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LIGHT TRANSPORT IN A FIBRIL FILM SHEET

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ABSTRACT

Fiber Optic Trans Illuminating Imaging System (FOTI) is used for analyzing the light emission spectra from the human body tissues and various cells. All the organs of human body tissues and cells contain various light absorbing micromolecules such as Water, Monosaccharide's, Oligosaccharides, Fatty acids, Amino acids, Minerals, Nucleotides, etc. and macromolecules such as Carbohydrates, Proteins, DNA, RNA, Lipids, High energy compounds such as ATP's and phosphate groups. The signal comes in the form of a change in the intensity or the peak position of optical absorption, fluorescence emission, reflection, surface plasmon resonance (SPR), surface-enhanced Raman scattering (SERS), and electro-chemical potential/current under various conditions leading to the development of corresponding biosensors. All the micromolecules and macromolecules have specific absorption characteristics. The basic principle of fiber optic transilluminating imaging system is the irradiation of a sample and the analysis of the transmitted or reflected light. The measurement is noninvasive technique and it is very useful for monitoring human body tissues at molecular level for various clinical and medical diagnostic applications. Application areas include medical equipment manufacturers such as production, environmental analysis, polymer identification, analyzing the protein content of grains in medicine and biology. Biological samples are composed of proteins, carbohydrates, lipids and nucleic acids. Each of these organic molecules has a unique chemical composition and a unique absorption spectrum. Fiber optic transilluminating imaging system allows quantification of the sample based on their absorption spectrum.

KEYWORDS: *Fiber, Optics, Light, Thin Film, Light Emitting Diodes*

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INTRODUCTION

The application of medical health care fields in diagnostics and clinical investigations are many. For example the determination of cholesterol in veins and arteries, the noninvasive measurement of glucose content in bled determination of body fat content, locating oral and gastro-intestinal cancer, providing qualitative information about the concentration of oxygenated and deoxygenated hemoglobin, characterization of a tissue sample and the differentiation of microorganisms, cerebral monitoring in neonates and stroke patients, studying the metabolism of the brain, tissue oxygenation, vascular monitoring, skin blood flow and burns measurement.

This research paper focuses on how fiber optic transilluminator can be used as a quantitative measurement of the skin and for the determination of blood oxygen saturation while taking various drug samples for gastric problem. In Table.1 the site of crohn's disease for various patients in the age group 23 to 71 years for male and female patients were listed. The affected sites in the human body were Duodenum, Ileum, Colon, Rectum, Small bowel. For the above disease in the human body, the medication’s taken by conventional medicine’s are given and there activity in the human body also mentioned [1]

SURFACE REFLECTANCE MEASUREMENT

Non-invasive fiber optical transilluminator is based on focusing a beam of light onto the body tissues. The light after transmission through the region of interest is modified by the tissue. An optical signature of the tissue is produced by the diffuse light that is backscattered by the tissue it has penetrated[2]. The properties of each layer of the tissue, epidermis, dermis, subcutaneous tissue, muscle, bone and associated blood flow contribute to these characteristics. At different wavelengths such as 620-645nm(red), 610-620nm(red, orange), 520-550nm(green) and 420-520nm(cyan), 460-490nm(blue), the transmission and diffuse reflection of light is considered as a function of thickness, color and structure of the skin, bone, blood and other material through which the light passes[3]. Analyzing the interaction of light with tissue can be done by monitoring the backscattered light radiation using photo detector and Infra-red photodiode [4]. Reflectance data therefore reveal information about the optical properties of a medium. These data form the basis for the numerous optical diagnostic tools being developed [5].

Figure 1: Experimental Set Up of Optical System.

IN VIVO EXPERIMENTS

The quantitative assessment of the skin in terms of its light scattering properties is important for analyzing the skin structure at molecular level [6]. A technique based on the in vivo measurement of fiber optic transilluminator spectra in the visible and near infrared ranges of the electromagnetic spectrum is presented [7]. This fiber optic transilluminating imaging system helps to interpret variations in reflectance with hemoglobin and melanin content of the test tissue medium. The forearm was chosen for convenience and also because it exhibits rapid cardiac pulsations. The following circuit diagram consists of a red light emitting diode (LED) at 660nm and a current sensitive PIN photo detector.

