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Lasers in Exotic Animal Practice

Stephen J. Divers
Department of Small Animal Medicine and Surgery (Zoological Medicine)
College of Veterinary Medicine
University of Georgia
2200 College Station Road
Athens, GA 30602, USA
sdivers@uga.edu

Introduction

Zoological medicine, as a discipline, has many inherent, unique challenges unrealized in more traditional veterinary practice. The obvious, the wide variety of species, is subtly surmounted by the even wider disparity in patient size. Patients may range from a 10 g finch to a 200 kg tortoise. Blood loss is usually not a problem with the latter, but is a critical concern with the former. Traditional medicine has taught the use of the surgical scalpel, which has always been considered the gold standard for surgical incisions. As with anything, the scalpel has its limitations. Cold steel surgery, even with the best technique, has the risk of excessive hemorrhage.

Recent times have seen the introduction of the surgical Laser to general veterinary practice. No longer is this sophisticated equipment limited to veterinary institutions and large referral practices. Recent graduates are entering the work force with advanced training. Printed media, animal programs on cable television and the Internet are (mis)informing owners on the advances in veterinary medicine, and as a result, newer techniques including laser are now in demand.

Laser Physics

As human medicine and surgery continue to advance, so many of these developments filter through to the veterinary profession, and laser surgery is one such technology. Since Albert Einstein theorized the concept of lasers in 1916 considerable development has produced equipment available to human, and subsequently, veterinary surgeons (Polanyi, 1978). The term LASER stands for **L**ight **A**mplification by the **S**timulated **E**mission of **R**adiation and relies upon the production of electromagnetic radiation in response to photon emission by the lasing medium (Polanyi, 1978; Arashiro et al., 1996).

The laser wavelengths fall between infrared and ultraviolet, which include the invisible and visible (400 -700 nm) light spectrum. The wavelengths of medical lasers range from 193 nm (UV-excimer lasers) to 10,600 nm (far-infrared lasers). Only lasers in the wavelengths of 400-700 nm (e.g. diode lasers) are visible to the human eye.

The power behind a laser comes from its ability to store energy in atoms, concentrating the energy and releasing it in the form of powerful waves of light energy. Specifically, an atom in its resting ground state in a given medium (e.g. solid crystal, liquid or gas) becomes excited to a higher energy state by absorbing thermal, electrical or optical energy. After the energy is absorbed, the atom spontaneously returns to its resting state by releasing that energy as a photon - this is called Stimulated Emission. This released photon resonates between mirrored ends of the laser chamber, further exciting other atoms in the laser medium. The momentum of the particles grows until finally a highly concentrated beam of light passes through a partially transmissive mirror at one end of the laser chamber (Figure 1). Just as sound passes through air, or a ripple in the water, light travels in waves. Frequency is the term for the number of waves that pass a point in time. The frequency of light (known as the number of oscillations per second) combined with its wavelength (the distance between one peak to the next) determine the color of light. Normal white light is incoherent, which means it contains many wavelengths radiating in all directions. For example, if light passes through a prism the beam is broken down into its different colors. Laser light, in comparison to normal light, is coherent, and consists of only one color, known as monochromatic. The last distinguishing feature of laser light, is that it is collimated, or non-radiating as is white light. Laser light travels in parallel beams, each reinforcing the beam next to it.

