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Characterization of an Optical Device with an Array of Blue Light Emitting Diodes LEDS for Treatment of Neonatal Jaundice.

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Abstract. Phototherapy is a treatment that consists in irradiating a patient with light of high intensity, which promotes beneficial photochemical transformations in the irradiated area. The phototherapy for neonates is applied to break down the bilirubin, an organic pigment that is a sub product of the erythrocytes degradation, and to increase its excretion by the organism. Neonates should be irradiated with light of wavelength that the bilirubin can absorb, and with spectral irradiances between 4 and $16\mu W/cm^2/nm$. The efficiency of the treatment depends on the irradiance and the area of the body that is irradiated. A convenient source of light for treatment of neonatal jaundice is the blue Light Emitter Diode (LED), emitting in the range of 400 to 500 nm, with power of the order of 10-150mW. Some of the advantages for using LEDS are: low cost, operating long lifetime (over 100,000 hours), narrow emission linewith, low voltage power supply requirement and low heating. The aim of this work was to build and characterize a device for phototherapy treatment of neonatal jaundice. This consists of a blanket with 88 blue LEDs (emission peak at 472nm), arranged in an 8x11 matrix, all connected in parallel and powered by a 5V-2A power supply. The device was characterized by using a spectroradiometer USB2000 (Ocean Optics Inc, USA), with a sensitivity range of 339-1019nm. For determination of light spatial uniformity was used a calibrated photovoltaic sensor for measuring light intensity and mapping of the light intensity spatial distribution. Results indicate that our device shows a uniform spatial distribution for distances from the blanket larger than 10cm, with a maximum of irradiance at such a distance. This device presenting a large and uniform area of irradiation, efficient wavelength emission and high irradiance seems to be promising for neonates' phototherapy treatment.

Key-words: Phototherapy; Neonatal Jaundice, Blue LED's; LED's array blanket; Spectral irradiance.
PACS: 07.60.-j; 87.85.0x; 42.15.Eq; 87.19.x-

INTRODUCTION

Phototherapy is a treatment that consists in irradiating a patient with light of high intensity, which promotes beneficial photochemical transformations in the irradiated area. The phototherapy for neonates is applied to break down the bilirubin, an organic pigment that is a sub product of the erythrocytes degradation, and to increase its excretion by the organism [1,2]. An elevated concentration of bilirubin in the neonate blood is known as neonatal jaundice [3-5]. The first clinical application of the neonatal phototherapy was reported by Cremer at al. in 1958. They observed that the bilirubin concentration in blood was reduced when the neonates were irradiated with light. Then, they constructed a phototherapy system using fluorescent lamps [4-6]. The jaundice control can be realized by two methods: by the neonate blood transfusion or irradiating the neonate with light [5-9].

The basic mechanism for the phototherapy action is by converting the bilirubin molecules into hydro-soluble and less toxic metabolic forms. Bilirubin molecules absorb light in the blue region of the spectrum between 400-500 nm [1-3,5,7,10]. Light corresponding to that spectral band can penetrate the epidermis, reach the subcutaneous tissue

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and it is absorbed by the bilirubin in the blood. Only bilirubin at not more than 2 mm of depth from the skin would be irradiated by the light [1,2].

In the literature was reported that the minimum spectral irradiance therapeutic dose is of the order of 4μW/cm^2/nm [1,5]. Nevertheless, it is recommended a spectral irradiance of at least 16 μW/cm^2/nm, since higher the intensity of irradiating light more efficient would be the phototherapy [1,5].

Another convenient light source for jaundice treatment uses blue light emitters diodes LEDs, which are simple, small and low cost devices. They operate with a low voltage between 1.6 to 3.3 V and the consumption power stands in the 10 to 150 mW region. LEDs present a narrow spectral emission band, being the linewidth of the order of 50nm. Some other advantages of using LEDs are the low heating and their long lifetime, well over 100,000 hours [9,11,12].

An optical system was developed by us using as a light source an array of LEDs emitting in the blue region of the spectrum, in agreement to the international norm IEC 60601-2-50, that rules on safety and performance of phototherapy equipments for treatment of neonatal jaundice [13].

The aim of the present study was the optical characterization of the developed equipment, though the measurement of the emitted spectral irradiance and the mapping of its radiation spatial distribution.

MATERIALS AND METHODS

The developed optical device consisted in an array with 88 blue LEDS (8 rows by 11 columns), connected all in parallel. The array was mounted onto a blanket made of an antiallergenic, anti-moldy and biocompatible foam. The blanket was constructed in a rectangular format (20x14 cm), which corresponds to the medium size of a neonatal. In this way, all the patient body area is being irradiated [13].

