

Light-Fidelity: A Crown to Optical Wireless Communication

Satyanarayan Purohit¹, Subash Dahal²

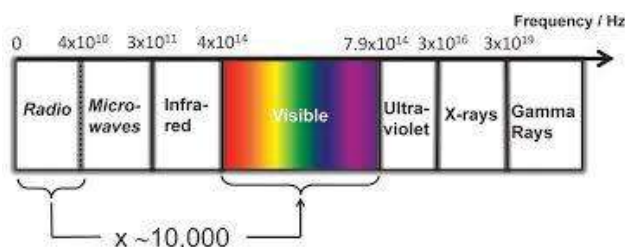
^{1,2}Department of Information Science & Engineering, Sambhram Institute of technology, Bengaluru

Abstract: In the modern era of technology INTERNET has become the major demand, as a result of these people are constantly in search of wifi hotspots. But the major backlog is its SPEED. LI-FI or new life of data communication is best alternate to wifi in optical wireless communication. Li-Fi is an optical wireless technology that use's LED'S for data transmission "Data through illumination" taking fiber out of fiber optics by sending data through LED's which varies in intensity faster than the human eye can follow, which was proposed by HERALD HASS. Li-Fi provides speed up to 500MBPS (30GBPS/ min). This paper provides an idea and technique of how Li-Fi based systems can be improved and developed. It is ECONOMICAL and ECO-FRIENDLY way of optical wireless communication

Keywords: light fidelity (Li-Fi), wireless fidelity (Wi-Fi), light emitting diodes (LEDs), optical wireless communication (OWC)

1. Introduction

Li-Fi Technology is new advent of wireless Communication. It has become a milestone in OWC and refers to 5G visible light communication technology. Since the bandwidth is fixed, rate of data transfer decreases as the number of devices that access the internet increases. Radio waves are the tiniest part of the spectrum that is available for this data transfer.



To overcome this problem Herald Haas a German scientist demonstrated the concept of Li -Fi technology and promoted it in the year 2011 in his TED global talk on Visible Light communication (VLC).

LED bulbs



Figure 1

Herald Haas referred to this light as D-light which can produce data rates higher than 10 megabits per second. He used red, blue, green and white LED bulbs for his demonstration.

Li-Fi is an optical version of Wi-Fi. Li-Fi consists of a wide range of wavelength and frequencies right from infrared to ultraviolet along with the visible light. Since Li-Fi uses visible Light Communication, there are no ill effects on the health of the class of the people dealing with it, as visible light is part of our life.

Moreover, in this spectrum 10,000 times more space is available and it also multiplies to 10,000 times more availability as a light bulb and street bulbs are available already. Since a large amount of light is being used in the technology, its free from internal and external hazards. This leads more use the Li-fi technology when compares with Wi-Fi.

2. Design of Li-Fi system

Li-Fi is highly based on VLC. VLC uses visible light between 400 THz and 800 THz for data transmission and illumination. For the wireless transmission of data, VLC uses fast pulses of light.

Major components of Li-Fi system are:

1) White LED with high brightness as shown in the figure 2. White LED used in Li-Fi system is transmission source



2) A Silicon Photodiode

Silicon photodiode as receiving element should have a good response to the visible light.



Conversion of basic light to electricity

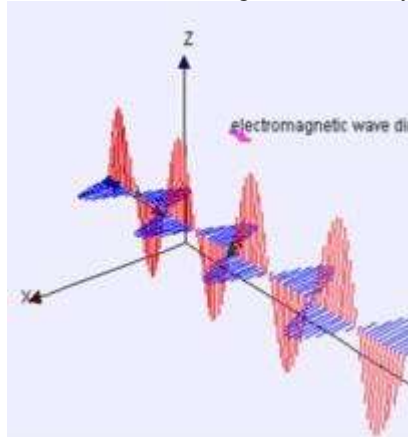


Figure 2

In 3D diagram shows a plane linearly. Polarized wave propagating from left to right with the same wave equation from left to right where
 $E = E_0 \sin(-t+k.r)$ and $B = B_0 \sin(-t+k.r)$

In a region with no charges ($\rho=0$) and no currents ($J=0$) such as in a vacuum, equation (1) is reduced Maxwell's equation

$$\begin{aligned} \nabla \cdot E &= 0 & \nabla \times E &= -\frac{\partial B}{\partial t} \\ \nabla \cdot B &= 0 & \nabla \times B &= \frac{1}{c^2} \frac{\partial E}{\partial t} \end{aligned} \quad \dots(1)$$

Taking the curl (∇) of the curl equation, and using the curl of the curl identity

$$\nabla \times (\nabla \times X) = \nabla(\nabla \cdot X) - \nabla^2 X$$

we obtain the wave equation (2)

$$\frac{1}{c^2} \frac{\partial^2 E}{\partial t^2} - \nabla^2 E = 0, \quad \frac{1}{c^2} \frac{\partial^2 B}{\partial t^2} - \nabla^2 B = 0 \quad \dots(2)$$

Which identify

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 2.99792458 \times 10^8 \text{ ms}^{-1}$$

C is the speed of light in the free space. In materials with

$$V_p = \frac{1}{\sqrt{\mu_r \mu_0 \epsilon_r \epsilon_0}}$$

relative permittivity ϵ_r And relative permeability μ_r , the phase velocity of light becomes

This is usually less than c.



