The "Right" Questions to Ask When Choosing a Laser

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FACT: Laser phototherapy, if administered by someone trained in the art, is beneficial in almost all of its forms and has no adverse side effects.

The differences between commercially available laser units lie solely in the wavelength, power density, pulse modulation, and aesthetics. From these parameters, you can derive the penetration depth, dose distribution, treatment time, and the estimated biological effect. There is *NOT* a "magic" wavelength or setting that is the cure for a disease, and to claim otherwise (as many distributors or salesmen do) is irresponsible. There are, however, certain operating regimes that give better results than others and are more effective for particular symptoms. And since the primary mechanism of action is the stimulation of the body's natural anti-pathological immune system, the range of symptoms for which this treatment modality is useful knows no bound.

Educating yourself on the meaningful parameters to use as the criteria for your comparison will prove invaluable as you can very easily sift through the mountains of marketing propaganda with a small set of simple questions.

Technical Specifications

Underneath all the bells and whistles, there are some key laser parameters that are of paramount importance, not only in determining quality of the technology, but also predicting the success of therapy.

1 FDA Class

The US Food and Drug Association classifies lasers according to their potential hazard to the eyes or skin. The danger has a fairly complex, non-linear dependence on wavelength and exposure time, but predominantly depends on power output of the laser. The classes are defined as follows:

- Class I - Inherently safe lasers that will either cause no damage by themselves (even in combination with optical instruments) or are enclosed in a housing that prohibits exposure during use (e.g. CD players or laser printers)
- Class II - (below 1 milliWatt) Emit visible light that will not cause eye damage unless intentionally kept from blinking
- Class IIa - Can be ultraviolet (UV) or infrared (IR) but whose effect would not be damaging unless exposed directly in excess of 1000 seconds continuously
- Class IIIa - (1 - 5 milliWatt; power density less than $2.5\,\mathrm{W/cm^2}$) (e.g. laser pointers) Can be dangerous if combined with optical instrumentation that changes beam size, and therefore power density
- Class IIIb - (5 - 500 milliWatt) Can permanently damage the eye with millisecond exposure. Primary reflections can also be dangerous. Can burn skin and be a fire hazard. Safety glasses necessary for anyone in immediate vicinity
- Class IV - (above 500 milliWatt) May cause serious, permanent damage without optical magnification. Even diffuse reflections can be dangerous in the immediate vicinity. Requires safety glasses (specifically for wavelength used), interlock switch, and emergency shutdown button.

2 Wavelength

The "therapeutic window" is defined by the blue curves in Figure 1: melanin (left) and water (right). Radiation outside this range is absorbed very well by these two molecules so shorter wavelengths (visible spectrum) will not penetrate far enough to be therapeutic without doing damage to the skin and longer wavelengths (mid- to far-IR) will cause thermal damage to tissue

because of this heightened absorption. The melanin absorption continues to rise steadily through to the ultraviolet region of the spectrum (an evolutionary adaptation that allows us to live in our harsh sunlit environment) and so lasers of shorter wavelength are germicidal, yet are mutagenic to our cells (i.e. skin carcinogenic). Mid IR lasers are mainly surgical in application and take advantage of the high water absorption to ablate cells; that is, vaporized the water in cells to cause highly specific (focused) thermal damage.

Lasers intended for therapy fall into the NIR for another reason. The principal chromophores (i.e. photo-acceptor molecules) in the human body are hemoglobin (the oxygen transporters at the heart of red blood cells) and cytochrome c oxidase (the terminal enzyme in the cellular respiratory chain). You can see from Figure 1 that their absorption spectra peak within this same therapeutic window. In fact, stimulation of either of these molecules by radiation throughout the NIR leads to increased cellular metabolism by increasing either the amount of oxygen available to the cells for processing or by enhancing the efficiency by which the cells convert the oxygen into useful energy (adenosine triphosphate, ATP).