Table 1 shows Deep red with 700nm, traditional red LED with 660nm, Orange red LED with 635nm, Orange color LED with 623nm, Amber LED with 594nm, traditional yellow LED with 588nm, traditional green LED(yellow green) with 567nm, emerald green with(true green) with 523nm, cyan with 503nm, aqua with 495nm, deep blue with 470nm,powder blue with 430nm,violet with 410nm. The spacing between the LED and the photo detector is 4mm. These two components are held in a position and the light signals are taken from the two components and connected to the corresponding points on the printed circuit board. The detector and LED are positioned with their surfaces perpendicular to the skin. The light backscattered from the tissue is detected using the photo detector (BPW 34). The detector output is converted into an equivalent voltage using a current to voltage converter and amplified. For analyzing the surface reflectance variations, the surface of the skin was heated with a hot water bag at 40˚C for 5 minutes so as to produce a change in blood circulation. The response of the skin to local heating is a blood volume change through the thermal regulation mechanism in the dermis. Reflectance data at 660nm was recorded for 10 individuals before and after hyperemia. Next the red LED at 660nm was replaced by an IR LED at 880nm and measurements repeated.

Table 1: Characteristics of Patients with Crohn's Disease

Case	Age / Sex	Site of Crohn's disease	Activity	Medication
1	43/F	Duodenum, Ileum	Slight	5-aminosalicylic acid
2	43/M	Ileum	Slight	5-aminosalicylic acid
3	30/M	Colon	Slight	5-aminosalicylic acid
4	39/M	Ileum, Rectum	Moderate	
5	49/M	Ileum, Colon	Slight	Sulfasalazine, Metronidazole
6	23/M	Ileum, Colon	Slight	Sulfasalazine, metronidazole
7	30/M	Ileum, Colon	Moderate	Sulfasalazine, Ibuprofen
8	51/M	Ileum, Colon	Moderate	5-aminosalicylic acid
9	23/M	Ileum, Colon	Severe	Methylprednilone 40mg / Daily)
10	45/F	Ileum, Colon	Moderate	Metronidzole
11	31/F	Colon	Slight	5-aminosalicylic acid
12	54/F	Ileum, Colon	Moderate	5-aminosalicylic acid, prednisolone(5mg / daily)
13	71/M	Small bowel	Slight	Sulfasalazine
14	68/F	Ileum, Colon	Slight	Sulfasalazine
15	54/M	Ileum	Moderate	
16	64/M	Colon	Moderate	Sulfasalazine, prednisolone(5mg every second)
17	47/F	Ileum, Colon	Slight	5-aminosalicylic acid

SURFACE REFLECTANCE RESULTS

The reflectance values measured using the fiber optic transilluminator and experimental set up for various human body region of interests prior to local heating. The values indicate difference in surface reflectance at both 660nm and 880nm corresponding to melanin content of the skin. Results pertaining to oxygenated hemoglobin have shown that oxygenated hemoglobin has less absorbance at 660nm compared to 880nm. A difference in surface reflectance before and after local heating for both 660mn and 880mn is observed. The values suggest that there is a significant increase in absorption for the hyperemic states for all the subjects of human body.

Figure 2 shows the apparent changes in top layer absorption are consistent with an increased blood flow in the dermis in response to local heating. A plot of natural logarithm of R/R_{ref} for varying source to detector separation. 'R' is the reflectance from the test medium after local heating and the reflectance value prior to heating is the reference reflectance value (R_{ref}.) In the difference in the red and infrared responses can be attributed to the differences in photon absorption at the two wavelengths associated with changes in blood volume and oxygenation.

At smaller separation there is an initial rise indicating significant absorption for the hyperemic state. But no change in oxygenation is observed at both 660nm and 880nm for smaller source to detector separation. The experimental analysis demonstrates that the transillumination is effectively diffusive and deeper penetration of the photon results at larger separations. But at deeper depths significant changes in tissue optical properties do not result with hyperemia. The results of this observation of various human body subjects clearly indicate that it is possible by using reflectance data to obtain quantitative information about the hemoglobin and melanin content, as well as basic information of the scattering properties of the skin and the underlying tissue.