In addition E and B are mutually perpendicular to each other and the direction of wave propagation, and are in phase with each other. A sinusoidal plane wave is one special solution of these equations. Maxwell's equations explain how these waves can physically propagate through space. The changing magnetic field creates a changing electric field through Faraday's law. In turn, that electric field creates a changing magnetic field through Maxwell's correction to Ampere's law. This perpetual cycle allows these waves, now known as electromagnetic radiation to move through space at velocity c.

3. Working

Implementation of Li-Fi is done through high bright white LED light bulbs. These are used for illumination by applying constant current. Output of light can be made to vary at extremely high speed by fast variation of current.

The logic behind working of Li-Fi is simple. If the LED is on digital 1 is transmitted and if LED is off digital 0 is transmitted.

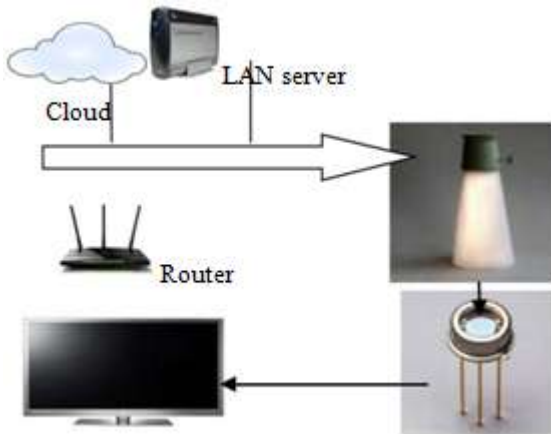
The operation of this can be tabulated as follows:-

LED	Signal transmitted	Power
ON	DIGITAL 1	
OFF	DIGITAL 0	

LED's can be switched on and off within nanoseconds. So that, the human eye cannot detect the data transmission and also allows us to transmit the data through light.

Enhancement could be made to be by using an array of LED's for parallel transmission or by combining three colors red, green and blue LED's. These 3 different colored LED is having 3 different frequency, each of which has a different channel for data.

To build a message, LED is flashed for a few couples of times or an array of LED's which is made of 3 different colors red, blue and green is used. LED is one end and photo detector is the other end. Single LED or multi LED does data transmission through visible light and photo detector at the receiving end receives the data transmitted through the light of LED and convert this light into electrical signals and pass it on to the device connected to it.



New stream of data can be generated by varying the data rate of the LEDs. The visible light communication data rate can be increased by parallel data transmission of LEDs. The Li-fi emitter has mainly 4 subassemblies:-

- 1) Enclosure
- 2) Printed circuit board (PCB)
- 3) Bulb
- 4) RF power amplifier (PA)

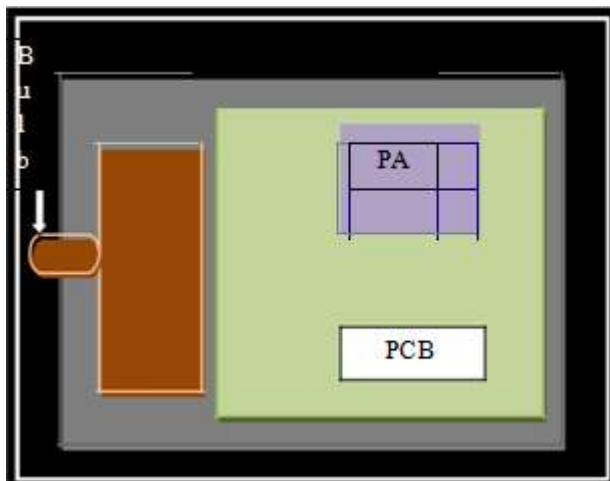


Figure 4: Block diagram of Li-fi sub assemblies

A radio frequency (RF) signal is generated by a solid state power amplifier (PA) and is guided into the electric field which is just above the bulb. The electrical inputs and outputs are controlled by printed circuit board (PCB) and enables the microcontroller to utilize different lamp functions. The contents of the bulb are vaporized to plasma state by the high concentration of energy in the electric field at the bulbs center. An intense source of light is generated by this controlled plasma state. All these components are enclosed in an aluminum enclosure as shown in the figure 5.