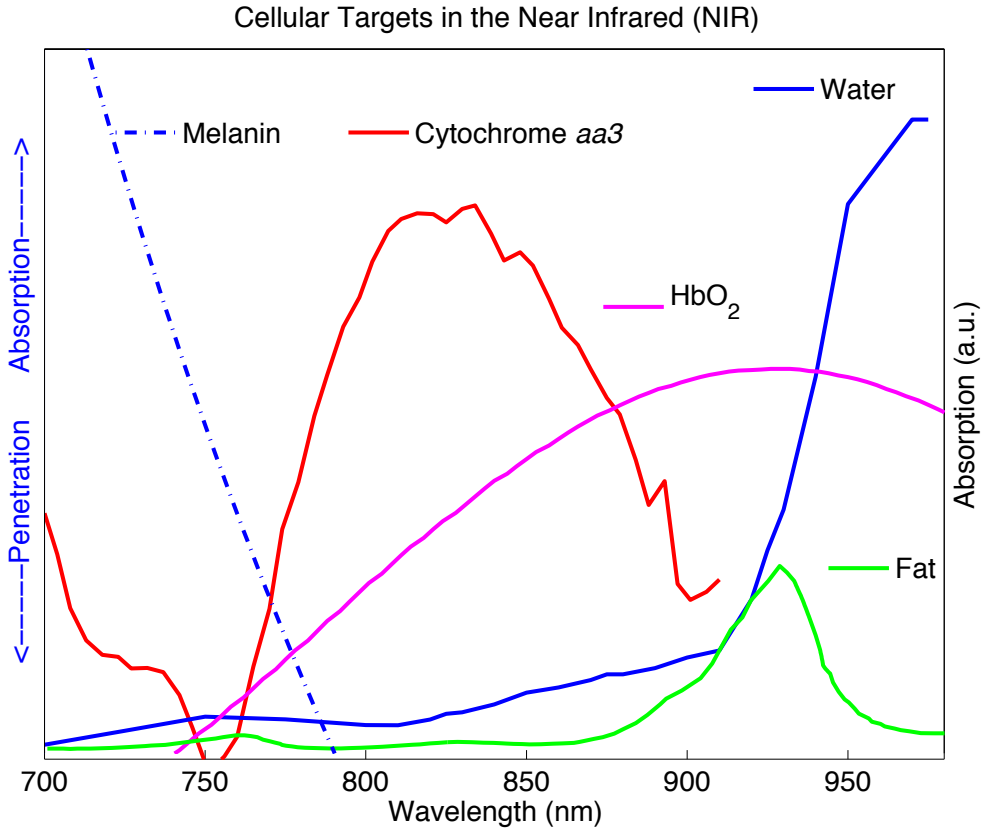

Figure 1: Cellular Targets in the NIR.

Laser stimulation in the NIR therefore boosts the body's natural immune system and can combat nearly any pathology to some degree. Some wavelengths are more suited to target different absorption peaks, while others do not specifically target anything. Furthermore, each wavelength provides different penetration depth. Some companies offer multiple wavelength beams with or without the ability to select which wavelength to use for a given treatment; this variability could prove very useful if treating different parts of the body or different depths in the same treatment area.

3 Continuous Wave (CW) or Pulsed

Delivery mode is another important question from which you can deduce the effectiveness of treatment as well as an estimate of treatment times. Continuous wave (CW) exposure refers to the absence of modulation; that is, the beam's intensity is constant in time. Because the beam is always at full intensity, calculating energy exposure is straightforward: power output in Watts times treatment time in seconds yields surface energy exposure in Joules.

Frequency modulation has shown some benefit *in vivo* despite some uncertainty in its effects *in vitro*. Modulation consists of turning the beam on and off on systematically at a given frequency. It is postulated that there is some thermal saturation in tissue from continuous exposure of radiation, and that pulsing the beam will allow both additional penetration as well as enhanced biological stimulation. Some lasers do not offer frequency modulation while others modulate up to 20,000 Hz.

Energy calculation is slightly more complicated with modulated beams, and is determined by the duty cycle (i.e. the fraction of the time the beam is on). Alternatively, if the pulse width is known, the duty cycle can be calculated (i.e. $pulse\,width\,(\text{seconds}) = \frac{duty\,cycle\,(\text{fraction})}{frequency\,(\text{Hz})}$). For example, if a beam is modulated at 100 Hz with a 50% duty cycle, then the beam turns on and off 100 times per second, and is on and off for equal amounts of time, so the energy calculation would follow as before, only corrected by the duty cycle in the form of a fraction (1/2). The pulse width of such a beam would be 1/200th of a second (5 milliseconds), so the beam is on for 1/200th of a second, then off for 1/200th of a second, and so on. If ran at 8 Watts for 10 seconds, the surface energy exposure would be 8 x 10 x 0.5 = 40 Joules.

4 Power

Power, given in Joules per second or Watts, quantifies the amount of energy emitted from a laser per unit time, which along with wavelength information, determines the rate of photon emission. With knowledge of the optical properties of the tissue to be irradiated, power is the principal quantity that determines both penetration depth and duration of treatment. Biological tissue is a highly turbid medium; that is, it strongly (exponentially) attenuates radiation through a combination of scattering and absorption. Figure 2 shows the 3-dimensional intensity distribution of a $1\,\text{cm}^2$, 800 nm beam in water.