LEDs model OSUB5131P from Optosupply (China), with a 5mm diameter, were employed. Their optical characteristics were: 50% power angle of 30°, peak emission wavelength at 472 nm with a narrow linewith of 50 nm and a luminous intensity of 6,250 mcd. The LED array was powered by a 5V power supply, with a current of 0.22 A through each one. In Figure 1 is shown a photograph of the equipment. It can be seen in the picture the blanket with the LED array connected to the power supply (on the right side); whereas, at the left can be observed a multimeter for electrical monitoring of the device.

Figure 1. Photograph of the equipment for neonatal phototherapy treatment.

Measurements of the spectral irradiance emitted by the LED array were carried out by using a spectroradiometer USB from the Ocean Optics Inc (USA), with a spectral response range between 339 and 1019 nm. The distance between the light source (the blanket with the array of LEDs) and the detector (positioned at the center of the illuminated area) was increased by 10 cm steps, from 10 up to a maximum of 40 cm away. This last distance was selected because it corresponds to the average distance that is recommended for neonatal treatment when conventional equipments of phototherapy are used. A picture of the experimental setup for spectral irradiance measurement as a function of the distance from the blanket is displayed in Figure 2. It can be seen the blanket with the LEDs array and the head of the spectroradiometer that it is being moved along an axis centered with respect to the array.

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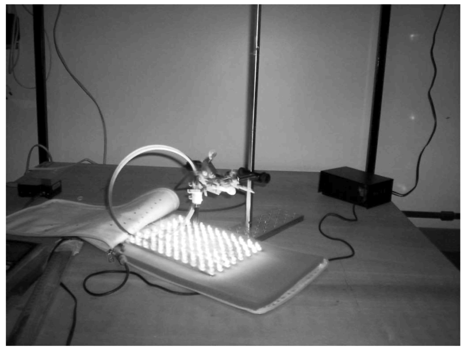

Figure 2. Experimental setup for spectral irradiance measurement as a function of the distance from the blanket.

The spatial distribution of the irradiance on different parallel planes away from the blanket was determined. It was used a radiometer, specially build for the experiment at the Instituto de Pesquisas Espaciais (INPE) de São José dos Campos – Brazil, and a Fluke 189 true RMS Multimeter. The radiometer sensor was a silicon solar cell with its response calibrated at 472 nm. The cell had a shunt resistance that converted the current in the solar cell into a voltage that was proportional to the irradiance. The illuminated area seen by the detector corresponded to its entrance aperture that was approximately 2 cm of diameter. Measurements were taken on planes separated by a distance of 10 cm to each other, up to a maximum of 40 cm from the blanket.

RESULTS AND DISCUSSION

Figure 3 displays the spectral irradiance emitted by the array of LEDs as a function of the wavelength for distances of 10, 20, 30 and 40 cm, between the luminous source (array of LEDs) and the spectroradiometer head. It is found that for a distance of 10 cm the spectral irradiance is a maximum, reaching the value of 77.0 $\mu W/cm^2/nm$ at the peak of 472 nm. This value is higher than the one obtained from other systems that use fluorescent or halogen lamps.

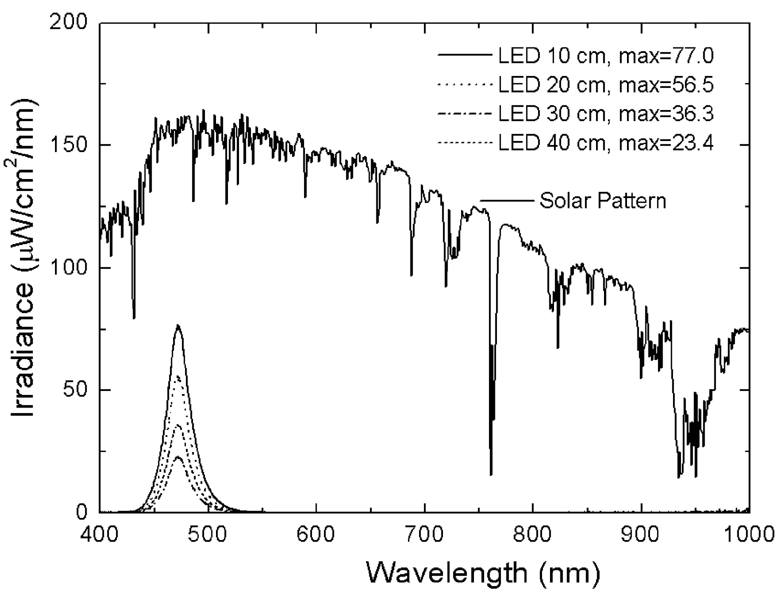

Figure 3. Spectral distribution of the irradiance emitted by the light source for distances from 10 to 40 cm.

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The spatial distribution of the irradiance at a distance of 10 cm, is shown in Figure 4. Data represent irradiance values averaged over the illuminated area seen by the detector. It is observed that is maximum at the center of the illuminated area, which also corresponds to the equipment center, reaching a value of 1,260 μW/cm^2. At regions away from the center, the irradiance decreases up to around 472.5 μW/cm^2 at the border of the LEDs array area, value that is still very high as compared to conventional equipments.

