DIODE LASER, A CO2 LASER OR A THERAPEUTICAL LASER FOR MY DERM CASES.

Lasers in Veterinary Dermatology
Mona J Boord, DVM, Diplomate ACVD, Animal Dermatology Clinic San Diego, California and Massey University New Zealand

History of Light Therapy in Dermatology
Light has been used in the treatment of dermatologic conditions for many years. Niels Ryberg Finsen, physician and scientist, investigated the use of light and reported that ultraviolet light could kill bacteria. He published his theory of phototherapy and beneficial use of phototherapy in 1893. He went on to publish “The use of concentrated chemical light rays in medicine”. In 1896, he founded the Finsen Institute for Phototherapy in Copenhagen. Finsen was most noted for inventing the Finsen lamp used to treat skin tuberculosis (lupus vulgaris). Of 800 patients treated ½ were reported as cured and most showed improvement of their clinical signs. In 1903, he received the Nobel Prize in medicine 1903 for this work. Ultraviolet light combined with psoralen has been used for decades as PUVA (psoralen and ultraviolet A) therapy for decades to treat severe psoriasis, eczema, vitiligo, mycosis fungoides and graft-versus-host disease.

Albert Einstein first proposed the theory of stimulating radiant energy in 1916. It was the study of atomic and molecular physics which stimulated the collaboration of engineers and physicists to produce the first Maser. This was stimulated emission of radiation through microwave amplification. In 1960 Theodore H. Maiman presented the first functioning optical ruby Laser (light amplification by stimulated emission of radiation) excited by a xenon flash lamp which produced a 1 billion watt pulse of 693.7 nm light wave for 1ms duration. Within a year of this Fred J. McClung and Robert W. Hellwarth developed a switching technique to shorten the pulse length to nano-seconds. This allowed peak power up to gigawatts of energy per pulse. The development of lasers with different wavelengths has allowed specialization in the field of laser therapy to remove tumors or vascular anomalies that could not be removed by other means. Adding pulse therapy to the use of laser dramatically decreases the side effects with these treatments. Not only can masses be removed, but port wine stains and telangiectasia can be removed. Various wavelengths target different depths in the skin to allow treatment of melasma with minimal scarring. Initially there was a lack of focus on further development of Q-switched lasers until 1980s. The theory of selective photothermolysis has changed cutaneous laser surgery.

Lasers in clinical practice
The laser is a tool which will augment your therapeutic options. There are many procedures that can be performed more easily with the laser then with traditional surgery. There are also procedures that cannot be done or wouldn’t normally be attempted with traditional surgery. The laser will also enhance the public image of a practice. The public is well educated and desires less painful alternatives to traditional surgery for their animal companions. Improved healing and increased comfort are non-economic factors that may lead to increased numbers of procedures and referrals.

For the future, there are many new diagnostic lasers being developed that will change the way we diagnose disease and tumors. These lasers work much like an ultrasound but instead of sound reflecting back to the probe, light is reflected back. As these light waves interact with tissue the percentages of water, hemoglobin, fat, melanin can be determined. The differences in fibrous nodules versus neoplastic tissue are being defined and sensitivity and specificity evaluated. The lasers can detect differences so subtle as to determine premenopausal vs postmenopausal breast tissue. Laser is also being used to determine surgical margins in burn wounds with increased accuracy in the first 24 hours following the burn.

Laser Light Properties
There are different types of lasers available, which produce different wavelengths of light, different beam intensity, and different temporal patterns of the laser beam. In the understanding of how to use a laser properly, some time needs to be spent in understanding the importance of these factors. The other factor affecting the choice of laser is the composition of the tissue to be treated, the depth of the lesion to be treated and the location of the tissue to be treated.

Traditionally the type of laser being used was named based on the lasing medium of the laser. The laser medium may be a solid, crystal, liquid or gas. Energy in the form of optical, electrical, chemical or thermal can be used to stimulate the atoms to a higher energy level from their ground state. When these atoms drop back into their resting state a photon is released. This all occurs within a lasing chamber (Fig. 1). The laser chamber typically has mirrored ends and the photons resonate through the lasing chamber (exception is the diode laser). Once a sufficient number of photons are available the laser will display a ready signal. When released a small percentage of the highly concentrated beam of photons is allowed to pass through a partially reflective mirror at one end into the laser wand or guide. This is our usable laser beam. The generation of the light beam and the size of the lasing chamber tends to make laser large and bulky.

