (irrigating solutions on the backstand will suffice).
c. The dedicated Laser Assistant will place the laser in the standby mode when it is not actively being used to treat the patient. The Laser Assistant will verbally notify the operating physician each time the laser is placed in the “ready” mode, and is able to be fired.
d. Any sponges or dry materials directly in the surgical field will be moistened (blood, saline, water or any nonflammable and nontoxic fluid may be used). This applies primarily to the Carbon Dioxide Laser but can apply to other lasers if used in open cases with dry materials present. Sponge counts will be made after CO2 laser cases that count the number of sponges and examine each one to ensure that it is intact and has not been cut into smaller pieces by the laser. Surgical control techniques with laser delivery systems offer control in situations where packing with moistened materials is not feasible. Appropriate backstops or guards should be used during some laser cases where it is appropriate. Laser use under fluid presents no fire hazard while the laser output is under the fluid (i.e. cystoscopy).
e. Flame retardant drapes will be used for surgical laser cases, or regular drapes may be moistened in the area around the surgical field or area where the laser handpiece or fiber is placed on the drapes.
f. Laser Ignition of intestinal gases – methane gas (flatus) from a patient is combustible, and peri-anal procedures with laser may present a fire hazard. Appropriate methods to control this potential hazard will be taken to include bowel preps, suction and irrigation, or covering of the anus with a wet sponge at the discretion of the operating physician. Deep packing of the anus with wet sponges up past the internal anal sphincter is to be discouraged because of the likelihood of spreading virus from perianal areas deeper into the anus, which may create medical complications that have adverse medical

consequences. The operating physician may choose the appropriate method of protection, including the deep anal packing when so indicated.

g. Flammable preps – the use of flammable preps is not precluded when using the laser, but appropriate precautions will be taken such as airing out drapes to prevent collection of combustible fumes underneath. Prepped areas should be dried before using the laser directly within that area. Special emphasis should be placed on hairlines such as facial or pubic hair that can retain prep solutions (including flammable hairspray) in the hair line. When utilizing the laser in these areas the hairline will be protected with a moistened towel held over the hairline, or by utilizing a water soluble lubricant such as K-Y jelly to provide a barrier between the hair and area of laser use.

h. Vaporization of Polymethylmethacrylate (PMMA) – Use of the CO2 laser to remove polymethylmethacrylate from within bone is a useful technique during joint revisions. PMMA produces toxic fumes when vaporized and is highly flammable, so that appropriate smoke evacuation and fire precaution techniques will be utilized.
    i. Smoke evacuation – in addition to the use of the large bore, high flow smoke evacuation, which filters out particulate matter, additional tubing will be connected from the output vent of the smoke evacuator and led to the negative pressure air vent in the treatment room (vented to the outside – not to another room).
    ii. Fire precautions – irrigating solution will be used intermittently to cool the area when the PMMA is being vaporized from the bone, and a container of solution will be immediately available in the sterile field to douse any flame that might be created.

i. Airway Laser Procedures – the following specific precautions will be taken to preclude and manage airway fires during laser use. This is an issue primarily with the CO2 laser used for microlaryngoscopy but to some degree can be an issue with Ho:Yag or Nd:Yag lasers during flexible bronchoscopy, or any case where a laser is used in or around the patient's airway:
    i. Anesthesia must minimize concentrations of FIO_2 and N_2O as much as possible when performing airway laser procedures. As low an FIO_2 as can be administered without compromising the patient's respiratory status is to be used. Patient O2 saturation levels shall be monitored. Compressed air, Nitrogen, or Helium, at the discretion of the Anesthesiologist, is to be used as the balance gas rather than increasing the percentage of N_2O[12] for the balance.
    ii. Explosive anesthetic agents such as Cyclopropane will not be used during laser airway cases.
    iii. An emergency tracheotomy kit/tray will be made available in the treatment room for all laser airway cases for use in the event of an emergency. The kit need not be opened unless it is required.
    iv. In the event a fire has occurred the first priority will be to re-establish the patient's airway and ventilation, including the use of emergency tracheotomy if required. The laser procedure is then terminated and all efforts will be made to assess and manage the injury to the patient.
    v. CO2 Laser Microlaryngoscopy:
        1. The patient's entire face/head, including lips and teeth shall be totally protected by packing with wet towels or coverings
        2. Standard PVC endotracheal tubes (ET tubes) shall not be used.
        3. Alternative airways/ventilation that may be used, as determined by the operating physician and anesthesiologist, include:
            a. Commercially available laser resistant endotracheal tubes, used according to manufacturer's recommendations. When used, the following procedures will apply:

[12] Nitrous Oxide supports combustion equally as well as oxygen

i. After intubation, inflate the cuff with sterile water to which a small amount of dye solution has been added.
ii. After the cuff is inflated with dyed fluid, pack off the cuff for additional protection with sponges/cottonoids that have been moistened.
iii. After intubation, tape the E.T. tube to the patient's face/neck to maintain proper positioning, utilizing a minimum amount of tape, so that the E.T. tube may be rapidly pulled from the patient during an emergency.
iv. Maintain a pail of water on the floor beside the operating physician in which to throw a burning E.T. tube during an emergency.
v. At any sign that the tube cuff has burst (discoloration from the dye seen in the airway), the patient will be extubated and properly re-intubated before proceeding with any laser use if the cuff has been burst.
vi. At any indication of a fire in the airway the operating physician will immediately disconnect the ventilation circuit from the E.T. tube while simultaneously and rapidly pulling the E.T. tube from the patient, throwing the tube into the pail of water, and alerting all personnel.

b. Norton Flexible Metal tubes – another alternative, where agreed upon by anesthesia and the operating physician, is the use of the all metal flexible endotracheal tubes, which are sized to fit the patient's airway so that no external rubber cuff is placed on the tube. If a rubber cuff is utilized then it will be treated the same as the cuff in laser resistant tubes as described above.
c. Jet Ventilation is another alternative method of ventilation, provided that an all metal cannula is used in place of the plastic cannulas so that no combustible materials are in the airway.

vi. Flexible bronchoscopy – with either Ho:Yag, Nd:Yag or KTP lasers.

1. The laser will be placed in the "ready" mode only when the laser fiber has been sufficiently advanced from the channel of the bronchoscope (1-2cm), both to avoid damage to the endoscope and to prevent igniting the plastic/rubber materials in the bronchoscope.
2. The laser will not be used in the direct vicinity of the tip of the endotracheal tube. The laser (and hence tip of the bronchoscope) will be used only past the distal end of the ET tube, and the ET tube placed as high as practical in the airway when using the laser at or just past the carina. Alternatives to work at the carina or within the trachea will include not using an ET tube at all, or the use of a rigid laser bronchoscope in lieu of a flexible bronchoscope.
3. Proper cooling of the fiber tip will be provided through the laser fiber/catheter, such as compressed air or fluid drips, according to the manufacturer's recommendation.
4. Enhanced cooling of the fiber/catheter tip will be provided when utilizing the laser in the area of metal mesh airway stents. Fluid drip is preferred but any aggressive method of tip cooling is acceptable, to prevent the laser fiber/catheter tip from igniting from the heat created in the mesh stent during vaporization.
5. Although this policy maintains that the type of endotracheal tube used during flexible bronchoscopies when using the laser past the mainstem bronchi is not the significant fire hazard it is with CO2 laser microlaryngoscopy, our policy will be to use only laser resistant tubes,

flexible metal tubes, or no ET tubes, during flexible laser bronchoscopies, as determined by the operating physician and anesthesiologist.

XX. Laser Maintenance and Service – shall be performed by qualified personnel as determined by the LSO.

a. Qualified service personnel may include the manufacturer's service technicians, third party service agents, or the hospital's biomedical engineers. Such service personnel shall have documented laser safety training, and documented service training commensurate with the level of work they are performing on the laser. The facility shall also accept NCLE Laser Certification as a repair technician as evidence of meeting this training requirement.
b. Periodic Maintenance, including calibration checks, shall be performed at six month intervals. Written service reports shall be maintained by the Laser Safety Officer and/or the hospital biomedical engineering department.

LASER SAFETY OPERATIONAL GUIDELINES

OFFICE DERMATOLOGY PROCEDURES

POLICIES AND PROCEDURES

Gregory Absten Feb, 2006
Professional Medical Education Association
www.LaserTraining.org

NOTE: These are generic Laser Safety Policies in a typical Dermatology / Aesthetic Laser practice and should serve as an excellent template for your own use. However, they MUST be modified to fit your specific situation.
If you would like to explore NCLE Laser Certification of your facility Laser Safety Program, including policies and procedures, we would direct you to www.LaserCertification.org and check for options under the Facility Laser Safety Program Certification. Your facility would receive the appropriate Certification Certificates.
Our own nonprofit Laser Training Institute offers On-site Laser Safety Compliance inspections, including options to guarantee your acceptance as an NCLE Laser Certified Facility (Laser Safety Program Certification).

These policies are designed for the safe use of lasers & IPL in dermatology. They incorporate all the applicable guidelines established by A.N.S.I Z136.3 standard “Safe Use of Lasers in Health Care Facilities”.

A. For purposes of documentation it is hereby reasserted that no ionizing radiation hazards exist with the common medical lasers in current use or IPL unit. X-Ray type precautions are NOT required for lasers, even for women in any stage of pregnancy.

B. A laser warning sign will be prominently displayed outside each entrance to the room in which the laser is being used. These signs shall conform to the standard OSHA/ANSI danger signs that will include the type and maximum power of the class IV laser being used.

C. All windows into the laser room (or any other viewing area into the room) must be protected against transmission of the laser light for all lasers/IPL except the CO2 laser. It may be achieved by placement of flame retardant opaque materials over the windows such as taping of towels, blinds, or other opaque cutouts for the windows.

D. Appropriate protective eyewear is required for all persons in the Nominal Hazard Zone (NHZ) during laser use. The Laser Safety Officer has designated the entire room (Laser Treatment Controlled Area) as the NHZ so that protective eyewear is required for all persons in the room. These glasses will be made available at the entrance to the room. The IPL (though not a laser) will also require appropriate safety glasses to be worn by personnel within the room. The LSO may from time to time determine that the NHZ, and the need for laser safety eyewear, is smaller than the entire room and may use their informed judgment to make this determination on a case by case basis as allowed by ANSI 136.3.

1. Safety glasses must be worn by all personnel in the NHZ at all times while the laser is in operation. The safety glasses must be specific to the wavelength of the laser being used. Protective eyewear will be labeled according to the optical density and wavelengths filtered. Safety glasses for the IPL unit will be the generic IPL safety eyewear or the more specific “light-speed” (model name) eyewear.
2. Viewing laser or IPL operation through a video monitor offers no risk to the viewer in any situation.
3. No safety glasses or filters offer eye protection against a direct, close range impact through the safety material into the eyes. Personnel will therefore not point the laser or fiber directly at any person's face. The laser fiber will always be handled as a "loaded gun" and pointed in a safe direction in the event of an accidental firing.
4. Eyewear and filters should be without defect. Frames should not be broken and separated from the lenses. Sideshields - if optionally used - should be in place, and no scratches should be on the front lenses. The laser operators or safety officer will make periodic inspections for these defects.
5. The patient shall be provided the same protective eyewear as personnel, or other types of eye coverings. In the event that treatment needs to take place on the face around the eyes, the eyes shall be protected by placing opaque coverings (ie towels) completely around their eyes so that no light shines through - or fitted with eye covers or commercial eye shields that provide similar protection. In the event the laser must be used directly on the eyelid or within the bony orbit of the eye, appropriate laser safety eyeshields will be placed between the lid and the eye to provide protection.

E. The laser will be operated only by those who have had training in laser theory, techniques of control, and operation of the laser(s) or IPL.

F. A program for laser safety training will be made available to ALL personnel working around the lasers. The LSO shall have discretion, according to ANSI standards, in delineating which personnel are required to undergo which levels of training. All of the training shall be documented and kept on file.

G. A Safety Audit of the facilities safety program shall be conducted at least once per year, under the supervision of the LSO. It shall include a review of all the safety policies and procedures, facility and equipment, personnel training, documentation, and substantial compliance with ANSI Z136.3 standards for the safe use of lasers in health care institutions, as related to the office use of the lasers currently employed in the practice – currently the 1064nm Nd:Yag, 532nm KTP, 1320nm Nd:Yag, IPL broadband, 10600nm CO2 and LED (non-laser) light sources (List whatever lasers or IPL’s you have).

H. Keys to lasers will be stored in an area accessible only to properly trained individuals. The key will not be left in the laser during storage.

I. Laser equipment and accessories will be stored in a safe and protected area.

J. It is the physician's responsibility to select appropriate settings such as power, spot sizes, power density, fluences, operating modes, pulse times and accessory operation during each procedure. Should the physician designate and train appropriate office personnel to perform the dermatological procedure(s) themselves, he will provide instruction on the selection of these settings.

K. Lasers will be checked for proper operation and test fired prior to each procedure.

L. The laser will be placed in the standby mode whenever it is not being fired, to prevent accidental firing into the field, prevent accidental fires, and preclude accidents that could occur if the laser and other footpedals are confused and fired during a procedure.

M. The operater - the person applying the laser to the skin - , and no other person, should control the laser footpedal or handswitch..

N. The laser footpedal should be situated separately from other footpedals such as electrosurgery or microscope controls.

O. LASER SAFETY OFFICER – The professional end user (clinical user) – (THE DOCTOR’S NAME HERE – OR WHOEVER YOU APPOINT AS THE LSO) - assumes the responsibilities of the LSO for the purpose of these policies, as allowed by ANSI 136.3 standards. NAME assumes responsibility of ensuring that all safety policies/procedures are followed, that appropriate training of personnel has occurred, and that the safety program is reviewed annually. This may be done directly or through delegation to responsible and trained personnel operating under the authority of the professional end user.

P. Operation of the Laser by nonphysicians for aesthetic procedures. The physician may delegate operation of the laser for this purpose to appropriately trained personnel, per the guidelines of the American Society for Laser Medicine and Surgery.

Q. A written record will be kept of laser maintenance, and include documentation of calibration each six months.

R. Flammable gases, such as Oxygen or Nitrous Oxide, will be used only if necessary during laser cases, at concentrations less than 40%, and the laser operator will examine the gas delivery system setup to minimize any fire risks. Minimum concentrations of oxygen below the 40%, required to adequately oxygenate the patient, will be used.

S. Startup and Shutdown procedures:
The laser manufacturer's recommendations for operation of the particular unit will be followed by the laser nurse / operator. - Refer to the laser checklist.

T. Fire precautions:
The CO2 laser presents the higher risk for ignition of dry and flammable materials and appropriate precautions will be taken when necessary, such as the use of moistened towels or sponges to drape the perimeter of laser treatment areas, and avoiding or protecting hair lines that might have hair spray or flammable prep solutions dried in the hair line. Personnel will be made aware of the location of office fire extinguishers.

U. Incident Reports:
Any suspected incidents putting patients or staff at risk of eye injury, or of potentially harmful treatment shall be immediately reported to Dr. Biesman. In the event of suspected eye injury appropriate eye examinations will be performed, and in the event of potential harmful treatment parameters, Dr. Biesman will medically evaluate the patient and appropriately manage any potential complications.

Attached: ASLMS recommendations for office based procedures, training and use of lasers by nonphysicians

END.

(Note that these are currently being updated)

American Society for Laser Medicine and Surgery Recommendations

PRINCIPLES FOR NON-PHYSICIAN LASER USE

Any physician who delegates a laser procedure to a non-physician must be qualified to do the procedure themselves by virtue of having received appropriate training in laser physics, safety, laser surgical techniques, pre and post operative care, and be able to handle the resultant emergencies or sequelae.

Any non-licensed medical professional employed by a physician to perform a laser procedure must have received appropriate documented training and education in the safe and effective use of each laser system, be a licensed medical professional in their state, and carry adequate malpractice insurance for that procedure.

A properly trained and licensed medical professional may carry out specifically designed laser procedures only under physician supervision and following written procedures and/or policies established by the specific site at which the laser procedure is performed.

Since the ultimate responsibility for performing any procedure lies with the physician, the supervising physician should be immediately available and shall be able to respond within five minutes to any untoward event that may occur. Ultimate responsibility lies with the supervising physician.

The guiding principle for all physicians is to practice ethical medicine with the highest possible standards to ensure the best interest and welfare of each patient is guaranteed. The ASLMS endorses the concept that use of properly trained and licensed medical professionals, under appropriate supervision, allows certain laser procedures to be performed safely and effectively.

Approved by the Board of Directors
American Society for Laser Medicine and Surgery, Inc.
April 15, 1999
(document to be reviewed on an annual basis)

American Society for Laser Medicine and Surgery Recommendations

ASLMS GUIDELINES FOR OFFICE-BASED LASER PROCEDURES

Introduction

Many laser procedures are safe and appropriate to the office setting. High standards of practice, similar to those in the institutional setting, should be maintained to ensure quality of care for the surgical patient who undergoes an outpatient surgical procedure in an office-based surgical facility.(1)

Laser Privileges

The mere acquisition of a skill is not the only criterion by which to measure qualifications. The office setting should not provide an opportunity for practice of inadequately trained personnel. Office staff must meet accepted standards of training and experience and would generally qualify for and hold privileges in an institutional setting.(2)(3) As new technology is introduced into the clinical setting, it is essential that all medical staff using the technology be appropriately educated and their skills assessed.(4)

Patient and Procedure Selection

Prudent selection of both procedures and patients appropriate for office-based laser procedures is critical. Procedures that have intrinsic risk or require technology not available in the physician's office are more appropriately performed in an institutional setting.

In order to determine and apply proper indications for a procedure and to select the appropriate patients for applications of the technology, comprehensive knowledge of the disease process and experience in management of patients with the disease is essential. Prompt recognition and management of complications can only be achieved when the individual or team member is fully qualified in all aspects of treatment of the disease.(5)

Patient Safety

Patients should receive clear pre-procedure instructions. Confirmation of important compliance issues such as NPO status should be documented.

Conscious sedation used as an adjunct for office-based laser procedures must be conducted safely. There must be appropriate instrumentation and expertise in managing respiratory depression and cardiac arrest. Oximetry and automated blood pressure monitoring should be routinely employed; electronic cardiographic monitoring should be available. Oxygen, drugs and equipment routinely used in cardiopulmonary resuscitation, including adequate suction, must be available.

The availability of emergency transport to an acute care facility willing to accept patients from the office should be guaranteed.

The laser procedure should not be compromised by lack of equipment required to perform the proposed procedure.

All office-based laser patients must be sufficiently recovered from procedures and sedation prior to discharge. Following procedure requiring sedation vital signs should be monitored and respiratory function and mental status assessed in a manner similar to hospitalized patients. If sedation has been used, the patient must be accompanied by a reasonable adult at discharge. Written instructions regarding common complications, directions for returning for emergency evaluation and caution as to continued functional impairment for many hours following conscious sedation are appropriate.

Periodic preventive maintenance and testing of bio-electrical equipment should be done by a qualified professional.

Standard protocols for both personnel and patient protection from infectious disease must be rigorously observed including body fluid isolation, proper specimen handling as well as proper instrument cleaning and disinfection.(6)

Records and Quality Assurance

Each patient should have at minimum a brief history and physical examination by the physician. Serious cardiopulmonary or other disease should be excluded by appropriate clinical, and if necessary, laboratory evaluation.

The patient chart should contain the clinical examination and evaluation, the justification for the procedure, the description of the treatment and the patient's status on discharge. Informed consent for the procedure should be documented in the chart consistent with local professional standards and applicable state law.

Records should be maintained so that complications and problems can be identified and compliance with recommendations for clinical and laser treatment ensured.(6)

Additional Resource

American College of Surgeons monograph Guidelines for Office Endoscopic Services (1991) and Guidelines for Optimal Office-Based Surgery.

References

(1) Accreditation of the Office-Based Surgical Facility: Bulletin of the American College of Surgeons, Vol. 80 (8) 1995.
(2) Standards of Training for Physicians for the Use of Lasers in Medicine and Surgery, American Society for Laser Medicine and Surgery, Inc. 1991.
(3) American National Standards Institute (ANSI), 11 West 42nd Street, New York NY 10036.
(4) Statement on Emerging Surgical Technologies and the Evaluation of Credentials: Bulletin of the American College of Surgeons, Vol. 79 (6) 1994.
(5) Statement on Issues to be Considered Before a New Surgical Technology is Applied to the Care of Patients: Bulletin of the American College of Surgeons, Vol. 80 (9) 1995.
(6) Guidelines for Office-Based Surgery: Quality Assurance: Bulletin of the American College of Surgeons, Vol. 79 (10) 1994.

Approved by the Board of Directors
American Society for Laser Medicine and Surgery, Inc.
April 15, 1999
(document to be reviewed on an annual basis)

American Society for Laser Medicine and Surgery Recommendations

EDUCATIONAL RECOMMENDATIONS FOR LASER USE BY NON-PHYSICIANS

Individual should be a licensed medical professional, and carry adequate malpractice insurance.

Individuals should be trained appropriately in laser physics, tissue interaction, laser safety, clinical application, and pre and post operative care of the laser patient.

Prior to the initiation of any patient care activity the individual should have read and signed the facilities policies and procedures regarding the safe use of lasers.

Continuing education of all licensed medical professionals should be mandatory and be made available with reasonable frequency (including outside the office setting) to help insure adequate performance. Specific credit hour requirements will be determined by the state, and/or individual facility.

A minimum of TEN procedures of precepted training should be required for each laser procedure and laser type to assess competency. Participation in all training programs, acquisition of new skills and number of hours spent in maintaining proficiency should be well documented.

After demonstrating competency to act alone, the designated licensed medical professional may perform limited laser treatments on specific patients as directed by the supervising physician.

Approved by the Board of Directors
American Society for Laser Medicine and Surgery, Inc.
April 15, 1999
(document to be reviewed on an annual basis)

Appendix B: LASER HAZARD CLASSIFICATIONS

The classification of laser hazards by ANSI is based upon the intensity of the emitted beam. It describes the ability of the laser to injure personnel. The higher the number, the greater the possible hazard. These are not to be confused with FDA classification levels, which relate to the type of medical device.

The description of these hazard classifications are contained within ANZI Z-136.1, the parent document to the A-136.3 used for Health Care Facilities, and available from the Laser Institute of America.

