DESIGN OF VISIBLE LIGHT COMMUNICATION SYSTEM

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ABSTRACT

Visible light communication often known as VLC is a recently developed technology, for low cost and highly efficient data transmission using visible light. VLC is a engineering in which a mere light bulb can send data using the same light signal. In this report we discuss about line of sight (LOS) visible communication system design. They include a transmitter, a channel and a receiver front-end. The transmitter contains an array of white LEDs and the receiver contains a photodiode in order to have the data transmitted through light. We discuss about the design of source and receivers in this paper.

Keywords: *Visible light Communication, Line of sight Communication, Lambertian emission pattern, Photodiode, Channel Path Loss*

INTRODUCTION

White LEDs is replacing the currently used incandescent and fluorescent lamps. Compared to traditional sources white LEDs have the advantages of long life expectancy, high lighting efficiency, no out-of-visible band optical spectrum (other sources have a function of UV and infrared frequencies as well in their spectrum), easy upkeep, low cost and environmental friendliness.

LEDs can be modulated at high frequencies very efficiently and thus can be employed for communication at very high data rates. Thus it is possible to utilize white LEDs for both illumination as well as communication. There are 2 advantages of using white LEDs for Visible light Communication. They are

1. It can attain high power transmission

2. The modulator signal can be well mixed with the white LED, reducing the price significantly

The primary function of white LEDs is to provide illumination. While the current LEDs mostly have fixed illumination pattern, beam control and array arrangements are necessary in order to satisfy a minimum requirement. Since commercially available LEDs have a limited modulation bandwidth, pre-equalization can be performed in order to improve the bandwidth for transmission.

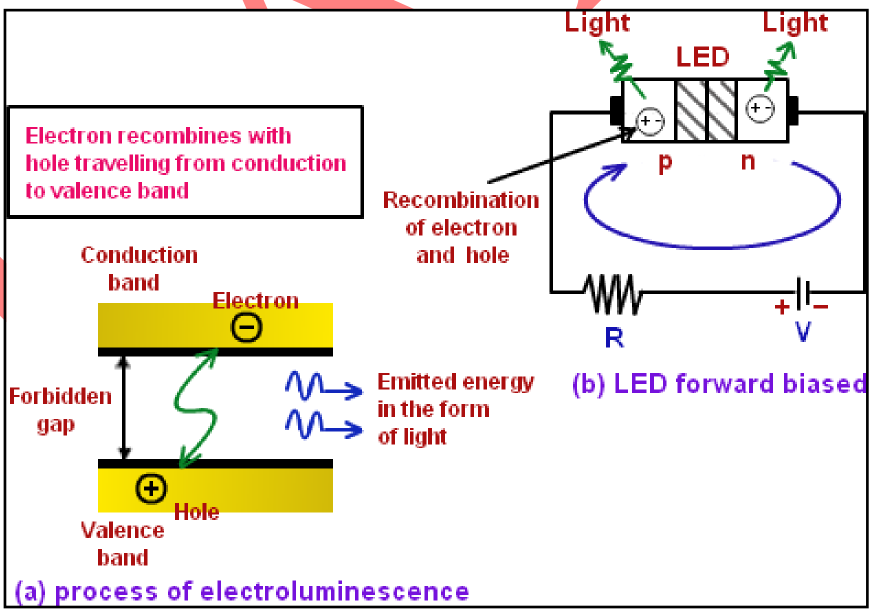
Receiver optimization is a key issue to achieve a high performance communication system. Based on the indoor channel properties and the noise sources in an indoor visible communication system, the photo detector, amplifier and equalization circuit should be designed to maximize the signal to noise ratio (SNR) and minimize the probability of error.

TRANSMITTER DESIGN

The transmitter in VLC is basically a white LED which is used for illuminating a room. The data or internet is received by the system with the aid of an optical transmission line and the modulator modulates the light signal to send information. A simple on-off keying modulation technique can be employed for transferring information. The data rate is so high that the flickering of light is barely noticeable for the people sitting inside the room.

There are 2 methods of creating white light.

1. By mixing the 3 basic colours (red, blue and green)
2. By using the blue light to excite the yellow phosphor so that blue and yellow mix together to give a light that appears white



LED works on the principle of electroluminescence. The electron is excited to conduction band with the help of electrical energy leaving a hole behind in the valence band. When the electron recombines with the hole it emits radiation equal to the bandgap energy and if this energy corresponds to wavelength in the visible region then it emits visible light.