Figure 2: Example of an actual *measured* 3-D dosimetric beam profile of the K-Laser K-1200 in a water phantom. For instance, a point (red arrow) that is 6.1 cm deep in water and 0.5 cm from the central beam axis will be exposed to radiation whose intensity is 29% of the full intensity at the surface of the skin. This type of information is crucial to determining the dose delivered to tissue at a distance inside the body.

For this reason, it is important to keep in mind your particular clinical application when choosing between lasers. If only superficial dermatology concerns you, than less intricate and less expensive Class II or III lasers may be suitable for you. If instead your focus is subcutaneous, and especially deep muscle or joint ailments, to achieve any analgesic or biostimulatory effects, these lower power lasers simply cannot deliver sufficient dose at depths in the body in reasonable treatment times.

Peak vs. Average Power

As mentioned above, for CW lasers, power is a very simple quantity that leads to straightforward energy calculations: peak power is equal to average power, which can be multiplied by treatment time to yield surface energy exposure. When frequency modulation and pulsing are introduced, so are some complexities in energy calculation as well as marketing gimmicks that are often misleading. Average power, the quantity from which energy calculations can be made directly, is the integrated energy emitted per unit time. If for example, you have a 10 Watt peak pulse with 10 millisecond width that pulses ten times per second (10 Hz), the average power is only 1 Watt because the total amount of energy emitted per second is only 1 Joule, even though the peak power is 10 Watts. In fact, the average power for a pulsed beam will always be less than the peak power because of the down time (duty cycle) of the beam. Super-pulsed laser companies often capitalize on the ignorance to this idea when they advertise their "high-powered" lasers with up to 50 Watt peak power, despite their (un-advertised) milliWatt average power.

5 Spot Size

Beyond mere power output, the treatment area is of paramount importance to understanding the number of photons delivered to the affected area. For comparison, a long tube 100 Watt fluorescent bulb like those in any office building is bright enough to light up an entire room, and it does, in fact, spread 100 Joules of light per second across the entire breadth of a room. If instead, that bulb were only as big as your fist (like a normal incandescent bulb), those 100 Watts would be much "brighter". Better still, if all of that light was collimated into a beam (as in a laser) the "brightness" would be extreme. The power output simply defines the number of total photons emitted, but it is exactly the concentration (density) of the photons that dictates the number of photons delivered to a target area.

From the spot size, then, we can calculate the more meaningful quantity of power density: average power (Watts) divided by spot size (cm^2) yields power density in $Watts/cm^2$. This value determines the penetration depth of treatment as well as the amount of heat a patient will feel during laser therapy. For a given power setting, smaller spot sizes concentrate all of the photons on a smaller area and so penetration will be deeper. Consequently, the heat will be more concentrated and the patient will feel it. The versatility to change the spot size during treatment will provide the ability to relieve any discomfort without discontinuing the treatment.

6 Collimated or Divergent

The target area, for the most part however, is not on the surface of the skin and so it is important to understand how the beam shape will change when delivered to non-superficial targets. If the beam is collimated, the spot size will remain relatively constant as the distance from the beam applicator is increased (lateral scattering occurs in biological tissue, but you can see from Figure 2 that the intensity in these "tails" is on the order of 10% or less). For divergent beams, however, (e.g. light stemming from LED or infrared lamps) the treatment area increases substantially at depths in the patient and so the power density dramatically decreases with depth. This beam diffusion will also decrease penetration depth of the treatment since fewer photons are traveling along the beam axis.

User Friendliness

Beyond helping people overcome their disease or condition, a laser is the source of reputation enhancement and income production and so it must also be aesthetically pleasing, easy to use, and allow high patient throughput.

7 Finger Switch

Turning the beam on and off needs to be accomplished in a quick and safe manner to avoid over exposure to the patient and unnecessary hazard to the administrator. Some laser companies do not offer any remote switching, requiring the user to move back and forth from the console for every necessary change. Others require a foot pedal as the beam regulator, which introduces another wire and tripping hazard. The most efficient and versatile technologies, however, offer a finger switch on the handpiece. Furthermore, some of these offer two different modes, a single-tap mode where the beam is on only when the button is depressed, and a two-tap mode where the beam turns on with one tap and off with another.

8 Pre-set Programs

Different ailments are better treated using different power, wavelength, frequency and treatment time settings, and so the technical versatility of the machine needs to be matched by a software platform that allows a simple way to identify and select the most appropriate settings. Of the laser companies that do offer variability of these parameters, the most practical ones provide tested protocols as pre-sets in their software. Some offer lists of conditions, while others offer a graphical interface that guides the user through the anatomy and severity of the condition.