Essentially all of the surgical lasers -- those that by definition are used to vaporize or burn tissues, or anything over 0.5 watt of average power -- are all classified as Class 4 lasers. These present potential burn hazards from even diffuse reflections of the beam, if close enough to the reflecting surface. The lower classes of lasers present potential eye hazards, varying in chance and severity with the class of hazard.

The Hazards increase with the Class of Laser progressing from: 1 – 1M – 2 – 2M – 3R – 3B - 4

CLASS 1 & 1M: These lasers (or systems) are exempt from general controls because they present no hazards when used under ordinary circumstances.

CLASS 2: These are very low power visible lasers which will not present hazards, even if viewed directly, for short periods of time. They are not intended for prolonged viewing **--** in the range not to exceed 1000 seconds (over 15 minutes of direct viewing). Common experience will reveal that one can not even stare directly into a 100 watt light bulb for that length of time without discomforting effects. This should put laser hazards into some perspective.

CLASS 2M: These are low power visible lasers which normally don't present a viewing hazard, but only because of the normal human aversion response. (Blinking and/or turning away within 0.25 seconds) They could present a problem if viewed for extended periods of time. It's interesting to note that this level of hazard also applies to many conventional light sources (like endoscopic light sources). They include low power lasers such as HeNe laser pointers or the grocery store scanners. The only way to be hurt is to intentionally overcome ones natural aversion and stare directly into the beam (This is about as hard as intentionally staring into the sun).

CLASS 3R: These lasers are safe if viewed only momentarily with the unaided eye, but the use of collecting optics may create the hazard.

CLASS3B: These are lasers that can definitely produce a hazard when viewed directly, including the intrabeam viewing of specular reflections (acutely reflected beams such as from a mirror like surface). Only the higher powered 3b lasers present hazards from diffuse reflections.

CLASS 4: These include most of the surgical laser systems, which produce hazards from both specular AND diffuse reflections. They may also present fire and skin burn hazards.

THE LASER TRAINING INSTITUTE[tm]

Professional Medical Education Assn., Inc
P.O. Box 522379 Marathon Shores, FL 33052

LASER COURSE POST TEST
- Laser Safety & Credentialling Module, 1 of 2 tests -
LASER HAZARDS & SAFETY

Name_____________________________________Date________________________

1. **Surgical laser systems which can vaporize or photocoagulate tissues are classified by ANSI as:**
   a. Class I systems
   b. Class II systems
   c. Class III systems
   d. Class IV systems

2. **The laser which presents a burn hazard only to the surface of the eye, and not to the retina is:**
   a. CO2 laser
   b. Nd:Yag laser
   c. Argon laser
   d. Pulsed dye laser, yellow

3. **Match the wavelength labeling of the safety glasses on the left, to the type of laser for which they offer protection on the right:**

Labeling on Glasses		**Type of Laser**	
____	10.6 micron	**a.**	Argon
____	1.06 micron (1064nm)	**b.**	CO2
____	488 to 515 nm	**c.**	Nd:Yag
____	2.1 micron	**d.**	Ho:Yag

4. **For which type of laser does the glass optics in microscopes offer protection to the user, in lieu of safety glasses:**
   a. CO2 laser
   b. Nd:Yag laser
   c. Argon laser
   d. Pulsed dye laser, yellow

5. **Which one type of endotracheal tube is to be avoided when using the laser (most likely the CO2 laser) directly in the airway**:
   a. Red rubber, wrapped with metal foil
   b. PVC, polyvinylchloride
   c. Silicone rubber
   d. all metal Norton tubes

6. **Which laser presents the highest risk of igniting dry materials, like dry 4x4 sponges, in the surgical field:**
   a. CO2 laser
   b. Nd:Yag laser
   c. Argon laser
   d. Pulsed dye laser, yellow

7. **Select ALL of the lasers below which can present a retinal burn hazard:**
   a. CO2 laser
   b. Nd:Yag laser
   c. Argon laser
   d. Pulsed dye laser, yellow

8. **What should be done to preclude damage to a flexible endoscope?**
   a. Fire the laser as it is advanced through the channel to clear it
   b. If the fiber gets stuck push hard to ensure it clears the channel
   c. Mark the fiber, or view directly on video to ensure it's outside the channel before firing.
   d. Flush the channel with saline while firing to absorb the heat of the laser.

9. **What should be done when using the Ho:Yag laser, through rigid arthroscopes to preclude damage to the optics in the rigid scope:**
   a. Flush continuously with saline to absorb the heat
   b. ensure that the fiber tip doesn't come too close to the telescope optic
   c. Use only the laser resistant scopes
   d. Have the telescope black anodized to reduce reflections

10. **Fiberoptic lasers such as the Nd:Yag <u>present a fire or burn hazard</u> to dry materials in which one of the following scenarios:**
   a. When the laser fiber is fired at a dry towel in the surgical field, but 9-12 inches away from the tip.
   b. When the laser fiber is fired at a dry towel across the room from the laser fiber.
   c. When the laser fiber is fired into a dry towel while the fiber tip is resting in the towel.

d. When the laser fiber is fired at a dry towel several inches away from the tip, while a contact fiber or tip is being used.

11. **For which laser does the glass in the windows of the operating room offer protection to viewers outside the room, so that NO additional window coverings are required:**
   a. CO2 laser
   b. Nd:Yag laser
   c. Argon laser
   d. Pulsed dye laser, yellow

12. **When moistening sponges in the surgical field as a precaution for laser use, which materials are both safe and adequate to prevent the sponges from igniting:**
   a. Saline
   b. Sterile distilled water
   c. blood
   d. Lactated Ringers
   e. All of the above

13. **For which laser can pools of irrigating solution serve as a backstop to the laser beam:**
   a. CO2 laser
   b. Nd:Yag laser
   c. Argon laser
   d. Pulsed dye laser, yellow

14. **What characteristic of anodizing instruments causes its reflectivity of CO2 laser beams to be significantly reduced:**
   a. the dulled surface of the instrument it creates
   b. the black coloration on the instruments surface
   c. a special process which changes the nature of the metal causing it to absorb <u>all</u> of the incident laser energy.

15. **Hysteroscopic surgery within the uterus, with a fiber laser system, should <u>NEVER</u> be used in which of the following configurations:**
   a. Bare fiber, which is cooled by the insufflating solution
   b. Catheter type fiber, which is cooled by pumping a solution through it
   c. Catheter type fiber, or contact tips, which is cooled by gas (air) flow
   d. Catheter type fiber with contact tips, which is cooled by pumping a solution through it.

16. **Which one of the following statements regarding the radiation risks of the laser "environment" to pregnant women is most true:**

   a. Pregnant women should avoid working around lasers during the first trimester.
   b. Pregnant women should avoid working around lasers during their entire term of pregnancy.
   c. Laser "radiation" presents no risks to women in any stage of pregnancy.
   d. Pregnant women should simply wear the radiation dosage tags to monitor

17. **Which item below which is <u>NOT</u> a responsibility of the laser nurse/technician, functioning under the authority of the laser safety officer, during a laser procedure:**

   a. Post appropriate Laser Danger signs on the door(s) to the room
   b. Ensure that the correct laser safety glasses are available and worn
   c. Inform the operating physician of the correct laser power and other laser settings to use for the procedure.
   d. Ensure compliance with the institutions safety policies and procedures

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LASER COURSE POST TEST
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LASER SAFETY & REGULATIONS

Name____________________________________Date_______________________

1. Which organizations provide guidelines or enforcement of laser safety/training:
   A. American Hospital Association (AHA)
   B. American National Standards Institute (ANSI)
   C. American Society for Laser Medicine & Surgery (ASLMS)
   D. Both B & C
   E. Both A & B

2. Who provides voluntary certification for laser nurses, operators & technicians?
   A. The FDA
   B. ANSI (American National Standards Institute)
   C. The Laser Training Institute
   D. Each hospital sets its own standards
   E. National Council on Laser Excellence (NCLE)

3. What best describes the ANSI safety regulations?
   A. They are federally required safety regulations with the force of law
   B. They are only suggestions from a volunteer agency and have no regulatory impact.
   C. They are voluntary standards by themselves, but are used as a reference by other agencies such as OSHA and JCAHO.

4 .Most Surgical lasers are classified as which Hazard Class of Laser (ANSI)?
   A. Class 1
   B. Class 2
   C. Class 3
   D. Class 4

5. All of the following are responsibilities of the LSO, EXCEPT:
   A. Ensure that warning signs are posted
   B. Ensure that physicians use appropriate power and exposure settings
   C. Ensure that the entire O.R. staff has been properly trained in Laser Safety
   D. Ensure that the lasers are properly maintained and serviced.

6. How often are formal Laser Safety Audits required to be conducted within a facility to be in compliance with ANSI recommendations?
   A. Every 6 months
   B. Every year
   C. No requirements
   D. Each time the Laser Safety Officer position changes

7. All Service Technicians should have:
   A. An authorized service technician certificate from the manufacturer
   B. A degree from a laser technical school
   C. Documented laser safety training and education
   D. Laser Repair Certification

8. Which is a non-beam laser hazard?
   A. Laser Plume
   B. Burns
   C. Eye Hazards

9. Which hazard is probably greater with surgical laser use?
   A. Direct hazards of the laser beam
   B. Improper surgical procedures & use of the laser
   C. Non-beam laser hazards such as electrical, etc..

10. The NHZ (Nominal Hazard Zone) requires that:
   A. All personnel wear safety eyewear upon entering the room
   B. All personnel wear safety eyewear only when inside the NHZ boundary
   C. All personnel must follow all control measures within the NHZ
   D. Both B & C

11. How often must the alignment of the laser beam be checked against its alignment beam?
   A. Every Six months
   B. Every Year
   C. Every Case

12. Who determines the boundaries of the Nominal Hazard Zone
   A. The operating physician
   B. The Laser Safety Officer
   C. The Laser Nurse/Operator in the room
   D. No one, it is already set as the entire room for medical use

13. Which organization can levy large fines against an institution/office for violation of laser safety standards?

A. ASLMS ,
B. OSHA
C. JCAHO
D. FDA-CDRH
E. AHA

14. What are the requirements for the Laser Treatment Controlled Area (LTCA, or the Laser Room)

A. Safety Eyewear must be made available upon entry to this room
B. Safety Eyewear must be worn when entering this room
C. Only authorized personnel are to enter this room
D. Both A & C

15. All Health Care Facilities, including hospitals, clinics, offices, etc. MUST appoint a Laser Safety Officer if lasers are used in the facility.

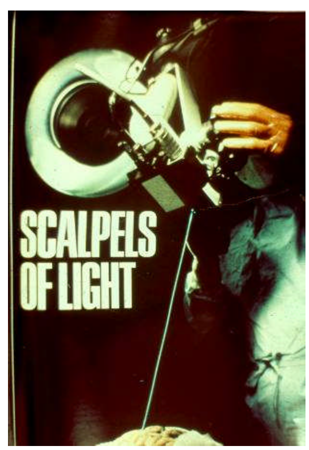
A. True
B. False

OVERVIEW OF CLINICAL LASER APPLICATIONS

Please note that as of Nov 2011 this review of Clinical Laser Applications is becoming somewhat outdated. However, it still contains much useful information so we'll continue to include it. Types of lasers and all of their clinical applications continue to grow at such a fast rate that it has become virtually impossible to include comprehensive information on all applications in this one manual. Please use this as a starting point and then do searches on the applications in areas of your own interest.

Gregory Absten, Michael Kochman MD, Harvey Wigdor DDS, J. Thomas Cox MD, Elliott Lach MD, James McCaughan Jr., MD, Brian Shumaker MD, Raymond Lanzafame MD

- **Ophthalmic, Argon Laser Pan Retinal PhotoCoagulation in Diabetics**
- **Gynecology, Cervical Ablation with UltraPulse CO2 Laser**
- **Gynecology, Ectopic Pregnancy with Contact Tip Nd:Yag Laser**
- **Gynecology, Adhesiolysis with KTP Laser**
- **Gynecology, Uterosacral transaction with KTP Laser**
- **Gynecology, Ovarian Cyst with KTP Laser**
- **Orthopedics, Intro to Ho:Yag Laser**
- **Orthopedics, Ho:Yag Menisectomy**
- **Orthopedics, Ho:Yag Condromalacia**
- **Orthopedics, Ho:Yag Percutaneous Lumbar Laser Discectomy**
- **ENT, CO2 Laser MicroLaryngoscopy**
- **ENT, KTP Tonsillectomy**
- **ENT, ET Tube Fires**
- **Cardiology, Ho:Yag Transmyocardial & Percutaneous Revascularization.**
- **PhotoDynamic Therapy for Cancer**



At this point in time, the medical applications of laser are so numerous that it is not possible to discuss them all in an introductory article on clinical use. We can cover most of the major, and more established laser procedures. This is not a procedural manual however, and no attempt is made here to explain the surgical techniques required for the various procedures. Such a manuscript would naturally require several volumes since it encompasses a myriad of procedures in many specialties. This article does overview most of the laser applications, and the interested reader is encouraged to research the appropriate clinical articles. This manual is an overview of the ENTIRE medical laser field and does not focus on just one area, such as dermatology or aesthetics. Readers are directed toward our specialty courses in these areas or more focused literature on those specific areas.

In particular, the ASLMS journal has published a series of 12 review articles from 1994-1995 which discusses the state of laser development in each of the major specialties. This series of articles alone would comprise a substantial book, consisting of almost 500 pages.

The advantages of laser surgery vary with each type of procedure, and sometimes from case to case. Realizing the full advantage of the laser assumes it is applied appropriately.

Conventional surgical techniques performed well will always give better results than misapplied laser. Some of the potential advantages of laser include:

-No-touch technique
-Reduced blood loss
-Limited fibrosis and stenosis
-Fiberoptic delivery
-Potential reduction in spread of metastasis
-Fewer instruments in the field (convenience)
-Reduced postoperative pain (selectively)
-Sterilization of the impact site
-No interference with monitoring equipment
(compared with some electrosurgical procedures)
-Dry surgical field (hemostasis)
-Reduced edema (when tissue manipulation is reduced)
-Precision (high degree of control over lateral damage - the quintessential advantage of laser over electrosurgery in many applications)
-Unique Capabilities - some systems (dermatology, ophthalmology, some others) provide a means of treatment either unavailable from other technologies, or of significantly better utility.

Many of the references in this segment refer to "surgical" laser uses, by which we mean lasers used in an operating or outpatient treatment room to cut and vaporize tissue. This is used in somewhat of an arbitrary fashion, but in discussions we differentiate ophthalmic laser use from "surgical" laser use even though both quite obviously involve surgery. Ophthalmic laser applications are very well developed, but utilize equipment in very different configurations than that used for "surgical" laser systems as a general rule.

Dermatological and Aesthetic procedures are now very prolific and use primarily the “non-surgical” aspects of the laser – in particular selective photothermolysis which allows destruction of certain structures in the skin (ie; hair, pigment, etc) through selective heating while preserving adjacent or underlying structures.

Overview of the different laser types by specialty application

The CO_2 laser is still among the most commonly used laser in an operating room setting. It has widespread applications that make use of its cutting and vaporizing abilities, because of the infrared output at 10,600 nm. Its secondary cautery effects are also helpful, but it certainly should not be considered bloodless surgery. It is not a fiberoptically delivered system and must be delivered through an articulated arm to whatever attachment is required, though some waveguide delivery devices are now available which somewhat mimic fiber use. Powers range from about 20 to 100 watts. Main surgery lasers should be at least 40 watts, and preferably in the 50-60 watt range. Higher power, up to 100 watts, is desirable if the money is available, but not necessary.

The Nd:Yag laser, near-infrared at 1064 nm, is also one of the more common surgical units - primarily for its use with "hot" contact fibers and probes. Its fiberoptic delivery, high power when needed, and now the contact probes and fibers for fine cutting and vaporizing, makes this a very versatile instrument in many specialties. General surgery, which sees little laser use otherwise, may develop significant use for contact Nd:Yag laser surgery (with contact probes on Yag lasers or with bare argon or KTP laser fibers). This contact approach is also widely used for laparoscopic procedures.

The problem with contact laser surgery, however, is its very high cost in probes. Newer types of "sharp" fibers, that precisely simulate the cutting effects of contact probes, will allow for the same applications without the high cost. Some of the special shapes of the contact probes, such as the chisel and rounded probes, are not duplicated by the "sharp" fibers. Though contact type procedures definitely expand the versatility of the Nd:Yag laser, it should not be viewed as a universal replacement for the other lasers.

Nd:Yag lasers, pulsed in the millisecond range, are used for aesthetic laser procedures including laser hair removal and skin rejuvenation. The Nd:Yag laser is used in aesthetics on darker skin types to prevent burns and pigmentary changes. These types of pulsed Nd:Yag lasers are configured differently than the CW Nd:Yag lasers used for surgery and are not interchangeable.

Diode lasers have more recently been developed to "drive" contact types of fibers as a “hot knife” for surgical laser uses. Diode systems are compact, portable and quiet laser systems, utilizing an array of solid state diode lasers emitting near infrared light. Current systems produce 60 watts or more of CW power.

Diode lasers have also seen strong usage in portable ophthalmic systems -- being used for intraoperative retinal coagulation’s and other work. They are also significantly used in dermatological procedures such as hair removal.

Diode laser use in Aesthetic procedures include the 810nm pulsed diode laser for Laser Hair Removal (for darker skin types, with Nd:Yag for the darkest skin types). The 810nm or 1450nm Diode is also used for skin rejuvenation. Diode lasers at 532nm are used in both aesthetic procedures and ophthalmology.

The Q-Switched Nd:Yag laser used in ophthalmology is a pulsed laser (pulsed - different than the Continuous Wave one used in surgery) used for its "cold cutting" effects on tissues within the eye. Dermatology also uses Q-switched Nd:Yag (and other) lasers for tattoo removal, but the ones in dermatology are not pulsed to the energy intensities of the ophthalmic systems.

The Argon laser is one of the most prevalent overall, though not in an operating room setting. Its primary use has been in ophthalmology as a retinal photocoagulator. It was previously widely used for vascular skin lesions in dermatology, though the copper vapor and dye lasers are more specific for these cosmetic lesions. The Argon laser is one of the systems used to “pump” **the Tunable Dye Laser** used in Photodynamic Therapy.

The KTP laser (Potassium Titanyl Phosphate) has a conventional Nd:Yag laser at its heart, but this Yag output is transmitted through a KTP crystal which has the effect of changing the "color" of the laser beam to green at 532 nm. This wavelength, though slightly different from the argon lasers, has the same applications and tissue effects of the argon - for all practical purposes. In some special applications in dermatology, where heat generation may be a problem, the KTP can produce somewhat "cooler" effects. The features and benefits of the hardware itself is different between lasers, but the surgical uses are very close if not identical. Argon and KTP lasers, although fiberoptic systems do not require use of special contract probes since they already achieve very similar effects without them. The KTP laser is more widely used for laparoscopic and endoscopic procedures than is the Argon, but primarily only for market acceptance reasons. The KTP laser is one of the systems used to “pump” the **Tunable Dye Laser** used in Photodynamic Therapy.

One additional feature of the KTP laser is that, since it includes the primary Nd:Yag laser, it may be purchased in a configuration which allows use of either wavelength - the green at 532 nm and the infrared of the Nd:Yag at 1064 nm – the KTP/YAG laser.

The Copper Bromide (CuBr) laser emits both a green beam at 511nm and a yellow beam at 577nm. It is an aesthetic laser system that can use either beam separately, or in combination to increase its versatility. It is utilized to treat red vascular lesions and veins, remove pigmented lesions such as age spots or freckles, treat acne and provide general skin rejuvenation, and physically ablate some lesions.

The Holmium:Yag laser is a mid-infrared laser emitting pulsed light at approximately 2.1u. This unit is extremely useful for joint arthroscopies. The pulsing and wavelength allow for a precise CO_2 laser like effect, but it also transmits through standard fibers and can be used under fluid. It is a powerful “lithoptripsy” laser but must be used under direct vision because of its tremendous power. Lower powered units are used in ophthalmic procedures.

Mid-infrared lasers such as the **Erbium:Yag** at 2.94u may see tremendous applications in orthopedics and dentistry as a highly precise "bone saw and drill". In the meantime they are used in dermatology for ablative skin rejuvenation.

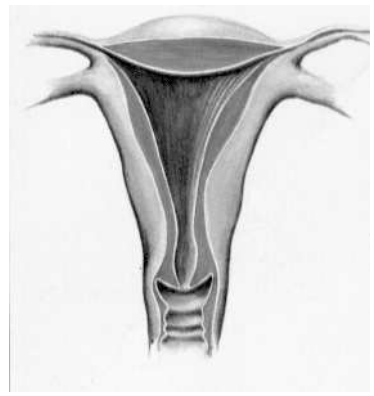
An entire class of pulsed laser systems has developed over the past few years for specific dermatological applications. These pulsed systems include the **Pulsed Dye**, **Pulsed Nd:Yag** -- both at 1064 nm and doubled to 532 nm, the **Alexandrite, Diode** and **Ruby Laser** systems. This is a major area of laser growth.

The Excimer Lasers consist of several different types - all producing pulsed ultraviolet light. Applications include correction of vision by corneal reshaping, and angioplasty in coronary and other vessels, plus treatment of psoriasis and other diseases in dermatology.

Overview of laser use in the major specialties

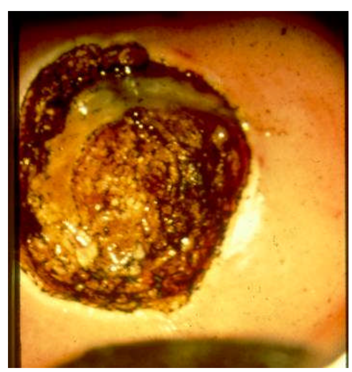
GYNECOLOGY

This specialty probably has the largest potential volume of uses for the CO_2 laser. It is used in colposcopy, operative laparoscopy, and laparotomy for infertility work. The CO_2 laser is the best system for lower tract gynecology of the cervix and vulva. Though electrosurgical LEEP procedures, in knowledgeable hands, can replace use of the laser in many patients, the laser remains the most precise way to treat vulvar/vaginal lesions, and on fragile or compromised cervices.



