Introduction

It is becoming more common for medical issues to be treated through a variety of physical treatments rather than chemical. Popular among those issues are those dealing with skin lesions and their associated negative effects on one’s health- both mental and physical. Somewhat of a broad category, skin lesions can entail Port-Wine stains, spider webbed veins, and more. Many of these are aesthetic in nature and can be treated via laser therapy. Along those same lines is the process of permanent excessive hair removal, which is a very common commercial procedure done by people across the globe. The research done looks through a lens towards these applications of lasers and how a streamlined system with cost-efficiency and ease-of-use would stand to provide an advancement of current methods. It is noted that the design process takes into account the necessary requirements for each separate situation and attempts to draw conclusions as to what parameters are acceptable.

Laser options

Focus of research: diode laser (pros cons etc; more to be added)

Lasers have a multitude of delivery options, each with a different medium for propagation with different operational parameters and limitation and usages. While the focus of this research will be the diode laser, it is important to understand the other options that are currently employed and have achieved clinical success.

Neodymium doped yttrium-aluminum-garnet lasers, or Nd:YAG for short, are crystal lasers that have a yttrium-aluminum-garnet crystal housing and is doped by neodymium, as suggested by the name. This laser in particular has a wavelength of 1064nm, with different uses in dermatology in treating vascular lesions other such skin disorders. The primary purpose of the laser is the breaking down of the red hemoglobin pigment.

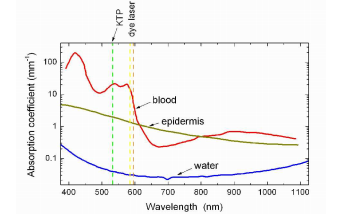
<http://www.troteclaser.com/en-US/Support/FAQs/Pages/Laser-Types.aspx>  
  
<http://www.dermnetnz.org/topics/pulsed-dye-laser-treatment/>

-Should I add more info in this part?

Port Wine Stains

Port Wine stains were the first of the skin lesions researched. Also categorized as a birthmark, due to the prevalence of appearance during the postpartum period of a newborn’s life, Port Wine stains are discolorations of the skin predominantly in the facial area. The color palette ranges from sanguine tones to more violet ones and the size often increases relative to the size of the face. **Insert photos for ref**. As is the case of many a disorder, these stains are the effect of genetic mutations, specifically in the GNAQ gene1**.** The end result of this mutation is the malformation of proper blood capillaries leading to swelling and characteristic discoloration.

Typically the offending regions lay 0.5mm to 1.5mm beneath the epidermis, which also suggests possibilities of infection and hemorrhaging due to increased vascular activity. Many different treatments have been suggested and tested, but the most effective has been found to be laser treatment. There have been established practices of different laser therapies with the main goal to utilize a pulsed laser to selectively damage the malformed blood vessels while leaving the skin intact. To accomplish this, the hemoglobin inside the vessels would be matched to an appropriate laser irradiation wavelength for the optimal absorption. This method, known as selective photothermolysis, assumes values of the absorption coefficient of the skin to be akin to that of water due to composition ratios2.



The chart shown in **figure X** has a relationship between the wavelength of a laser and the associated absorption coefficient of the blood, epidermis, and skin tissue (essentially water). Ideally, the coefficient of the blood would be higher than that of the epidermis and the water coefficient would be minimized. According to the graph, the optimal wavelengths are achieved through either a KTP laser or dye laser at around 530nm and 595nm respectively.

It is noted, however, the laser is not only absorbed but also participates in scattering in all directions throughout the tissue, modeled by Rayleigh and Mie theories2. Scattered light can also be internally refracted or exit as reflected light.

Along with the aforementioned parameters, the spot size of a laser is a crucial factor in achieving desired deployment of heat. The spot size is characterized by its diameter, determining the penetration depth of the beam. This penetration depth correlated to the spot size must be balanced with the scattering as well as attenuation that take place due to the distribution of light.

A practical setting also requires that the laser is not continuously on, as it would damage the skin by burning it. Naturally, heat is not a contained package, and will diffuse from the target location to its surroundings, presenting the unwanted possibility of collateral damage, contrary to the end goal of selective photothermolysis. The question that naturally follows is that of pulse duration, asking for a criterion stipulating the allotted time until the surrounding tissue is damaged. Another factor influencing the application is the fluence of the laser pulse. The fluence is defined as the “optical energy delivered per unit area”4, and take the units of . The pulse duration would work in conjunction with the absorption coefficient, fluence, and penetration depth parameters to form an outline of design constraints necessary for successful laser treatments.

According to a clinical trial done by several researchers at the Cochrane Group, both a pulsed dye laser and an Nd:YAG laser produced successful results in reducing the birthmarks throughout several treatments with the latter laser being slightly favored. They were far from perfect, however, with patients experiencing “Short‐term side‐effects included pain, crusting, and blistering in the first two weeks after treatment.”3

There are a variety of laser delivery systems offered in other clinics such as the Laser & Skin Surgery Center of New York7. Their options include “V-beam” lasers, which are pulsed dye lasers, Alexandrite lasers, Nd:YAG lasers, a combination of a 532nm KTP laser in conjunction with the 1064nm YAG laser in the “Excel V laser”5, and a CO2 fractional laser (“Fraxel”)6. Each of these options has seen clinical success, but offer the disadvantage of being specialized equipment. Often large and cumbersome, the machines required for the operation are not optimized for consumer use, and requires specialized knowledge as well as a hefty investment.

Laser Hair Removal

Similar to the treatment of skin lesions, laser hair removal uses many different types of lasers and systems. The main goal of is typically to permanently destroy hair growth in targeted locations, an improvement in many ways over the ubiquitous short-term solutions that have a variety of drawbacks. Waxing is extremely painful, for example, with possibilities of infection and skin irritation. Shaving can have similar effects of irritation as well as being only a temporary solution with new growth being prickly and uncomfortable. The standard has thus been set with the emergence of laser removal as an option.

