Chapter 8

High Brightness LEDs Supplied by Electronics Converters Used in Tissue Healing and Cell Rejuvenation

Alexandre Campos, Yasmim Guterres,
Eduardo B. Bauer and Mauro C. Moreira

Additional information is available at the end of the chapter

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1. Introduction

The rapid development of high brightness light emitting diodes (LEDs) makes feasible the use of LEDs, among other light sources (such as laser, intense pulse light and other incoherent light systems), for medical treatment and light therapy. This chapter provides an overview of LED application in human health and the results in healing and cell rejuvenation [1].

The technique of LEDs used in tissue treatments is called LED Therapy and from now on we will treat it this way. With the use of electronic converters that supply the high brightness LEDs it is possible to control the spectral composition, allowing to obtain the wavelengths desired to apply the human tissue to obtain efficacy in phototherapy. High brightness LEDs can be easily integrated in digital control systems for the purpose of providing a variation in spectral composition over a phototherapy treatment stage. The colors emitted by the high brightness LEDs operate differently, i.e. depending on which layer of the human tissue that will be applied to light and which type of which will combat disease. In the skin, the red light has restorative action, healing and analgesic, while blue has a bactericidal action [19]. The intensity of the beams of light emitted by LEDs on the skin is lower, since its cells maintain a good interaction with the light [2, 21]. The high brightness LEDs respond effectively in the therapeutic application and can be used a variety of electronic converters that control the output current, output power, the duty cycle and other parameters that directly interfere in luminous efficiency and length of wave offering a positive response in phototherapy treatments.

LED Therapy is gaining ground every day in various areas, including in medicine, dentistry, physical therapy and aesthetics [20]. Biomedical engineering has made great strides in their research on the application of LEDs in the treatment of pre-malignant lesions and malignant, in the treatment of rejuvenation and acne, hair loss, skin lesions, wound healing in post-operative incisions in the patient's psychological recovery, where the lights are applied to the environment and on other fronts of medicine. In dentistry the development of modern photopolymerizable materials represents a great advance for restorative dentistry because they allow excellent aesthetics, ease in handling and control of the clinical time [3, 23].

Advances in the medicine are encouraging and research in the area grows every day, the intent of this chapter is to present a study and results in healing and cell rejuvenation.

2. Action of LED Therapy in human tissues

The photobiostimulation caused by irradiation with LEDs has a number of outcomes such as increasing cell proliferation rate, the production rate of fibroblasts and collagen synthesis. LED Therapy is known for its anti-inflammatory and healing properties and it can be used as an independent procedure of the conventional treatments of clinical medicine, but it should always be accompanied by a health professional with knowledge of the tissue pathology, cell rejuvenation and photobiostimulation cell. Different applications of LED Therapy may be performed as a function of wavelength (nm) of light penetration in tissue (mm). The relationship between these parameters demonstrates that the penetration depth of light into tissue, as shown in Figure 5.

2.1. Light penetration in human tissues generated by the action of high brightness LEDs arrangements

The processes of refraction and reflection of light emitted by LEDs in human tissues are responsible for the dispersion of light, as shown in Figure 5. However, the action of light is peculiar because the response to these processes can vary from person to person undergoing therapy.

Despite the high dispersion, the degree of penetration is significant, approximately 50% of the incident radiation to reach the substrate directly below the skin of the patient [4]. The fabric layers to be submitted to receive a red light portion scattered radiation given where a small tissue area can absorb light in the dermis and epidermis. This is due to the presence of photoreceptor layers that can be constituted of amino acids, melanin, and other acids. Typically each type of photoreceptor is sensitive to a particular wavelength.

Thus, light can be absorbed by the tissue which depends on the color and wavelength. For example, red light, near infrared, easily penetrates the fabric because this light radiation is not blocked by blood and water as other wavelengths.

Wavelengths less than 630nm, such as yellow, blue and green are significantly blocked by hemoglobin in the blood, so that they do not penetrate deeply [5].

Wavelengths greater than 900nm are blocked by the liquid portion of the skin and connective tissues. Many wavelengths can emit a large amount of energy above the infrared range and

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cannot be seen by the human eye; this type of radiation may produce a certain amount of heat to interact with human tissue [5].

2.2. Action of light emitted by high-brightness LEDs in human tissue

The blue is in the range of 430 to 485nm. The green is in the range of 510 to 565nm. The yellow is between 570 to 590nm. The red is in the range of 620nm to 700nm, to the point that it does not become visible anymore in the range of 740nm. Some companies that manufacture LEDs say that the yellow light helps remove wrinkles. There is also some interesting research, which emphasizes that the application of blue light helps in the elimination of a bacteria that causes some forms of acne [20].

The phototherapy with the narrow band blue light seems to be a safe treatment and one additional effective therapy for treatment of mild and moderate acnes. Some researchers suggest that the green LED light can help against cancer, but this color cannot penetrate more than the skin. Figures 1, 2, 3 and 4 show prototypes that emit light in the red, blue, green and amber colors.

2.2.1. Action of red light emitted by high brightness LEDs

Red light emitted by high brightness LEDs (in the range of 630nm wavelength) promotes increased cellular energy synthesis (ATP) restructuring fibroblast collagen and elastin fibers stimulating the production of new fibers. It also assists in enhancing the flow of blood and oxygen to the skin and capillaries, increasing cellular metabolism and strengthening the walls of the capillaries. The red light is also an excellent treatment for scarring, inflammation and hard-to-heal ulcers. The red light emitted by high brightness LEDs when in contact with tissue injury has regenerative and major impact on healing characteristics. Patients with physiological difficulties of tissue healing can get great results with this therapy.