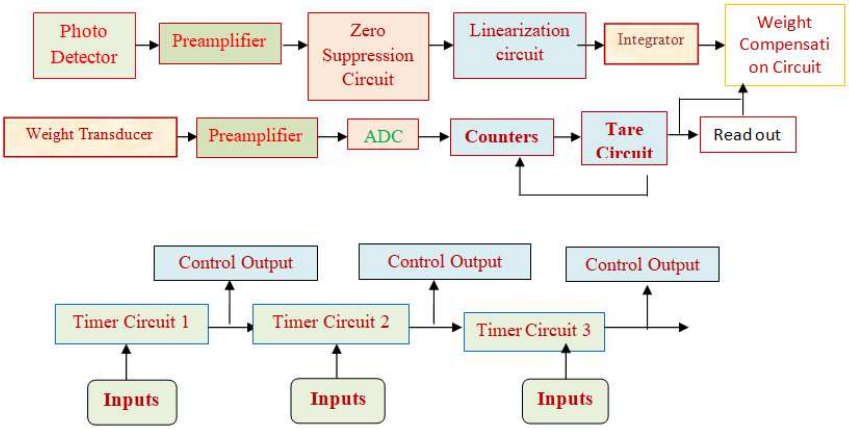

Figure 2: Block Diagram for the FTIR experimental Set-Up.

BLOOD OXYGEN MEASUREMENT BY REFLECTANCE

Monitoring the oxygen level in a patient's blood is one of the standard methods adopted in the clinical environment, due to the need for continuous assessment of tissue oxygen saturation. International standards for safe practice in medicine highly recommend continuous use of a quantitative monitoring of oxygenation, such as blood oximetry during the various stages of patient care. Assessment of blood oxygenation is an essential part of monitoring the status of anesthetized patients. During surgery, Hypoxemia is one of the most feared problems associated with anesthesia. The purpose of continuous measurement of tissue oxygenation is to provide warning of hypoxemia. Treatment can be initiated before the hypoxemia because there is a possibility of irreversible changes. Researcher’s reviews have shown that a reduction in hypoxemic events occurred when blood oximetry was used.

Need for Fiber optic Tran Illuminator

Before the advent of noninvasive blood oximetry, the common practice was to draw blood from the patients and analyze the samples at regular intervals several times a day or even several times an hour using laboratory equipment. These in-vitro analyses of instruments were either blood gas analyzers or haemoximeters. The availability of noninvasive techniques has led to the avoidance of bleeding arterial insufficiency, embolisation and infection, which were seen after the puncture of the body part in the case of invasive techniques. Transmittance oximeters are the type of noninvasive blood oximeter available today. They are so called because the light used to determine blood oxygen saturation is "transmitted" from a light emitter on one side of the body part to a light receiver on the other side.

These oximeters require the sensor to be placed on an extremity and so can only be used on limited areas of the body. Suitable sites are fingers, toes or earlobes in adults or hands and feet in neonates or children, which are said to be "transilluminated". But in certain applications like obstetrics where fetal oxygen status during labor is a crucial parameter, no transilluminable fetal part is available. This is one great disadvantage as it limits the usage of these oximeters to certain areas of the human body like the ear lobes, finger tips etc., Hence blood oxygen determination at non-transilluminable areas of the human body is not possible as the detection of the transmitted signal becomes impossible. These transmittance oximeters are also unreliable when blood flow to the extremities is reduced due to shock, cold temperature, vascular disease or patient movement.

These involve some amount of site preparation before the probe assembly is fitted to the body. Furthermore, many of the alarms due to hyper perfusion, motion artifact are false, thereby wasting hospital time and resources. The drawbacks of the existing transmission pulse oximeters have paved the way for reflectance oximetry. The reflectance based oximeters use a sensor with light emission and detection elements on the same surface of the body part. The optical elements are thus located on the same plane. In this method the light backscattered by the body is used to determine oxygen saturation. Reflection originates from non homogeneity in the optical path. Reflectance oximeters measure functional saturation, which is defined as the percentage of oxyhaemoglobin ($HbO_{2)}$ compared to Hb, which is the sum of HbO_2 and reduced Hb.