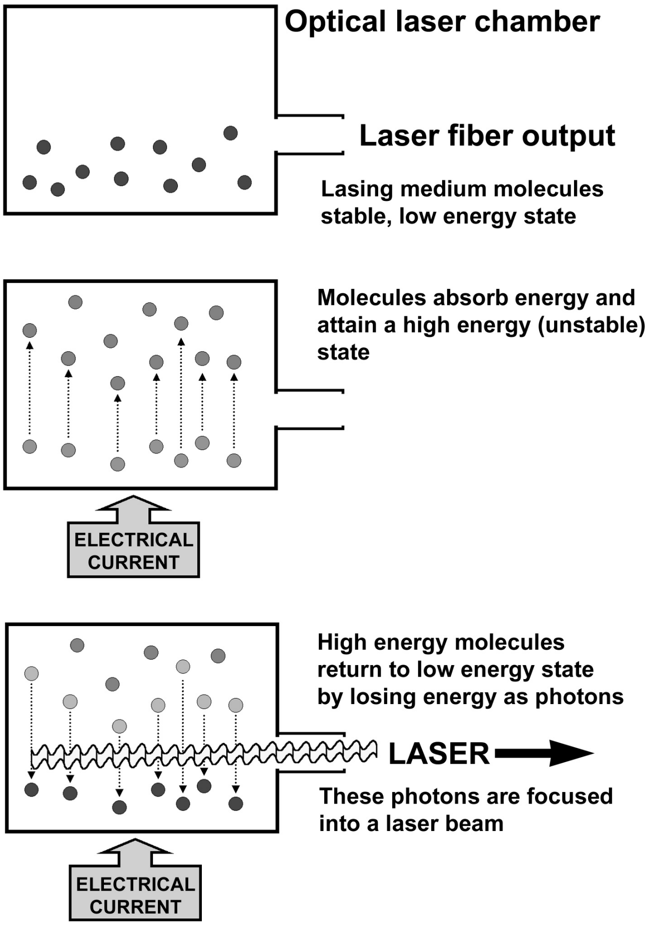


Figure 1. Diagrammatic representation of the production of laser. The top diagram demonstrates the resting lasing medium molecules within the optical laser chamber. As energy in the form of electrical current is applied so these molecules attain a higher energy level and become unstable (middle). There is a constant effort to return to a more stable state and the molecules achieve this by losing energy in the form of photons (bottom). These photons leave the optical chamber via the laser fiber output as a laser beam.

Laser Classifications

Laser safety classifications in the US by the American National Standard Identification (ANSI) and globally by the International Electrotechnical Commission (IEC). The classifications below from the revised system (2002) apply to non-magnified laser devices.

Class 1: safe under all conditions of normal use.
Class 2: applies to only visible light lasers (400-700nm). These devices are considered eye-safe because the blink reflex will limit exposure to less than 0.25 seconds. Intentional suppression of the blink reflex could lead to eye injury. Most laser pointers are class 2 devices.
Class 3R: 3R lasers in the visible spectrum have continuous wave (cw) emission of 5mw or less. These devices are considered safe if handled carefully with restricted beam viewing
Class 3B: 3B lasers are hazardous to the eye when viewed directly. For visible and infrared devices emission power is limited to 0.5W. Protective eyewear, key switch and safety interlock are required safety features.
Class 4: Class 4 lasers include all lasers that emit power in excess of 3B limitations. Eye protection is needed to limit both direct and diffuse reflected exposure. Key switch and safety interlocks are also required safety features. Most scientific, industrial, military and medical lasers fall into this category.

Surgical Lasers

There are a variety of lasers available, but carbon dioxide (CO_2) and diode models are probably most common in veterinary medicine today (Palmer and McGill, 1992; Arashiro et al., 1996; Schick and Schick, 1994; Courey et al., 1999; Sapci et al., 2003; Silverman et al., 2007; Hernandez-Divers et al., 2008, 2009). Both lasers produce an immediate area of tissue vaporization, surrounded by a zone of irreversible photothermal necrosis, and a further outer-most zone of reversible edema (Figure 2). When utilizing proper technique and a small laser tip, the cellular destruction is limited to a region only three to four cells away from the target area, minimizing tissue devitalization. As a result, the laser incision has less lateral tissue damage than either cryosurgery or electrosurgery, but is comparable to radiosurgery.

There are currently more CO_2 lasers in veterinary practices than any other type and they offer the advantages of accurate, non-contact surgery with minimal tissue penetration and a reduced collateral thermal injury of