Figure 1. Arrangement of high brightness LEDs that emit red light.

2.2.2. *Action of blue light emitted by high brightness LEDs*

Blue light emitted by high brightness LEDs (in the range of 470nm wavelength) acts as a bactericide because its wavelength reaches the surface of the skin (epidermis) producing oxygen and generating oxidative stress destroying bacterias such as those that develop acne.

The action of blue light emitted by high-brightness LEDs is indicated for patients with inflammatory acne, as this therapy reduces bacterial growth and reduces inflammation. LED blue light therapy helps to kill the acne causing bacteria, reducing inflammation and providing a general rejuvenation effect on the skin. Blue light emitted by high brightness LEDs can be used to reduce cellulite and stretch marks and if combined with the red light the result will be more significant.

The action of light acts directly on the excessive production of fat by inhibiting excessive sebaceous secretion, oxygenation, aiding tissue regeneration, and stimulating the production of collagen and elastic fibers.

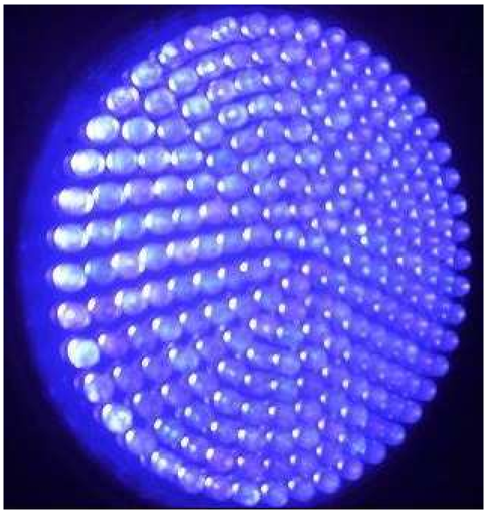

Figure 2. Arrangement of high brightness LEDs that emit blue light.

2.2.3. *Action of green light emitted by high brightness LEDs*

Green light emitted by high brightness LEDs (in the range of 530nm wavelength) can be used in the improvement of skin metabolism, pigmentation, and effects of aging. It provides a control of melanin absorption, aids in whitening pigmentation spots and provides an overall effect of hydration. It also prevents the formation of stains, freckles, and helps to reduce them. It keeps the skin smooth and moisturized.

2.2.4. *Action of amber light emitted by high brightness LEDs*

The amber LEDs have a wavelength of 617nm. The irradiation of amber has both draining and detoxifying properties, improving blood and lymph circulation, reducing edema, stimulating

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Figure 3. Arrangement of high brightness LEDs that emit green light.

the presence of water and causing a calming effect in case of redness caused by rosacea or sunburn.

For aging, the collagen fibers are presented densely packed together, to receive the amber light. The enzyme releases ions receivers which immediately adhere to the cytoplasmic membrane of the cells, creating a non-thermal thickening effect of collagen fibers. The reflection of light by the tissues in these conditions gives a healthy expression to patients. It has a draining action, stimulates blood and lymph circulation, and reduces swelling.

Figure 4. Arrangement of high brightness LEDs that emit amber light.

3. The importance of wavelength in the therapeutic application

The response to the treatment with LED Therapy depends on several factors, but the most important is the wavelength and light penetration into the tissue beyond the physical, organic and genetic characteristics of the patients, which may provide a more efficient biological response one to another.

Some studies indicate that the wavelengths in the range of 620, 680, 760 and 820nm may be most suitable for health treatments [6]. Commercially available LEDs emit light at certain specific wavelengths, for example, 630, 660, 850 and 880nm. These values may not be accurate, it is possible to have a small variation during the operation in real time where this change can be due to temperature, input or output, electrical current and power dissipation. Currently the electronic converters and the quality of manufacture of high brightness LEDs can considerably reduce this variation. The wavelength of 630nm generated by certain LEDs can affect peak 620nm and 660nm wavelength generated by the LEDs is approaching the peak of 680nm, for example [6]. When operating the LEDs with currents in milliampere range, you can improve the input waveform of [20], this fact is important to have control of the desired wavelength.

To perform the therapy a medical evaluation is required to get the correct diagnosis and indicate the most appropriate treatment and which wavelength should be applied.

3.1. Relationship between the penetration depth and the wavelength in human tissues by applying light emitted by the high brightness LEDs

The light penetration into human tissue is directly connected to the wavelength, that is, the larger the wavelength the longer is their penetration in the human tissue, as these wavelengths are specific and are within the visible light spectrum [6, 22]. Therefore, the application of a given wavelength is directly related to the color. Each color has a certain wavelength respecting the chromaticity diagram. The color used depends on the type of treatment to be applied. The electronic converters can control the wavelength through duty cycle, which facilitates the relationship between the depth of penetration with the desired wavelength.

3.2. Cell photobiostimulation

There are areas of medicine and veterinary where the LED Therapy has an important role to play, as shown in Figure 6. These are: (i) wound healing, tissue repair, prevention of tissue death; (ii) the relief of inflammation, chronic diseases and injuries, with their pain and edema associated; (iii) relieving the pain and neurogenic some neurological disorders [7].

One of the photobiology principles is that visible light can have an effect in a living biological system. Photons must be absorbed by electronic absorption bands belonging to some molecular chromophore or photoreceptor. Figure 6 depicts the biological response as a function of wavelength, frequency, or energy of the photons and should resemble the absorption spectrum of the photoreceptor molecule [24].