The exception to the big and bulky “ordinary” laser is the semiconductor lasers, more commonly known as diode lasers. They work similarly to a light-emitting diode (LED) light such as we use as a lecture pointer. Please note an LED is NOT the same as a diode laser. Diode lasers tend to be more compact and less expensive than traditional lasers with lasing chambers but only certain wavelengths can be produced with diodes. An ordinary diode is two layers of treated silicon (P-type lacking some electrons) and N-type with more electrons). In an LED the electric current flows in one direction and the energy dispensed is in the form of a photon (Fig. 2).
Of course the early diodes had little power. In order to increase the power a semiconductor laser stack is used. Stacking the laser diodes allows more power to be produced and also allows the generation of multiple wavelengths at the same time (Figure 3).

Diode lasers can be used as surgical lasers or for “low level laser therapy” “LLLT”. This terminology is confusing as some authors refer to LLLT as “low level light therapy” when using LED light vs laser.

The wavelength of the beam depends on the lasing media. The lasing media is usually the product the laser is named after. For example, in a CO$_2$ laser the lasing media is CO$_2$ and it produces a wavelength of 10,600nm. This wavelength is in the far infrared (IR) range and is invisible to the human eye. Helium neon was the lasing media of the older red laser pointers. Argon, Krypton and potassium titanyl phosphate (KTP) lasers produce light in the blue green range. Eximer lasers produce light in the ultraviolet range (UV). There are dye and diode lasers with adjustable wavelengths in the near IR. Yttrium Aluminium Garnet (YAG) is a clear crystal that may be embedded with Neodymium (Nd), Holmium (Ho), or Erbium (Er) to create (Nd)YAG lasers in the near IR, or (Ho)YAG and (Er)YAG lasers in the far IR.

As the wavelength of all the photons are the same, the laser beam is a pure monochromatic color and interacts with tissue in a predictable way. Normal white light is polychromatic with all the colors of the rainbow.

The laser chamber releases the photons into the waveguide. The light is collimated it retains its shape and accuracy of delivery. A laser beam can be sent from earth to the moon to target a mirror approximately 1 meter in size with accuracy and a round trip time of 2.3-2.7 sec. Without atmospheric interference laser levels are accurate from 1-3mm over 100 meter distances.

Coherence is a challenging topic to explain. I learned it to be photons in phase cause light amplification. Coherence produces a brighter light. Starlight is considered the most coherent light. Pin point lights are more intense. As the photons are traveling between the two mirrors within the laser chamber create a mirror-tunnel further stimulating emissions. In the center of this a pinpoint forms. Think of it like an infinity mirror, where the center looks like a tiny distant star. Where this becomes important is when you look at a 100 watt incandescent light bulb it may be uncomfortable to look at but it does no permanent damage to your retina. Compare this to a ¼ watt laser beam that can permanently burn a mark in the back of your retina.

Coherent light can be thought of as sharp when focused. This is how we can cut with light. Coherence is the difference between laser therapy and other forms of light therapy.

- Finsen lamp with filter
- Laser diode
- Light emitting diode (LED)
The beam intensity is the amount of energy per area of tissue. The terms power, power density, energy and energy density may sound like more jargon but when using a laser one must understand what these terms mean and how to apply this knowledge to the particular application. Not doing so does affect the outcome of the procedure.

Power describes the laser beam we are starting with and is measured in Joules/second = Watts. CO₂ lasers are available with continuous wave powers from 1 milliwatts (mW) for a pointer up to 3 kilowatts (kW) used for welding. The medical CO₂ laser we will be using is available in 15, 20, 30 and 40 watts. Low-level laser therapy (LLLT) uses a low-power laser or a light-emitting diode (LED) in the 5 – 500 mW range (similar to a DVD player). This typically is not enough power to heat tissue and another term for these lasers is cold laser.