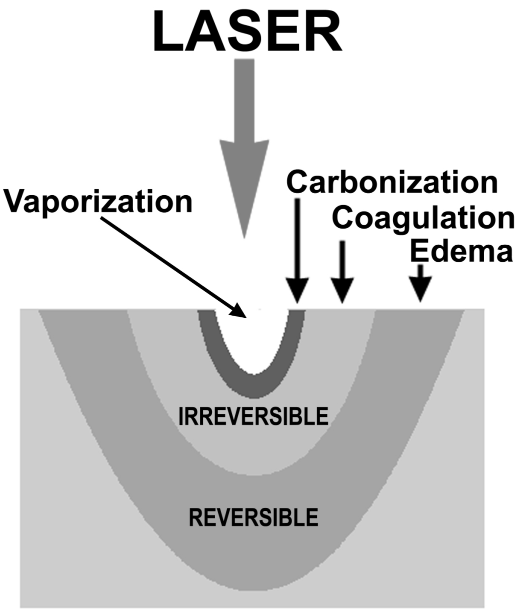
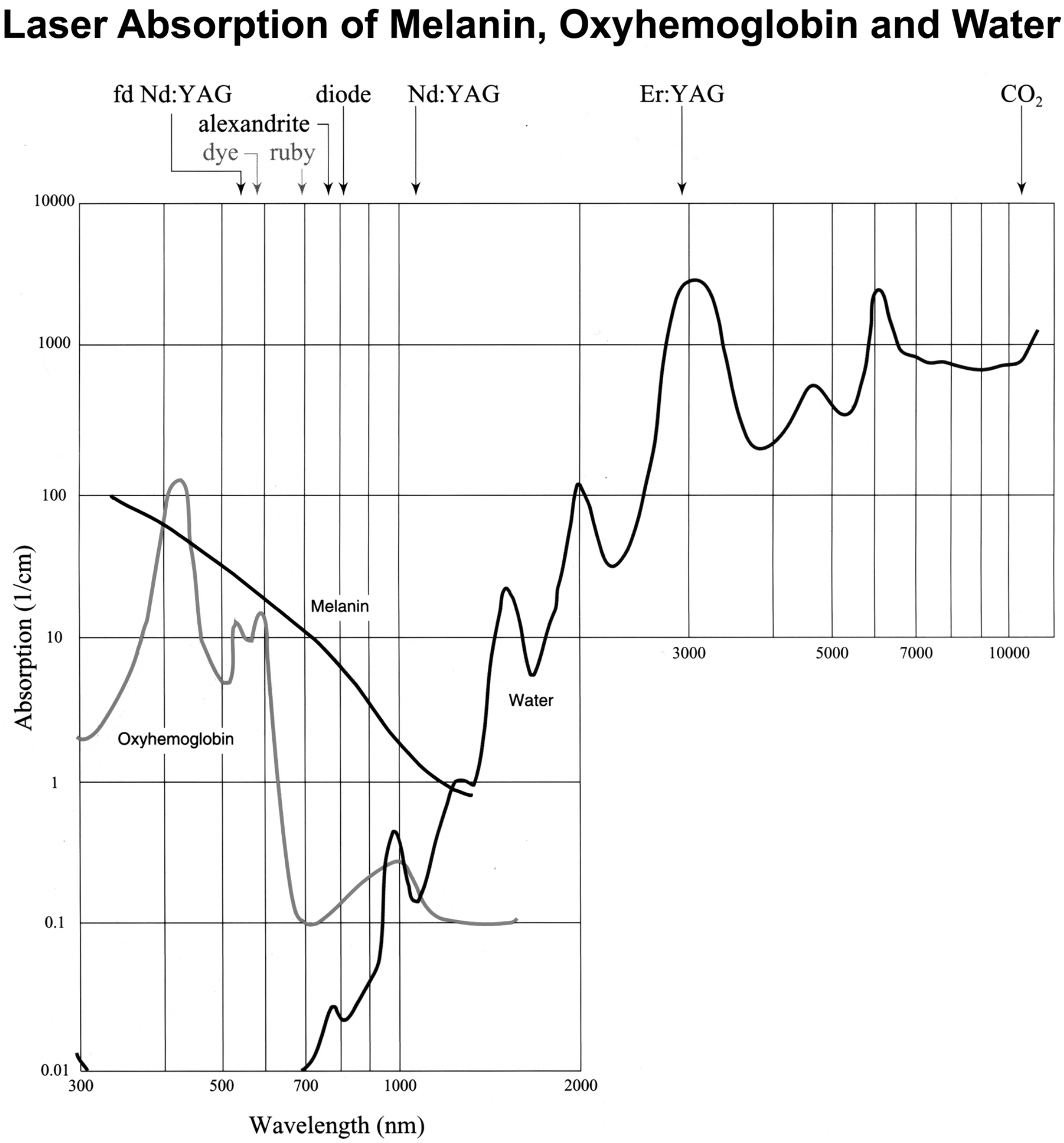


Figure 2 (left). The effects of laser on biological tissue. The primary area of vaporized tissue is surrounded by a thin layer of carbonization (char) and then by a zone of thermal necrosis due to coagulation. The outer-most layer is edema, and is reversible.