The fact that a structured action spectrum can be built on the hypothesis of cell photoreceptors and absorption pathways stimulated by light.

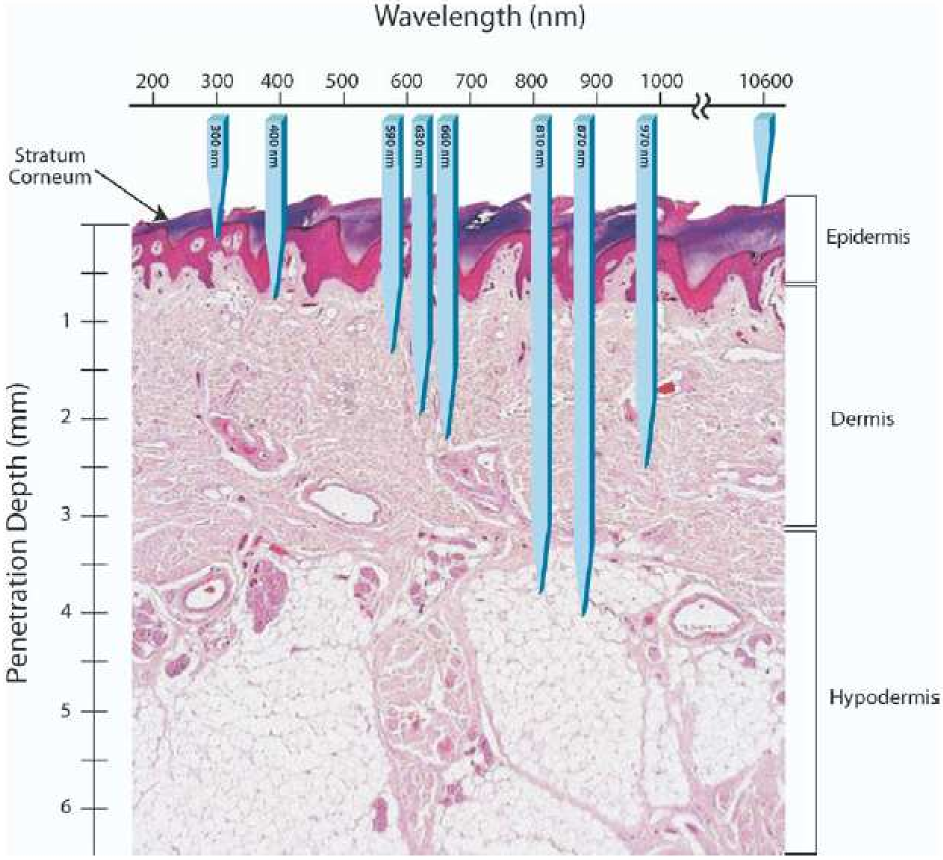

Figure 5. Action of color and depth of penetration in human tissue. Optical penetration depth.

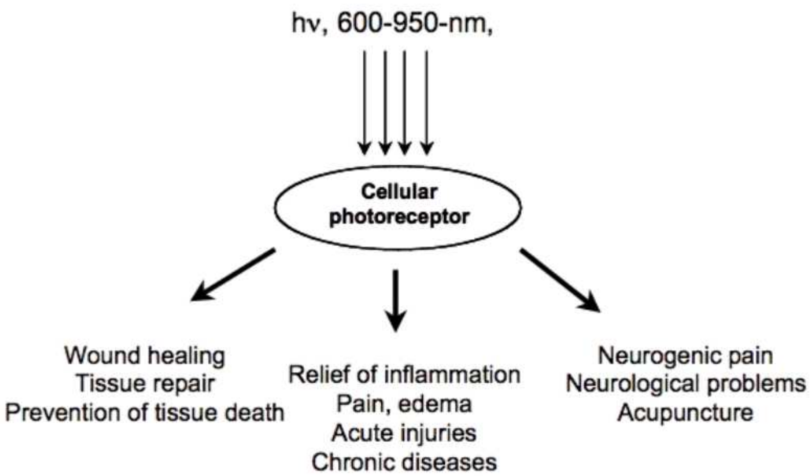

Figure 6. Schematic representation of the main areas of application of LED Therapy.

One should take into consideration some optical properties of tissues. Both the absorption and scattering of light in tissue are wavelength dependent (both much higher in the blue region of the spectrum than the red), chromophores (hemoglobin) has bands of high absorption and the wavelength less than 600nm [7]. For these reasons they are called "optical window".

The water begins to absorb wavelengths longer than 1150nm and acts tissue at wavelengths in the range of red and NIR, wherein the tissue penetration becomes maximized (Figure 7). Furthermore, blue, green and yellow light may have significant effects on the cells because its therapeutic interaction is proven every day.