The main component of Li-fi emitter is bulb assembly. It constitutes of sealed bulb embedded in the dielectric material. The dielectric material used serves for the 2 purposes

- 1) For the RF energy transmitted by the power amplifier (PA), it acts as a waveguide.
- 2) It acts as an electric field concentrator that focuses energy in the bulb.

Bulb subassembly

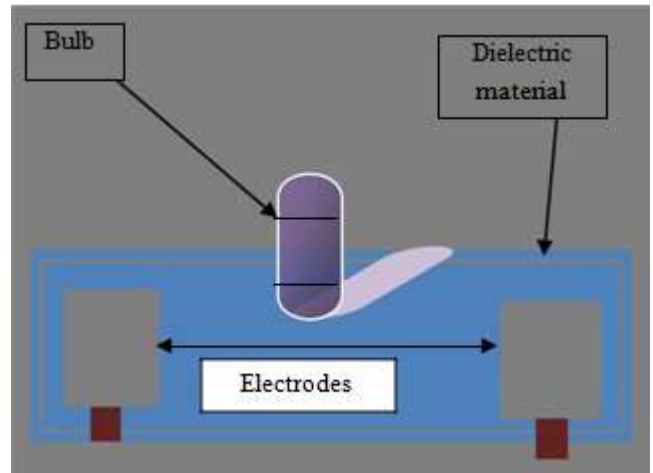


Figure 5

The material in the bulb is rapidly heated to plasma state by the energy from the electric field. This emits light of high intensity and full spectrum. This includes advantages such as high brightness, high luminous intensity of the emitter. The entire arrangement is robust without any degradation.

The failure mechanisms which are associated with tungsten electrodes and glass to metal seals result in useful lamp life of 30,000+ hours. Above this the outstanding combination of high temperature plasma and digitally controlled solid state electronics results in an economically produced family of lamps which are scalable in packages from 3,000 to over 100,000 Lumens.

Literature Survey

Neil Savage states that As LEDs become a more common source for room lighting, they're opening a new pathway for linking mobile devices to the Internet, with the potential for wider bandwidth and quicker response time than Wi-Fi.

Herald haas states that these are pursuing ultra parallel visible light communication, which would use multiple colors of light to provide high-bandwidth linkages over distances of a few meters. Such a Li-Fi system, as it's been dubbed, could supplement or in some instances replace traditional radio-based Wi-Fi, they say. The 802.11ad Wi-Fi standard for the 60-gigahertz radio band has reached just under 7 GB/s, so Li-Fi would more than double that rate. It's estimated that the Li-Fi market will be worth more than \$6 billion by 2018, according to analysis by Markets and Markets.

4. Applications

Few applications of Li-Fi system are:-

- 1) Mobile devices such as laptops, smart phones, tablets can be directly interconnected using LiFi. Higher data rates are provided shortrange communications and it is more secure
- 2) Li-Fi is an alternate to electromagnetic interference of radio-frequency waves which are hazardous to the environment.

- 3) It is an added advantage to use Li-Fi in the hospitals and healthcare as it does not emit electromagnetic interference. Therefore does not interfere with an MRI scanner and other medical equipments.
 - 4) Underwater communication: use of RF is hazardous to marine life as there is strong signal absorption in water. Short range communication has a solution through Li-Fi.
 - 5) For vehicle-to-vehicle and vehicle-to-roadside communications, LED's fixed in the headlights of the vehicles and traffic signals can be used which in turn helps with safety of road and the management of traffic. Li-fi car lights could even alert other drivers when vehicles are too close.
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5. Limitations

- 1) Artificial lights cannot penetrate through any opaque material and walls, but radio waves can penetrate. So Li-Fi will never be as fast as Wi-Fi enabled device in the open air.
- 2) Since the bandwidth of radio waves is depleting, Li-Fi can still be a boon although it has few limitations.
- 3) Li-fi works efficiently only with LEDs and florescent light, but very low with bulbs.
- 4) The use of very high frequencies 400-800 THz limits to point to point communication and very short distance as well.
- 5) Since light is the main component of data transfer the facilities can be adapted with very easy infrastructure for installation.

Comparison between Li-Fi and Wi-Fi

<i>Factors</i>	<i>Li-fi</i>	<i>Wi-Fi</i>
Speed of data transfer	>1GBPS	150MBPS
Medium	Light	Radio waves
Operation cost	Low	High
Freq. Of operation	THz	2.4Ghz
Network topology	Point to point	Point to point
Power needed	High	Low
Security	High	Low
Connectivity	High	Low

6. Conclusion

In our paper we have described how Li-Fi technology came into existence and took a lion share in Optical Wireless Communication. As we have stated at the beginning, Li-Fi uses visible light for its operation which cost effective and eco-friendly. Therefore, it has many advantages over Wi-Fi, which uses Radio spectrum of data transmission. As radio-waves are affecting the ozone layer, it is hazardous to living creature so, we must reduce the use of these waves. And the best replacement for this would be Li-Fi.

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