**LASER THERAPY SIMPLIFIED  
Science and Physiology   
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**HISTORY AND PHYSICS**

Einstein first envisioned the concept of laser radiation back in 1917. However, it was not until 1960 that the first laser was built by Theodore Maiman. It was another 25 years or so before technology advanced enough to make lasers safer, easier to use, and cost effective. Dr. Endre Mester is credited with the discovery of the biostimulative properties of red and near infra-red light.

LASER is an acronym that stands for Light Amplification by the Stimulated Emission of Radiation. All lasers work in a similar manner. You must have a medium of some sort that is made up of atoms capable of reaching a meta-stable or “excited” state. When you put energy into the system electrons reach a higher energy state. When they fall back to their stable state, they give off the energy in the form of a photon. The chemical medium will dictate the wavelength of light that is produced and the wavelength will dictate what function this particular laser is best suited. We are going to discuss medical lasers only and therapeutic lasers specifically.

The two most important features that determine the optimum use of a laser are its wavelength and power. Laser light in the red and near-infrared range has biostimulatory properties. Roughly, this corresponds to wavelengths between 600nm and 1100nm. The shorter wavelengths are absorbed more superficially and therefore do not have the ability to penetrate as readily as the longer wavelengths. Wavelengths in the visible red range (650nm-660 nm) are highly absorbed by melanin and other superficial receptors. These can enhance wound healing. They may also stimulate trigger points, acupuncture points, and/or cause release of secondary messengers that may improve other deep-seated conditions. From absorption spectra data we know that the wavelengths near the 970nm range have moderate increased absorption by water. With the higher-powered lasers, this can create some thermal gradients and increase circulation in these areas. It is also near the peak of the Hb absorption curve. However, the 905 nm wavelength is even closer to the peak of the hemoglobin absorption curve. Recent studies have indicated that this wavelength creates as much as a 30-50% increase in O2 release to the tissue over the 970-980 nm wavelengths. The most important discovery was related to wavelengths nearer the 800nm range (750-830). These are at the peak of absorption for the cytochrome-C oxidase enzyme. This is the rate-limiting step in the conversion of O2 to ATP within the electron transport cycle. These wavelengths will accelerate the production of ATP within the mitochondria. There is new interest in the 1064nm wavelength particularly for its photochemical effects. This wavelength is farthest from the point of maximum melanin production, has a relative trough in the water absorption spectrum, and is still at the upper level of the cytochrome C oxidase absorption band. Therefore, it has very good penetration depth along with potent biostimulatory abilities. Having all 4 (or 5) wavelengths can give you a synergistic effect and/or a wider range of treatment options across a broader spectrum of clinical conditions and patients which will result in better clinical outcomes.

We have emphasized the importance of wavelengths for proper clinical applications. The second most important parameter that will dictate how effective a laser will be is the dosage. Power is the rate at which laser energy is being delivered and is measured in watts (W). There are four things that happen to laser energy when it strikes tissue. Some energy will be reflected back. Some will penetrate all the way through without interacting with the cells. Some will be scattered. Finally, only about 20%-40% actually gets absorbed by the tissue at the cellular level to have a biologic effect. Power (Watts or mWatts) multiplied by time (Seconds) will dictate the total amount of energy that is delivered to the tissue. This will be the dose and is measured in Joules (J). There is a certain amount of energy or dose that is needed to elicit a clinical response. This dose must be able to reach the target tissue. This aspect of penetration and dosage is an important concept which many fail to address when discussing proper laser treatment parameters. The scatter and absorption coefficients and the optics of the target tissue will determine the rate of decay of the incident beam. The success you will have with any therapeutic laser is a result of the wavelength of light and the power (dosage) which it can deliver to the target tissue. Enough photons must stimulate enough cells within the target tissue to have any clinical impact. There is a very wide margin of safety and the only statement that can be made with certainty is: “If you do not deliver an adequate dosage, there will be little to no effect from laser therapy.”

One very important concept to remember is that you cannot completely make up for a lack of power with time. (You can’t turn on a single light bulb and just wait a while for the room to get brighter!) Due to the nature of light and the constant scatter and absorption, you must have at least a minimum threshold of power in order to deliver the proper dosage depending on the size and depth of the condition being targeted.

Two other parameters to keep in mind when treating patients. The first is what we call the time domain of the Laser. This is related not only to hand-speed during laser application but also to the pulsing frequency or “strobe” effect of how the laser light is emitted. The more important thing is the pulsing rate of delivery by the laser. The pulse rate with which the laser is being delivered will have differing physiologic effects on tissue. Lower pulse rates and continuous wave for example are better for pain modulation while higher frequencies are more anti-inflammatory. Different tissue types also seem to respond more efficiently to differing pulse rates. It may not only be as simple as the rate but even the amount of time the laser is on vs off could affect tissue response in a more positive manner. These are still being studied but current literature consistently shows that adding some pulse frequencies to your treatment protocols produces better results overall than just Continuous Wave (CW) delivery. Super pulse is another laser delivery mode which aids in penetration and mitigating thermal and absorption effects of pigmented tissue. Keep in mind that the protocols already set-up in most therapeutic lasers simplify all these parameters in an easy to use “point-and-shoot” technique. Having multiple, adjustable wavelengths, power, and pulsing frequencies gives you the most versatility to treat the widest range of clinical conditions both superficial (dermatologic) and deep (musculoskeletal/neurologic); acute and chronic; mild and severe.