The use of argon, KTP, and Nd:Yag lasers is also seeing strong use in gynecology. Each system may be manipulated to cut, vaporize, or coagulate tissue. The bare fiber systems of the Argon and KTP are among the nicest for laparoscopy using non-contact techniques (though contact fibers may be used with these lasers too).

Laser uses in Gynecology generally include:



- Cervical Intraepithelial Neoplasia (CIN)
- Vulvar Intraepithelial Neoplasia (VIN)
- Endometrial Ablation for Menorrhagia
- Uterine septum's
- Vaginal intraepithelial Neoplasia (VAIN)
- Condyloma Accuminata
- Laparoscopic Procedures (all types)
- Uterine Fibroids

In laparoscopy the laser provides a significant advantage in providing a method to treat mild to moderate endometriosis at the time of the diagnostic look. It can vaporize or coagulate endometriomas and dissect adhesions. It is good for freeing up stuck tubes and ovaries and can totally eliminate abdominal bleeding. The CO_2 laser has been the primary instrument to this point for laparoscopy. The articulated arm and need for a laser coupling cube has been awkward, and smoke production creates the need for continuous high flow insufflation to clear the smoke and maintain pneumoperitoneum. Fiberoptic laser systems are the definite trend in laser laparoscopy because they are easier to work with and eliminate much of the smoke. These include the argon, KTP, Ho:Yag and Nd:Yag (particularly with contact probes) lasers. The Argon and KTP seem nicer for general laparoscopy, and the Nd:Yag with contact probes makes a slightly nicer incision for ectopic pregnancies.

Abdominal cysts and tumors may be excised or vaporized with similar benefits. The ability to vaporize tissue with minimal surrounding damage, even when associated with dense and extensive tissue adhesions, has proven of great value for patients with complications of pelvic inflammatory disease.

Uterine myomas may be removed by vaporization or excision. A microlaser myomectomy provides hemostasis and precision when removing fibroids.

CO2 Laser Laparoscope 1

Laser has been used in cornual reimplantation. Radical procedures, such as radical vulvectomies, and excision of large vascular tumors are performed with laser for better hemostasis.

One of the most common previous uses of the CO_2 laser was the treatment of cervical intraepithelial Neoplasia (CIN) by either ablation or excision. This is most commonly done through the colposcope. The Nd:Yag laser with contact probes will perform an adequate excision or ablation, but significantly slower than a CO_2 laser, with more conduction heat transfer. For routine conizations laser use has been largely replaced by the electrosurgical LEEP procedure.

Proper laser vaporization of the cervix provides advantages over LEEP, knife conization or cryotherapy. It leaves the cervix in a more viable condition, with no stenosis and minimal scarring. It is possible to tailor the treatment to the extent of the disease and give assurance that the entire diseased area was treated. It eliminates the heavy discharge associated with cryosurgery and is significantly more precise. Laser colposcopy is an outpatient or office procedure for ablations - a significant advantage. The LEEP procedure has substantially replaced laser vaporization for cervical work, though one of the resulting problems of LEEP -- because it is so easy to perform and inexpensive -- is that over treatment of patients has become a significant problem, and it is very easy to remove too much cervix too quickly.

Similar advantages of laser are gained in the laser treatment of vaginal intraepithelial Neoplasia (VIN), and the laser remains the preferred method.

Genital warts such as Condyloma Accuminata may be treated to advantage with the laser. The CO_2 laser not only vaporizes the lesions (frequently through the colposcope) but can also flash sterilize the skin between lesions. In more extreme cases the laser cleanly vaporizes a shallow layer of skin between the exophytic lesions. This kills the latent virus and reduces frequency and extent of outbreaks by decreasing the viral load on the immune system. The pulsed dye laser is similarly used to decrease this subclinical virus and reduce the load, though it is not as effective at eliminating the exophytic warts. Argon or KTP lasers may be used for superficial lesions through the colposcope, but this is not nearly as precise as the CO_2 laser. Contact probes on the Nd:Yag are used to superficially vaporize the warts in a contact fashion, but also have higher heat conduction than the CO_2 laser properly used.

In the future, HPV may be treated in a non-surgical fashion with photosensitizing drugs and a dye laser, or gold vapor laser. This is an area known as Photodynamic therapy, now used to diagnose and treat cancer, but applicable to many other areas.

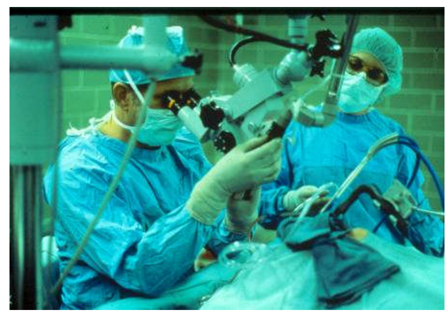
Laser has proven beneficial for many types of operative hysteroscopy. Uterine septae may be cut with contact probes on the Nd:Yag, or bare fibers with the argon or KTP lasers.

The use of the Nd:Yag in hysteroscopy began with endometrial ablation as a treatment for chronic menorrhagia. The procedure, which may be performed on a same day surgery basis, uses the laser to "cook" the endometrium, creating a type of Asherman's syndrome of scarring of the uterus. Not all women become totally amenorheic after treatment, but almost all are happy with results. Retreatment is possible if desired. The use of the "roller ball" on a resectoscope, and more recently the “hot balloons” have largely replaced this application of the Nd:Yag laser. One modality is not inherently safer than the other, but there is some question as to which might actually destroy tissue deeper and more uniformly. The laser continues to be commonly used for septae, fibroids, etc..

FETAL SURGERY

The Nd:Yag laser is used for fetal surgery. The laser fiber may be used to photocoagulate blood vessels in the placenta for problems of "twinning" whereby the vasculature of the placenta sometimes compromises fetal development. Here the Nd:Yag laser is used with a bare fiber delivered endoscopically under direct vision to coagulate feeder vessels.

OTORHINOLARYNGOLOGY (ENT) and MAXILLOFACIAL SURGERY



This is one of the best uses for the CO_2 laser because of the no-touch technique, long "reach" of the laser, absence of postoperative swelling or stenosis, dry operative field, and greatly reduced postoperative pain. The same is true of the argon and KTP lasers if coupled to a micromanipulator.

Laser uses in ENT generally include:

- Laser Stapedectomy
- Allergic Rhinitis
- Papillomatosis
- Nodules
- Laser arytenoidectomy
- Laser Bronchoscopies (rigid & flexible)
- TMJ laser arthroscopies
- Leukoplakia
- Endoscopic Sinus Surgery
- Turbinectomy
- Laryngeal / subglottic stenosis
- Granulomas
- Excision of Carcinomas
- Tonsillectomy
- Snoring-Laser Assisted Uvula Palatoplasty (LAUP)
- Tongue Surgery

Application of the laser to laryngeal diseases requiring microlaryngoscopy has provided a degree of precision otherwise impossible. The argon and KTP lasers may be focused to spots even smaller than that of the CO_2 laser - though their absorption is more diffuse. The precision cutting and excellent healing is an even greater advantage than the hemostasis. Postoperative pain is minimal and most procedures may be done on a same day surgery basis. The need for tracheotomy is reduced. These cases require general anesthesia and appropriate safety precautions must be taken because of the flammability of the endotracheal tube.

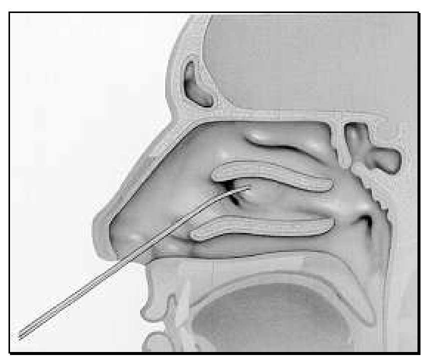
Surgical applications of the laser in microlaryngoscopy include vocal cord nodules, polyps, hyperkeratosis, granulomas, arytenoidectomy, Reincke's edema, cysts, webs and laryngeal stenosis.

All airway lesions are more critical in the child than the adult because of the size of the airway. The treatment of congenital and acquired lesions in pediatric surgery has proven the laser to be a remarkably effective tool. It is ideal for infants. Its properties of hemostasis, enhanced visibility, lack of postoperative edema and scarring all contribute to its successful application in pediatrics.

Recurrent respiratory papillomatosis occurs throughout the anterior nasal cavity, subglottis and mainstem bronchi. These relatively inaccessible locations make the CO_2 laser ideal for removal of all visible papillomas by vaporization. Complete hemostasis allows all visible lesions to be destroyed under constant visual control. There is minimal damage to underlying tissue and the airway can be maintained so that tracheotomy is usually unnecessary. Recurrences are not eliminated, but a large percentage of patients go into a year or more of remission after two or more excisions with the laser.

CO_2 laser may be delivered through a rigid laser bronchoscope. It is used in the palliation and treatment of multiple diseases including recurrent respiratory papillomatosis, tracheal and bronchial stenosis, acute bronchial and tracheal granulation, tracheal membranous webs and palliation of tumors.

The CO_2 laser has been used for intranasal work such as turbinectomy, choanal atresia, and telangiectasia. Contact probes on the Nd:Yag laser, or argon or KTP laser fibers, work better than the CO_2 for most intranasal cutting and vaporizing because of the vascularity. Laser has also been used effectively to treat rhinophyma, polyposis, synechia and granuloma.



In nasal sinus endoscopy, the fiberoptically transmitted lasers work well in opening passages and providing hemostasis. The Ho:Yag laser has been shown to be beneficial in making clean osteotomies because of its pulsing characteristics. The KTP laser is another of the more frequently used systems for endoscopic sinus surgery.

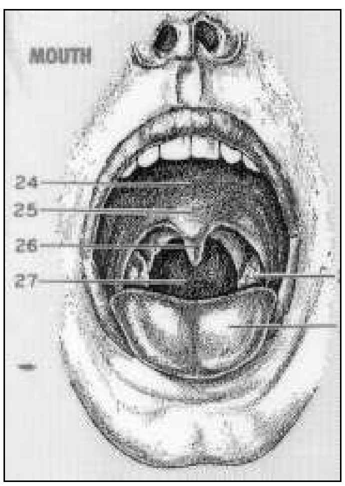
Laser tonsillectomy is most appropriately carried out in patients with coagulopathies such as hemophilia. Proponents of laser tonsillectomy on normal patients point out improved hemostasis and reduced postoperative pain. The fiberoptic systems, used in contact with the tissue, are the most convenient for this application, though CO_2 lasers may also be used. Patients have less post-operative pain and swelling, and are able to begin eating earlier.

Lesions of the oral cavity, such as leukoplakia and other benign lesions, may be excised or vaporized. Tongue releases may also be performed with the laser.

Laser Assisted Uvulo-palatoplasty (LAUP - the "snoring" procedure) has become quite popular with the general public in the last few years.

Conventionally, the soft tissue in the palate may be resected by knife and electrosurgery under general anesthesia in order to firm up the palate and reduce or eliminate snoring in those patients who qualify for the procedure. Lasers (CO2, Argon, KTP, contact Nd:Yag) may be used for this conventional procedure instead. This provides more hemostasis than a cold knife, and offers much less pain than the use of electrosurgery. This conventional procedure is still performed under general anesthesia under one setting.

In the newer "snoring" procedure, the CO2 laser is used on the soft palate to superficially ablate the surface over a period of sessions, inducing contracture and tightening of the soft palate. This procedure is performed as an outpatient procedure on qualified patients and seems to be well tolerated and received by the general public. A scanned or pulsed laser system works the best in order to eliminate excessive heat conduction from the laser into the tissues. A special handpiece may be used with the CO2 laser which allows for simultaneous evacuation of laser plume from the oral cavity while the lasing takes place.



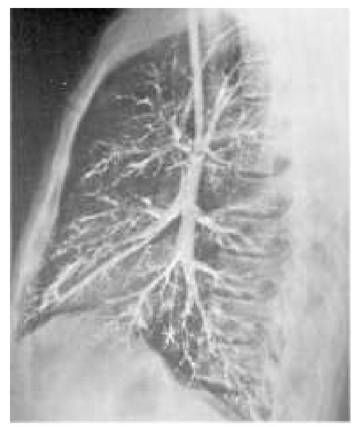
Actual bilateral incisions may be made with the laser for LAUP. These are vertical incisions (by laser) through the palate at the base of the uvula. The uvula is then ablated to reduce its size by about 50%. It is then shaped by the laser to approximate a normal uvula. The palate heals for 3-4 weeks and the procedure is repeated as necessary to cause progressive retraction.

Argon and KTP lasers have been used successfully in otology for stapedotomy because of their small spots. The laser punches a series of holes in the footplate of the stapes that allow an area to be tapped out (like a postage stamp) with minimal mechanical trauma to middle and inner ear structures. The prosthetic piston will be placed in this hole.

Though more developmental, the CO_2 laser has also begun to see use in this application, the primary difference being that it is emitted in a short timed burst to create one small round hole into which the piston is inserted. This short burst in the superpulse mode, with the laser finely focused, helps create the smallest hole (around 0.5mm). Not all CO_2 lasers may be configured to this degree of precision.

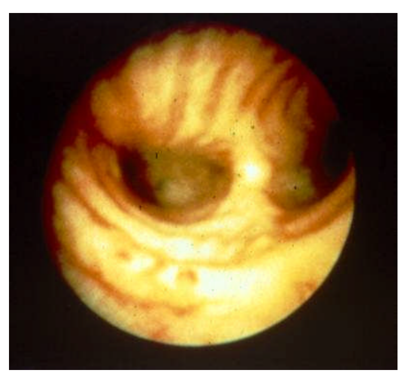
Lasers have also been used for tympanoplasty, myringotomy, treatment of fixed malleus syndrome, and removal of growths.

PULMONARY MEDICINE



Tumors of the trachea and bronchi may be palliated with the CO_2, argon, KTP, Nd:Yag or Ho:Yag lasers. Photodynamic Therapy becomes more of a treatment than palliation if caught very early, but can also be a palliative procedure.

The CO_2 laser is precise, somewhat hemostatic and immediately vaporizes the obstruction. A rigid CO_2 laser bronchoscope, and coupler cube, is required for delivery of the beam. The long focal length of the laser lens also causes to beam to remain in focus for a long distance. This is a potential hazard and one must carefully avoid penetrating the trachea and underlying great vessels.



An obstructive bronchial adenocarcinoma at left shows complete obstruction prior to the Nd:Yag laser treatment. On the right, Nd:Yag laser therapy about 1 week post treatment.

The Nd:Yag laser is also used to treat airway obstructions, probably more effectively than with the CO_2 laser. The Nd:Yag can be used with the bare fiber to achieve coagulation, then debride the necrotic tissue with the scope, or, contact probes may be used to more finely chisel and vaporize a lumen through the tumor. A combination of these techniques may be desirable. The contact probes seem to be one of the more effective and safe ways to open an airway, since a high degree of control prevents dangerous collateral damage.

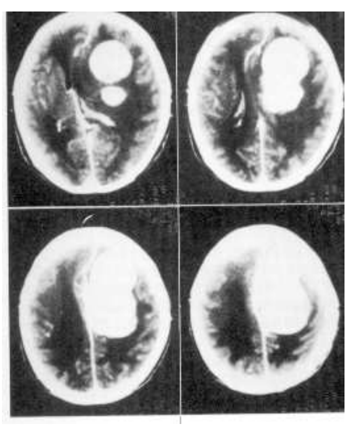
A flexible bronchoscope may be used with the fiberoptic lasers for access to bronchi beyond the carina, though when the tumor is more accessible, a rigid scope is preferred because of the ability to better debride tissue, better suction and manipulation at the tip of the scope. A special rigid bronchoscope is available from several companies that has been modified for fiberoptic laser use by swiveling the proximal port and providing channels for fibers.

Ordinarily one must be very conscious of the deep coagulation the Nd:Yag can achieve. Powers are frequently limited to around 25 watts for 0.5 seconds for safety reasons since most tumors would be overlying the carina or large vessels around bronchi. The coagulation could extend into the underlying vessel, causing necrosis and perforation within one or two days. A good visualization of the anatomy and use of lower power helps prevent this. Contact probes limit the damage to about 1 mm. Tumors that occupy the mid portion of the trachea may be handled more aggressively.

Argon and KTP lasers do not cook this deeply and do not pose the same hazard level as a bare fiber Nd:Yag.

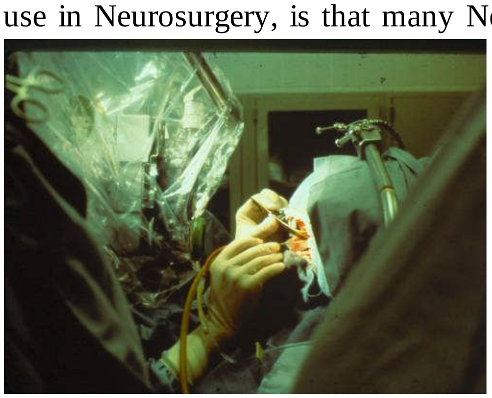
Extraluminal tumors that compress the airway cannot be treated with lasers by bronchoscopy.

NEUROSURGERY



Lasers have been used in this specialty in one form or another for over 25 years. In spite of their advantages, their use in Neurosurgery is still not commonplace. One reason for this is the lack of total control in real time of the laser effects (primarily secondary heat conduction but also fine control over ablation). Automation of laser functions, such as mircrorobotics and ablation dosimetry, may overcome these obstacles and lead to more widespread use and greater versatility.

One of the unfortunate consequences of the "long" term laser use in Neurosurgery, is that many Neurosurgeons are familiar with only the older laser technology on which they learned. These produced continuous wave emission which resulted in lack of some control over unwanted thermal spread. Secondary heat could destroy adjacent nerves and neural tissues and was not

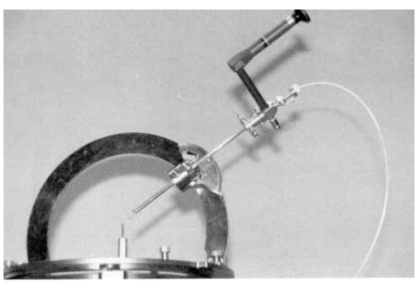


immediately apparent in the zone of ablation. Newer laser systems which emit high fluence pulses almost totally eliminate this unwanted thermal spread and provide an extremely high degree of ablation control -- measured in fractions of millimeters.

The primary instrument in Neurosurgery has been the CO_2 laser, for the same reasons as for microlaryngoscopy. The CO_2 laser is an ideal instrument for microscopic use, long "reach" into small holes, and precision. Its ability to vaporize allows its use in debulking tumors.

The Nd:Yag is a very useful adjunctive type of laser for this field. It has been helpful in shriveling very vascular tumors, and has begun to be used in treating certain aneurysms and arteriovenous malformations (AVM's), though the latter two are still very investigational. Contact probes on handpieces, used while viewing through the microscope, offers a more precise way to use the Nd:Yag for closing down small feeder vessels.

Endoscopic approaches to Neurosurgery have enabled the fiberoptic lasers to provide expand the "reach" of the neurosurgeon through these small endoscopes. The Nd:Yag, Argon and KTP lasers are the predominate fiberoptic systems. The most common indication for ventriculostomy is currently the treatment of obstructive hydrocephalus, for opening multiloculated cysts within the ventricular system.



As endoscopic approaches expand in Neurosurgery, fiberoptically delivered lasers will become more useful to allow tissue cutting and vaporization down these narrow channels.

Most craniotomies may be made small when performing laser surgery. An orange sized tumor could be removed through a quarter size opening by coring the center of the mass. Fewer instruments are in the field and that, coupled with the good hemostasis, makes it much easier to see anatomy. In debulking techniques of large bloody tumors it offers an atraumatic, no-touch instrument, reasonable hemostasis and good visibility.

The no-touch technique with the CO_2 laser is a significant advantage here. The less pulling, tugging and manipulation of tissue that is done the better the patient's postoperative recovery. Many laser patients are alert, up and around the day after surgery.

Meningiomas which have tough dural attachments may be easily "peeled away" with the CO_2 laser. Their use for acoustic neuromas has become a standard due to their precision and preservation of the acoustic nerve. Lasers are similarly ideal for tumors around the optic chiasm and nerve to preserve function. Low power, short pulses help eliminate heat spread into the nerves. Tumor remnants may be shaved one cell layer at a time from arteries, with no damage to the underlying vessel. Correct technique is critical here.

The Nd:Yag laser, when used in a non-contact manner to desiccate and coagulate large tumors, causes it to pucker and peel away from normal brain tissue.

In transphenoidal hypophysectomy, the CO_2 laser offers an atraumatic, no-touch technique that eliminates instruments in the narrow canal of the speculum. Soft pituitary lasers are suckable and do not require use of a laser. Recurrent adenomas, particularly those that have been treated with radiation therapy, are hard and rubbery, and very difficult to remove. The laser is ideal for this purpose.

Spinal tumors also benefit from a no-touch technique, particularly intramedullary tumors. Manipulation of the cord is kept to a minimum, resulting in less damage to both cord and nerve roots. Laser may be used for fenestration of syringomyelia to offer a permanent fluid pathway. Intractable pain has been treated with laser lesions of the dorsal root entry zone (DREZ), a more precise and controlled method than other techniques.

The CO_2 laser has been used to dissect away back muscle for spinal surgery and laser discectomy. Both are less established uses although they certainly exhibit no undue risks or complications. The argument for taking down muscle is that the patient does not experience spasm, as occurs with electrocautery. Postoperative back pain is markedly reduced. The Nd:Yag laser with contact probes, though slightly slower, can more easily achieve a nice, clean dissection of muscle with better hemostasis.

The laser is used to remove fractured disks by vaporization while compressing the vertebrae in a continuous fashion to "feed" the cartilage into the beam. Ordinarily the cartilage is pulled from the intervertebral space in different pieces.

The Ho:Yag laser has been very useful in percutaneous discectomy. After a needle is placed within the nucleus of the disc, the laser fiber is inserted to vaporize a small volume of material. This decompresses the disc and relieves pressure on nerves. Endoscopic systems are also available which allow the use of the laser through a tiny endoscope inserted into the disc.

Argon and KTP lasers may be used in a fashion similar to the CO_2 laser, through a micromanipulator, but in a much more limited way. They will cut and vaporize small areas of tissue, but are not able to debulk tumors to the same degree as a CO_2 laser because of the lower total power limitation.