In the case of a design targeted towards this application, looking at the anatomy of the hair is imperative to the elucidation of proper parameters. The hair follicle is the structure housing the hair shaft, beginning at a bulb in the dermis and terminating at the epidermis. Most relevant to the goal of permanent hair removal is the hair bulb, which dictates the growth of the hair. Inside the hair bulb are cells known as keratinocytes hosted by the hair matrix8. Production of terminal hair (thicker and more pigmented than vellus hair) can be halted with damage to the follicle and its constituents all the way down to the bulb and ultimately the hair matrix.

Mentioned earlier was selective photothermolysis, where a certain chromophore (hemoglobin in the case of port wine stains) was heated through the use of a laser according to the properties differentiating it from its surroundings. Many of the parameters maintain their significance and should be examined accordingly.

Temperature Measurement

Due to the nature of this application being ultimately towards human skin, care must be taken not to cause excessive damage or harm. As such, a temperature feedback system would be a proficient way of preventing the laser from burning the skin. Theoretically, if the temperature of skin reaches a certain threshold (which would be set lower than the burning point) the laser will be shut off for safety precautions. By monitoring the skin through a sensor, the data can be processed with a microcontroller. Comparing the measured temperature to the set threshold, the microcontroller can shut off the driver circuit for the laser when it reaches the predetermined value.

There are many ways of temperature measurement, but the most practical of them for this application is non-contact infrared sensing. Even among infrared sensors are broad ranges of parameters that must be chosen to fit the design. The first one to account for is the physical size of the package, since it should be able to fit within a housing in conjunction with the laser being used. Ideally, due to the limited housing space, the infrared sensor would have a profile of around 5mm or less.

Several options were examined for their applicability to the design. Initially, Texas Instruments’ TMP006 thermopile sensor was purchased. It fulfilled the parameter of the size, with the device itself being 1.6mm x 1.6mm, which was sufficiently small, and the sensor within it having the dimensions of 0.33mm x 0.33mm. This integrated thermopile was well within the operating range of temperatures, with an operating voltage of 3.3V. For the responsivity of 50%, an FOV of 90 degrees was stated. As a digital sensor with internal ADC and references, the TMP006 maintains a reasonable response within the range of 4-10um wavelengths IR radiation, which is enough for the temperatures of hair follicle and skin burning. Using the

The problem with this particular sensor was the response time, with the data taken at a period of time that wouldn’t be able to produce comprehensive data. The temperature pulse is too fast for the capture by this sensor. A solution that was explored was that of taking multiple of these sensors (See Schematic A) and “firing” them in succession with each a different capture window. After modeling this on Eagle (Schematic B), there were problems with routing as well as in the intrinsic nature of the chip actively averaging the values taken. Since the pulse-width of the temperature spike is low, it would be rendered null through an average.

Yet another issue with using this sensor is its practicality for prototyping. Due to the ball-grid array package of the chip, mounting on a PCB would be difficult, possible requiring the use of more than two layers and presenting the chance for the grid to be misplaced. It is offered pre-mounted on a board by Adafruit, but is too large in this case. These considerations resulted in the decision that the TI TMP006 was not going to be fit for this application.

Next sensor examined was the Melexis MLX90615 infrared non-contact sensor. This sensor has a can package with through-hole pin mounting. Internally, the MLX has a digital signaling processing unit amplifier and ADC akin to the TMP006. With a diameter of 5mm (5.5?), the can’s size was reasonably small and within the design parameters. The range of measurable object temperature also was suitable, being -40 to 115 Celsius.

This sensor was connected to an Arduino and the data was taken, then processed from the MLX. After the data was processed, the resulting temperatures found were displayed on an LCD display. To properly determine the functionality of the sensor, a precursory test was conducted. Water was heated in a glass beaker while the sensor recorded temperatures during heating then during cooling. Room and starting water temperature was 30.1 degrees Celsius and peak temperature was 103.1 degrees Celsius. The time between taken data points was 100ms. As a result, during the time frame, 79053 points were recorded for a comprehensive look at how the device performed over time. Figure M is the graph.

Control System and Android App

The system needs to be controlled, with the temperature sensor data being outputted to a display, and for the data to be recorded and graphed through MatLab. Similarly, the laser would need to be controlled in terms of its pulse width and current supplied to its driver circuit through an embedded system. These processes were threaded through an Arduino microcontroller to a Bluetooth module. This module communicates with an Android phone though a custom app that was created. Through this app, these parameters could be controlled, and the continuous sensor data could be read. Although there are a few bugs with the UI of the app, it accomplishes its task.

-Software flowchart and how the code works

-Control of laser pulse

Driver Circuit

The first thing to do was the protection of the laser from any electrical/static discharges that could potentially damage the semiconductor device. In order to do this, a laser diode specific ESD absorber was chosen. The L44-228-X ESD from LASORB is a 2-pin package with a through-hole mounting style designed for red lasers operating between 1.9 and 2.7V (laser is to be operated at 2.2V?). There was a preliminary ESD band shorting the pins on the laser. Once the LASORB was soldered on with the corresponding anode pin to the laser anode, this band was removed. At this time, twisted strand wires were soldered to the pins of the laser. These were chosen over solid wire due to flexibility and integrity issues that solid wire would have after repeated bending.

-Heatsink, driver circuit, power mosfet, power supply/current source

Works Cited

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- I still gotta add datasheets for the sensors and stuff and format the citations and figures

-Im going to attach the schematics A and B for the tmp006 separately