The final parameter of importance is the target tissue. Hair and skin color and hair coat thickness can affect laser penetration. The shorter wavelengths in the near infra-red still have some absorption in melanin. The darker animals will absorb more laser energy in the skin or coat. We need to be cautious of the superficial effects to avoid thermal injury that can occur to the coat and, rarely, to the skin. Even most dark coated small animals have light skin. In those few animals that actually have pigmentation in the skin, we need to watch for signs of discomfort if using very high powers in direct contact. As long as the proper scanning technique is used there is little potential for any superficial irritation. The more important aspect to keep in mind is that the absorption in the skin is reducing the dosage delivered to the deeper tissues. A contact delivery mode with a head that is durable, adjustable, and easy to clean again adds to the versatility, ease of use, and safety of your laser therapy. There is no head or delivery system that has proven to be superior to any other at delivering laser energy. All therapeutic lasers have a contact delivery head system and most of these can also be used in non-contact. Some have heads that are only meant to be used in contact. The use of these will be discussed later.

**PHOTOBIOMODULATION**

Healing begins at the cellular level. Cellular chromophores within the blood stream and the mitochondria absorb the laser energy. Specifically, it is water (peak at 970-980 nm), hemoglobin (peak at 904-905 nm), and cytochrome-c-oxidase (peak at 790-830 nm) that are being targeted. This causes an improved efficiency of the respiratory chain leading to an increase synthesis of ATP. In addition, reactive oxygen species and NO and SOD are produced and there is a shift in the redox state. A cascade of secondary effects can then take place including DNA and RNA synthesis; activation of fibroblasts, macrophages, and lymphocytes; growth factor release; neurotransmitter release; vasodilation; collagen synthesis; improvement of cell membrane permeability and function of the Na+/K+ pump. Increased metabolic activity will increase oxygen and nutrient availability which leads to enhanced protein and enzyme production. These factors will accelerate/stimulate cell reproduction and growth which leads to faster repair of damaged tissues, moderate the inflammatory response, and provide analgesia.

These cellular reactions result in three major clinical benefits for the patient: pain reduction; inflammation reduction including swelling, edema, and bruising; and accelerated and improved tissue healing. These events are often happening simultaneously and naturally complement each other. Inflammation is a result of both vascular and cellular consequences. The laser ‘moderates’ inflammation by the following actions: There is production of NO along with other mediators which stimulate vasodilation. This facilitates removal of cellular debris along with activation of the lymphatic drainage channels. But more importantly it reduces ischemia and all the negative events associated with a negative oxygen balance in tissue. Angiogenesis is stimulated as well which increases oxygen and nutrient transport to improve tissue repair and therefore reduce inflammation. Production of ROS and SOD helps stabilize cellular membranes and balance the detrimental effects of free radical activity, respectively. Enhanced WBC activity aids the removal of cellular debris. Lymphocyte activity is mediated to give a beneficial response between the T-helper and T-suppressor cells. There is increased production of PGI2 which has anti-inflammatory activity similar to other COX inhibitors. At the same time, there is a reduction in Interleukin 1 and other pro-inflammatory cytokines.

Reducing inflammation will have a measurable effect on the level of analgesia. There is also direct pain relief by the release of endogenous endorphins and opioids both locally and centrally. Laser irradiation suppresses the depolarization of the afferent C-fibers. It helps restore the action potential of the damaged nerve back to the normal healthy level of ~70mV thereby increasing the stimulus needed to produce a painful response. (This relates to our attention to pre-emptive analgesia and preventing the “wind-up” effect.) There is a reduction in bradykinin levels. Axonal sprouting and nerve regeneration will occur and will alleviate the pain associated with the damaged tissue. In addition, the accelerated repair process in general will reduce pain sensitivity related to structural stress and imbalance.

All the afore mentioned mechanisms that help reduce inflammation, stimulate angiogenesis and vasodilation, and aid in clean-up of cellular debris, will also increase oxygen and nutrient transport to the area to accelerate and improve tissue repair. Increased ATP production will accelerate cellular function including growth and reproduction. Fibroblast proliferation and collagen synthesis is enhanced and more organized which leads to a reduction of scar tissue and improved tensile strength. There is more rapid epithelialization. Cellular differentiation and maturation increase the number of osteoblasts, myofibroblasts, and other muscle regenerating precursors. Laser therapy can reduce healing times by 30%-50%. It is not just faster healing; it’s better healing! It is this direct stimulation of tissue repair, regeneration, and remodeling that is unique to laser therapy. And this is why we are improving or resolving conditions that were traditionally less responsive before laser therapy was added to our current treatment regimens.

Our goal for “pain management” is not to just make the patient comfortable. We want to get the patient back to their normal activity and/or performance level. Restore ROM and improve muscle strength and function. Reduce the potential for re-injury. Become an active member of the family again. With the proper therapeutic laser in your armamentarium, you have the best chance of achieving these goals.

**References available upon request**