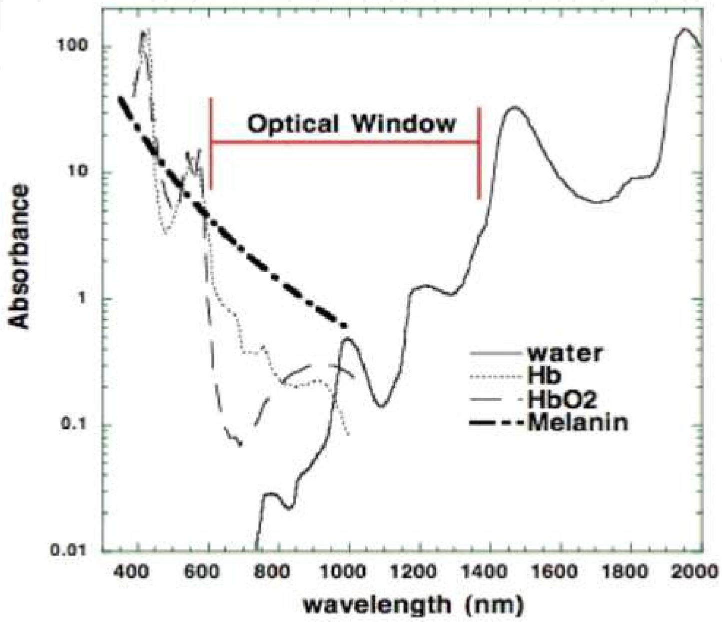

Figure 7. Optical window in tissue due to reduced absorption of red and NIR wavelengths (600-1200 nm) by tissue chromophores.

4. Electronic converters used to supply high brightness LEDs

The application of electronic converters switched to supply high brightness LEDs is critical because these converters have higher efficiency than linear converters. Thus, there are several possibilities of implementing converters DC/DC insulated and not insulated. The converters that are chosen must attend all the control and the power delivery to the high brightness LEDs [8]. Resonant converters help to reduce the peak power; they have low switching losses and low electromagnetic interference. Therefore, these topologies are useful for LED applications.

Depending on the characteristics of the electronic converters applied to LEDs more favorable characteristics should be observed to its applicability. Several converters can be used to supply the LEDs, preferably those that have a natural control over the output current.

DC/DC converter for high brightness LEDs should have a current source characteristic at its output, which already limits the inrush current, acting as an inherent protection circuit. To minimize the variations current it is preferable that its output current is not pulsed, which also minimizes the filter output current and allows the use of capacitors with longer life.

4.1. Converters not isolated commonly used for supplying high brightness LEDs

Buck converter, shown in Figure 8, is widely used in power high brightness LEDs. The current source attribute in the output makes this very interesting electronic converter, essentially because its output current can be continuous. Thus, the output capacitor C may have a small value and is unnecessary to use an electrolytic capacitor, which has the characteristic of a considerably short lifetime.

The output inductance L can be designed to provide a small ripple current, maintaining stable optical characteristics and the temperature of the LED junction.

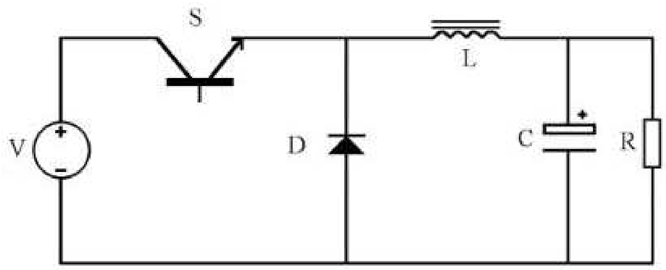

Figure 8. Buck converter.

If the output capacitor is removed from this type of DC/DC converter, the current on the LEDs is no longer purely DC because it contains a pulsating component. If the converter is a Boost or Buck-Boost converters, LED load is powered by an almost square with a sufficiently high reactance wave. The electronic converter CUK, in its basic structure consists of a fusion of two converters (Boost and Buck) in series using only a controlled switch. The union in series of these two converters permits the entry and exit can operate in continuous conduction mode and the static gain of the converter is the same Buck-Boost converter. Buck converter output enables obtaining a low current ripple in the LED, even for a small amount of C. ZETA converter comprises a Buck-Boost converter in series with an input Buck converter output. Similarly the CUK converter, the Buck converter on the output allows to obtain a low ripple current on the LED. SEPIC converter is composed of a Boost converter at the input, in series with a Buck-Boost converter output. All of these topologies may be used to supply the high brightness LEDs, some have more positive characteristics for the LEDs, such as the control of the output current.

4.2. Converters isolated commonly used for supply high brightness LEDs

Currently there is a considerable range of converters that can be used to supply LEDs, such as that with galvanic isolation. This sort of application employs the Flyback, Push Pull, Forward and Resonant converters [9]. The Figure 9 shows a system that supplies power to the LEDs using galvanic isolation.

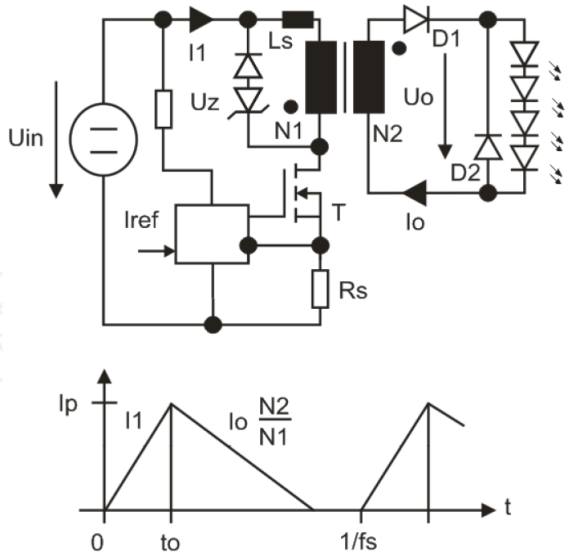

Figure 9. Representation of a LEDs supply the galvanic isolation system.

4.3. Topologies used in research

After reviewing several possible topologies for using as a power source for high-brightness LEDs two converters were chosen, one with galvanic isolation, the Flyback, and one without galvanic isolation, the Buck.