Figure 3 (below). The absorption coefficients of haemoglobin, melanin and water and shown in relation to various lasers. The diode is more selective for haemoglobin and melanin (pigmentation), whereas the CO_2 has a far greater affinity for water.



only 0.05 - 0.2 mm, compared to 0.3 – 0.6 mm with diode lasers. This effect is primarily due to the CO_2 laser's preference for intracellular water. Nevertheless, despite these differences, the diode compares well to both CO_2 and neodymium-yttrium aluminium garnet (YAG) lasers.

There are certain advantages that the diode laser has over CO_2, specifically:

1. the ability to function in fluid environments (e.g. intestinal tract, fluid-filled abdomen or coelom, and bladder);
2. improved haemostasis, i.e. able to seal blood vessels up to 2 mm in diameter, compared to 0.6 mm with a CO_2 laser; and
3. fiber-optic capability for use with a variety of endoscopes.

CO_2 Lasers

The CO_2 laser comes in a variety of sizes and power capacities. All of the CO_2 lasers are class IV. The invisible 10,600 nm beam is beyond the visible wavelength. When laser light is absorbed by a cell, the water within the cell is boiled and the cell essentially explodes. The cell denatures into smoke and the cell remnant, called char. This smoke, which has been documented to contain DNA, bacteria and viruses, should always be evacuated with a filtered vacuum. When the laser is used for cutting, cellular destruction is limited to a region only three to four cells away from the target area, thus minimizing tissue devitalization. In contrast, tissue destruction can be deliberately maximized for purposes of tissue ablation. Tissue cutting versus ablation can be controlled either by tip size, or by "defocusing" the laser's beam. "Focusing" the beam allows the surgeon to use the laser's intensified light beam to "cut" tissue, whereas, "defocusing" the beam allows the laser to "ablate" the tissue. "Ablation" is especially useful for removing small growths or tumors. In some situations it is preferable to "ablate" the tumor rather than cut it off. What this means is that the laser beam is defocused on the tumor, and instead of cutting it away, the laser literally disintegrates it. Of course, this is an important consideration if histopathology is anticipated.

There are three factors that determine the tissue impact of the delivered laser beam: spot size, power and exposure. Spot size refers to the diameter of the aperture that contains 86% of the laser's beam. There are several tips that permit precise control of spot (cutting) size. The tip sizes range anywhere from 0.3 - 3.0 mm, with the most commonly used tips being 0.4- 0.8 mm. With focused beam tips, the distance of the tip from the target tissue determines the actual spot size at the target. For most tips the focal distance is typically 1-3 mm. Power is measured in watts, which is defined by the amount of energy applied over time (defined as Joules/second). Power is adjusted on the laser by adjusting the wattage. The greater the wattage, the higher the power. Power density is affected by the size of the target area. If the spot size is small, the power is concentrated. If the spot size is large, the power is spread out over a larger area, and the power density is decreased, thus producing a lesser tissue effect. Exposure is also a user controlled variable. Exposure is determined by the duration of the applied laser. The greater the exposure, the greater the tissue impact. Exposure can be delivered as continuous, repeat or single pulse. Surgical precision is increased respectively.

Diode Lasers

Diode lasers come in a variety of sizes but 15, 30 and 60 watt versions are probably most common. Most are class IV gallium-aluminum-arsenide diode lasers, with wavelengths often varying between 810 nm and 980 nm. The laser beam is transmitted from the base unit to surgical site by a solid quartz-core, fiber-optic cable. A visible light beam is combined with the invisible laser beam to facilitate aiming. Laser fibers come in a variety of sizes (400-1000 mm) and shapes, including flat, conical, orb tips, and air/water cooled. The fibers may be used through the instrument channel of a variety of rigid and flexible endoscopes, or in hand-pieces for open surgical use. Unlike the CO_2 fiber, a damaged diode fiber can be trimmed and reused.