DERMATOLOGY AND PLASTIC SURGERY

Elliot Lach MD
Gregory T. Absten

NOTE: This chapter is simply intended as an introduction to aesthetic, dermatological and plastic surgery laser applications. Readers wanting more information should refer to our specific Aesthetic Laser Training materials available on our website at http://www.LaserTraining.org

The CO_2 and Argon lasers were the first systems used in Dermatology and Plastic Surgery. They were first used as instruments for cutting as well as coagulating. This field is now dominated primarily by Aesthetic procedures such as skin rejuvenation, hair removal and elimination of blemishes and lesions.

Because most of the dermatological lasers target structures below the epidermis, heating and consequent adverse reactions become a major consideration in these laser procedures, because of melanin at the dermal/epidermal interface absorbing the light and becoming hot. A variety of external cooling methods are therefore almost always used in these types of procedures to protect the epidermis.

The CO_2 laser‘s relatively indiscriminate appetite for anything containing water yields good interaction with the entire skin surface regardless of inherent color or vascular status. Therefore it is a useful tool for removing or debulking skin, as well as oral, rectal, and genital mucosa.

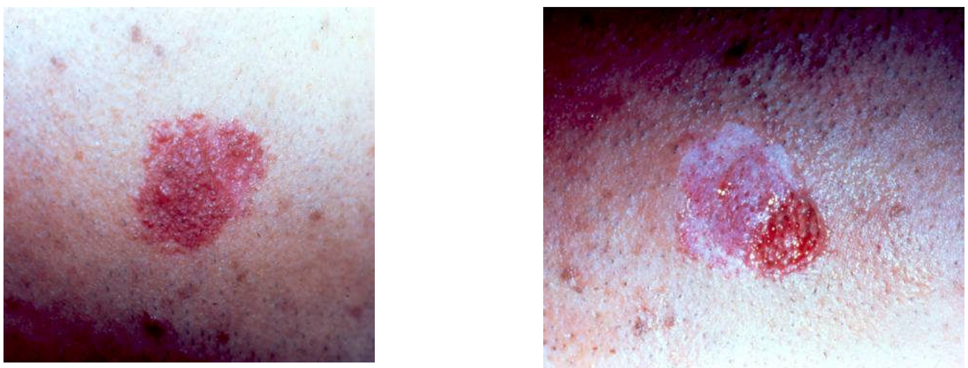
The Argon laser on the other hand has important absorption by red hemoglobin so that blood vessels close to the skin would be good laser energy targets. Melanin containing skin lesions as well as darker or tanned skin also absorbs at the Argon wavelength and competes for this laser energy. KTP has the same applications as the Argon. The Copper Bromide laser has two wavelengths – green at 511nm and yellow at 577nm. The green beam is used for pigmented lesions and the yellow beam for vascular lesions and red veins.

These lasers, regardless of their theoretical specificity, in the process of target absorption, had the potential for overheating adjacent skin structures resulting in scarring. They were delivered as continuous wave systems, meaning that they were always in the "on" mode delivering laser energy to the patient's skin. Only if the operator manually turned the laser away from the patient would the skin be protected. This resulted in undue exposure times that yielded not only biological target destruction but also significant collateral tissue damage.

Mechanical gating systems were introduced as were electronic pulsing systems in order to modulate the laser exposure time to the skin. While it was necessary to let the laser light have the opportunity to interact with the intended light absorbing target, prolonged exposure time beyond what is known as the thermal relaxation time resulted in excessive heating. Critical to this is the concept of

[Heat energy x exposure time = tissue damage]

Rapidly passing one's finger through a candle flame for example, results in no tissue destruction due to the short exposure time and relatively cool candle flame temperature. However, the same time spent in a high temperature welding torch flame or a longer exposure time in the same candle flame will cause a severe burn.



A small Angioma treated partially with a CO2 Laser on a scanner. CO2 lasers are not the customary lasers to treat these types of lesions (Pulsed Dye or KTP are), but this illustrates very well the effect that controlled heating of the tissue creates on such vascular malformations. The vessels stricture down due to the heat and disappear.

The past few years has seen the refinement of laser systems used in Dermatology and Plastic Surgery which are predominantly pulsed systems -- eliminating many of the operator dependent disadvantages and providing consistent results based on dosage of light. These lasers have been aimed at the treatment of benign pigmented lesions and vascular lesions. Hair, being a melanin containing structure of the skin is an easy and natural target for pigment seeking lasers. Skin wrinkles, by virtue of the fact that they are water containing skin structures are also good targets.

It should be pointed out here that, in practice, there is a difference between "Aesthetic & Cosmetic" laser procedures, and medical Dermatological procedures. More and more non-physicians and non-dermatological physicians are engaging in Laser Assisted Hair Removal, Skin Rejuvenation and similar procedures, and this is really different than a medical dermatological practice. The former treats benign cosmetic irregularities that are relatively easy to treat with few risks or side effects. A medical dermatological practice also treats these "easy" targets, as well as managing real medical dermatological lesions including pre-cancerous and cancerous ones, or areas that are more at risk such as around the eyes.

Laser uses in Dermatology / Plastic Surgery include:

Port Wine Stains	Superficial varicosities
Hemangioma	Skin Resurfacing
Nevus and benign skin lesions	Nonablative skin rejuvenation
Scar revisions	Acne treatment
Reduction of wrinkles	Verruca
Hair removal (laser depilation)	Actinic Cheilitis
Tattoo removal	Laser Blepharoplasty
Cafe-au-lait	Psoriasis
Telangiectasia	

Laser light in the visible portion from about 400-700nm are virtually entirely (99%) absorbed within a 4mm depth in skin.

Tunable dye lasers, pulsed in the 300-900 microsecond pulse range in yellow light, or 10+ millisecond range (longer pulse widths do not produce the purpura of shorter microsecond pulses, but also are not as effective on very fine structures), are used for very selective applications in cosmetic type vascular skin lesions. This is a process known as selective photothermolysis. The color selectivity of the beam and target blood vessels, plus the short pulse width to prevent unwanted collateral damage from conduction, results in very specific destruction of vascular lesions.

The pulsed dye laser at 585-595 nm (yellow-orange) and Copper Bromide yellow line at 577nm, are used as a very selective and precise photocoagulator. The wavelength, coupled with short pulse widths, achieves precise vascular coagulation beyond the abilities of the continuous wave argon. It has been found that an increase in the wavelength to 585, 590, and even 600 nm retains its ability to target hemoglobin. Although hemoglobin has an important peak absorption at 577 nm, skin penetration increases as one shifts toward 600 nm due to the fact that another pigmented skin component, melanin, is much more invisible to the laser at these wavelengths. Less competition from melanin results in more laser interaction with hemoglobin.

As mentioned in earlier chapters of this book, a laser has specific color parameters and therefore targets only what it “sees”. A pure white surface to any laser is reflective and the laser therefore sees no target with which to interact. Similarly a white surface painted with hemoglobin will interact well with a laser at 577nm. Once the target is eliminated however, assuming that there is no secondary heat build-up, the laser will bounce off harmlessly from the surface.

Should char form, heating by the laser will continue due to the resultant carbonaceous wound bed that may continue absorbing the laser's thermal energy.

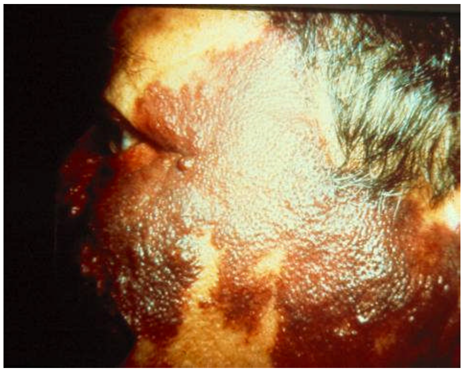
The older copper vapor laser, producing yellow light at 578 nm or green light at 514 nm, shares a similar color laser light but is delivered via a different pulsing configuration approaching quasi-continuous, with very small spot sizes. Copper vapor laser is administered as more of a fine pinpoint to trace vessels, while the pulsed dye covers more of a block surface area. However, use of the Copper Vapor has largely been replaced by the more reliable Copper Bromide technology emitting light at 511nm and 577nm.

The continuous wave dye lasers, tunable from yellow to orange to red, are effectively used where more heat build-up is desirable, such as high flow vessels around the nose. These systems are also variable in color output whereas the pulsed lasers are usually factory preset or "tuned" at one color.

Pulsed lasers, because of color selectivity and/or photo acoustic types of effects within the dermis or epidermis, are used to photocoagulate pigmented cutaneous lesions such as port wine stains, capillary hemangiomas, telangiectasia, "strawberry" marks, Campbell DeMorgan senile angiomas, and acne rosacea. They are also used to remove tattoos, hair, recalcitrant warts, treat pyogenic granulomas, sebaceous adenoma, and the Peutz-Jegher syndrome. Less established uses include keloid scars, subcutaneous varicose veins, striae, road skid and other sources of traumatic tattooing, nevi, and lesions of the Osler-Weber-Rendu syndrome.

Port wine stain vascular malformations involve an increase in the number of vessels in the sub-epidermal zone. Lasers, except for the CO_2 and Erbium, transmit through the epidermis as if through a window pane and coagulate vessels within the dermis. The treatment for port wine stains is performed as a series of applications over several months, resulting in gradual fading. Test areas are first performed to determine which laser, and parameters, provides the best cosmetic result. The pulsed dye laser, emitting yellow light around 585 nm, is most commonly and best used for extensive port wine stains.

Light Portwine stain on a child treated with the Pulsed Dye Laser System at 585 nm.

Thick portwine stain (cavernous hemangioma actually) pre and post laser treatment

The treatment of recalcitrant warts (Verruca) is now an important application of the tunable dye laser. Where once the CO_2 laser was used to vaporize the wart resulting in a prolonged healing course, the tunable dye laser delivered in a series of one or more sessions will eliminate the wart leaving normal skin.

Warts are caused by temperature sensitive viruses. Traditional treatment includes super-cooling the wart with liquid nitrogen. High heat will also eliminate viruses. It is not known whether the heat of the laser is critical to the wart eradication or rather that the dye laser is coagulating the blood supply of the wart while not causing permanent damage to the skin. The end result regardless, is virus suppression or successful wart eradication.

Lasers for benign pigmented lesions target the melanin in melanosomes as the target chromophore. Pulsed dye lasers of about 510 nm are used for pigmented lesions, compared to the 585 nm used for vascular lesions. These include the following lasers for pigmented lesions:

SHORT-PULSE LASERS FOR BENIGN PIGMENTED LESIONS:

LASER	WAVELENGTH (NM)	INDICATION
Short-pulse dye	510	Epidermal lesions
Q-switched Nd:Yag	532	Epidermal lesions
	1064	Dermal lesions
Q-switched Ruby	694	Epidermal or Dermal lesions
Q-switched Alexandrite	755	Epidermal or Dermal lesions

Epidermal pigmented lesions may also be treated satisfactorily with continuous (CW) or pseudo-continuous lasers, and include the following:

CONTINUOUS (OR QUASI- CW) LASERS FOR EPIDERMAL PIGMENTED LESIONS

LASER	WAVELENGTH (NM)
Argon	488, 515
Tunable Dye	504 and greater
Copper Bromide	511
Krypton	521, 531
KTP	532

Hair removal lasers consist of Nd:Yag, Diode, Alexandrite, Ruby and Intense Pulsed Light Systems. Variations occur with pulse widths, energies and the skin cooling systems employed. As a general rule darker skin types require the longer wavelength Nd:Yag and Diode lasers. Red hair seems to work best with the ruby laser. Anything will remove dark hair from light skin, but white hair is impossible to remove by laser. The entire method is selective photothermolysis – trying to heat the hair follicle up to the point of destruction without generating heat in overlying epidermis or surrounding structures (melanin competes to absorb the laser & generate heat).

Tattoos may be removed with the laser which provides good, but not always perfect results. Visible or infrared lasers selectively obliterate the dye in a tattoo. Previously used systems included the Argon, KTP, Krypton and CO_2 lasers. Pulsed systems are now routinely used to provide better fragmentation of the dye granules with consequent absorption by macrophages. These pulsed systems include the pulsed Nd:Yag, pulsed Nd:Yag doubled to green light, Ruby and Alexandrite lasers. Other systems include Copper-Bromide and Mercury-Vapor (laser like) – but these systems, nor IPL, are recommended for tattoo removal.

Multi-Colored Butterfly tattoo removed from a young woman's shoulder with CO2 laser. Note that a small scar can be seen with this, but the original image of the tattoo cannot be made out. Other lasers eliminate the scarring but may leave a residual light image of the tattoo. Experience and a selection of different lasers to choose from optimizes results.

Some of these systems may also be used on pigmented or vascular lesions, and the overlap in applications for any given system leads to some of the confusion for which laser is "best" suited for a dermatological practice. The answer is that no one system does everything the best, and multiple systems are usually required to provide quality treatments. See our Aesthetic Laser Procedures Home Study Course for more information on these treatments.

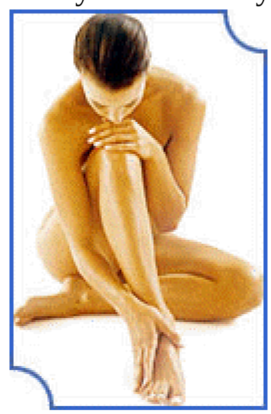
There are advantages and disadvantages to each system depending on the preferences of the user. Some lasers are able to deliver their pulses at quicker rates than others -- reducing the frustration factor and allowing patients to be treated more quickly, or more patients to be treated in a given time. The expensive dye kits in some lasers last much longer than others. Some lasers like the pulsed Nd:Yag can cause explosive type effects superficially resulting in blistering of the skin.

Some techniques which call for use of the Nd:Yag, and use of the Alexandrite laser, can eliminate this type of effect. Color of the target pigment is sometimes a problem since each laser may work on only certain colors of pigment. This is one reason that the Pulsed infrared Nd:Yag is also offered with its doubling capability to green - to expand its use on certain pigments and allow use on vascular lesions. Some lasers are delivered through an articulated arm rather than a more convenient fiberoptic hand piece. Some lasers deliver higher fluence pulses, allowing use of larger spot sizes and providing shorter treatment times.

Skin resurfacing has been a major beneficiary of the pulsed CO_2 laser. This type of "laser-brasion" provides a very controlled and superficial ablation of the epidermis. Consequent healing results in very youthful "new" skin. This applications requires a very high fluence laser. Using an ordinary continuous wave CO_2 laser would provide very unsatisfactory results. The Ultrapulse CO_2 laser is most predominantly used in this procedure. The very high fluence pulses are beyond that of ordinary superpulses in CO_2 lasers. A predecessor to this approach has been to add a laser scanner to the output of an ordinary CO_2 laser in order to gain control and uniformity over high power density spots. The Swiftlase, SilkTouch, and Feathertouch each scans the focused continuous wave CO_2 beam in a pattern which provides uniformity and control over the beam. The Er:Yag laser provides a less aggressive method of skin resurfacing with good results and less down time compared to the CO2. The YSGG is recently (2007) stepping in as an intermediate between the CO2 and Er:Yag laser.

Another method of skin resurfacing is fractional ablations, or fraxel, which involves creating thousands of tiny “pinhole” coagulative zones in the skin without ablating the entire surface. This provides less down time than ablative techniques and the healing occurs from within these small microchannels outward. An Er:Glass laser at 1540nm is typically used for this.

The YSGG laser (Yttrium Scandium Gallium Garnet) is used for ablative resurfacing that is an "in-between" type of laser effect between that of the deep ablation and heat of the CO2 and the more superficial ablation of Er:Yag. It leaves a thin protective coagulative zone that peels away in a few days, revealing fresh vibrant skin underneath. It is currently (2007) exclusively marketed by Cutera Laser as the "Pearl" laser.



Both lasers and Intense Pulsed Light (IPL's) systems have been used for a nonablative rejuvenation of skin over many treatments. The laser causes no surface damage but causes a deep heating in the dermis. This generates an inflammatory type of reaction. The resulting healing process builds collagen under the skin and strengthens and tightens it. It involves fewer risks and complications than ablative skin resurfacing but is not nearly as effective.

Due to its high affinity for water, the Er:Yag laser (Erbium:Yttrium Aluminum Garnet) has been shown to be very effective for skin resurfacing also. It is an infrared laser with a wavelength at approximately 2.94u. It is even better absorbed by water than the CO_2 laser therefore its penetration into the skin is actually protected by water by effectively being "doused out "when water is encountered. This property results in a laser capable of a "freshening" peel rather than a deeper excision. This results in quicker healing times but also in reduced clinical efficacy when treating deeper wrinkles. Collagen restoration seen with the CO_2 laser has not yet been shown to be comparable when using the Erbium laser.

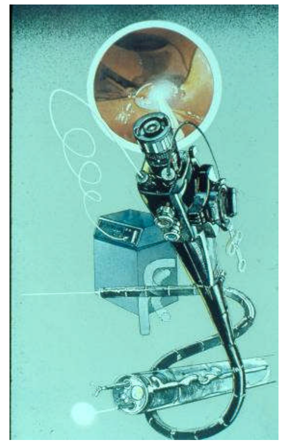
Some laser manufacturers have equipped lasers with a combination of the Erbium and CO_2 lasers. Others have added scanners in order to control the depth of laser penetration so that Erbium can mimic a CO_2 laser and vice versa.

All types of surgical lasers produce a sterile field. This is excellent to guard against sepsis. The laser seals lymphatics, so it is of potential benefit in treatment of cutaneous malignancies.

The CO_2 laser has been used in gynecology, and general surgery to reduce blood loss. The scalpel contact probes for the Nd:Yag laser are excellent for use in breast surgery. The skin incision may be made with a knife in order not to cause a skin burn, and the rest of the dissection performed with the contact Nd:Yag laser. Hemostasis is excellent, with minimal (less than 1mm) spread of damage.

Contact probes are also excellent for raising skin flaps. The dissections are very clean, with no charring, and exceptionally dry but take more time to complete. CO_2 lasers may be used as well, but they are harder to control to avoid penetrating and perforating thin flaps.

GASTROENTEROLOGY



Argon, KTP and Nd:Yag lasers have been used endoscopically in the treatment of gastrointestinal disease, however the Nd:Yag is the primary treatment modality.

Laser uses in Gastroenterology generally include:

- Esophageal Obstructions
- AV Malformations
- Fistula Repair
- Hemorrhoidectomy
- Pilonidal Cysts and Sinuses
- Hemorrhagic telangiectasia
- Colonoscopy
- Colorectal tumors
- Fissure Repair
- Abscesses

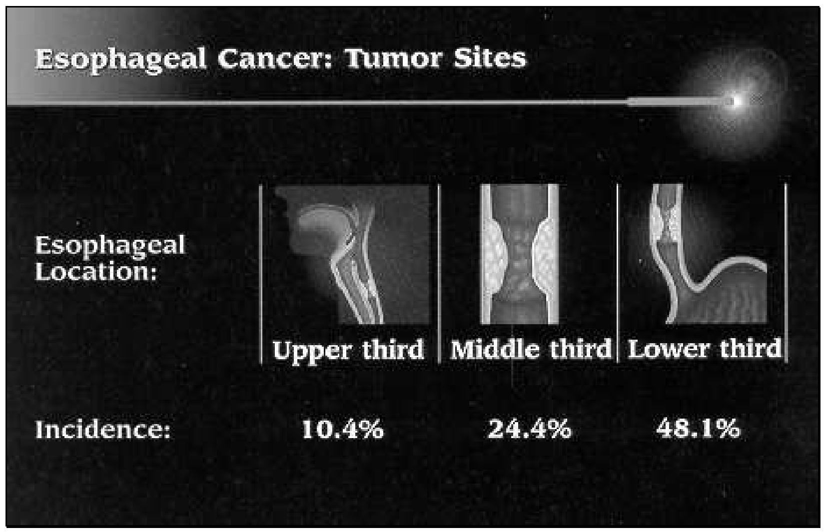
Since the widespread performance of laparoscopic cholecystectomy by General Surgeons, more demand has been created for an ERCP approach to common duct stones. Here the pulsed dye laser (laser lithotripsy) producing green light at 504nm may be used through the endoscope to fragment even impacted stones.

The Nd:Yag laser may be used in the endoscopic treatment of bleeding from peptic ulcers. Hemostasis may be achieved by using the laser fiber either in a contact (with probes) or non-contact fashion. In cases which are actively bleeding at the time of endoscopy, and are situated in an area that is difficult to access for contact or heater probes, the laser offers the advantage of being able to coagulate without touching. A jet of coaxial CO_2 gas is delivered down the fiber sheath to cool the tip and clear blood from the field of view. The high flow rates of the gas can cause problems in managing the overdistension which is created. Some Nd:Yag lasers allow the use of fluid through the sheath of the fiber to keep it cool, which eliminates the distension problems.

Contact probes may be used to coagulate GI bleeders (not duplicated by sharp fibers), require much less power than free beam Nd:Yag, and offer the advantage of mechanical pressure to coapt the vessel walls as it is heated.

Angiomata of the GI tract also respond well to laser, but are of no value for the more diffuse lesions, such as hemorrhagic esophagitis, gastritis, or duodenitis. Laser has little if any value in the treatment of esophageal varices.

Recanalization of advanced, obstructive tumors is an excellent use of the Nd:Yag laser as a palliative measure. It can provide relief of symptoms, particularly for the dysphagia associated with advanced esophageal and other tumors unsuitable for other forms of treatment.



Obstructions may be coagulated in a non contact fashion, then debrided. Care must be taken at the anterior wall, because of the deep Nd:Yag scatter, to avoid tracheal-esophageal fistulas.

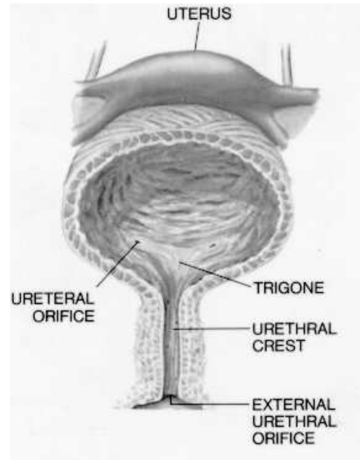
Obstructions may also be opened with the use of contact vaporizing probes. Limited lateral thermal necrosis decreases the concern for T-E fistulas, however, if one does not parallel the true lumen, it would be possible to vaporize through the wall of the esophagus. Guidewire and other techniques are used to avoid these problems. Argon and KTP lasers will open obstructions similar to the Nd:Yag with probes.