Flyback converter is more robust and has the advantage of being isolated, but it may show some noise in the output. Buck converter controls the output current better and offers a good response, but it has the disadvantage of not being isolated.

In summary, these two converters have been selected because their characteristics are more suited to supply the arrangements proposed by LEDs. The expected results should be quite satisfactory [9, 20].

4.3.1. Flyback converter

The Flyback converters of levels below 100W of power are widely used for the several applications and also for lighting with LED, normally, operating in discontinuous mode. This mode of operation is appropriate to control the current. The proposed topology is observed on Figure 10 and it was developed to supply the array of LEDs, which produce red light [9].

The red color has a greater wavelength (in the range of 647 to 780nm) and penetrates more deeply into the tissue. Thus, it is indicated for healing and recovering deep tissues [9].

The Flyback converter employed in the experiments owns a universal voltage input and its maximum output voltage is 5V.

The maximum output current is 2A. His frequency of switching is 100kHz.

The proposed arrangement of red LED contains 90 high-intensity LEDs of 5mm, with wavelength in the range of 400 to 730nm. The current in each LED is around 20mA.

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Figure 10. LEDs powered by a Flyback converter.

The source was designed to support up to 100 LEDs.

These tests are being conducted in patients with proper authorization and with the participation of five doctors, two surgeons, and three dermatologists, at Hospital Regional do Oeste in Chapecó, SC - Brazil.

The voltage produced on the LED was 4.1V and current of the LEDs around 570mA. The values obtained were close to the simulation and design [12, 13].

4.3.2. Buck converter

The second converter developed has the Buck configuration as shown in Figure 11, with the following characteristics: Input Voltage DC-13V (after one stage rectified by with a Flyback converter) and the output voltage reaches 6V and maximum output current reaches 1A [20]. The frequency of switching is 52kHz. The source has total isolation, even in short-circuit conditions in its terminals [10].

Figure 11. Buck converter.

This topology has the same versatility of a Flyback converter and supplies the array of LEDs.

The voltage produced on the LED was 3.8V and current of the LEDs around 580mA. The values obtained were close to the simulation and design [11].

5. LED Therapy automation using an embedded system integrated with a control software

The main goal here was to provide a control interface of the therapy between the healthcare professional and the patient, giving them the possibility to monitor the phototherapy sessions progress and to treat the patient in a simple and effective way.

There are already lots of resources available in the market that use LEDs for skin disease treatment, like skin cancer or even aesthetic purposes, among others. When a new treatment is discovered, the creation of a new essay is necessary and therefore a new product is created. This project proposes a solution for this problem integrating hardware with control software. With the control software acting over the embedded system, it's possible to program new assays for each treatment; acting directly over the LED's, and dynamically minimizing the costs over new products every time a new treatment is discovered

5.1. System overview

The system is divided into two parts: the embedded system and the control. The embedded system contains a microcontroller, a LED board and an Ethernet Module for communication with the application [12]. The control consists of a database server and an application, as shown in Figure 12.

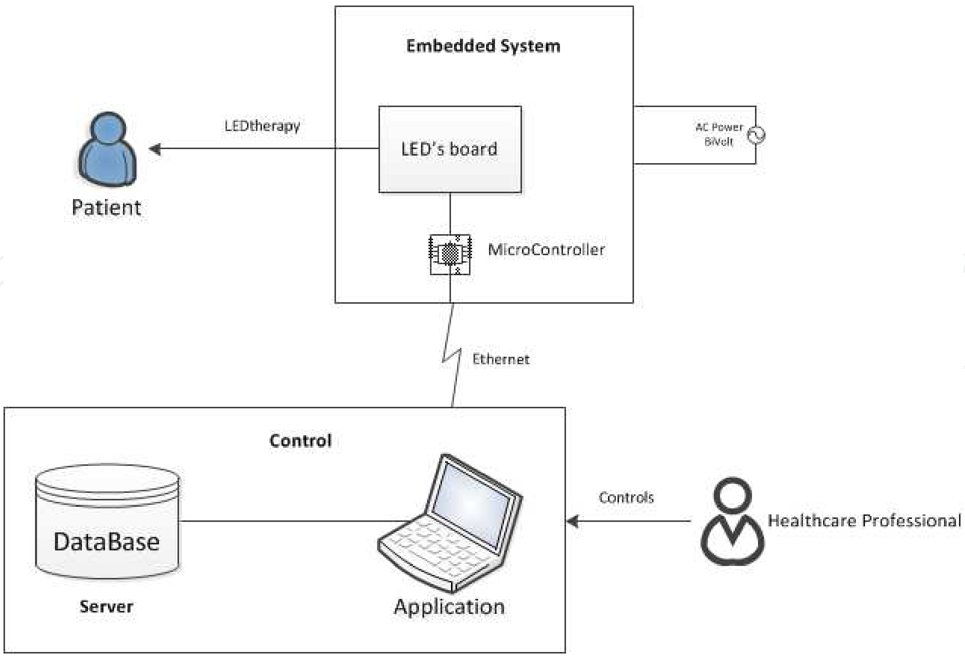

Figure 12. Automation of phototherapy with high brightness LEDs using an embedded system integrated with a software control.

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Through the control application, it is possible to register a patient or start a treatment session. The treatments are mapped to the database as essays that determine the variable values for each pathology. The variables are: the colors and the time of firing the LED arrays [25]. The communication between Embedded System and Application control is possible through the Ethernet Protocol [16].