Multiple Wavelengths FOTI

Non-invasive measurement of blood oxygen is done in the spectral region from 450nm-700nm, in which light transmission is sufficient to provide both a large penetration depth and an acceptable detected intensity. The determination of the concentration of Hb and HbO_2 requires the measurement of reflectance at a minimum of two different wavelengths. At shorter wavelengths ($\lambda<650$nm), the extinction coefficient of the hemoglobin becomes much higher, thus limiting penetration. At longer wavelengths ($\lambda>700$nm), the absorption of water dominates. Hence two wavelengths, one near red (i.e. 660 nm) and another near infrared (i.e. 880 nm) are chosen for measurement. At the shorter wavelength (660nm). The absorption of light by Hb is more and at longer wavelength (880om), HbO_2 absorbs more light. In other words, at 660nm HbO_2 reflects light more effectively than Hb. This is reversed at 880nm, Hb reflects light more effectively than HbO_2. Thus when both wavelengths of light are passed through a sample of blood, the intensity of light transmission at 660nm is primarily a function of the concentration of HbO_2 in the blood sample, whereas the transmission at 880nm is determined primarily by the concentration of Hb. The concentrations of HbO_2 and Hb are expressed in relative terms (I) as the fraction of hemoglobin that is in the oxygenated form. This is known as percent oxygen saturation. Therefore,

$$\%\ \text{oxygen saturation} = (HbQ_2\ 1\ H_t) \times 100\ \%$$

Where H_t is the total hemoglobin present in the blood sample.

Description of the Fiber Optic Tran Illuminator

The schematic of the designed fiber optic transilluminator prototype is shown in the Figure 3.2. The fiber optic transilluminator comprises of the following sections.

- **Probe Assembly**

The probe consists of a current sensitive photo detector, a red LED and an IR LED. Two wavelengths 660nm and 880nm have been chosen to maximize the precision of the measurement of HbO_2 and Hb. The probe assembly is as shown in Figure 3.3. The spacing between the red LED and the detector is 3mm and between the detector and the IR LED is 8mm. The spacing 1s chosen in such a way that there must be perfect phase detection between transmitted and backscattered light. The detector, red LED and IR LED are placed such that their surfaces are perpendicular to the skin. The photodiode interface needs to be fixed such that the backscattered rays from the human tissue are made to fall perpendicularly on the surface of the photodiode. These three components are held in position by a Velcro strip. Leads are taken from the three components and connected to the corresponding points on the PCB.

- **Light Delivery**

For transmission of light into the human forearm, a switching circuitry is used. Square waves of two different frequencies, one at 5V, 1 KHz to modulate the LED at 660nm and the other at 5V, 15KHz to modulate the 880nm LED are generated and provided as input to the switching circuit. The frequencies are selected so that there is significant phase difference between the transmitted and backscattered light signal.

Figure 3 shows the two LEDs are switched at a suitable speed before being transmitted into the human forearm. For this another square wave generator which provides 100Hz switching signal is used. The red LED and IR LED are driven by the outputs of the switching circuit in an alternate manner. The switching circuit is constructed using IC 7408 and IC 7401. A signal at the switching frequency and a square wave at lKHz are given as inputs to one AND gate whose output is used to drive the red LED. An inverted switching signal at the same frequency and a square wave at I5KHz are given as inputs to another AND gate whose output is used to drive the IR LED. The light emitted out from the LEDs is then transmitted into the tissue.

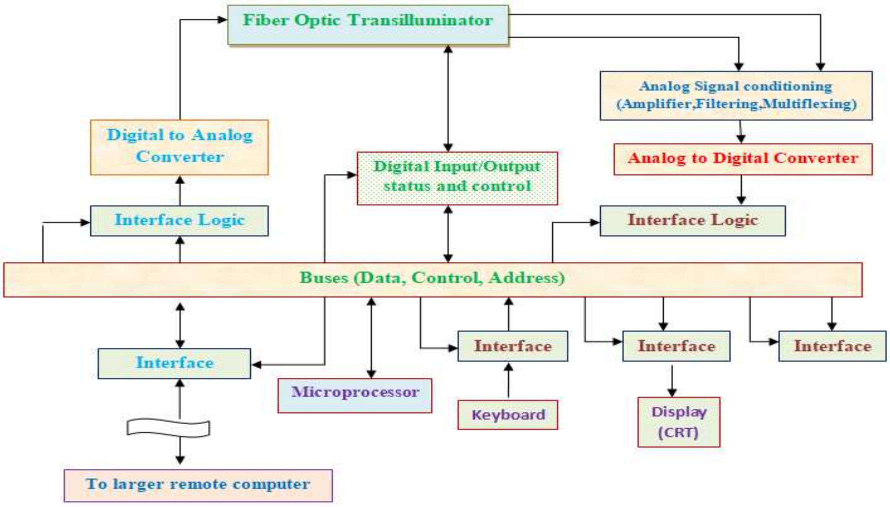

Figure 3: Block Diagram for the Experimental Set Up.