The diode laser can be used in direct contact with tissue (contact mode) or at a distance from tissue (non-contact mode). In contact mode the fiber tip is coated with a thin layer of carbon. This is most easily achieved by lightly burning a sterile wooden tongue depressor with the tip of the laser fiber at 10 watts. The carbonized tip absorbs virtually 100% of the laser beam, which causes the tip to instantly heat up to ablative tissue temperatures at relatively low power settings, usually just a few watts. The heated tip can then be used to incise, excise and coagulate tissue while a 0.3-0.6 mm zone of thermocoagulation provides excellent haemostasis of vessels up to 2 mm in diameter. The advantages of carbonized fiber tips are minimized collateral damage and reduced tissue penetration (more comparable to those of CO_2 lasers). This is possible because of the dramatic reduction in both laser power and duration required to achieve a given superficial effect.

This carbonized-tip technique was developed by human neuroendosurgeons who, while keen to use laser technology, were concerned about the potential risks of using high-energy laser in close proximity to vital structures such as the basilar artery in third ventriculostomies. Such concerns are equally applicable to exotic animal surgeons who often find themselves working inside small delicate patients. For general tissue ablation the 1000 mm orb fibers can be used but, for microsurgery or endosurgery, the 400-600 mm fibers with carbonized micro-conical tips provide much greater accuracy and finer control.

In non-contact mode the laser is aimed at the tissue from a short distance. The degree of tissue penetration, coagulation and vaporization depends upon laser type and power setting, duration of exposure and tissue characteristics, e.g. water content, hemoglobin content and pigmentation (Figure 3). Generally, the diode lasers can penetrate tissue to a greater degree than other lasers (up to 4 mm in non-pigmented tissue) in non-contact mode. Penetration is greatly reduced to around 0.3 mm when carbonized tips are used in contact mode. The higher wavelength of the 980 nm diode laser may provide an advantage of being less affected by tissue pigmentation and more selective for water and hemoglobin. In practice, contact mode is more accurate and controllable, while non-contact mode is more diffuse with deeper penetration.

For open surgery, the laser fiber is usually housed within a hand-piece that is held much like a pen. The fiber tip is gently stroked across the tissue, either in contact or non-contact modes, until the desired incision or ablative effect is obtained. When used down the operating channel of an endoscope, the fiber is used in contact mode and the entire scope-fiber unit is moved as one. Gentle stroking movements of the scope-fiber unit are used to produce the desired effect, and always under direct visual control.

Power settings tend to vary; 2 - 4 watts for endoscopic surgery, 4-8 watts for general surgery, and 5-10 watts for tissue ablation. For general surgery the power is usually continuous, but when dealing with very delicate structures a pulsed output is preferred. Pulsing gives time for the tissue to cool during the interpulse periods, and helps reduce collateral thermal damage. The pulse duration and interpulse interval can both be varied to give complete control.

Therapeutic Lasers

Laser therapy is a painless use of laser energy to generate a photochemical response in damaged or dysfunctional tissue. Laser therapy can alleviate pain, reduce inflammation, and accelerate recovery from a wide range of acute and chronic conditions. Cleared by the FDA in 2003, Class IV Laser therapy has become established for many musculoskeletal injuries, and has gained in popularity in general practice (Godine, 2014). Many claims have been made by therapeutic laser companies, some may be exaggerated and most have yet to be objectively determined and assessed in veterinary medicine. Laser therapy has been credited with:

- Reduction in inflammation due to vasodilation, activation of the lymphatic drainage system, and reduction of pro-inflammatory mediators.
- Improved analgesia by suppression of nociceptors, an increase of stimulation threshold, and an increased release of tissue endorphins.
- Acceleration of cellular metabolism, reproduction and growth by improved cellular energy and nutrient uptake.
- Angiogenesis in damaged tissue.
- Reduction in fibrous tissue formation
- Acceleration of nerve cell regeneration.
- Improved wound healing by stimulating fibroblasts and collagen production.

At the University of Georgia, we use therapeutic laser commonly in a variety of species as an adjunct to managing traumatic injuries including de-gloving injuries and fractures, as well as more chronic conditions including osteoarthritis.

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