5.2. System model

In this section the prototype details will be shown, such as: the application operation, embedded system operation and the database server details [16].

5.2.1. Application

The control application was written in JAVA language. The application aims to perform the user interface with the proposed system. Through the application the user can perform the following tasks:

- Register new patients, which are going to be stored in the database;
- Visualize the stored patients in the database;
- Connect the patient to a treatment; and
- Initiate a new session of the treatment.

The application stores the results of each treatment session.

5.2.2. Embedded system

The embedded system purpose is to communicate with the application and to execute the treatment over the patient. The embedded system is based on the Atmega328p AVR microcontroller present in the Arduino UNO board. It also has a LED board and an Ethernet Module ENC28J60 and resistors. The Figure 13 shows the prototype schematics. The database server aims to store all the patient data and the treatments as well. It's in the database that the LED treatment sequence is also stored. The chosen Data Base Management System (DBMS) was the PostgreSQL version 9, because it doesn't have license costs and it's capable of storing all the needed data [13, 14, 16].

Tree arrays were assembled on a phenolite board with tree blue, yellow and red LED colors. Each array has thirty LEDs of the specified color which are powered by the corresponding Arduino pin and a common ground.

Where, (A) Ethernet ENC28J60 module, (B) Resistors, (C) Arduino UNO and (D) LEDs array.

The LEDs board is composed by three arrays of high brightness LEDs with the following characteristics:

- Red array: The red light emitting LED array contains 30 high brightness LEDs of 5mm, with wavelength between 725nm and 730nm. Operates at 3, 3V and 20mA.

- Blue array: The blue light emitting LED array contains 30 high brightness LEDs of 5mm, with wavelength between 465nm and 470nm. Operates at 4V and 25mA.
- Yellow array: The blue light emitting LED array contains 30 high brightness LEDs of 5mm, with wavelength between 585nm and 590nm. Operates at 3, 6V and 22mA.

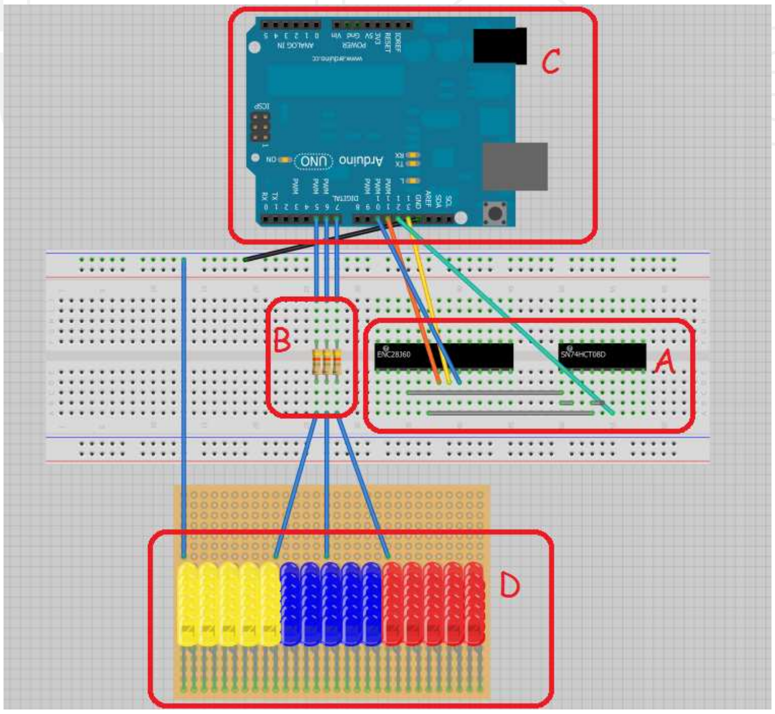

Figure 13. Prototype schematics.

Figure 14 shows the prototype used in the laboratory.

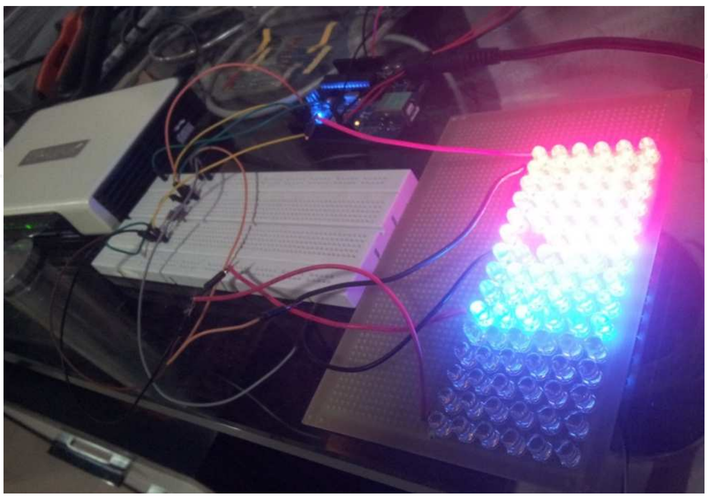

Figure 14. Numerous tests were performed with the prototype before manufacturing the device.

6. Types of treatment and response to therapy

The concentration of light coming from the LED bulb can concentrate light to a certain point of light that can have a high ratio in millicandelas, but passing through the skin undergoes a dispersion of its light concentration. The rate control devices are important because the total light energy emitted by the LED or energy in Watts per square centimeter in units of mW/cm^2 is essential [15].