Most commercial white light LEDs are lambertian sources with huge beam angles. In many real application scenarios, these divergent sources do not give the required illumination. In order to improve the efficiency and illumination a beam controller along with an LED array is considered.

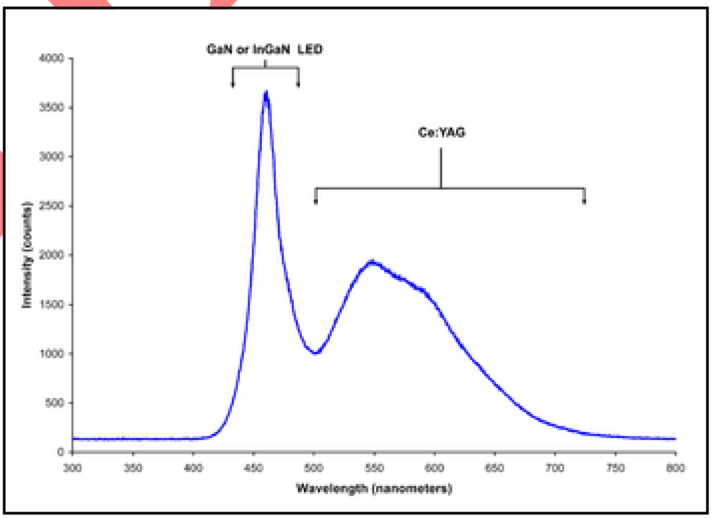
MATERIALS USED FOR PRODUCING WHITE LIGHT

In the first method we get white light by mixing the 3 basic colors (RGB). This method is called multi-colour white LEDs. These LEDs require electronic circuits to hold in the blending of these colors. Even if the emission direction changes by a small angle, a different color might be developed. Hence it is not used practically as the price goes up.

The second method is to use blue LED to excite yellow phosphor which produces a luminosity that appears to be white. The method calls for coating one color (mostly blue LED made of InGaN semiconductor) with different phosphor materials (mostly yellow phosphor to complement the blue LED) to produce white light. The InGaN LED is coated with Y3Al5O12:Ce phosphor, commonly known as YAG: Ce phosphor, (which is also called as yellow phosphor) to raise the white illumination.

Phosphor based LED's efficiency losses are due to heat loss from stokes shift and also other phosphor related degradation issues. But the luminous efficiency of phosphor based LED is much more eminent than the normal LED because the human eye is more sensitive to yellow light than other colors in the visible spectrum.

Another method to develop white light is based on epitaxial growth of Zinc Selenide (ZnSe) on ZnSe substrate.. It simultaneously emits blue light from the active region and yellow light from the substrate. A new style of wafers composed of gallium-nitride-on-silicon (GaN-on-Si) is being applied to produce white LEDs using 200-mm silicon wafers. It is predicted that by 2020, 40% of all GaN LEDs will be made with GaN-on-Si



Presently there are 2 cases of white LEDs in the market: 1-chip LEDs (blue LED with yellow phosphor) and 3-chip LEDs (red, green and blue chips), the former being dominant because of its simplicity of mass production.

EFFECIENCY PARAMETERS

Color	Wavelength range (nm)	Typical efficacy (lm/W)	Typical efficiency (W/W)
Red	620 < λ < 645	72	0.39
Red-orange	610 < λ < 620	98	0.29
Green	520 < λ < 550	93	0.15
Cyan	490 < λ < 520	75	0.26
Blue	460 < λ < 490	37	0.35