Power divided by the area of the beam is the power density. Power density is measured in Watts/cm². So consider the sun’s power. When you go outside and it is cloudy, the power is the same but some of that power is being absorbed by the clouds. When the clouds part you can feel the full power and warmth of the sun. If you then take a magnifying lens and focus the sun’s light (power) to a spot on your hand, you can get a localized burn from the same amount of power being concentrated to a smaller area. Surgical laser hand pieces often have a focusing lens. This causes a converging of the photons to a plane of maximum power density (focal point). It is important to understand the focal point of the laser you are using. Using the 10 watt CO₂ laser in a continuous wave as an example, a 2mm tip will deliver 320 Watts/cm². This is only enough to warm tissue and create tissue damage. A CO₂ laser needs to deliver 4500-5000 Watts/cm² to ablate tissue efficiently. A 10 Watt laser through a 0.8mm spot will only deliver 2000 Watts/cm². Changing to a 0.4mm tip will increase the beam intensity to 8000 Watts/cm².

Energy density adds the dimension of time. It is measured in Joules/cm². As the amount of time increases so does the amount of energy delivered to the tissue. If used correctly this results in vaporization of the desired tissue. If used incorrectly the energy can cause tissue damage just as longer exposures of skin to UVA, UVB and UVC results in damage to the skin and apoptosis +/- neoplastic transformation.

Temporal patterns of delivery have been designed and shown to better direct the laser energy to the desired tissue and spare the surrounding tissue. For most lasers the energy delivered to the target tissue creates heat (Photothermal reaction). The longer it takes to cut or vaporize tissue the more time the peripheral tissue is heated. This may create collateral thermal damage and delay wound healing. The absorbed light denatures proteins, causes mitochondrial swelling and vacuolization thus at some point causes irreversible cellular damage. The hyperthermia may also destroy adjacent blood vessels. The goal with proper use of the laser is to reach a tissue temperature of 110 – 150 degree C quickly without superheating the tissue. As this temperature is reached the tissue will contract and char will form. The char is the remaining cellular contents once hydrogen, oxygen and nitrogen have been vaporized. The char changes the optical properties of the tissue and will affects energy absorption and transmission. Therefore time should be taken during surgery to wipe away char buildup. Thermal injury is most likely to occur with continuous-wave (CW) delivery. Thermal relaxation is the time it takes for tissue to cool. This knowledge has been utilized to produce lasers with different temporal patterns to deliver pulsed beams versus continuous beams of energy. This allows improved surgical precision and decreases unwanted collateral tissue damage. By applying a high energy in rapid pulses there is specific selection of the energy being delivered to the specific tissue selected and not the surrounding tissue. There is a higher pulse of energy allowing the target tissue to reach the vaporization temperature quickly and then there is a brief discontinuation of energy applied to the tissue allowing adjacent cells to cool thus decreasing peripheral tissue damage and improve wound healing. These patterns are called chop-wave or pulse, Super pulse, and pulsed super pulse. In the Chop wave the laser is set to a percentage of delivery such as 40%. Duty cycle is the measure of the laser is “on” / second. So a duty cycle of 1:10, 0.1 or 10% means the beam is on 10% of the time and off 90%. This raises the peak power compared to the average power. The pulse repetition rate may also be adjusted and the rate of measure is Hertz (Hz). So 1 pulse per second would equal 1 Hz. Development of Q-switching allowed the creation of ultrashort pulses and the ability of photons to build exceeding the gain of the medium. The resulting beam has a higher peak power and results in improved vaporization and less peripheral tissue damage.
Delivering the beam to the tissue

The mode of delivery depends upon the wavelength of the beam and whether or not the beam is absorbed in water. The laser beams with longer wavelengths in the far infrared range are absorbed in water. These wavelengths are delivered through hollow tubes with mirrors. These tubes can be articulated arms or wave guides. For shorter wavelengths near IR and shorter optical fibres and all endoscopes may be used. Optical fibres have the advantage of being more highly flexible. However because the light “bounces” within the fibre it does diverge at the end. The spot size is determined by the fibre size. A 600 micron fiber has a 600 micron spot size at its tip. Because the beam diverges quickly once it leaves the fibre, the fibers must be held very close to or touching the target to maintain power density.