Detection

The light reflected from the subject is detected using a PIN type photo detector. BPW34. Since the photo detector is current sensitive, the output of detector is converted into an equivalent voltage using a current-to-voltage converter. The voltage levels obtained after the current-to-voltage converter are not sufficient to drive the gates. In the demultiplexer, the signal is therefore amplified. Since the signal is a multiplexed version of red and 1R components, a demultiplexer is used to separate out these two signals. The demultiplexer is similar to the switching circuit used at the transmitter. The difference between the transmitter switching circuit and the demultiplexer lies in the signals given as the input. The inputs from the amplifier is given as one input to the AND gate in IC 7408. The other input is the switching signal. The second AND gate inputs are amplifier output and the inverted switching signal.

Thus, the red and IR components are obtained as the outputs of the two AND gates. There exists a phase difference between the transmitted and backscattered light and this difference is detected using a phase detector which is the next stage. Any phase change between the transmitted and backscattered light signal is converted into an equivalent voltage by the converter. This is accomplished by using an XOR gate. When two signals of the same frequency but different phase are given as inputs to an XOR gate, the output will be a measure of the difference in phase. For one XOR gate, the input to the red LED and the corresponding output from the demultiplexer is given as outputs. For the other XOR gate, the input to the IR LED and the corresponding output from the demultiplexer is given as inputs. The peak value of the converters output is detected using a peak detector. The overall circuit diagram of the fiber optic transilluminator is as shown in Figure 4

Data Acquisition and Processing

For processing and display of blood oxygen saturation from the measured voltages, analog to digital conversion is done using PCL 207 ADC/DAC card. It provides 25000 samples/sec acquisition rate and a resolution of 12 bits. The 12 bit conversion gives an overall accuracy of 0.015%. The voltage values obtained from peak detector are fed as input to channels 0 and 1 which is used for determination of percentage oxygen saturation. These voltages correspond to the amount of HbO_2 and Hb present in the tissue bled. These values stored in an array are used to plot the waveforms. Software has been developed to compute the percentage oxygen saturation. The ratio of HbO_2 to that of H_t, is computed using the values obtained from the ADC interface. Oxygen saturation is computed from Equation (3.1) using the Ratio Computation algorithm. The online display of the percentage oxygen saturation versus time is done using the Display algorithm

RATIO COMPUTATION ALGORITHM

- The ratio of HbO_2 to H_t 1s determined from the values stored in the respective arrays.
- The ratio computed is stored in another array for the only one display of the percentage oxygen saturation.
- The look-up table has equivalent percentage oxygen saturation values for the ratio determined.
- Based on the result obtained from the look-up table the subject's critical status is monitored.
- The online display of the percentage oxygen saturation versus time is achieved by following the steps in the Display algorithm

DISPLAY ALGORITHM

- Auto detection of graphics drivers is performed.
- Graphics and local variables are initialized.
- The results of initialization are scanned.
- If any error occurs, then a descriptive error message is displayed.
- Then all graphics settings are reset to their default by setting the view port to the entire screen and moving the current position to the left hand corner of the screen.
- The voltage values stored in the array are plotted against time.
- The graphics system is shutdown by deallocating all memory allocated by the graphics system.
- The screen is then restored to the mode it was in before the graphics was initialized.

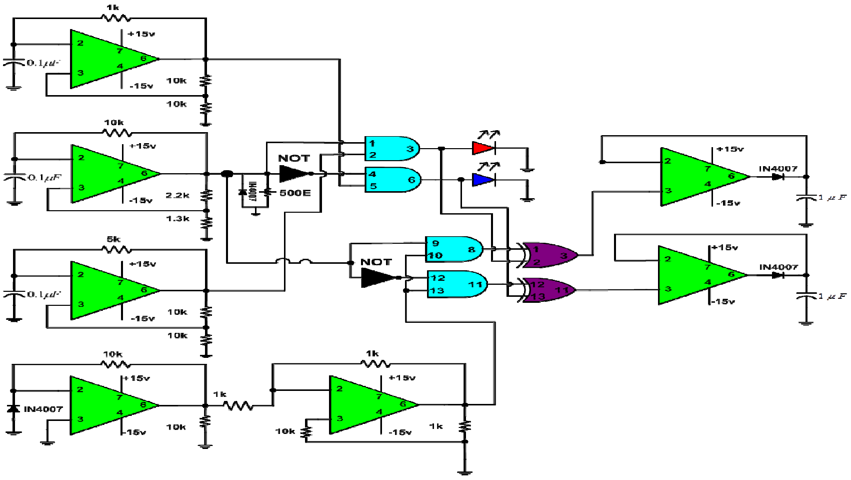

Figure 4: Circuit Diagram for Fiber Optic Transilluminator.