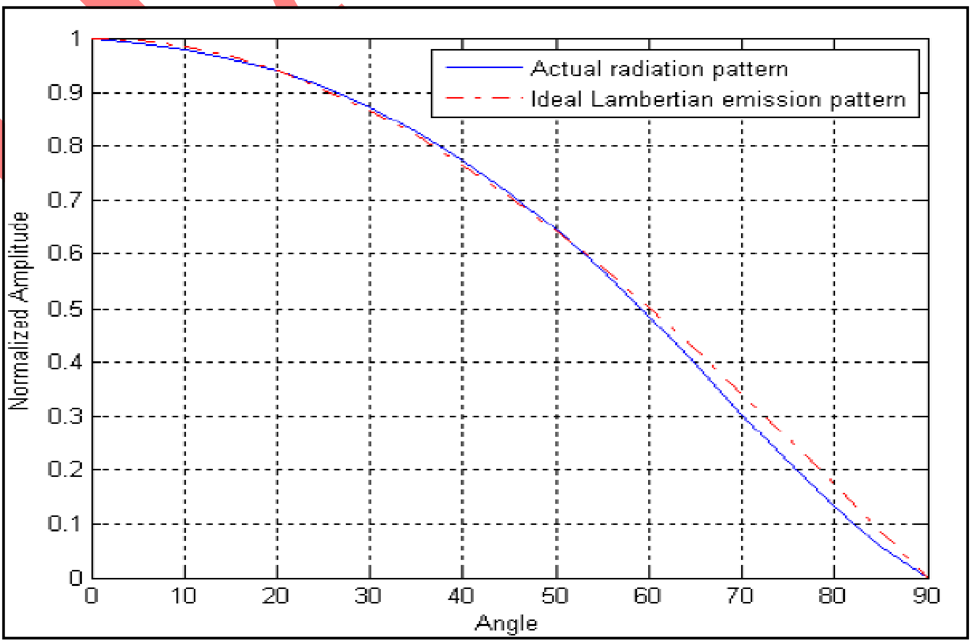
It has been established from the table that blue has a very good efficiency when compared to other LEDs but the efficacy is very less. The phosphor coating helps to increase the efficacy by increasing the luminous intensity. Hence the blue LED coated with phosphor is the best means to produce white light.

White light has a very broad bandwidth and the voltage drop (ΔV = 3.5V). Hence it can be effectively used to transmit data at a very high data rate.

CHANNEL PATH LOSS

Air is the medium between the emitter (LED) and the receiver (photodiode). There exists a lot of noise which might affect the signal. This noise can be additive or convolutional. Noise can change the modulated signal and corrupt it. The major sources of interference in an indoor VLC system include ambient light noise (background solar radiation), ambient light induced shot noise in the photodetector and the electrical pre-amplifier noise.

An experiment performed shows that there is a slight deviation of the emission pattern from the lambertian emission pattern. The results are plotted on a graph.



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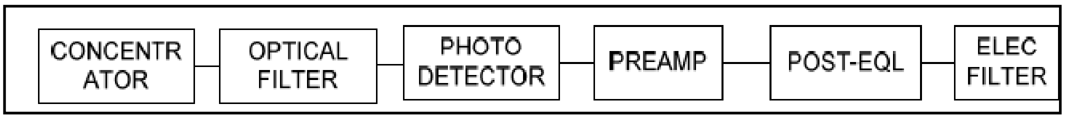
RECEIVER FRONT END DESIGN

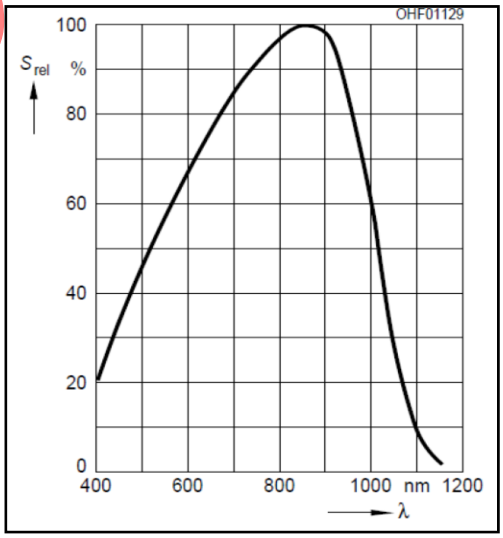
A typical indoor optical wireless communication receiver front end usually consists of a concentrator, an optical filter, a photodetector, a pre-amplifier, a post equalizer and an electric filter as shown in the block diagram.



The concentrator helps in concentrating all the radiation available on the photodetector in order to reduce all possible errors. Since white light has a huge bandwidth the data can be modulated only at a particular frequency. An optical filter is used so that only the modulated frequency passes through and all other frequencies are cut-off. Photodetector is the most important part of the receiver as this component converts the optical energy into electrical signals or the data which was transmitted. The blocks after the photodetector is used to improve the quality of the data obtained for further use.

Generally there are 2 kinds of photodetectors that can be utilized in a Visible Light communication system: the photodiode and the image sensor. The photodiode has been widely adopted in optical communication system with relatively large received optical power. The advantages of photodiode include its large receiving bandwidth and low cost.