If the designer decides to use his knowledge to choose a less expensive way to manufacture power supply, then the power converter should be about 2 or 3 times more than the total of its light energy. The maximum light output of the output device is the source of half the power (W = Volt x Amps) of the transformer. The mW/cm^2 is the total light energy in mW divided by the length and breadth of the array of LEDs in cm.

6.1. Criteria, control and response to treatment of the patients who were treated by red and blue light emitted by high-brightness LEDs

Patients who are subject to the treatment will be properly classified with the criteria established by the doctors who assist in the implementation of therapy. Among them, age, sex, physical condition and mental health. The therapy was performed with LEDs Hospital Regional do Oeste in the city of Chapecó/SC, Brazil.

The first case is from a patient who had put breast prosthesis. The prothesis were large and a few days later, streaks appeared (Figures 15 and 16). Stretch marks are linear atrophies which arise due to the disruption of elastic fibers that support the middle layer of the skin. Generally, this breakup is from mechanical stress, such as excessive stretching of the skin, or physiological stress, stimulated by hormones. When the fibers are broken, they are filled with blood, becoming primarily redish, but over the time they acquire a white color. This patient underwent a medical evaluation and its treatment was approved. 15 sessions were held in 44 days. The application time for each session was 40 minutes. After the treatment the reduction was 95% (Figures 17 and 18). The use of LED Therapy is completely painless and leaves no sequel. The Figures 19 and 20 show the results of treatment.

Figure 15. Patient with stretch marks on breasts before application of therapy.

Figure 16. Patient developed stretch marks after placing silicone breast.

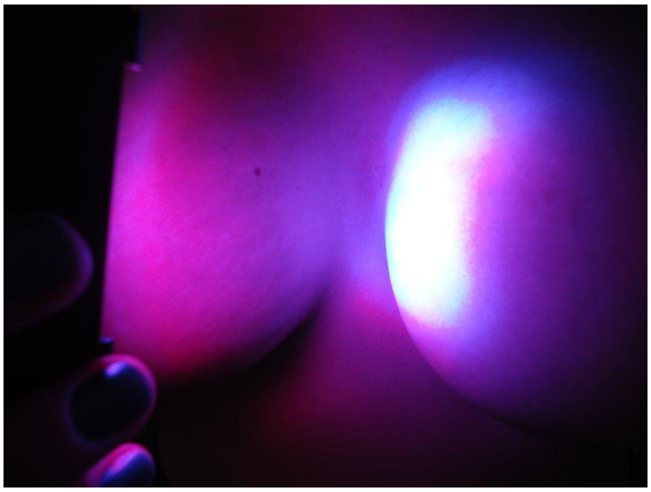

Figure 17. Application of therapy with LEDs that emit blue and red lights.

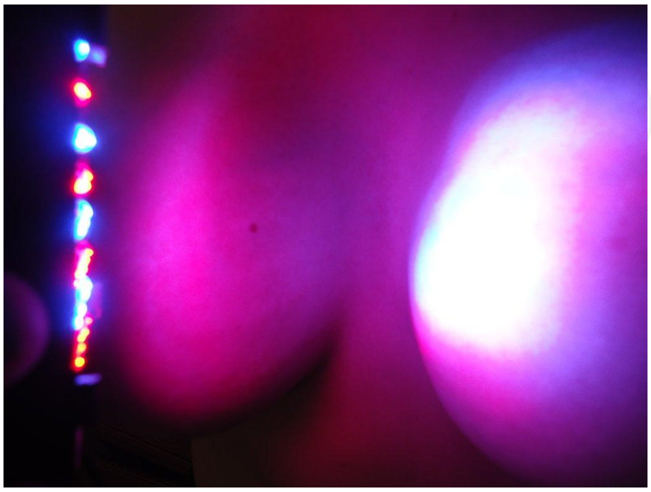

Figure 18. Application of the array of LEDs during treatment.

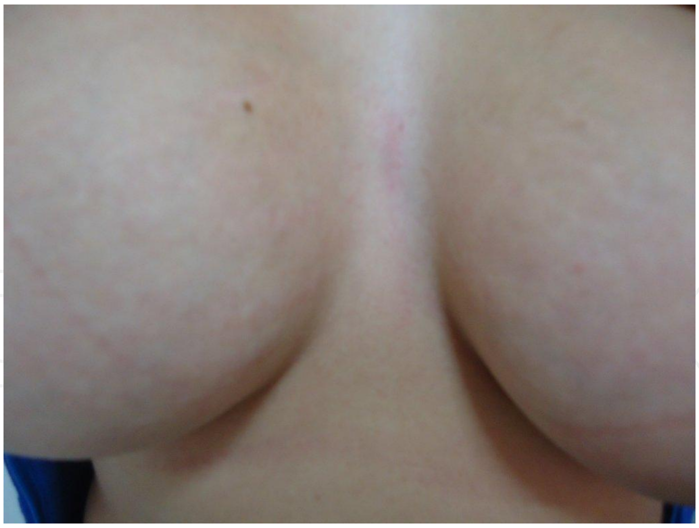

Figure 19. Result after treatment.