9 User-defined Programs

Some clinicians find their own protocols more effective than the pre-sets available or have conditions not included in those pre-sets. Accordingly, the best laser software platforms offer user-defined programs to be entered, saved, and logged. With such input capabilities, some offer patient log files to further expedite the treatment process, so that if John Doe comes in twice a month for lower lumbar treatment, for example, then he would have his own file that not only tracks the power, wavelength, frequency, and treatment time settings, but also the number and date of his prior treatments.

10 Training and Certification

As discussed in Section 1, lasers have the potential to cause permanent skin and eye damage if not handled properly. As such, it is very important to be fully trained not only in the use, but also the safety protocols for laser use. A company that sells you a laser without training you either has a laser that is not dangerous (and therefore is useless therapeutically) or is irresponsible. There are of course varying levels of education ranging from a page-long checklist of safety procedures to online tutorials and continuing education webinars. Some companies even require that you pass a test on the mechanisms and history of laser therapy. Some companies charge for these consultation while others include it with purchase. The more thorough the training the better.

11 Upgrade/Update

Technology, as a rule, is always growing and equipment becomes obsolete. It is important to buy a device that will grow with you, or that you know never outlive its purpose. Hardware upgrades, whether it be power increase, frequency expansion, or fiber-optic evolution, are unavoidable on the time scale of decades, regardless of the starting point. Knowing the limits of the device, however, can keep you from having to take a middle step in your hardware upgrades. For example, average power densities above $20\,\mathrm{W/cm^2}$ will only be used for surgical applications because such high densities will ablate tissue. If you are using the laser for pain relief or biostimulation, you know you will never need a laser over a certain power rating and so it is a safe bet that if you purchase one that delivers $10-15\,\mathrm{W/cm^2}$, you will never have to upgrade your hardware.

Software, however, evolves much faster and so it is important to choose a laser whose software platform is readily expandable. Some companies offer upgrades if you send your machine back to them, while other offer remote ways to upgrade/update your software (e.g. USB ports, downloadable updates, etc). Other companies offer no such upgradability.

12 Marketing Package

Odds are that if you are considering incorporating a laser into your practice, then you understand that there is not only the potential to help your patients, but also the potential to expand your business and enhance your profits. As such, you should also be interested in ways to spread the word that your practice employs this technology and market laser therapy in your community. You may already have an established network of patients and a plan for how you will inform them of your technological expansion, but this can also turn into an expensive endeavor. Some laser companies help you with this, supplying waiting room DVDs, marketing brochures, advertisement fliers, business plans, pricing suggestions, and more. While some companies charge extra for a marketing bundle, the top companies provide these materials at purchase.

13 Warranties

Even the most sophisticated technologies have issues (just ask NASA or Apple) but how a company warranties their products is crucial to the decision. Depending on the number and complexity of "moving parts" in a particular laser, this can be a

complicated question. Warranties range in coverage of the laser diode itself, or the fiber optic coupling, the entire apparatus, and everywhere in between. Some even offer the option to purchase additional warranties.

14 Service

If something does go wrong with your product, how long will you be out of operation? Some companies make you send in your unit until they inspect it, then once they find the problem, they have to ship it off somewhere to fix it, and you are left without a machine for weeks on end. Others send you a loaner while they run diagnostics. In any case, this is a vital issue to consider, for your own sake.

15 PRICE POINT

Everything always boils down to price point: how much it will cost you, how much you can charge for treatments, if insurance will pick up the tab, etc. The most important criteria is that you are comparing apples to apples. The purpose of this article is to guide you through all the marketing propaganda to the key concepts involved and the vital characteristics of the laser that is best suited for your use. Line up several competing laser products side-by-side and ask the right questions. Below you will find a spreadsheet template to aid is this comparison. Laser phototherapy is an invaluable modality that can substantially increase your patient's quality of life, while simultaneously enhancing your practice. Good luck in your search.

• FDA Class?			
• Wavelength(s)? ○ If multiple, can you choose to use either individually or both simultaneously?			
• Continuous Wave (CW) or Pulsed? ○ If pulsed, Frequency Range? ○ Duty Cycle?			
• Power? ○ Peak Power? ○ Average Power?			
• Spot Size?(to calculate Power Density) ○ Variable or Fixed?			
• Collimated or Divergent?			
• Finger Switch? Or Foot Pedal? Or Neither?			
• Pre-sets? ○ If so, how many?			
• User-Defined Programs? ○ If so how many?			
• Training and Certification? ○ If so, included in price?			
• Upgradeable? ○ If so, remotely or have to send unit in?			
• Marketing Package? ○ If so, what does it include? ○ Is it included in price?			
• Warranty? ○ If so, what does it cover? ○ How long for each component?			
• Service? ○ Turn over times? ○ Over the phone?			
• PRICE			

Figure 3: Laser Comparison Template