Photodynamic Therapy, with red light dye lasers and photosensitizers, is now FDA approved for certain obstructive esophageal tumors. Combined with Nd:Yag laser ablation for immediate symptomatic relief, PDT is an excellent palliative treatment for these patients.

COLORECTAL SURGERY

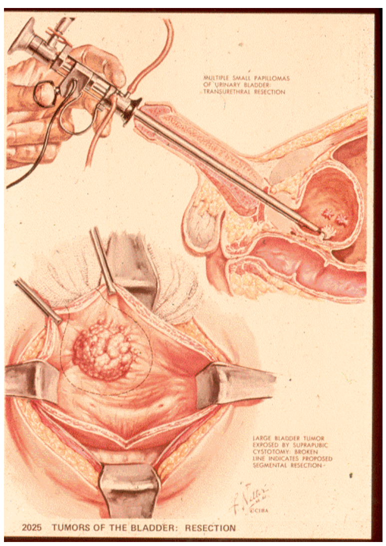
Hemorrhoids have been treated very advantageously with both CO_2 and Nd:Yag lasers. The CO_2 is used primarily for externals and skin tags, and the Nd:Yag for shriveling feeders to the internals. Contact probes in the Nd:Yag may be advantageous here. Techniques vary widely. The Ali method combines some of the advantages of cryosurgery, laser and banding techniques.

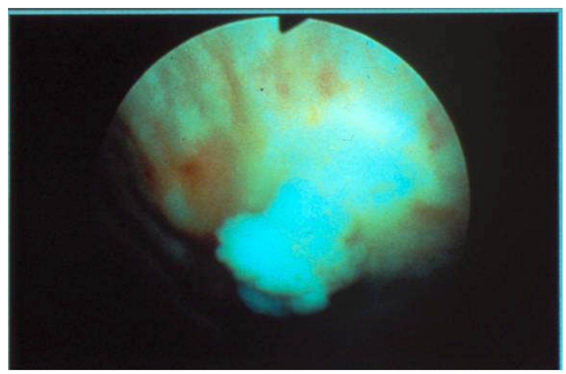
UROLOGY



Applications of lasers for superficial lesions (warts and carcinoma of the penis) have found an established role. The use of the Nd:Yag laser for treatment of superficial bladder tumors is also an excellent application but not widely adopted. Laser lithotripsy dominated the interest in Urology in the 80s, and laser prostatectomy in the 90s.

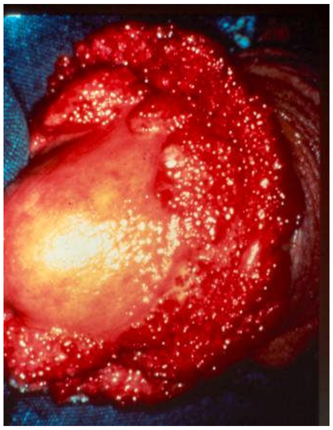
The Nd:Yag laser is the primary instrument for endoscopic procedures, and the CO_2 laser for external ones. Argon or KTP may be used endoscopically and are useful for very superficial bladder tumors. The diode laser (semiconductor), a more recent comer to medicine, has seen applications in urology similar to the Nd:Yag laser.





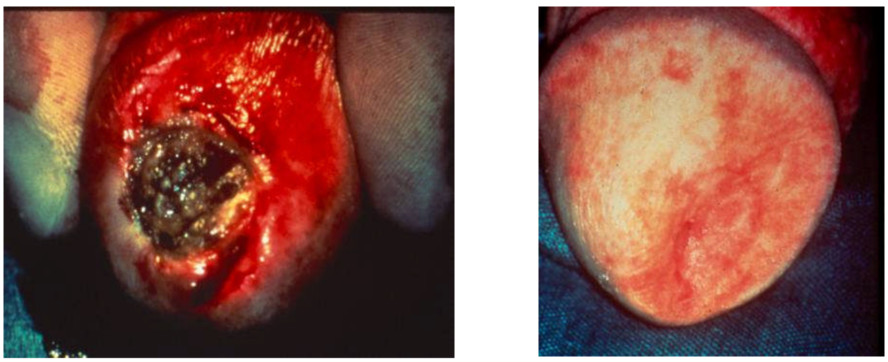
At the upper right is a superficial bladder tumor immediately post Nd:Yag laser coagulation. It will slough off in 2-3 days. There will be no bleeding and the patient will not need a catheter.

Similar to gynecologic applications, the CO_2 laser can vaporize and sterilize condylomata and external lesions. The pulsed dye laser is also effective at killing subclinical virus to reduce the load on the immune system. Partial nephrectomy may be performed with the CO_2 laser or contact Nd:Yag laser to significantly reduce blood loss and retain maximum function in the remaining portion of the kidney. When performing operative laparoscopy, the lasers offer the same advantages of convenience, precision, hemostasis and extended "reach" that applies to other specialty use.



Extensive Penile Condylomas treated with the Nd:Yag Laser.
Pre & Post

The CO2 Laser is generally used for such condyloma (warts), but many urologists already have access to a Nd:Yag and it can provide satisfactory results.



A penile carcinoma treated exclusively with the Nd:Yag laser. The customary procedure would be penile amputation to save the patient's life. This patient refused the surgery and Nd:Yag laser treatment was used. The penis was photocoagulated through its full thickness. This type of treatment does not physically ablate or remove the tissue, it simply "cooks" it. Tissue regeneration then begins to occur along the existing cellular architecture and in this anecdotal case eliminated the cancer and saved the penis.

One of the developmental uses of low power density CO_2 laser is for tissue fusion (welding). This includes some work being done to reanastomose the vas deferens using this fusion technique. The 1318 nm Nd:Yag is approved for this welding application, and other lasers - some with tissue glues or target chromophores are being explored.

Laser uses in Urology generally include:

- Bladder Tumors
- Urethral strictures
- Condyloma Accuminata
- Penile Carcinoma
- Laparoscopic procedures
- Interstitial Cystitis
- Ureteral Calculi
- Prostatectomy
- Vasectomy Reversal (investigational)
- Partial Nephrectomy

Urethral strictures have been successfully treated with both argon and Nd:Yag lasers, with the argon and KTP having worked better for the longer strictures. The vaporizing contact probe with the Nd:Yag laser may be an excellent approach to strictures but little experience has been acquired.

Laser Assisted Prostatectomy utilizes the Nd:Yag and/or Ho:Yag laser for coagulation and/or ablation of the prostate. The laser is fired circumferentially around the prostate to close feeding vessels, and the prostate then sloughs over the next few weeks. Because of the configuration of the anatomy, it is very difficult to accomplish this with conventional fibers. "Side-shooting" fibers have been developed to allow delivery of the laser sideways out of the fiber. Prostate removal has been successfully accomplished before with the use of large contact probes, the primary benefit of which is that recanalization of the lumen is immediate. A combination Ho:Yag / Nd:Yag laser is now being offered so that coagulation/hemostasis of the prostate is achieved with the Nd:Yag, and immediate recanalization achieved with the Ho:Yag wavelength.

Two general approaches have been taken to laser prostatectomy. TULIP (Transurethral, ultrasound guided, laser induced prostatectomy) involves more complicated and expensive instrumentation. TULIP requires the use of probe tip incorporating an ultrasound transducer, a right angle delivery device and a pressure balloon. Patient results are encouraging, but it has not become popular, probably due to the cost of the required technologies.

VLAP (Visual Laser Ablation of the Prostate) has become more widely accepted because it is performed with mostly conventional instrumentation, and the use of side-firing fibers or contact probes. The prostate is directly visualized and the laser used circumferentially to photocoagulate the prostate. Additionally the obstructing prostate may be immediately ablated with contact tips or probes, or the Ho:Yag laser.

Lasers used for Laser Prostatectomy include primarily the Nd:Yag and high power Diode Lasers, and adjunctively the Ho:Yag laser.

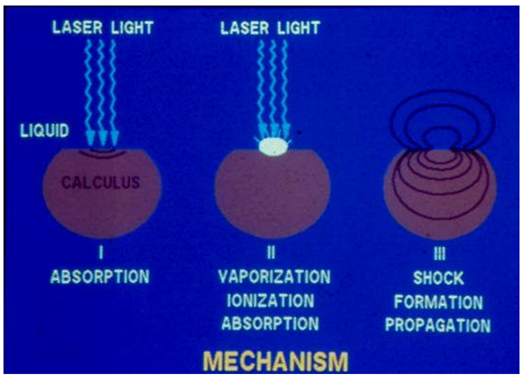
Before laser prostatectomies, the primary use of the Nd:Yag laser in urology has been the transurethral treatment of multiple, superficial bladder tumors. The laser fiber is passed through the cystoscope with a fiber deflector on the bridge. It is passed into the bladder while instilling with water. The laser causes a homogenous band of necrosis in the mucous membrane of the bladder down to the serosa without seriously compromising the mechanical stability of the bladder wall or causing perforations.

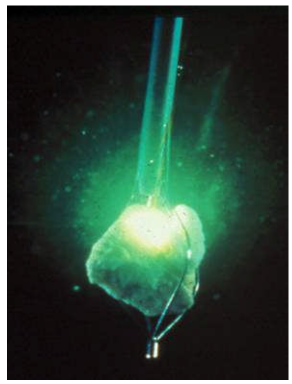
The photocoagulation is contactless (except when using contact probes), bloodless, and interrupts lymphatic drainage. Transurethral catheter drainage of the bladder is eliminated and the procedure itself does not take very long to perform. Some procedures are being performed in an office setting.

Tumors up to two centimeters or so may be totally eliminated by the laser while larger ones may be removed via a cutting loop and the tumor bed then laser coagulated. Second sessions for larger tumors are necessary. The laser is especially useful for small, multifocal bladder tumors.

The Nd:Yag laser has been used clinically to treat bladder tumors, penile carcinoma (see previous illustration), urethral strictures and prostate cancer.

A pulsed dye laser producing green light at 504 nm is used to fragment kidney stones. A transurethral approach is necessary and a very slender fiber is advanced until it abuts up to the stone. The fiber is sometimes advanced through the sheath of a Dormea basket, which holds the stone during the procedure. The laser impact develops a type of shock wave that mechanically disintegrates the stone. It works on impacted stones, and those within the pelvis - areas that are more difficult for extracorporeal shock wave lithotripsy (ESWL) to handle. It is also approved for use on biliary stones and sees use during ERCP for impacted common duct stones - as mentioned previously.

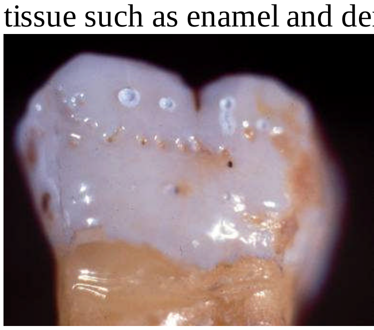




More recently other types of pulsed laser system have been used for lithotripsy. These include the Ho:Yag laser, Alexandrite, and pulsed Nd:Yag laser systems. These higher energy pulsed systems must be used under direct vision to preclude damage to the ureter, which doesn't happen with the pulsed dye laser. The Ho:Yag laser has really become predominate now in urology (2007). It might be thought of as the "big gun" compared to the "little gun" of the pulsed dye laser. One caveat however is that the Ho:Yag laser must be used under direct visualization because it can easily perforate the ureter (or any other material for that matter), unlike the pulsed dye laser.

DENTISTRY AND ORAL SURGERY

Laser work in these fields is primarily divided into soft tissue such as the gums, and hard tissue such as enamel and dentin.



Experimental CO2 Laser impacts in-vitro on a tooth shows the type of crater that can be made. This is a safety concern when performing other oral cavity procedures with the CO2 laser and care must be taken to protect the teeth from accidental impacts.

The CO_2 laser is being used clinically to perform gingivectomy. It has been particularly useful in treating patients with dilantin hyperplasia of the gums because it reduces or eliminates bleeding, sterilizes as it vaporizes, and results in significantly less postoperative pain than conventional techniques. Additionally, the spot may be defocused to vaporize and "sculpt" areas of gum rather than just incise. One must be careful not to mark underlying teeth with the laser, however an osteal retractor placed between gum and teeth may serve as an adequate backstop. The contact probe on the Nd:Yag laser has been shown to incise soft tissue without marking of underlying enamel.

CO2 Lasers are excellenct for soft tissue ablations on oral mucosa. Here leukoplakia is being treated with a superficial ablation of the mucosa. When done with adequate power densities for a clean ablation, patients experience minimal postoperative discomfort, there is no bleeding, and the site is sterilized as it is vaporized.

CO_2 lasers have also been used to vaporize dental caries, and to "sculpt" enamel in preparation for an amalgam (filling). This is a developing area of dental laser use, having been performed thus far by Doctor J. Melcer in France, who has the most experience. Appropriate technique considers the heat buildup of the laser to avoid damage to the pulp, by pulsing and irrigation.

A development in recent years in dentistry is the use of a fast-pulsed Nd:Yag laser delivered through a slender fiber. It will "chip" away at damaged enamel from caries to prepare for restorations. It may "anneal" microtubules in the teeth in the treatment of sensitive teeth, and will be used in periodontal disease to sterilize and firm up gums and strengthen root attachments.

The Erbium:Yag laser is the latest to see approvals in dentistry for hard tissues. It also is used for amalgam preparation and like most lasers, has the advantages of no whine from the drill and vibrations in the patient’s mouth.

GENERAL SURGERY

Raymond Lanzafame MD

The general surgeon encounters a wide and varied array of clinical conditions and operative scenarios in daily practice. Many different surgical skills and modalities are required to achieve acceptable outcomes for the patient. There are oftentimes several treatment options and surgical procedures that are equally efficacious for a particular disease process. One need only consider the options available to treat breast cancer as an example of this phenomenon. Surgeons often differ as to what particular instruments are the most useful during the conduct of specific technical aspects of surgical procedures. While the motto of the Stanley Tool Corporation, “The right tool for the right job” is apropos; surgeons will differ in their definition of the right tool. Such decisions are often based on preference rather than on necessity. Any surgical procedure *can* be performed using lasers. However, there are no general surgical procedures for which the laser is the *sine qua non*.

General surgeons use a wide variety of laser wavelengths and laser delivery systems to cut, coagulate, vaporize or remove tissue. The majority of “laser surgeries” actually use the laser device in place of other tools such as scalpels, electrosurgical units, cryosurgery probes or microwave devices to accomplish a standard procedure like mastectomy or cholecystectomy. Lasers allow the surgeon to accomplish more complex tasks. Proper use can reduce blood loss, decrease postoperative discomfort, reduce the chance of wound infection, decrease the spread of some cancers, minimize the extent of surgery in selected circumstances, and result in better wound healing, if they are used appropriately by a skilled and properly trained surgeon. They are useful in both open and laparoscopic procedures. Lasers are used in both contact and non-contact modes depending on the wavelength and the particular clinical application. These devices are interchangeable to some degree, assuming that the proper delivery device and laser parameters are selected. However, the visible light and Nd:YAG lasers should not be used for skin incisions, since they are less efficient than the carbon dioxide laser and result in excessive thermocoagulation of the wound edges.

Common surgical uses include wound debridement and ulcer excision, breast surgery, cholecystectomy, hernia repair, bowel resection, hemorrhoidectomy, solid organ surgery, and treatment of pilonidal cysts. Lasers are used on a routine basis by a relative minority of general surgeons. The majority of them use lasers for wound debridements and special cases. The carbon dioxide laser remains a surgical mainstay for these applications. Laser facial resurfacing and other cosmetic procedures are beginning to pique the interest of surgeons. Fiberoptic capable lasers such as the KTP/532, Nd:YAG, holmium, and the argon laser are used for laparoscopic or endoscopic applications due to their ease of adaptability to these procedures.

A CO_2 laser is useful for the incision, excision and vaporization (ablation) of tissues. The surgeon should generally select the minimum spot size and the highest fluence that can be managed safely. This increases the efficiency and speed of the procedure and enhances hemostasis. A 125mm hand piece is the most commonly used delivery device for free hand application. Using the beam in focus will produce optimal results for skin incisions and fine dissection of tissues. Defocusing the beam permits greater transfer of heat to the underlying tissues and improves hemostasis during the division of muscular and parenchymous organ tissues. Tissues should be maintained under constant traction to facilitate the dissection and the surgeon should maintain a relatively slow, steady hand speed. It is also important to divide tissues completely in a v-shaped plane in order to achieve the maximum speed and efficiency. Generally, these devices should be used at 25-40Watts for skin incisions and 60Watts for incision of fat, muscles and other tissues. It is generally helpful to use not more than 60W for soft tissue incision since the laser is more difficult to control and since the potential for a flash fire in the wound due to aerosolization of liquefied fat can occur. Liquefied fat should be aspirated to increase efficiency and prevent flash fires due to the diesel effect. $C0_2$ lasers capable of generating outputs greater than 60W can be used for effective and efficient ablation of bulky lesions and expeditious debridements of large areas.

$C0_2$ laser wavelengths are available for both open and laparoscopic use. Rigid waveguides are capable of carrying high fluences, while flexible waveguides are more practical for outputs of 30W or less. These delivery systems are not practical for skin incisions but have been used for numerous other applications.

The $C0_2$ laser sterilizes as it cuts and vaporizes in a non-touch fashion. It is useful for wound debridements and in situations where decreasing or eliminating wound contamination is desirable. Use of this laser either freehand or with scanners facilitates hemostatic burn surface debridements. Recent developments with erbium laser delivery systems will make the Er:Yag laser an attractive alternative for these procedures in the future.

Laser utilization offers several advantages during operative laparoscopy. These devices can provide substantial convenience and time savings for the surgeon by enhancing precision, control and hemostasis while decreasing the need for instrument swapping. Dissection and hemostasis in areas of inflammation and scar can be facilitated and the potential for stray energy damage, which is a known hazard of electrosurgery, can be minimized. Although virtually all laser wavelengths have found some utility in laparoscopic procedures, the KTP:YAG, holmium and YAG laser with sculpted fibers or contact tips are the most versatile and are the least intrusive on endoscopic visualization. The argon laser requires the use of camera and/or eye gear filters that alter the color of the image and can decrease the intensity of the image as much as 70%. These systems often employ a shutter mechanism that engages the eye safety filter only when the laser is being fired.

All of the fiber capable lasers can be used under water or saline irrigation and are effective in cases with edema. These properties provide substantial advantages over monopolar electrosurgical devices. However, the surgeon must understand the laser tissue interaction for the particular wavelength and delivery system chosen in order to minimize the potential for iatrogenic injury. For example, the Nd:Yag laser is capable of photocoagulating as much as 2cm of tissue when applied in a free-beam mode, with much of the photothermal coagulation occurring 4mm beneath the target surface. This occurs due to forward and back scattering of light in the tissue. Using a contact tip or sculpted fiber results in much of the laser energy being absorbed at the tip of the instrument and thereby produces zones of coagulation similar to these seen with electrosurgical devices or the KTP/532 laser. Contact YAG laser procedures are generally performed at 10–25W.

The KTP laser is a versatile tool for both open and laparoscopic procedures. This wavelength is intensely absorbed by hemoglobin, myoglobin and melanin and the laser is capable of both contact and noncontact use. It cuts, vaporizes and coagulates tissues efficiently, with a zone of injury that is intermediate between a $C0_2$ laser and an electrosurgical unit used in coagulation mode. KTP laser incision is efficient over power outputs between 8 and 25W.

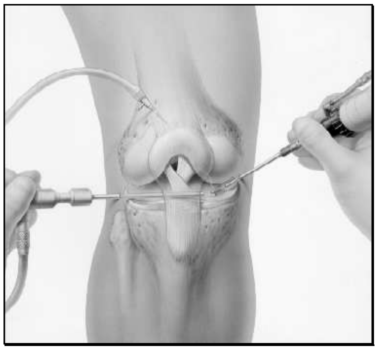
Generally speaking, the fiber capable lasers are easier to learn to use initially, since the surgeon is able to maintain tactile feedback as the fibers contact the tissues. These lasers should generally not be used for skin incision and are best used on tissues deep to the dermis. The power densities, and hence speed of action of argon, KTP and holmium lasers may be increased by using smaller fibers if desired. Contact Nd:Yag tips and sculpted fibers behave most like optically-driven cautery with cutting speed and efficiency reaching a plateau once the tip is heated. The surgeon should remember that these tips can remain quite hot for several seconds after the beam is deactivated. Iatrogenic injury or adherence to the wound can occur at this time if careless tissue contact occurs.

Pulsed dye lasers are also used in general surgical procedures, particularly for the management of common duct stones at the time of cholecystectomy or during perioperative ERCP. These laser systems are also quite helpful in the fragmentation of renal and Ureteral Calculi.

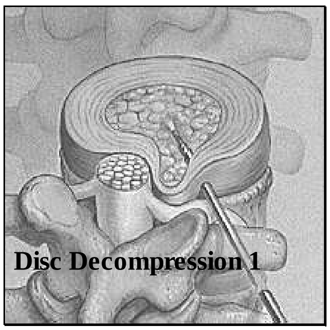
Lasers have been useful in the palliation of obstructing esophageal, bronchial and colonic lesions both with and without photosensitizing agents such as Photofrin®. Most of these procedures are performed using flexible or rigid endoscopes.

Some surgeons reserve lasers for specialty procedures such as tumor resections including, non-anatomic resection of liver metastasis, in patients with bleeding disorders, and in the treatment of infected or contaminated wounds. These versatile instruments can provide many advantages and are a useful addition to the armamentarium of the surgeon, who is conversant with their tissue effects and delivery systems. However, it is unlikely that lasers will completely replace scalpels, electrosurgical devices and other “standard” instruments. Some procedures such as laparoscopic herniorrhaphy and many parts of “laser surgeries” are better performed without one. Nonetheless, surgeons would do well to become comfortable with laser technology and use it in clinical practice. Beginners will achieve better results and improved outcomes by graded use of these devices on simple procedures initially and tackling more complex procedures as operative experience increases.