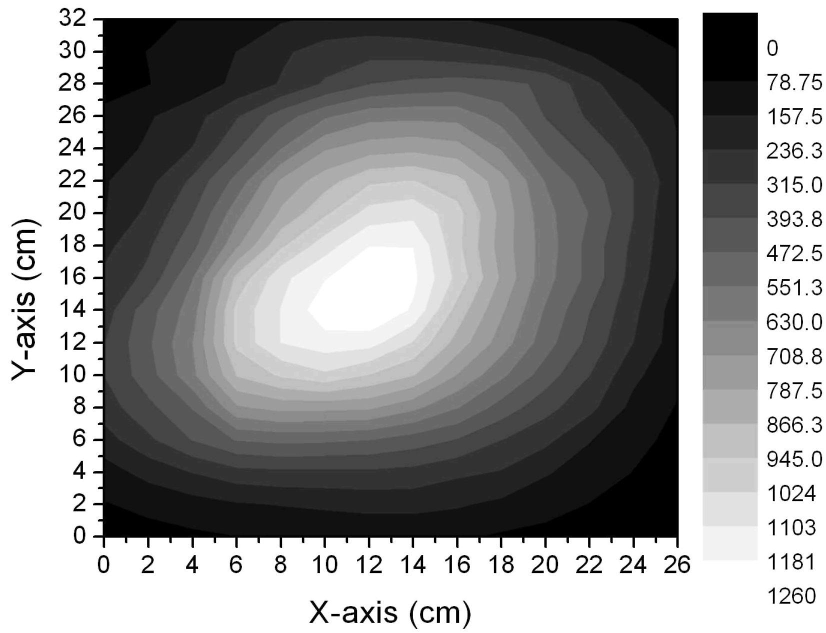

Figure 4. Spatial distribution of the radiation. The sidebar with the gray tons stands for the incident irradiance in μW/cm^2.

The therapeutic efficiency of the neonatal phototherapy equipments depends on the initial serum concentration of bilirubin in the patient before the treatment, wavelength of the light source employed, distance between the patient and the luminous source, irradiance dose and the corporal area exposed to the light. Besides of that, we have also the intrinsic characteristics of the neonates, such as weight, nutrition status and associated pathologies [1-3,5,6].

Actually, several light sources are being used; nevertheless, all present some advantages as well as some drawbacks. For instance, the light from a white fluorescent lamp can irradiate a large corporal area of the neonate; but, its radiance is low and the emission spectrum is very large, covering the spectral range from 380 to 770 nm. Since, bilirubin absorbs only radiation between 400 and 500 nm, all the light from the white lamp outside that band are converted in heat; because of that, fluorescent lamps should be located at big distances from the patient, of the order of 30 to 50 cm, to avoid overheating of it [5,9].

The light from halogen lamps, known as the special blue light, used for neonatal phototherapy was introduced in clinical practice in 1972. Since then, several works have demonstrated that the special blue light produces faster and bigger reduction of the serum bilirubin concentration as compared to the traditional systems using fluorescent white light. Systems using halogen lamps present a good spectral irradiance between 25 and 35 μW/cm^2/nm; but, they can not be situated very near to the neonates because of the overheating and burning problems. It is recommended a distance of 40-50 cm from the patient. Even that halogen systems can illuminate an area of 20 cm of diameter, its irradiance is high only at the center [5,9]. Because of that, they are efficient for small neonates (up to 1,500 g of weight), but quite inefficient for bigger patients (2,500 g or more) [2,9].

Since the phototherapy acts thought the patient skin we can conclude that the amount of the corporal area exposed to the light is also an important parameter for the treatment efficiency. As larger the area and closer the light source to the patient better is the phototherapy treatment [2-4].

The light intensity on the neonate varies inverse to the distance between the light source and the patient. The irradiance for a conventional equipment using fluorescent lamps increases from 4 μW/cm^2/nm for a distance of 30 cm up to 12 μW/cm^2/nm when the distance is reduced to 10 cm from the patient; but, at such a distance may be

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overheating and dehydration of the neonate. Usually, a conventional system with fluorescent lamps is positioned at 30 cm from the patient; whereas, the one that uses halogen lamps is maintained at 50 cm [2].

Further tests of the device performance are needed to be done before it can be used for clinical applications.

CONCLUSION

Results of the developed device characterization indicate that the device presents a large and uniform area of irradiation, efficient wavelength emission for jaundice treatment, high spectral irradiance, simplicity, low weight, low heating and low cost. Furthermore, when its optical proprieties are compared to that from other phototherapy devices actually in use (with fluorescent or halogen lamps) it is found that this device fit better the jaundice treatment optical requirements. Finally, it can be concluded that the developed device is a very promising candidate for neonates' phototherapy treatment.

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