The interactions of laser light with tissue include:

1. Reflection of light without penetration of the target tissue
2. Transmission of light through the tissue
3. Scattering of light within the tissue
4. Absorption into the tissue and transforming the energy into a photo-thermal reaction
5. Photo disruption where the high energy pulse generates a shock wave
6. Photochemistry is which the light energy reacts with a chemical and stimulates a chemical process in the tissue “Photobiomodulation”

What determines which of the above interactions that will occur is based on the composition of the target tissue and wavelength of the light beam. The various wavelengths are preferentially absorbed by tissue based on the tissue’s composition. Thus a laser is chosen for a procedure based upon the optical properties of the target. In our case, this is skin. Tissues have different energy absorption coefficients based on their water, hemoglobin, melanin, and protein contents. Melanin and hemoglobin are present in the skin. Tissues of this color absorb blue and green wavelengths but not red wavelengths. Therefore a krypton or KTP laser is a better choice to remove a port wine stain or an angiomatosis lesion. Water is clear but does absorb light of longer wavelengths in the infrared range. Also the shorter the wavelength, the deeper the light beam may penetrate tissue. This may cause damage to tissues deeper than the target tissue and must be taken into account. Therefore the best laser for a procedure depends upon what type of tissue is being lasered. The CO\(_2\) laser is very nice as it does not penetrate tissue deeply. This allows very precise dissection of tissues during surgery.

Photobiomodulation is used to reduce pain and inflammation and is claimed to accelerate healing and promote regeneration of tissue. How this occurs is based on studies of cell cultures, animal models and clinical studies. How laser light interacts with the tissue and its mechanisms reported are extensive. In short the coherent light of the laser is polarized by the tissue. Chromophores in the tissues absorb photons and organelles absorb the electromagnetic energy. The electron transport mechanisms in cell membranes, mitochondria and epithelial tissue are stimulated. There is increased production of ATP and synthesis of DNA and RNA are increased. Also enzymes are stimulated such as Nitric oxide and reactive oxygen. It is believed the coherent light and polarization of light is critical to the success of LLLT. Therefore there is much debate about the other forms of light therapy such as LEDs and broadband light that were placed under the nomenclature of photobiomodulation therapy. In a review article the author quite frustrated in reviewing the studies comparing light therapy to laser therapy states “The fact is that numerous creators of “pseudo-lasers” are actively (and quite successfully) trying to sell such products under the brand name of “LLLT”\(^3\).
Which laser is best for which type of tissue?

$\text{CO}_2$ has a very long wavelength of 10,600nm. It is highly absorbed by water creating a photothermal interaction. This results in vaporization of the tissue with high water content with minimal scatter, shallow penetration, and minimal peripheral tissue injury. These features make the $\text{CO}_2$ laser very useful for most cutaneous procedures. Due to the long wavelength of the $\text{CO}_2$ laser, it can only be delivered by hollow waveguides and articulated arms; therefore, it cannot be utilized for endoscopic procedures. Argon and KTP lasers have short wavelengths of 524 and 532nm respectively. For tissues high in hemoglobin, argon lasers and KTP lasers are preferentially absorbed. The problem with these lasers is their short wavelength allows them to transmit through tissue that does not have high hemoglobin content. This can result in peripheral thermal tissue injury. To minimize damage the amount of energy delivered to the target tissue should be closely monitored. Between these two lasers are diode lasers and neodymium yttrium aluminum garnet (Nd:YAG) lasers with wavelengths of 635 – 740nm, and 1,064nm respectively. Water and hemoglobin will absorb these wavelengths but the $\text{CO}_2$ laser is better absorbed by water and argon is better absorbed by hemoglobin. The more specific the laser wavelength is for the type of tissue the less energy needs to be applied and therefore the depth of thermal injury to surrounding tissue is less. Dye lasers have variable wavelengths of 400 – 1000 nm depending on the dye. They have been used together with photosensitizers for photodynamic therapy. Eximer lasers have very short wavelength in the ultraviolet range and are popular in human dermatology cases to treat psoriasis and vitiligo.