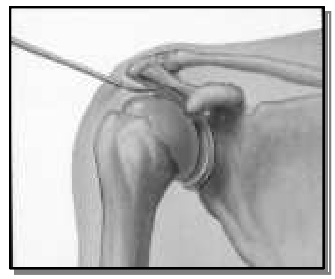
ORTHOPEDICS



The Holmium:Yag laser has accelerated the use of lasers in orthopedics for joint arthroscopy and spinal work. The Ho:Yag laser, which is a pulsed and fiberoptically delivered system, may be used under fluid in standard arthroscopy. The very small fiber handpiece provides excellent reach into the corners of tight joints without damaging other structures, and provides excellent cutting, sculpting and hemostasis. For discectomy, the fiber is delivered through a small needle which has been placed in the nucleus of the disc to provide decompression. Endoscopic systems are also available which allow the use of the laser through a tiny endoscope inserted into the disc.



Disc Decompression 1



Both the CO_2 and Nd:Yag lasers have been used in arthroscopy. The CO_2 laser, because it won't work through fluid, is somewhat awkward to use, but it does work. Several companies now have arthroscopic attachments available for use on their CO_2 lasers. The Nd:Yag laser is used with contact tips for arthroscopy. Care must be taken to not break or lose these tips while in the joint.

The CO_2 laser has been used both with a handpiece and through the microscope to vaporize polymethylmethacrylate in the shaft of the femur when replacing artificial joints. Irrigation is necessary to avoid flaming, and high smoke evacuation eliminates the noxious fumes. The laser is best used to core the glue, leaving only a thin crust to chisel out.

Orthopedic laser uses generally include:

- Joint arthroscopies (all types)
- low level laser therapy for pain
- Endoscopic Carpal tunnel release
- Laser discectomy (decompression)
- PMMA vaporization (joint revisions)

An exciting prospect for reconstructive orthopedic microsurgery is the use of laser to achieve tissue fusion (welding). This has been done with low power density CO_2 lasers, and with argon lasers. A 1.3 micron Nd:Yag laser, with programmed dosimetry, has FDA approval for laser fusion on several types of tissue. Other lasers have been used with tissue glues or target chromophores. Best results have so far been shown on vessels, nerves and vas deferens.

OPHTHALMOLOGY

Ophthalmologists were the pioneers of lasers in surgery. Lasers have been used for precise photocoagulation of the retina since the mid-1960's. The argon laser is the primary photocoagulator. Krypton lasers, with their yellow and red wavelengths, are also used by retinal specialists to achieve greater control in the macular area. Q-switch, and to a lesser degree mode-locked, Nd:Yag lasers (not the same type used in surgery) see heavy use in ophthalmology. All these lasers may be used as stand alone units, or commonly the argon and krypton are combined in one housing and delivered through the same slit lamp. Some companies also allow mating of their Q-switched Nd:Yag into the argon/krypton slit lamp.

Uses and applications in Ophthalmology generally include:

- Diabetic Retinopathy
- Ischemia producing retinal conditions
- Choroidal Neovascularization
- Photorefractive Procedures
- Oculoplasties
- Retinal tears
- Open & Closed angle Glaucoma
- Posterior Capsulotomy
- Trichiasis
- Blepharplasties
- LASIK

The use of the CO_2 laser has been very minimal. As a vaporizing instrument it has been used to excise scleral tumors. It has also been used to create bloodless scleral flaps. The 10,600 nm wavelength cannot be transmitted into the eye as can the argon and Nd:Yag, so it can only be used for open procedures. It has been used in the past through intraocular probes containing infrared windows at the tip, to cut vitreal strands, vaporize small tumors and weld detached retinas, but this laser is rarely if ever used for this anymore.

Here a patient is being treated for diabetic retinopathy by placing hundreds of tiny argon laser burn marks on the retina to shut down out-of-control blood vessel growth.

Argon is the common ophthalmic laser, either used in an office or clinic setting through the slit lamp, or intraoperatively with intraocular probes. Patients with diabetic retinopathy suffer from a proliferation of blood vessels on the retina which are fragile, tend to bleed, and may even tear the retina because of retraction of the vitreous. Pan retinal photocoagulation (PRP) with the argon laser may slow or stop progression of the disease, but cannot restore vision already lost, at least in most situations. Numerous lesions are placed on the periphery of the retina to stop proliferation of the vessels. The pigment seeking qualities of the beam causes absorption in the pigment epithelium and the photoreceptor area. A green only option on the argon allows deeper penetration of the beam with less damage to surface retinal vessels.

The exact mechanism of the induced changes in the retinal microcirculation are not clear. The general principle is that oxygen tension levels are changed so that new vessels do not have to constantly develop. This also provides better oxygenation in the remaining photoreceptors which can actually improve vision in some cases.

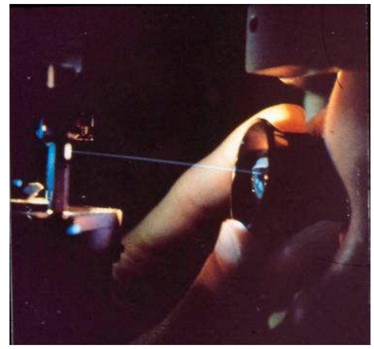
Krypton lasers produce yellow, green and red light. For work in the macular area this light will spare the macula lutea and be absorbed in the pigment epithelium. The yellow xanthophyll pigment is contained in the macula and will not absorb yellow light at all and red light very poorly. Red light is used in treatment of subretinal neovascular membranes. It spares surface vessels and the macula, and destroys the pathologic subretinal blood supply.

Some types of senile macular degeneration (SMD) are very responsive to laser treatment.

A novel approach to closure of choroidal neovascularization has been developed at Tufts University in Boston. This involves angiography with a photoactive dye (CASPc) which is activated with 675nm laser light. The resulting photochemical reaction causes closure of the neovascularization. This a type of Photodynamic Therapy.

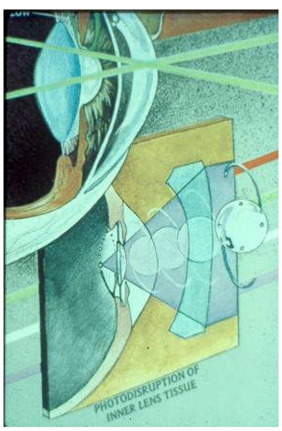
Photodynamic Therapy using the 630nm red laser light is shown here. The small diffuser on the surface of the eye provides a uniform distribution of light from the front, while another "hocky-puck" type of diffuser probe (difficult to see here) simultaneously provides light to the back of the eye.

Lasers have also been used in different ways to treat glaucoma. In closed angle glaucoma, iridotomy may be performed with the laser to open a channel for fluid flow between the anterior and posterior chambers. Argon lasers are used for this, but an iris that is blue or light colored does not absorb the light as readily as a dark one. Using the argon to cauterize a spot on the iris, then performing the iridotomy with a Q-switched Nd:Yag, seems to work easier on these light colored eyes. Laser iridotomy has a problem with long term patency, but it is an simple procedure that may be easily and quickly reperformed. The surgical alternative to laser iridotomy is iridectomy. This invasive surgical procedure requires operating room time and facilities. Medication will probably still be required to control intraocular pressures, even with laser treatment.

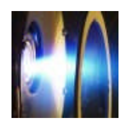


Argon laser trabeculoplasty has been used to treat open angle glaucoma. The laser creates multiple lesions around the periphery of the iris into the trabecular meshwork. It thermally shrinks the mesh, creating larger spaces for fluid to flow through. The contact lens that is used for treatment has an angled mirror around the edge to bounce the light into the meshwork. Patients can usually maintain acceptable intra-ocular pressures with minimal medication.

Pulsed Nd:Yag lasers, of the Q-switched or mode locked variety, produce nonlinear effects at a small focal point. Tremendous peak powers in the millions of watts delivered in an ultrashort burst cause a tiny concussive effect at the 50 micron spot. One can see the spark and listen to the crack as it literally snaps apart a membrane. The intense focus of the laser pulse creates an ionization effect on the target and works by sonic, or acoustical means - a little sonic boom. This is a cold cutting effect sometimes called photodisruption, and the lasers are called photodisruptors. The ionized plasma - the spark - absorbs the laser light and forms a shield which protects the retina from the beam. The large cone angle of focus also helps protect the retina.

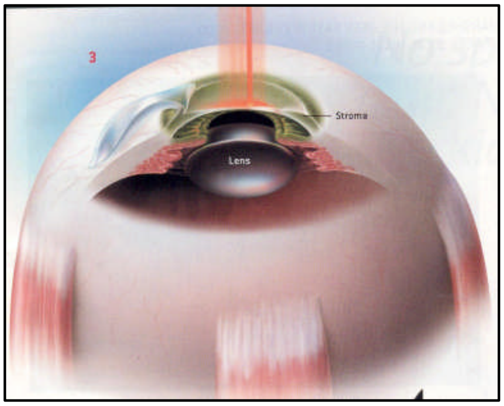


The primary use of photodisruptors is secondary to cataract surgery, for posterior capsulotomy. They are also used for vitreoretinal and glaucoma surgery, and to cut internal sutures.

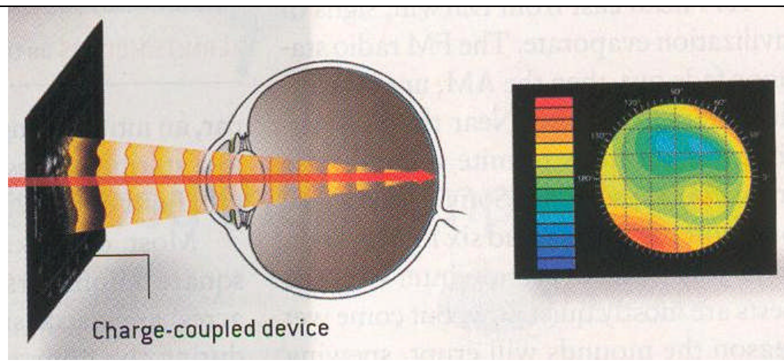


In posterior capsulotomy, the laser is not actually used to remove the primary cataract. Although on cataracts suspected of being very hard, the surgeon sometimes will "crack apart" the hard lens in the clinic with the laser before taking them to surgery for conventional surgery. This makes it easier to remove a hard cataract. When the diseased lens is removed, the posterior capsule is left intact to provide support for the intraocular lens implant (IOL) and decrease the likelihood of some postoperative complications. Unfortunately, this membrane later becomes clouded in a large percentage of these patients. Without laser, an invasive surgical procedure is required to open the clouded membrane. Instead, the laser snaps an opening in the membrane in just a few minutes with several laser shots.

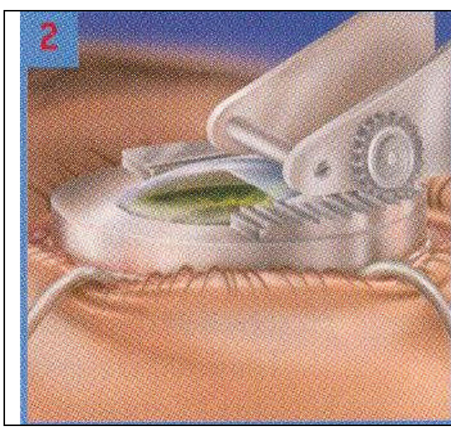
When a photodisrupting laser is used for procedures that may involve a blood supply, such as cutting vitreal strands, an argon laser should be available. If the cold cut of the Nd:Yag creates a small intraocular hemorrhage it is important to be able to cauterize it immediately with the argon.



The 193nm argon fluoride laser is used extensively for refractive surgery on the cornea – to eliminate one's eye glasses to correct for nearsightedness. The laser is used for corneal sculpting in a procedure called the LASIK procedure. This laser is computer controlled to create exact contouring of the cornea according to a treatment plan. This wavelength removes organic material (tissue) by a type of photodecomposition of molecular bonds, and does not directly generate heat to remove tissue. Refinements in this procedure include wavefront guided LASIK to produce exact corrections over all areas of the cornea, and the use of femtosecond pulsed lasers to create the initial corneal flap to an exacting degree of precision, whereby the ArFl laser is then used for the subsequent LASIK procedure.



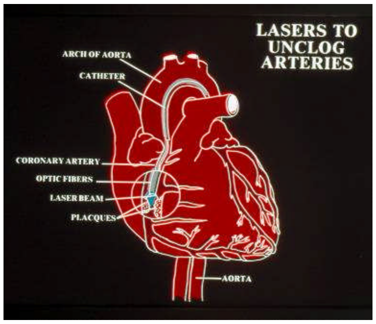
Wavefront guided Lasik surgery bounces a different laser beam off the retina and senses the reflection on a CCD (Charge Coupled Device). Software displays the ocular aberrations as small as 0.05 microns (blue area on the screen) and directs the laser to vaporize specific points on the stroma to correct for these aberrations. Regular Lasik surgery ablates a standard symmetric area which provides a good result, but not nearly as precise as wavefront guided Lasik.



One of the "weakest links" in the Lasik procedure has been the mechanical cutting of the intial corneal flap, to get to the stroma underneath. It creates a flap about 0.15mm thick with this motorized microtome device. This portion of the procedure however is prone to some unavoidable variation from person to person.

In newer Lasik procedures another laser creates this flap with extreme accuracy and precision by using femtosecond pulses to create a sheet of microscopic "steam bubbles" under the surface which creates the uniform dissection and allows the flap to just be peeled backwards.

CARDIOVASCULAR SURGERY

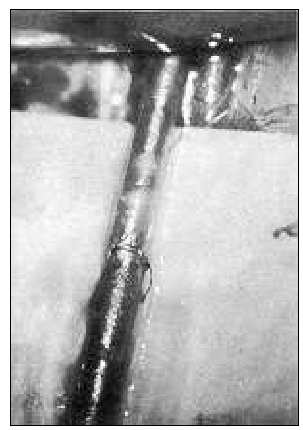


Laser work in this area centers primarily around either tissue fusion (welding), or laser recanalization to open closed vessels. Work has been done in this area with just about every type of laser imaginable. It is impossible to predict just which type of laser or delivery system will ultimately prove superior, but the major approaches will be discussed. It is useful to see what has been done before, in order to keep current methods in proper perspective.

Lasers have been examined for treatment of coronary artery disease, ventricular and supraventricular arrhythmia's (including laser treatment through catheterization), hypertrophic cardiomyopathy and congenital heart disease. Most laser developments in this field are directed at improving upon non-laser approaches, and include laser angioplasty, laser thrombolysis, transmyocardial laser revascularization, PDT, treatment of arrhythmia's and/or diagnostics.

Laser uses in Cardiovascular medicine generally include:

- Peripheral laser angioplasty
- Transmyocardial Revascularization
- Laser welding (investigational)
- Coronary laser angioplasty
- Laser Thrombolysis
- Arrhythmic Node ablation



Tissue fusion of small vessels is occurring experimentally in laboratories and has been used clinically in a few cases. These are primarily performed now with low power diode lasers, but started many years ago with CO2 and Argon lasers. [13]

A 1.3 micron Nd:Yag laser, programmed for the correct dosimetry on various tissues, is also being investigated as a better alternative than the CO_2 laser for tissue fusion.

More recently, Laser "Soldering" techniques have shown great promise. These use a variety of dyes to enhance localized absorption of laser, or sometimes fibrinogen type "glues" which are heat activated by the laser. Laser techniques

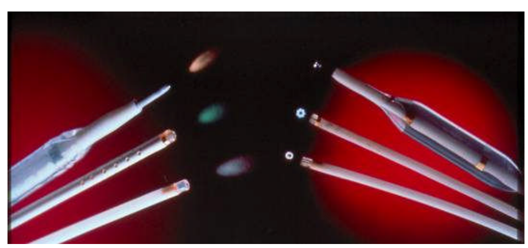
[13] Low power density CO_2 lasers are pulsed (gated) on the seam to create an immediate and permanent laser weld with power densities in the broad range of 5 to 80 watts/cm^2. One way to achieve steady, low power density is to use a milliwatt output laser. This produces a very stable output which may be focused to microspot sizes and still retain a sufficiently low power density. This has worked the best for CO_2 lasers. It is also possible to use low power (0.5 - 3 watts) from a conventional CO_2 laser and simply broaden the spot sufficiently to achieve very low power density. Some regular surgical CO_2 lasers have milliwatt capability. Normal output CO_2 laser tubes are not very stable at very low milliwatt powers and this is not an optimum solution. It is possible to use an attenuator delivery system for a regular CO_2 laser and achieve stable milliwatt powers.Argon lasers used with handheld fibers at 0.5 to 3 watts output may be used to weld arteriotomies with good results - investigationally. Argon has also been used to achieve vessel fusion.

for joining tissues, coupled with other surgical technologies, will be a major advance in the coming century.

Laser recanalization of blood vessels is still a hot topic in laser medicine. Fibers are passed through endoscopes or catheters into the vessel and fired to open the blockage. The type of laser used and its delivery system are two separate areas of development. Argon, Nd:Yag, Ho:Yag and Excimer lasers have all been examined. Delivery systems used include bare fibers, hot metal tips, sapphire probes, "ball tip" fibers, quartz domed fibers including multigang bundles, and handheld needle delivery systems for CO_2 lasers as an intraoperative approach. The original approach of using “Hot Tip” metal balls on the end of fibers worked but was less than satisfactory - to be polite. They are an approach from the past. The results were not very good and resulted in many strictures. They were primarily used with the argon or Nd:Yag laser as the heat input. These bullet shaped tips come in a variety of configurations to provide only heating effects at the tip, or a combination of laser/hot tip effect. They may be placed over a guidewire, or used on their own. The laser energy makes the metal tip so hot in the front, that it vaporizes away obstructions with limited if any damage at the sidewalls of the probe. Such an approach no longer has a place in cardiovascular medicine, but it’s interesting to see how this field started. The Nd:Yag sapphire probes have been used in the same fashion as the hot metal tips, using a combination of focused laser and heat energy.

Original Hot Tip Fibers (1980’s)

A free beam argon laser, delivered by a small fiber through an integral catheter, was also used for peripheral vascular use. They are not used currently but the approach was unique. An integrated microlens at the tip of the fiber causes a large divergence which allows vaporization to occur only at the very tip of the catheter and not downstream. This type of system "nibbles" its way through an obstruction.



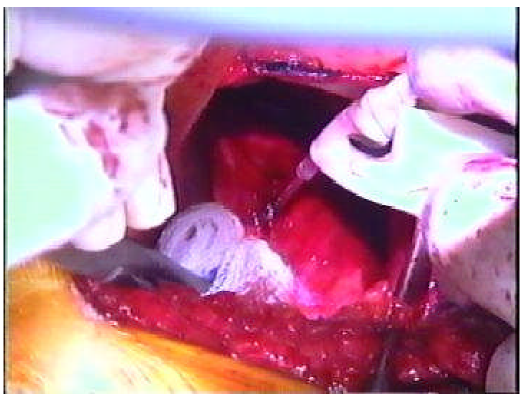
Newer methods of multigang fibers using short pulse lasers such as the Excimer produce MUCH better results - particularly in small vessels. Catheters which incorporate laser fibers can be designed in many different configurations including multiple fiber ring catheters. (AIS shown here)

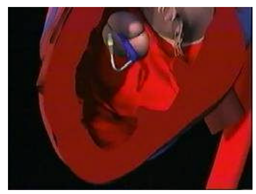
Laser use for opening of blood vessels has evolved toward the pulsed laser systems, because these can remove tissue precisely without generating excessive heat in the process. These pulsed systems are the Ho:Yag and Excimer lasers. Along with the choice of the type of laser, comes a myriad of fiber/catheter designs. The configuration of the catheter will probably be more important that the actual laser used, provided it is a high energy pulsed system. Typical multifiber coronary laser catheters consist of 50-100 micron fibers arranged circumferentially in an array around a guidewire lumen.

Laser has also been combined with conventional balloon angioplasty to improve results. One of the potential problems with balloon dilatation is dissection and/or fracture of plaques on the vessel wall -- which may then reclose the lumen. A laser is fired through a fiber which is contained within the balloon itself as the balloon is inflated. This diffuse, but very warm, laser beam then helps "weld" the plaques against the vessel wall.

Photodynamic therapy is also being used to "clean out" plaques from inside diseased vessels. On the 50% of the experimental vessels in which this works it does a superb job of restoring normal intimal physiology.

Transmyocardial Laser Revascularization (TMR) is an exciting area receiving much interest worldwide. This unique approach creates epicardial to endocardial channels for direct myocardial revascularization. This approach helps patients with diffuse disease who are not candidates for conventional surgery or angioplasty. A Ho:Yag laser fiber with special tip is inserted percutaneously. It is used to drill holes to a predetermined depth within the the ventricles, which in turn spurs on new collateral vascularization during the healing process.





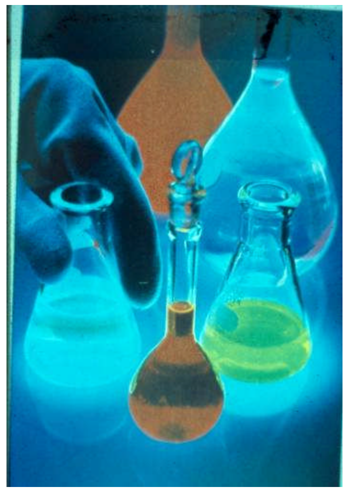
At left a Ho:Yag fiber is used directly on the myocardium in an open TMR procedure. The graphic above illustrates a steerable catheter design that allows TMR to be performed from inside the ventricles with a percutaneous approach (PTMR) through femoral or brachial arteries.

The laser approach to this procedure was introduced by Doctor Mirhoseini in Milwaukee Wisconsin with CO2 Lasers. A CO2 laser system for clinical use (the Heart Laser) has been developed by PLC systems. It typically produces about 1mm channels which are placed every cm^2 of treatment area using approximate 1000 watt pulses of 30-40msec from a CO2 laser. The Transmyocardial approach with CO2 Lasers requires an open procedure.

The 308nm XeCl excimer laser is used for retrieval pacemaker leads. It is also used extensively around the world for angioplasty, but this use is still pending approvals in the U.S. as of 2007.