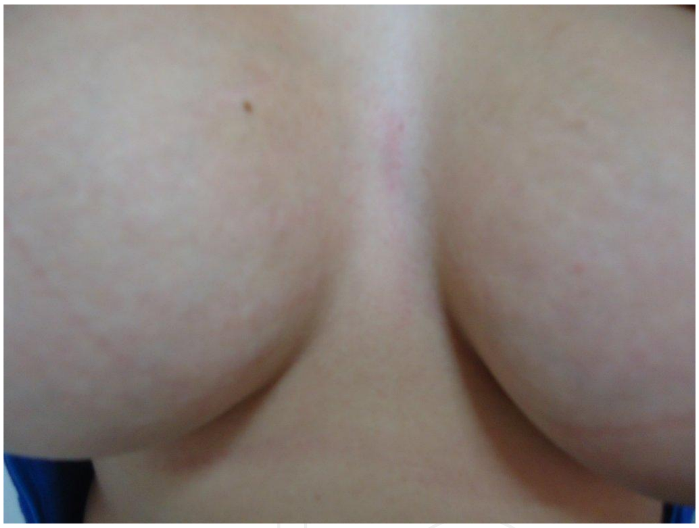

Figure 20. The striations were eliminated.

The second case is a patient who had stretch marks on her hip in the region of the buttocks. She underwent a medical evaluation and the treatment was initiated. 20 sessions were held for 49 days. Each session was 40 minutes long. A reduction of 87% of the hips as shown in Figure 21 has occurred.

In this procedure the Buck converter, which is supplied by the LEDs, was used that emit red and blue light.

All patients who underwent treatment fulfilled all requirements and recommendations of the medical staff. All International Laws and National research in human beings were observed. All protocols required by the Brazilian Ministry of Health and the Ethics Committees of Hospital Institutions.

Figure 21. Outcome of treatment for stretch marks.

The Figure 22 shows some prototypes that were manufactured to perform the therapy.

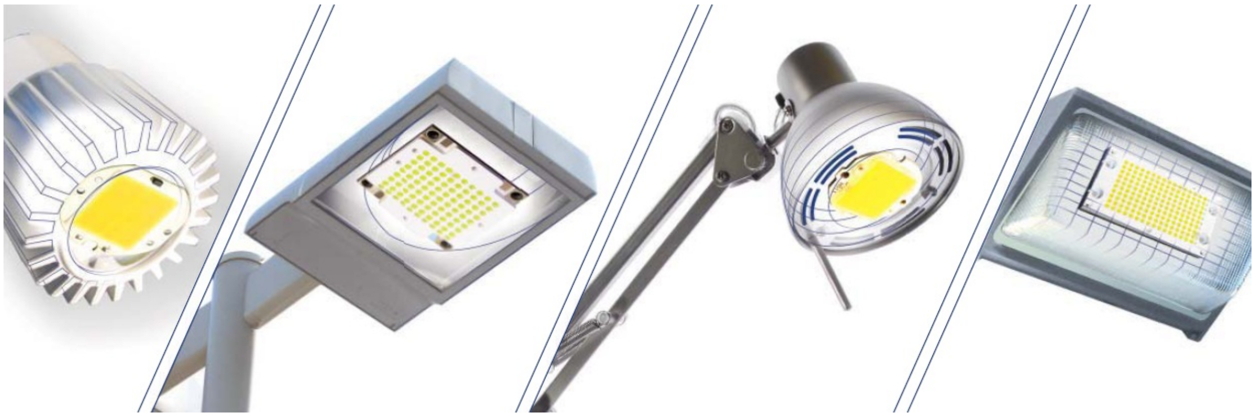

Figure 22. Prototypes that are being manufactured.

7. The future of LED therapy

The application of high brightness LEDs in human tissue has been growing every day. Several scientific institutions have explored this theme. Many researches are underway on the use of therapy with the LED in order to improve their application and to determine if there are other applications which may be used. The therapy is applied within the visible light spectrum and each color has its application and its therapeutic purpose.

The red color that is in a range of 600-700 nanometers, is effective in human tissues and shows excellent results in wounds and sores. The higher wavelengths, including infrared, are more sharp and can reach the bone. Studies also suggest that the spectrum between 400 to 500 nanometers, in the range of blue color, can be effective in the treatment of skin disorders, including acne, stretch marks, cellulite, skin blemishes and scarring.

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Probably in the next few years, LED Therapy will be the main treatment for wounds, such as post-surgical wounds and unhealed as diabetic ulcers. Scientists seek to test the technology of LED Therapy in other clinical situations, such as spinal cord injuries and treatment of Parkinson's disease, cerebrovascular accidents, brain tumors and regeneration of tissues and organs [17].

With the advancement and development of new applications of LEDs in health, manufacturers of these devices will increasingly improve these devices that every day demonstrate its usefulness and its application to human health.

8. Conclusion

The application of LEDs in interaction with the human tissues shows a great interest of manufacturers and researchers. The correct use of LEDs in this context directly depends on the tissue nature where it wants the light to interact [10].

Several parameters are important for satisfactory results, such as wavelength, the kind of color, temperature control of the LED, the characteristics of the used converter, control the brightness, output current, duty cycle and all the observations made in the previous sections of this work.

This is because a small spectral change can lead to a major shift in the lighting characteristics. LEDs are increasingly becoming a great option to help cure various diseases and to prevent others [18].

Thus, this work contributed to the development of LED application in human tissues showing that the effect of the emission of light through the high brightness LEDs offers a new treatment option for opening new ways of therapeutic technique LED Therapy applied to human tissues [20].

Author details

Alexandre Campos[1], Yasmim Guterres[2], Eduardo B. Bauer[3] and Mauro C. Moreira[4*]

*Address all correspondence to: mcmoreira41@gmail.com

1 Federal University of Santa Maria/UFSM, Brazil

2 Federal University of Santa Catarina /UFSC, Brazil

3 University of Vale do Itajaí /UNIVALI, Brazil

4 Federal Institute of Santa Catarina /IFSC, Brazil

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