Real Time Plot of Oxygen Saturation

The reflectance values obtained from the ADC interface are used to compute the percentage oxygen saturation. These calculated values are stored and sketched using the graphics system. The real time plot of oxygen saturation obtained for a person in normal condition is shown. The probe was attached to subject's forearm and measurement was carried out. A normal person has an oxygen saturation of 100%. On the top corner of the online plot, the current value of percentage oxygen saturation is displayed simultaneously.

Comparison Reflectance Values of HB and HBO$_2$

The stored values, which correspond to the amount of Hb and HbO$_2$, are sketched using graphic system. This graph serves as a comparison of the amount of Hb and HbO$_2$ in the blood. The variations in the amplitudes of Hb and HbO$_2$ lead to corresponding change in the percentage oxygen saturation. Depending on the patient's condition, this percentage varies. The graph is plotted with Time in seconds on the X-axis and Amplitude in volts on the Y-axis and is shown. The analysis of data described in this chapter demonstrates the assessment of the tissue optical properties by measurement of reflectance. Research reviews (Kalpana, D et al, 2006) on surface reflectance indicate their use for numerous medical applications.

In vivo experimental analysis on the variation of reflectance for different complexioned subjects and variations under hyperemia are first performed.

Results indicate that quantitative information regarding the hemoglobin and melanin content as well as the scattering properties of the skin and the underlying tissue can he obtained. Secondly, reflectance for measurement of blood oxygen is explored. A fiber optic transilluminator with simple sensor application and direct measurement has been described. This meets the requirements of compactness, cost effectiveness and ease of use. This system overcomes the limitations present in the other prevalent techniques. With these features the system could be a good monitoring tool during surgery and postoperative period. Further the switching principle utilized in the system can be applied to a much larger number of sources for the simultaneous determination of the concentration of more chromospheres.

Figure 5: Fiber Optic Skin Film Biosensor.

REFERENCES

1. *Zheng Tang, Wolfgang Tress, Olle Inganäs, Light trapping in thin film organic solar cells, Materials Today, Volume 17, Issue 8, 2014, Pages 389-396, ISSN 1369-7021, https://doi.org/10.1016/j.mattod.2014.05.008.*
2. *Steve Albrecht, Sebastian Schäfer, Ilja Lange, Seyfullah Yilmaz, Ines Dumsch, Sybille Allard, Ullrich Scherf, Andreas Hertwig, Dieter Neher, Light management in PCPDTBT:PC70BM solar cells: A comparison of standard and inverted device structures,*
3. *Organic Electronics, Volume 13, Issue 4, 2012, Pages 615-622,ISSN 1566-1199, https://doi.org/10.1016/j.orgel.2011.12.019.*
4. *Alexander Koppelhuber and Oliver Bimber, "Towards a transparent, flexible, scalable and disposable image sensor using thin-film luminescent concentrators," Opt. Express 21, 4796-4810 (2013)*
5. *Kathrin Happel, Edgar Dörsam, and Philipp Urban, "Measuring isotropic subsurface light transport," Opt. Express 22, 9048-9062 (2014)*
6. *Vladimir Gasparian, Zhyrair Gevorkian and Oscar del Barco," Light transport in one-dimensional arrays of infinitesimal magnetoactive dielectric sheets: Theory and numerical simulations" Physical Review(2013), DOI: 10.1103/PhysRevA.88.023842.*
7. *Shu-jen Lee, Aldo Badano, and Jerzy Kanicki, "Monte Carlo Modeling of the Light Transport in Polymer Light-Emitting Devices on Plastic Substrates" IEEE Journal Of Selected Topics In Quantum Electronics, Vol. 10, No. 1, January/February 2004*
8. *Aditi Malik, Preeti singh, "Free Space Optics: Current Applications and Future Challenges", International Journal of Optics,Vol.2015,Article ID 945483,7pages,2015.*