Overall, for the most daily procedures in the veterinary dermatology practice, the $\text{CO}_2$ laser is the laser of choice.

What are the risks or safety issues when using laser in the veterinary practice?

With proper training and conscientious adherence to safety protocols the risks are very manageable. Most of the lasers being used in veterinary clinics produce heat and vaporization of the tissue. This creates a plume of smoke. The plume may contain viable organisms (bacterial or viral) as well as cells and can be irritating when inhaled. There are laser safe surgical masks available for use. The plume must be removed during the procedures with a smoke evacuator. The evacuator has a filter that should be changed based on hours of use. The surgical technician is responsible for logging the amount of time the evacuator is in use. Eye protection must be worn by all attending staff and the patient at the time of surgery. The type of eye protection will depend upon the type of laser being used.

As mentioned previously, there is heat generated by the laser, therefore surgical preparation should not include flammable products such as alcohol. Accidental fire can occur with flammable liquids, oxygen, paper drapes, or methane gasses. It is imperative to prevent endotracheal tube fires. There are laser-safe endotracheal tubes available or the practitioner can protect standard tubes with saline or sterile water soaked gauze when using lasers well absorbed by water. If surgery is being performed around the anal area, water soaked gauze should be placed in the anus.

If proper technique is not utilized, the surgeon, staff, or patient may receive accidental skin burns. Remember the laser is a light energy much like a laser pointer used in lecturing. If the laser pointer is aimed at a hole in the projection screen the light will continue on to whatever is behind it. When cutting through tissue it is common to cut through one area more quickly then another. If the laser is passed over the area already incised it continues on and burns the tissue beyond. This may be the surgeon’s finger or another tissue on the patient. Burns can be minimized by directing the beam at the surgical site, accurately using the foot pedal to activate the laser beam and using sterile water soaked gauze or tongue depressors as a backstop. The surgical technician should put the laser in standby mode when not in use to prevent accidental discharge and burns.

The light from the laser can also be reflected and if reflected into the eye can create damage. Care should be taken not to aim the light at surgical instruments. There are laser instruments available with ebonized or burnished finishes which decrease reflected light. Personnel in the operating room must all
wear protective eyewear. The type of eyewear needed varies with the type of laser. Regular glasses or safety lenses are sufficient for the CO₂ laser. The patient's eyes should also be protected. Again sterile water soaked gauze may be placed over the eyes or there are special eye-cups and masks available.

For more information, the American National Standards Institute publishes a book of safety standards and regulations called *Safe Use of Lasers in Health Care Facilities*.

**What are the advantages of using laser over traditional surgery?**

One of the big advantages with most photothermal lasers is the sealing of small blood vessels. Using the laser provides a very dry surgical field even in highly vascular areas. A feline rhinectomy to remove squamous cell carcinoma may have taken 30 – 45 minutes with traditional surgery to control the hemorrhage, and with the CO₂ laser the procedure takes about 15 minutes.

Another very important benefit is decreased post-operative pain. The laser energy is painful at the time of surgery and general or local anesthesia must be used. However, post-operatively patients seem less painful and return to normal behavior more quickly. This can best be seen following a feline onychectomy or rhinectomy. The cats that have had a rhinectomy often are grooming and eating normally within 4 hours of their procedure. Subjectively, cats receiving traditional surgery for rhinectomy appear sensitive on their nose and don’t tend to eat for a day or two post-surgery.

Another benefit is decreased swelling. The laser energy does not crush or tear tissue; it vaporizes it. It also seals lymphatics thereby decreasing swelling. However if there is significant peripheral tissue damage due to incorrect use of the laser, thermal damage will result in additional tissue swelling and delayed healing.

Finally, the laser is a wonderful surgical tool that allows the veterinarian to offer surgical procedures that may be more difficult or not possible with traditional surgery techniques. The laser is an expensive tool but can certainly pay for itself in the dermatology clinic and probably pay for itself more easily in the general practice.

**References**

4. [https://www.explainthatstuff.com/semiconductorlaserdiodes.html](https://www.explainthatstuff.com/semiconductorlaserdiodes.html) diode light Figure 2