The photodiode is connected in reverse bias. Any light falling on it will create an electron hole pair and the current of this electron is measured. The more the intensity of light the more is the current generated. The responsivity of the photodiode is such that it gives maximum current for a particular wavelength of light.



COST OF THE SYSTEM

Indoor visible light communication system is very cost effective. The main cost is the modulator which modulates the data and sends it to the LED and the receiver model. The LED array might cost around Rs100. The modulator and the demodulator together will cost around Rs1000. The cost of the photodiode depends on the wavelength at which the light is modulated. Here is a table which contains the prices for different specifications:

LED	Luminous Intensity	Color	Price
RL5-R12008	12000 mcd	Red	$0.59
RL5-W18030	18000 mcd	White	$0.99
WP7113IT	80 mcd	Red	$0.15
LW514-BULK	32000 mcd	White	$0.66

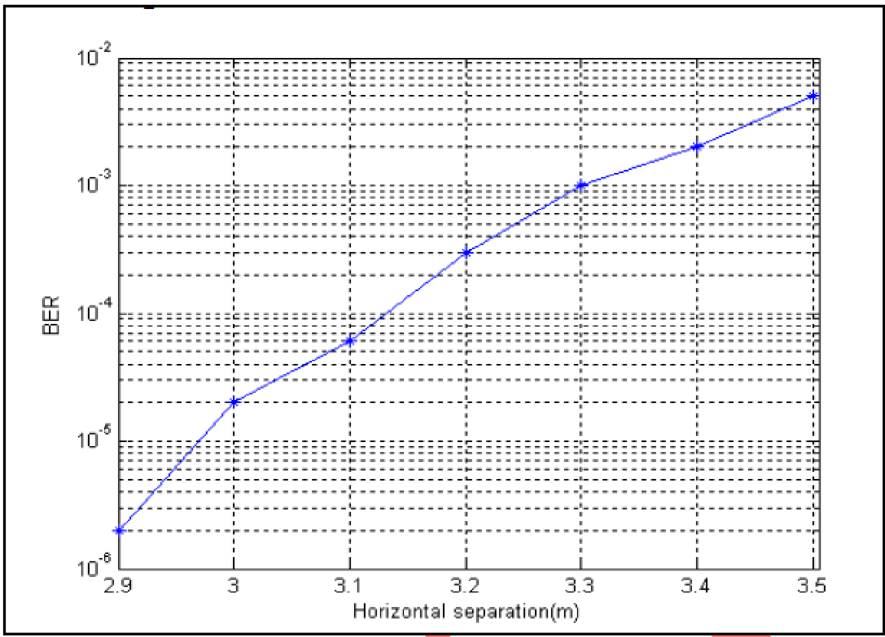
Categorical Value Analysis of LEDs

Photodiode	Spectral Range	Wavelength @ Peak Sensitivity	Cost	Response Time
SFH 203 P	400-1100 nm	850 nm	$0.72	5 ns
SFH 229	400-1100 nm	850 nm	$0.66	10 ns
AD800-11-TO52-S1	300-1100 nm	600 nm	$211.24	1 ns
PD70-01C/TR10	150-1200 nm	900 nm	$0.83	50 ns
PD15-22C/TR8	400-1100 nm	900 nm	$0.47	10 ns
PS1.0-6b TO	350-1100 nm	925 nm	$32.33	30 ns/10 ns
720-BPW21	400-1100 nm	550 nm	$6.70	1.5 us
PDA10A	200-1100 nm	750 nm	$283.00	150 MHz BW ~ 6.7 us

Categorical Value Analysis of Photodiodes

PERFORMANCE OF THE SYSTEM

The BER performance of a visible light Communication system according to an experiment conducted is given below



It was found that for a physical separation of around 2.9m to 3m between the source and the receiver the BER was negligible. The distance between the roof and flooring of a room is around 3m and hence this system will be very much suitable for very high speed communication.

CONCLUSION

Visible Light communication is expected to replace the internet connection provided through telephone cables. It is expected that optical fibers carry data till the buildings and internet connection inside buildings will be provided by the white LED fixed in the rooms for illumination. Some other applications of Visible light communication are:

1. Smart lighting
2. Mobile connectivity
3. Vehicle and transportation
4. Defense and security
5. Underwater communication
6. Hospitals and health care
7. Location based services, etc

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