PHOTODYNAMIC THERAPY

Photodynamic therapy (PDT) involves the use of a photosensitizing agent to treat malignant tumors. In this instance a porfimer sodium (Photofrin) is the photosensitizing drug used and is activated by 630 nm (red) light produced from an argon pumped dye laser. A Hematoporphyrin Derivatve (HpD) and DiHematoporphyrin Derivative (DHE) were used previously, but the porfimer sodium has been found to be more effective. Other photosensitizing agents and wavelengths are being investigated. The laser is used because of its ability to produce intense levels of monochromatic light. Other light sources may be used, such as filtered slide projectors, but these are not as effective and cannot be delivered through fibers.



A variety of photosensitizing agents are in development for Photodymanic Therapy. Each one will have a specific wavelength where it is activated best. Infrared wavelengths penetrate tissues deeper though, and this is within the range of some chlorophyll derivative drugs under development. PDT will see widespread use outside of just cancer treatment.

Fluorescence of some tumors upon illumination with a Wood's lamp was noted as long ago as 1924. This principle was then used as a localization technique by the systemic injection of Hematoporphyrin, beginning in 1942. Lipson reported the use of Hematoporphyrin derivative which was shown to have superior tumor localization to that of Hematoporphyrin. The use of HpD then transitioned from diagnostic to therapeutic use when Diamond reported in 1972 the destruction of experimental tumors by white light exposed after HpD injection.

Tom Dougherty's group at Roswell Park Memorial Institute has been studying the response of a wide variety of malignant tumors in man to PDT with various photosensitizers. He reported complete or partial response of 111 out of 113 cutaneous and subcutaneous malignant lesions in 1978.

The broadest based clinical work with PDT is the series of Doctor James McCaughan at Grant Medical Center / Medical Laser Research Foundation in Columbus Ohio – now retired. Doctor McCaughan has been treating patients since the early 80s with PDT, and the series crosses many specialties.

From the results obtained by various investigators so far, it is clear that PDT with Photofrin is a valid treatment. The Photofrin is initially distributed through all the cells but begins to clear out of normal tissue after several hours. An initial dose is injected as a single intravenous bolus. A maximum difference in concentration levels between tumor cells and normal cells occurs in two to three days. Normal tissue does retain some Photofrin and this is complicated by the fact that different tissues retain various concentrations. Skin, liver, kidney and spleen hold onto the Photofrin longer than other tissues. Bronchial mucosa retains one of the lowest concentrations so endobronchial tumors are among the easiest to treat.

The goal of dosimetry is to calculate dosages of drug and light so that activation of the higher concentrations of Photofrin occurs while remaining below the necessary threshold to activate Photofrin in normal tissue. This is controlled by dosage and timing of the Photofrin injection, color, intensity and distribution of the light, and its method of delivery.

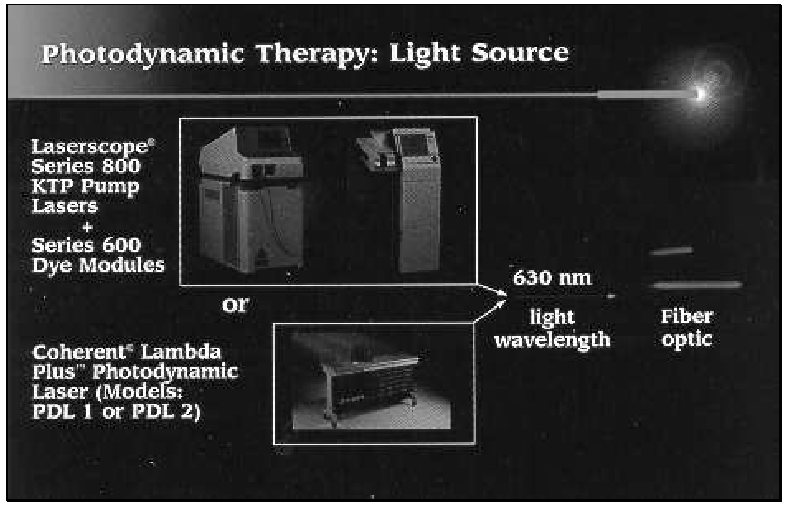
Until recently, most patients treated with this form of therapy have previously exhausted the full gamut of conventional therapies of surgery, radiation, immunotherapy and chemotherapy. Results have been encouraging enough for a few investigators to utilize PDT for some early lesions as the primary form of treatment.

The absorption spectrum of Photofrin has peaks which may be utilized to activate the drug. Blue light of about 405 nm is absorbed most strongly but a lesser absorption peak also exists in the range of red light at 630 nm. The red light, however, will penetrate tissue much better than the blue. Red light will scatter up to approximately 2 cm through skin. The amount of light energy delivered to an area is measured with a radiometer and time is calculated to deliver doses of between 25 joules/cm^2 and 150 joules/cm^2, depending on the tumor.

The drug is activated by the light through singlet oxygen production. The vessels of the tumor's blood supply are implicated strongly in the phototoxic process. Gross tissue effects proceed from moderate or severe edema to complete necrosis of the tumor exhibited by a black eschar.

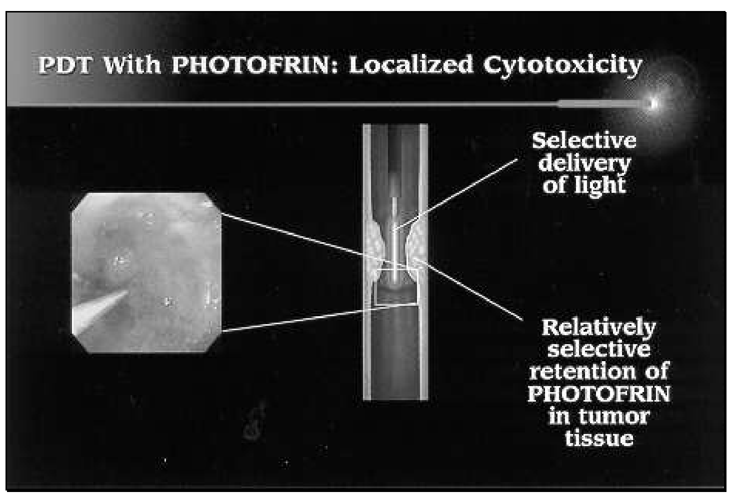
Though close to general FDA approvals, PDT is still investigational for many cancers, and has not been proven curative for most malignancies. It will in all probability be used as an adjuvant therapy and, for some neoplasms, the primary form of treatment. Its mechanism is independent of previous or subsequent chemotherapy and/or X-ray therapy.

There are side effects and complications to this form of treatment. Patients may undergo an increased photosensitivity of the skin to sunlight for about one month after treatment, and light precautions are generally imposed for 4-6 weeks afterward. Full thickness necrosis of tumors of the intestinal tract may lead to fistula formation. Endobronchial treatments may cause production of gelatinous secretions and edema of the airway causing obstructions. Post treatment hemorrhage is possible following necrosis of tumor and any involved vessels.



Current technology with lasers and fiberoptics makes it feasible to deliver high intensity light to almost any site in the body, at surgery, or through endoscopes and needles. PDT may then be used to treat malignancies that are not responsive to current modalities. It may be used to treat nonresectable lesions of the pancreas or brain. Combination therapies with systemic treatment, ionizing radiation or hyperthermia are possible since PDT is a local treatment.

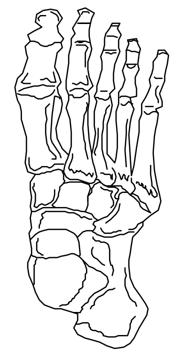
One of the exciting developments is the potential use of PDT to treat clinical and sub-clinical HPV infections seen as extensive condylomata in gynecology practices. CO_2 lasers are now used advantageously in treatment of resistant infections, but the use of PDT would be tremendously better for patients and physicians. The DHE localizes in the HPV virus, allowing selective destruction of all the latent virus in a painless treatment. Postoperatively they may be inflamed and sore, but not hurt like an extensive CO_2 vaporization.



PDT is now FDA approved in the USA for use in Gastroenterology to treat esophageal tumors, in Thoracic / Pulmonary Medicine for endobronchial tumors and in ophthalmology for subretinal neoplasias. FDA approvals in other specialty areas are still forthcoming.

In dermatology and cosmetic use it is being used quite extensively with the topically applied photosensitizer (Levulan or Kerastick). It is used for treatment of “pre-cancerous” lesions such as Actinic Keratosis, but also widely used for the treatment of ACNE and general skin rejuvenation using a non-laser “Blue Light” source. It is sometimes call the “Blue Light Treatment” for this reason.

PODIATRY



The CO_2 laser is the most commonly used in podiatry, though the Ho:Yag laser sees much interest for ankle arthroscopy.

Laser uses in Podiatry generally include:

- Verrucae Plantaris
- Heel fissures
- Matrixectomy
- Excision of Neuromas, cysts, etc.
- Heel spurs (controversial)
- Callus, Cysts, Corns, etc.
- Fungus nails
- Subungual hematoma
- Scar excision
- Ankle arthroscopy

CONCLUSION

The laser is a tool, not a technique. It significantly expands the ability to perform less invasive procedures such as various arthroscopies, discectomy, ventriculoscopy, laparoendoscopy, etc.. It is these endoscopies which transform many procedures to an outpatient setting, and the laser frequently provides a tool to make these endoscopies easier, safer or sometimes more effective. In other cases, such as skin resurfacing or reshaping of the cornea to correct vision, the laser itself provides a very unique capability.

In some procedures the laser has proven to be the absolute tool of choice, while in others it may simply be a preference of the surgeon.

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LASER COURSE POST TEST
- Clinical Laser Applications Module -
CLINICAL LASER APPLICATIONS

Name______________________________________Date_________________________

1. What is a major use of the Nd:Yag laser for Gynecology?
   A. Hysteroscopic Hysterectomy
   B. Laparoscopy with contact tips on the fibers
   C. Tubal cauterizations

2. Which technology is the "safest" (most predictable control) for dissecting ureters from the pelvic sidewall during laparoscopy?
   A. Laser
   B. Electrosurgery

3. Which laser has been used in Fetoscopy to treat "twinning" syndrome in developing fetuses in utero?
   A. CO2
   B. Excimer
   C. Pulsed Dye
   D. CW Nd:Yag

4. Which laser is most universally the "best" system for ENT for microlaryngoscopy?
   A. CO2
   B. KTP
   C. Pulsed Dye
   D. CW Nd:Yag

5. In nasal sinus endoscopy, the laser seemingly best suited to drill osteotomies is:
   A. CO2
   B. KTP
   C. Ho:Yag
   D. CW Nd:Yag

6. Laser Assisted Uvulo-palatoplasty (LAUP) is performed with which laser?:
   A. CO_2
   B. KTP
   C. Ho:Yag
   D. CW Nd:Yag

7. Which procedure is the "snoring" procedure:
   A. Laser Tympanoplasty
   B. LAUP - Laser Assisted Uvulo-palatoplasty
   C. Laser Ritidines procedure
   D. Leukoplakia ablation by laser

8. Which is the primary laser for Neurosurgery in craniotomy?
   A. CO_2
   B. Argon
   C. Nd:Yag
   D. Ho:Yag

9. Pulsed Dye lasers in dermatology are used primarily for:
   A. Tattoos
   B. Dermal lesions
   C. Vascular lesions (port wines, telangiectasias, etc)
   D. malignant lesions

10. The following systems are ALL pulsed laser systems for dermatology EXCEPT:
    A. Frequency doubled pulsed Yag (532nm)
    B. CW CO_2
    C. Ultrapulse CO_2
    D. Alexandrite

11. Skin resurfacing is best accomplished by which lasers:
    A. The pulsed dye system with hexascan scanner
    B. Either the Ultrapulse or Silktouch (scanned) CO_2 lasers
    C.CW Dye laser with the drug HpD
    D. CW CO_2 lasers

12. The objective in laser treatment of the prostate in urology is:
    A. To treat any potentially malignant tissue
    B. To make as much money as insurers will pay
    C. To open the urethra into the bladder as hemostatically as possible and minimize trauma
    D. To restore sexual function as best possible

13. For which procedure are "side firing" fibers for Nd:Yag (or Diode) lasers used in urology:
A. Interstitial Cystitis
B. Multifocal bladder tumors
C. Prostatectomy related procedures
D. Urethral strictures

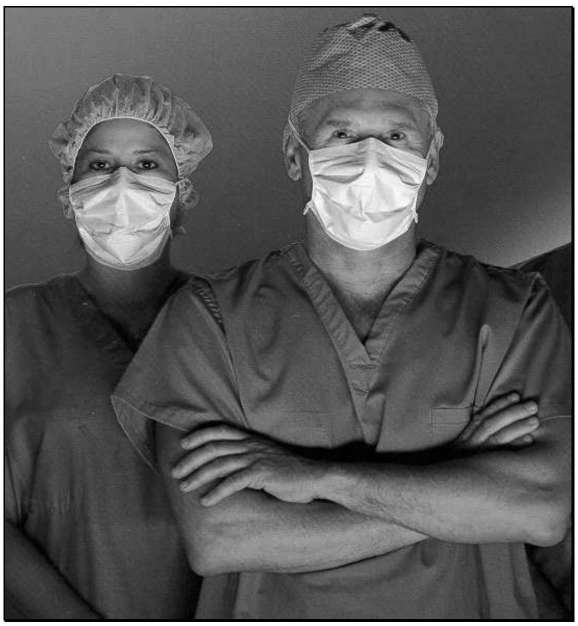
14. Which laser is the primary system used for joint arthroscopies?
A. CO2
B. KTP
C. Holmium Yag
D. Nd:Yag

15. Which laser is used for corneal reshaping (Photorefractive Keratectomy) or alternatively LASIK (Laser assisted insitu keratoplasty) in ophthalmology to correct vision ?
A. CO2
B. Argon
C. Q-switched (ophthalmic) Nd:Yag
D. Diode
E. ArFL Excimer at ~ 193nm
F. XeCl Excimer at ~ 308nm
G. Alexandrite

16. PDT (Photodynamic Therapy) is a combination of photosensitive drug therapy along with activating light therapy to treat primarily:
A. Endometriosis
B. All types of cancers
C. debulking of obstructing tumors
D. Emphysema

THE LANGUAGE OF LASERS

An Encyclopedic Glossary of Laser Terms



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THE LANGUAGE OF LASERS

An Encyclopedic Glossary of Laser Terms

Ablation Volume removal of tissue by vaporization

Absorption Uptake of light energy by tissue, converting it into heat

Absorption Coefficient Factor describing light's ability to be absorbed. Optical properties of different tissue alters the absorption.

Accessible Radiation Radiant Energy to which it is possible for the human eye or skin to be exposed in normal usage.

Acousto-optic Interaction between an acoustic wave and a light wave, used in beam deflectors, modulators, and Q-switches.

ABSTENism A technically incorrect description, used intentionally to more easily teach correct laser concepts. The concept is taught correctly, though the exact mechanics may be overly simplified.

Active Medium (Laser Medium) The material used to emit the laser light.

Aiming Beam A HeNe laser (or other light source used as a guide light. Used coaxially with infrared (Carbon Dioxide & Nd:Yag lasers) which are invisible. Red HeNe's may be somewhat difficult to see on blood in the field, and green HeNe's are available as a substitute guide light.

Alexandrite A solid state synthetic crystal, doped with chromium, used as an active medium. Emits light near infrared light at 755 nm. Usually used in a Q-switched delivery to create high fluence pulses. Used in dermatology for tattoo removal.

Amplitude The maximum height of a wave - implies power.

Argon The gas used as a laser medium. It emits blue/green light at 488 and 515 nm.

Articulated Arm A Carbon Dioxide laser deliver device consisting of hollow metal tubes with joints which allow the "arm" to move. Mirrors are located at each joint to reflect the laser beam. These arms may also be used with other lasers that are unable to transmit through standard fibers, such as certain Excimers.

Attenuation Decreasing the intensity (power) of light as it passes through a medium. It can be measured in optical density or decibels, as well as a percentage or fraction of the light loss.

Average Power The average level of power in a series of pulses. It equals energy times the number of pulses divided by the time interval. For instance, a superpulsed CO_2 laser of a maximum 500 watt pulse, may produce only an average power of 20-30 watts. Average power also determines the overall speed at which an ablation occurs.

Aversion Response Movement of the eyelid / head to avoid exposure to a noxious stimulant or bright light. It can occur within 0.25s, including the blink reflex time. Lasers are generally considered "eyesafe" if the MPE is longer than 0.25s .

Beamsplitter A device which divides incident light into two separate beams, one reflected and one transmitted. Besides laser devices, beamsplitters can be seen as an attachment to a laparoscope, allowing the viewer to directly view through the laparoscope while simultaneously using a camera and monitor, though the lighting of each is less than optimum because of the attenuation that occurs with the splitter.

Birefringent Has a refractive index that differs for light of different polarization.

Biostimulation The use of low power light (milliwatts), usually laser, to stimulate metabolic activity on a subcellular level. Experimentally examined for pain relief and wound healing.

Blink Reflex See aversion response.

Brewster's angle The angle at which a surface does not reflect light of one linear polarization. Used as Brewster windows on the ends of ion laser tubes.

Carbon Dioxide (CO_2) Molecule used as a laser medium. Emits far infrared light at 10,600 nm (10.6u). Lasers are made as sealed tube or flowing gas units. Carbon dioxide is also used as the insufflation gas for laparoscopy, which is not to be confused with CO_2 laser laparoscopy.

Cautery Achieving hemostasis of bleeding vessels, usually by heat from laser or electrosurgical units. Technically, cautery is by direct application of a hot object, but is commonly used to also describe laser or electrosurgical hemostasis.

Chromophore Optically active (mostly colored) material in tissue which acts as the absorbing medium of laser light. Water is the dominant chromophore for CO_2 and Ho:Yag lasers, while melanin and hemoglobin are the dominant chromophores for argon lasers.

Coagulation Destruction of tissue by heat without physically removing it. Refers mostly to protein coagulation rather than hemostasis.

Coating Material applied in one or more layers to the surface of an optical element to change the way it reflects or transmits light.

Coherence Orderliness of wave patterns by being in phase in time and space.

Collimate To make light rays parallel (a straight beam of light)

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

Combiner Mirror The mirror in a laser which combines two or more wavelengths into a coaxial beam - i.e., CO_2 and HeNe beams.

Contact Probe — Synthetic ceramic material, like sapphire, used with laser fibers to allow touch of tissue with the probe. The laser is used as the energy source to heat the probe to high temperatures. Direct conduction heating then creates intense and precise cutting and vaporizing effects. Advantages to these contact modalities lie in the high degree of control which comes from actually touching tissue in order to create effects.

Continuous Wave (CW) — Constant, steady state delivery of laser power. CW delivery of laser light can deliver energy at high average powers, but is also more conducive toward lateral spread of heat from the intended site. This contrasts with pulsing modes and superpulse which can more highly localize the heat generation.

CuBr — Copper Bromide Laser. A salt that volatolizes into a gas vapor upon heating. Produces dual wavelengths of 577nm yellow and 511nm green. Primarily used for aesthetic procedures.

Cryogenic — Related to the production of low temperatures.

Decibel — A logarithmic comparison of power levels, abbreviated dB, and defined as the value: 10 $\log_{10} (P_2/P_1)$ - i.e., 10 times the base-10 logarithm of the ratio of the two power levels. Used more in telecommunications industries than medicine.

Dichroic Filter — Filter that allows selective transmission of colors.

DHE — DiHematoporphyrin Ether. A photosensitizing agent used in PDT. DHE is a more refined form of HpD. Porfimer Sodium (Photofrin) is now used in place of the DHE.

Diffraction — Deviation of a beam (a wave of light or even water), determined by the wave nature of radiation (light) and occurring when the radiation passes the edge of an opaque obstacle.

Diffuse Reflection — A reflection of a laser beam from a surface at a very wide angular so that the intensity of the reflected beam becomes very low and unlikely to present a hazard. Diffuse reflections are normally not hazardous, except for very high power lasers.

Diffuser — An optical device or material that homogenizes the output of light causing a very smooth even distribution over the area affected.

Diode — An electronic device which preferentially conducts current in one direction but not the other. Diodes can emit light (laser diodes) or detect it.

Diode Laser — A semiconductor diode laser in which the injection of current carriers produces light by recombination of holes and electrons at the diode junction between p and n doped regions. (Refer to more detailed electronics manuals) Small diode lasers are currently used in ophthalmology as photocoagulators, and in surgery to drive shaped fibers for use as a type of "hot knife".

Divergence — Increase in the diameter of a laser beam along with the increase in distance from the exit aperture. This is also referred to as beam spread. Lasers are low divergence beams.

Dosimetry — Measuring the amount (joules dosage) and intensity (power density) of light delivered to tissue.

Electro-optic — The interaction of light and electric fields, typically changing the light wave. Used in some modulators, Q-switches, and beam deflectors.

Electron Negatively charged particle of an atom. Transitioning of an electron to different energy orbital levels gives rise to the generation of light from the atom.

Electromagnetic Spectrum The span of frequencies (wavelengths) considered to be electromagnetic radiation. These include light and electricity, and span the range from radio waves to cosmic rays.

Electrosurgical Unit (ESU) The correct terminology for modern monopolar (unipolar) and bipolar surgical units - frequently, but incorrectly, called cautery. ESU are the primary alternative to laser for endoscopic, hemostatic dissection of tissues. A common misconception however is that ESU is "safer" to use than laser and the opposite is true. ESU has many more variables allowing for "stray current" burns and, in fact, many more such accidents occur with ESU than with laser.

Embedded Laser system A laser whose assigned class number is higher than the inherent capability of the laser in which it is incorporated. Engineering controls limit the accessible radiation allowing an overall lower classification of the entire system.

Endoscope An instrument inserted into the body through an orifice (either existing or surgically made) that allows viewing and manipulation of tissue. They may be rigid or flexible, large or miniature. Advanced endoscopic access for surgery is a major growth area for the future of medicine.

Energy Expressed in Joules (watt/seconds). The ability to accomplish work. Energy may take many forms from mechanical to electromagnetic.

Er:Glass Erbium Glass Laser. 1.54u. Used for skin resurfacing in the “Fractional Ablation” procedure producing microchannels of coagulation. Transmits through glass fibers, but does not transmit through fluid.

Er:Yag Erbium Yttrium Aluminum Garnet Laser. 2.9u. Used almost exclusively for skin resurfacing, although has many potential “hard tissue” applications in dentistry and orthopedics. Does not transmit through glass nor fluid.

Excimer "Excited Dimer". A gas mixture used as the basis of the excimer lasers emitting ultraviolet light. They are short lived molecules containing a rare gas such as xenon and a halogen such as chlorine. These include lasers like Argon Fluoride and Xenon Chloride, as well as others. Excimer lasers derive their high degree of thermal precision from the pulsing nature of the laser. Some wavelengths will additionally produce cutting effects by photodisassociation, a non-thermal ablation.

Excitation Energizing a material into a state of population inversion, a necessary prerequisite of lasing action. May be accomplished with light, electrical or chemical energy.

Extended Source A source of optical radiation (light) that can be resolved by the eye into a geometric image, in contrast to point sources of radiation (lasers / stars / sun) which cannot be resolved into a geometric image. Point sources focus to small spots.

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

Far-infrared Laser
One of a family of gas lasers emitting light at the far infrared wavelengths of 30-1000 micrometers. In medicine, CO_2 lasers are frequently called far infrared even though they emit light of only 10.6 micrometers, because it is the longest infra red wavelength currently in use in medicine.

Femtosecond
10^{-15} seconds. Shorter than picoseconds or nanoseconds. (Much faster than a speeding bullet!) Mostly used for scientific research.

Fiberoptics
A system of flexible quartz or glass fibers with internal reflective surfaces that pass light by allowing thousands of glancing reflections. Many hundreds or thousands of individual fibers are needed to transmit an image, but only single fibers are used to transmit laser light during procedures. Typical sizes for general surgical use would be from 600 microns (0.6mm) to 1000 microns (1.0mm). Some fibers may be as small as 100 microns (0.1 mm) for surgical use.

Fire Retardant
Material which does not support combustion without an external source of heat such as laser.

Flashlamp Pumped Dye Laser
(See Tunable Dye Laser) This laser is energized by a bright pulsing arc lamp, giving rise to a high peak power output pulse of the laser for lithotripsy (green light) or dermatology (yellow light).

Fluence
An energy concept which considers both radiant exposure (and power density) in joules/cm^2 from the surface and exposure from ALL other directions. Common usage of the term for medical applications considers this rate of energy delivery only upon the surface of the target (Radiant Exposure) from impact of the laser beam and incorporates the concept of FLUX - how quickly the energy is delivered. In marketing literature, one will see the term "High Fluence" pulses, which may be technically incorrect but gets across the idea of high energy delivered very quickly.

Fluence Rate
Exposure dose rate from ALL directions through a unit surface area (including backscatter) in W/cm^2.

Flux
See Radiant Flux.

Focal Point
That distance (focal length) from the focusing lens where the laser beam has the smallest spot diameter, and hence greatest intensity. Fiberoptically delivered systems generally do not focus, they simply diverge from the end of the fiber. Focal point is the point of convergence of the rays of light.

Free Electron Laser
A laser in which stimulated emission comes from electrons passing through a magnetic field that varies in space. These are large and expensive installations requiring a linear accelerator. Several are installed at medical institutions as research devices, because they can be electronically tuned to deliver various wavelengths and power levels. They are currently too large and expensive to see routine use as surgical or therapeutic devices.

Fused Silica
Synthetic silica (SiO_2) formed from highly purified materials.

Gated Pulse
A discontinuous burst of laser light, made by timing (gating) a continuous waver output. This is usually accomplished in fractions of a

second, such as .05 to 0.5 seconds (millisecond range), but usually not in the microsecond range. The qualifying characteristic of this type of "timed" pulse is that the peak power of the pulse does not exceed it's average power, as does a true laser pulse.

Gaussian Curve
Normal statistical curve showing a peak with even distribution on either side. May either be a sharp peak with steep sides, or a blunt peak with shallower sides. Used to show power distribution within a laser beam. The concept is important in controlling the beam geometry of tissue impacts with some lasers such as the Carbon Dioxide laser.

Glass — An amorphous solid, typically made mostly of silica (SiO_2) unless otherwise identified. Silica glasses are transparent to visible and some near infrared light. Laser fibers are made of this.

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

Hemostasis — The ability to stop bleeding. Not to be confused with cautery, which means the specific application of a hot object to accomplish hemostasis. Electrosurgery is NOT cautery in this sense. The quintessential advantages of laser in general surgical use is that they accomplish reasonable hemostasis, but with extreme precision of any lateral heat damage unavailable by electrosurgery.

HeNe — Helium Neon Laser. A laser producing low power (milliwatts) red light (630 nm) used as a guide light for infrared lasers such as the Carbon Dioxide or Nd:Yag, or experimentally for biostimulation - use of the laser to speed healing or treat pain. Green wavelengths of the HeNe are now available as the guidelight for infrared lasers, but require changing of the internal optics. Grocery store checkouts use a red HeNe as the scanning beam.

Hertz (Hz) — Unit of measure to express frequency of periodic oscillation in cycles per second.

Ho:Yag — Holmium Yag laser. (Actually Holmium Chromium Thulium, Yttrium Aluminum Garnet Laser) Mid infrared laser emitting pulsed light of approximately 2100 nm. This is the primary laser used in orthopedics such as for arthroscopy.

Hologram — A three dimensional picture made by interference patterns created by the coherence of laser light. They are created as transmission, reflection or integral holograms - different ways of creating or viewing. Some work has progressed in examining holograms for pathological sampling, and interferometry (a type of holography) is routinely used for commercial stress testing of materials. A hologram is philosophically significant in that the ENTIRE picture is contained within any microscopic portion of the plate.

HpD — Hematoporphyrin Derivative. A photosensitizing drug used with photodynamic therapy as a treatment for cancer. A more refined version, DHE or DiHematoporphyrin Derivative, is now more commonly used.

Impact Size — The size of crater, or width of incision, left by a laser impact. This is related to the spot size of the beam, except that impact size will vary depending on how the energy is applied, and how traction is applied to tissue.

Index of Refraction
The ratio of the speed of light in a vacuum to the speed of light in a material, a crucial measure of a material's optical characteristics. Usually abbreviated as *n*.

Infrared Invisible wavelengths longer than 700 nm and shorter than about 1 mm. This includes lasers such as the Alexandrite, Nd:Yag, Ho:Yag, Diode lasers (some), and Carbon Dioxide laser.

Installation Supplying and connecting electrical power, water, or other utilities to HCLS.

Intensity Power per unit solid angle.

Intrabeam Viewing Viewing angle where the eye is exposed to all or part of the direct laser beam.

Ionizing Radiation
Radiation commonly associated with X-ray, that is of a high enough energy to cause DNA damage without any immediate thermal effect to the tissue. This contrasts with non-ionizing radiation of surgical laser systems. In this broader sense, both light and electricity of any type are electromagnetic "radiation".

Irradiance See Power Density - Power per unit area.

Joule A unit of energy - Laser energy is sometimes described in joules per second (watts of power). A power of 1 joule per second is known as 1 watt and is the rate of energy delivery.

KTP Potassium Titanyl Phosphate. An Electro-optical crystal used to change the wavelength of a Nd:Yag laser from 1060 nm (infrared) to 532 nm (green). KDP (diphosphate) may also be used to create this type of green light laser.

LASER Light Amplification by the Stimulated Emission of Radiation. A device that produces intense beams of pure colors of light, usually converting electrical energy into light energy.

Laser Controlled Area Area where the occupancy and activity of those in the area is subject to control and supervision for the purpose of protection from radiation hazards.

Laser Medium (Active Medium)
The material which is stimulated to emit the laser light, and for which the laser is usually named. They may be solid crystals, gases, liquids, or semiconductor materials.

Laser Safety Officer Person appointed by administration to administer a laser safety program, who is responsible for effecting the knowledgeable evaluation of laser hazards, and is authorized and responsible for monitoring and overseeing the control of laser hazards.

Laser Surgeon No such thing - But some surgeons do use lasers to advantage as surgical instruments at times. The truth is that a good surgeon performs well with whatever tool they choose to use. Lasers sometimes allow for better or easier surgery.

Laser System — Assembly of all the electrical, mechanical, plumbing and optical components which comprise an operating laser.

LED — Acronym for Light-Emitting Diode. A semiconductor diode which emits incoherent light by spontaneous emission.

Limiting Aperture — Maximum diameter of a circle over which irradiance and radiant exposure can be averaged.

Limiting Exposure Duration — Exposure duration which specifically is limited by design or intended use.

Maintenance — Performance of adjustments and procedures specified by the manufacturer which are performed by the user to ensure proper performance of the product.

Maser — Microwave equivalent of a laser.

Maximum Permissible Exposure — The level of laser radiation (exposure) to which a person may be exposed without hazardous effects or adverse biological changes in eye or skin.

Metal Vapor Lasers — A class of lasers using vaporized metal as the laser medium, such as copper vapor emitting yellow light at 578 nm, and gold vapor emitting at 630 nm red light. Applications include dermatology and photodynamic therapy.

Metastable State — The state of an electron within an atom, just below a higher excited state, which the electron occupies momentarily before destabilizing and emitting light.

Microprocessor — A digital chip (computer) that operates and monitors many lasers. An excellent tool to keep available for any microprocessor, including home computers, is a nerf bat, which allows one to harmlessly express the frustration levels which such electronics cultivate in humans. (Actually most microprocessor lasers work just fine)

Mode — A term used to describe how the power of a laser beam is distributed within the geometry of the beam. (See gaussian curve) It is also used to describe the operating mode of a laser such as continuous, timed, or pulsed.

Mode Locking
A process similar to Q-switching except that the pulses produced are even shorter (about 10^{-12} seconds) and emerge in short trains of pulses instead of singularly. It is usually achieved with a dye cell. These both produce high peak power laser pulses such as used in ophthalmic lasers for cold cutting of membranes.

Monochromaticity
Waves are monochromatic when they are all of the same wavelength (color). Lasers are called monochromatic even though some produce multiple colors, because each color line is very narrow (pure).

Nanometer Abbreviated nm, a measure of length, a billionth of a meter, or 10^{-9} meter. This is the usual measure of light wavelength. Visible light ranges from about 400 nm in the purple to about 750 nm in the deep red.

Nanosecond one billionth of a second (10^{-9} second). Longer than a picosecond or femtosecond, but faster than a microsecond. This is associated with Q-switched ophthalmic Nd:Yag lasers, and some other pulsed laser systems.

Nastygen a phrase coined by Jim McDaniel to describe hazardous materials such as various laser dyes which are “nasty” if not carcinogens.

Nd:Yag Neodymium Yttrium Aluminum Garnet Laser. A mineral crystal used as a laser medium to produce near infrared light of 1060 nm. A variation of this laser produces a "harmonic" of 1300 nm.

Nd:Yap Neodymium Yttrium Aluminum Perovskite Laser. Pulsed laser system at 1340nm.

Neodymium The rare earth element used as the active element in a Nd:Yag laser.

Nominal Hazard Area where the level of direct, scattered or reflected radiation during normal usage Zone exceeds the MPE. Exposure levels beyond the NHZ boundary are below the appropriate MPE level.

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

Nonlinear Effect
An effect which is not a normal linearly increasing temperature rise induced by the laser. This refers to the plasma "spark" and associated acoustical shock wave created by some pulsed lasers, such as used in ophthalmology as a "cold cutting" laser, or used to break apart kidney and biliary stones.

Operation Performance of the laser system over the full range of its intended functions. It does NOT include maintenance and service.

Optical Breakdown
Plasma formation by stripping electrons off atoms/molecules. This is created by high laser energies focused within small spots. They create a small plasma "spark" and shock wave which can cold cut tissue or fragment hard materials like stones.

Optical Cavity
(Resonator) The space between the true laser mirrors where the light is amplified and lasing action occurs.

Optical Density
Logarithm to the base 10 of the reciprocal of the transmittance: $D_\lambda = -\log_{10} \tau_\lambda$, where τ_λ is the transmittance at wavelength λ.

Oscillator
A laser cavity with mirrors so that stimulated emission can oscillate within it. This would therefore be the laser tube when capped with mirrors at each end.

Output Coupler
The partially transmissive mirror that allows the laser beam to escape from the optical cavity (resonator).

PDT
Photodynamic Therapy. The use of photosensitizing drugs, activated by certain pure colors of light produced by the laser or other light sources, to achieve selective tissue destruction. Its current major use is as a selective treatment for many cancers, but it has wider ranging applications to select out diseased tissues.

Peak Power
Highest instantaneous power level in a pulse. See also average power for how peak power, pulse width and frequency of the pulse are related.

Perioperative
Time from the decision of surgical intervention to the follow-up of home/clinic evaluation. Includes pre-operative, intra-operative and post-operative phases.

Phase
Waves are in phase with each other when all the troughs and peaks coincide and are "locked" together. The result is a reinforced wave of creased amplitude (brightness).

Photocoagulation
Tissue coagulation caused by light (laser). This may or may not involve hemostasis. Tissue coagulation occurs when egg white turns white in a frying pan.

Photodisruption
Creating an acoustical shock wave by high energy pulsing of a laser. (See nonlinear effects and optical breakdown) This is the term generally used by ophthalmologists to describe the "cold cutting" effect of a pulsed Nd:Yag laser on the posterior capsule in secondary cataract surgery.

Photofrin
Trade name of the drug made by Sanofi pharmaceuticals which is used as the photosensitizing agent in Photodynamic Therapy for cancer. A porfimer sodium.

Photometer
An instrument for measuring the amount of light visible to the human eye.

Photon
The basic particle of light. A Quanta of Electromagnetic Radiation. Light may be viewed as either a wave or a series of photons. - Also biblically referenced as the "nature" of GOD.

Picosecond
10^{-12} seconds. Longer than a femtosecond, but shorter than a

nanosecond. Associated with Mode locked ophthalmic Nd:Yag lasers. Definitely a fast pulse.

Plasma — The 4th state of matter in which electrons have been stripped off the atoms. A lightning bolt is actually plasma. The extremely high internal temperatures (several thousands of degrees) expands materials rapidly setting up an acoustical shock wave (Thunder). When this is confined to a 50 micron spot within the eye, a gentle "snapping" effect will cut membranes.

Plasma Shield — The ability of the plasma to stop transmission of the laser light past the "spark". This serves as somewhat of an additional safety mechanism for ophthalmic procedures.

Plume — Aerosolized vapor created by vaporization of tissue or metals. Cellular debris and noxious or infectious materials might be contained in such plumes. These are surgically generated, most commonly, by laser and/or electrosurgery.

Polarization — Alignment of the electric and magnetic fields that make up an electromagnetic wave (including light). It normally refers to the electric field. If light waves all have a particular polarization pattern, they are called polarized.

Pockel's Cell — An Electro-optical crystal used to achieve a Q-switch, the fast nanosecond pulsed of very high peak powers.

Point Source — A source of radiation (light) whose dimensions are small enough to be neglected in calculations, as compared to the distance between source and receptor.

Population Inversion — A state of the laser active medium, in which it has been excited to a point where more atoms or molecules are in a higher energy state than in a lower resting state. This is a necessary prerequisite for lasing action.

Power — The rate of energy delivery expressed in watts (joules per second)

Power Density — (Irradiance) The amount of energy concentrated into a spot of particular size - the exposure dose rate incident upon a surface (W/cm^2). It is expressed in watts per square centimeter, and applies equally to laser and electrosurgery. It is the brightness of the spot and affects how quickly vaporization occurs within the spot. Too low a power density results in undesirable tissue burning or charring. Too high a power density may result in loss of surgical control of the beam and perforations. Eye hand coordination with a laser can generally be ascribed to the power density. Low or high laser powers may result in high or low power densities, depending on the size of the spots to which they are focused.

PRF — Pulse Repetition Frequency. Number of pulses per second.

Protective Housing — Covers over the laser which prevents access to laser exposure above MPE levels.

Pulse — A discontinuous burst of laser light with high peak powers in a short pulse, usually in microseconds or less. The qualifying characteristic of a true laser pulse is that the peak power of the pulses is much higher than the average output power, or the peak power delivered is much higher than the laser could otherwise sustain in a continuous wave mode. Buttons on the face of a laser which say "pulse" may only be a timer for a continuous wave beam - different than a true laser pulse.

Pulse Duration — Duration of the pulse, usually measured as the half-power points of the leading and trailing edges of the pulse.

Pulsed Laser — A laser which delivers its energy by single or repetitive pulses, which are generally less than 0.25s in duration.

Q-Switching — Switching the "quality" of a resonator to produce very high peak powers (millions of watts) of light for very short nanosecond bursts. This is frequently achieved with a pockel's cell. At high enough energies it creates the "sparking" and shock wave associated with photodisruption. (See plasma, mode-locking, nonlinear effects, photodisruption)

Quartz — A natural crystalline form of silica. Used in making of laser fibers (quartz fibers), which are simply a grade variation of silica glass (SiO_2).

Radian (RAD) — Unit of angular measure equal to 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 — radiometric unit of brightness in J/(cm^2-sr)

Radiant Energy — Energy transferred, emitted or received in the form of radiation in units of Joules (J).

Radiant Exposure — Exposure dose incident upon a surface (J/cm2)

Radiant Flux — Instantaneous power level in watts. Also called Radiant Power.

Radiant Intensity — Beam power per solid angle (J/sr); seldom used in laser safety

Radiant Power — See radiant flux.

Radiometer — An instrument to measure power in watts in electromagnetic radiation (light). Different from a photometer.

Reflectance — Ratio of total reflected radiant power to total incident power. Also called reflectivity.

Reflection — Changing the pathway of light by "bouncing" from physical surfaces. See Specular and Diffuse Reflections.

Refraction — Bending of light as it passes between materials of different refractive index.

Refractive Index

The ratio of the speed of light in a vacuum to the speed of light in a given material. The differences in the refractive index of the core of a laser fiber, and that of its outer cladding, is what keeps the laser light bending inside the flexible fiber. (See Total Internal Reflection)

Repetitively Pulsed Laser

Laser emitting multiple pulses occurring in sequence with a PRF greater than or equal to about 1 Hz.

Resonator

A region (laser tube) with mirrors on the ends and a laser medium in the middle. (See also Oscillator) Stimulated emission from the active medium resonates between the mirrors, one of which lets some light emerge as a laser beam (see output coupler).

Selective Photothermolysis

A process of selective destruction of certain targets. This applies primarily to skin procedures. A wavelength and pulse duration of light is chosen that will be best absorbed by the target (hair follicle, pigment, capillary, etc) creating enough heat to destroy it, but being insufficient to damage adjacent or overlying structures.

Silica

Silicon Dioxide, SiO_2, the major constituent of ordinary glass.

Speckle

Coherent "noise" produced by laser light. It gives a mottled appearance to holograms viewed in laser light. This speckle can also be used as a screening device for near and far sightedness - depending on which way the speckle appears to move when one moves their head from side to side while viewing the speckle pattern.

Specular Reflection

A reflection of a laser beam from a surface, which significantly retains the low divergence angle of the beam -- preserving its ability to create potential hazards. Specular reflections are most hazardous when the surface is flat (mirror like). They are less hazardous when produced from a curved surface (like the curve of a cylindrical surgical instrument).

Spot Size

The mathematical measurement of a focused laser spot. In a TEMoo beam (gaussian curve) it is the area that contains 86% of the incident power. This is the optical spot size and does not necessarily indicate the size of the laser impact crater that will be made. (See impact size)

Superpulse

An operating mode on the Carbon Dioxide laser describing a fast pulsing output (250 to 1000 times per second), with peak powers per pulse higher than the maximum attainable in the continuous wave mode. Average powers of superpulse are always lower than the maximum in continuous wave. This mode is used to attain very clean incisions or vaporization’s with the laser, with little extraneous heat generation. The disadvantage is that maximum average powers available drop when the laser is switched to a superpulse. (See also Ultrapulse)

Thermal Relaxation Time

The rate at which a structure can conduct heat. When pulse times of a laser are shorter than the time required for heat to spread from the target, the heat damage will be confined to that desired within the target. This is why pulsing a laser is so useful and produces such clean results. It is seen in superpulsing and ultrapulsing, Ho:Yag lasers for arthroscopy, and pulsed dye and metal vapor lasers for dermatology.

Threshold

The excitation level at which laser emission starts.

Threshold current

The minimum current needed to sustain laser action, usually in a semiconductor laser.

Total Internal Reflection
Total reflection of light back into a material when it strikes the interface with a material having lower refractive index at a glancing angle. (See refractive index) This is how laser fibers work.

Transmission: Passage of the laser energy through a medium without absorption.

Transmittance: Ratio of total transmitted radiant power to total incident radiant power.

Tunable Dye Laser
A laser using a jet of liquid dye, pumped by another laser or flashlamps, to produce various colors of light. The color of light may be tuned by adjusting optical tuning elements and/or changing the dye used. Common medical applications include multiple colors in ophthalmology, red for PDT, yellows for dermatology, and green for lithotripsy.

Ultrapulse A commercial trade name given to an enhanced version of a superpulse on an RF excited Carbon Dioxide Laser. An ultrapulse laser is able to achieve very high energies per pulse and sustain very high average powers from the laser - the chief disadvantages of previous superpulses. This is partially achieved by the way the power spike is created and its resulting shape. Ultrapulse produces very clean laser incisions and vaporization's.

Ultraviolet Part of the Electromagnetic Spectrum at wavelengths shorter than 400 nm, to about 10 nm, invisible to the human eye. These wavelengths incorporate the Excimer lasers.

Visible Radiation (light) Electromagnetic Radiation which can be seen by the human eye. Describes wavelengths between approximately 400nm and 700 nm.

Watt (W) Unit of power or radiant flux. Watt = Joule per Second.

Waveguide A delivery device for Carbon Dioxide Lasers commonly used for endoscopic use. The laser beam is focused into the thin hollow waveguide, where it is delivered out the end of the tube by hundreds of glancing reflections from the inside walls of the waveguide. The term waveguide also applies to certain types of laser resonators, but the common use is of the delivery instrument.

Wavelength Distance between two successive points on a period wave of the same phase.

X-ray A very short wavelength of electromagnetic radiation producing ionizing effects commonly associated with radiation hazards. Surgical lasers do NOT produce X-rays or ionizing radiation.

YSGG Laser Yttrium-Scandium-Gallium Garnet Laser. Mid-infrared at 2790nm Used for skin resurfacing – effects in between CO2 and Er:Yag lasers