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TOWARDS THE GREEN COMMUNICATION SYSTEM: LI-FI

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Abstract
With the demand for radio spectrum increasing tremendously, there is a pressing need for a better technology that is capable of giving more bandwidth at lesser implementation cost and reduced inimical effects to the environment. Thus, LIFI or light fidelity, which uses visible light for communication through LEDs can be an alternative. This paper discusses various aspects of li-fi and its superiority overwi-fi. Furthermore, it also deals with the implementation of li-fi in real life.

Introduction
There are around 2,405,518,376 internet users sharing the radio spectrum in today's world [1]. Naturally, all of us have become victims of the slow speed at peak hours. Each year, the number of users continues to increase and it becomes more difficult to accommodate each one of them. Consequently, we need to move onto using other regions of spectrum. But, x-rays and gamma rays have serious health issues. Hence, we resort to visible light communication. Harold Hass, coined the term "Li-fi" or LIGHT FIDELITY and is a believer of the fact that using LEDs, thousands of data streams can be sent at high speeds in parallel.
The technology being used to accommodate multiple users is SIM OFDM(subcarrier index modulation –orthogonal frequency division multiplexing) and QAM (Quadrature Amplitude Modulation) in combination with On-OFF shift keying is used for modulating each user data. [2].It has an ability to reduce peak system power, thus, finds its use in optical wireless communication.
Li-Fi is a 5G technology which is based on the Visible Light Communication (VLC). It is also part of the IEEE 802.15.7 standard for short range wireless optical communication using visible light. [3]

Fig1. LiFi Bulb

Principle
The heart of Li-Fi technology is the high brightness LEDs. Light emitting diodes can be switched on and off very fast as the switching time in these devices is in the order of nano-seconds. Due to this speed, the rate is in the order of Giga Hertz. At present, commercial LEDs are limited to 1mm. Research is on to reduce its size to 1um,resulting in a hundred times faster speed and thousand times lesser space compared to the original LEDs. [4]
VLC is a data communication medium, which uses visible light between 400 THz (780 nm) and 800 THz (375 nm) as optical carrier for data transmission and illumination. In this type of system, fast pulses of light are used to transmit information. The rapid toggling of the LEDs between ON and OFF state, gives rise to a binary sequence of 1's and 0's, which isn't visible to the human eye. Hence, output appears constant. Data rate of the order of 100 Mbps is achieved by using high speed LEDs
The range of the optical frequency band is wider than that of the radio frequency band. The LEDs are capable of providing intensities that cover the optical range, thereby efficiently utilizing the entire spectrum.

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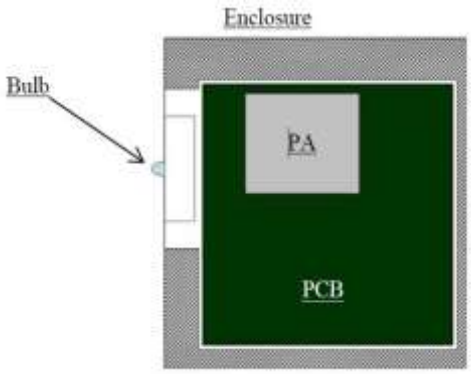

Fig2. Construction

Construction

LIFI system consists of a transmitter section and a photodiode as the receiver.
The emitter system consists of 4 primary sub-assemblies:

1. **APCB (printed circuit board)** controls the electrical inputs and outputs of the lamp and houses. The microcontroller is used to manage different lamp functions.
2. An **RF (radio-frequency)** signal is generated by the solid-state **power amplifier** and is guided into an electric field about the bulb. The bulb content is vaporized into a plasma state due to the high concentrated energy of the electric field. This controlled plasma generates an intense source of light.
3. All of these subassemblies are contained in an aluminum **enclosure**
4. The bulb sub-assembly is the main. A sealed bulb is embedded in a dielectric material which serves two purposes. It acts as a waveguide for the RF energy transmitted by the PA and concentrates the field in the bulb to focus the energy. The energy heats the material to a plasma state which emits light of full spectrum.[5]

This is very advantageous due its good color quality, high brightness, and has a long life and the solid state electronics and the plasma combination is very economical.

Working and implementation

For setting-up an all-optical wireless link, we need the following:

White LED

It is the source of data to be transmitted. LED is the most preferred source of light as it consumes lesser power compared to other light sources.

An added advantage with is that, the lifetime of LEDs is quite long, hence the cost of replacing the components is reduced. They also provide good visibility, which enhances the clarity in viewing the input. To further increase the data rate, parallel data transmission using LED arrays, may be used where each LED transmits a different data stream. LEDs of different colors may be used for different channels simultaneously, as each color represents a different frequency.[7]

Switch

It is used as a control mechanism for generating binary inputs. When the switch is in the ON position, the LED is supplied with a high voltage from the battery. Hence, the LED turns ON, thereby indicating logic 1. Similarly, logic 0 is generated when the switch is OFF. The required message sequence is modulated and is observed by the pattern in which the LED flickers.

Silicon photodiode

A silicon photodiode which shows good response to visible wavelength region serves as the receiving element.

The general principle behind a photodiode is that when a light is incident on the depletion region of a semiconductor, free electrons and holes are generated.

These electron-hole pairs generate a current, which is proportional to the intensity of the incident light. So, when the light from the LED is received, it is converted to photo current and has to be amplified through an operational amplifier, so that it can be detected with minimal errors.

White LED

Finally, to verify the output, an LED is placed on the receiver side. This LED receives the amplified photo current. The LED glows when the current is high, i.e., when the input signal is a binary 1 and is OFF for binary input of 0. The block diagram of the circuit is given below

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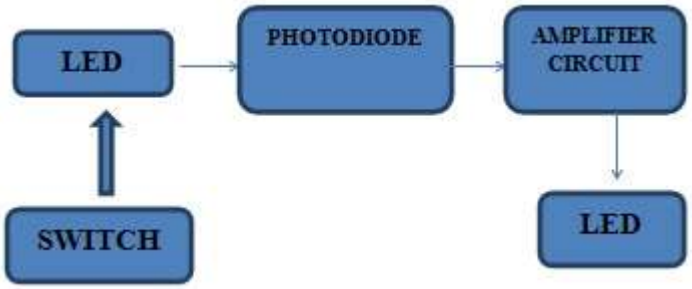

Fig 3: Block Diagram of a Li-Fi Set Up.

Parameter	**Li-Fi**	**Wi-Fi**
Carrier	Light	Radio frequency wave
Speed of data transfer	>1Gbps	150Mbps (IEEE)
Spectrum Range	10000 times greater than Wi-Fi	Limited (Frequencies below 3THz
Operating frequency	In Tera Hz (400-800)	2.4 GHz
Cost	Cheaper than Wi-Fi because there is no license	It uses radio spectrum which is Licensed
Security	Highly secure	Not very secured because Radio waves can penetrate through walls
Usage	Everywhere (No restriction)	Cannot be used underwater and in critical environments like hospitals, petrochemical industries etc

OLEDS

According to a Scottish researcher, getting better control of the light emitted from Organic LED (OLEDs) could lead to faster links between the Internet and mobile devices.[8]

OLEDs on top of the LEDs can act as a color conversion layer, multiplexing the signals into other colours. OLEDs are malleable. Due to this it would be easy to imprint a diffraction grating into them. Such gratings could control the direction in which the signal was sent.

By using this in the LIFI system can get a higher bandwidth by using different colours to send diverse signals.

OLEDs are light - emitting diodes in which the emissive electroluminescent layer is a film of organic compound which emits light in response to an electric current.

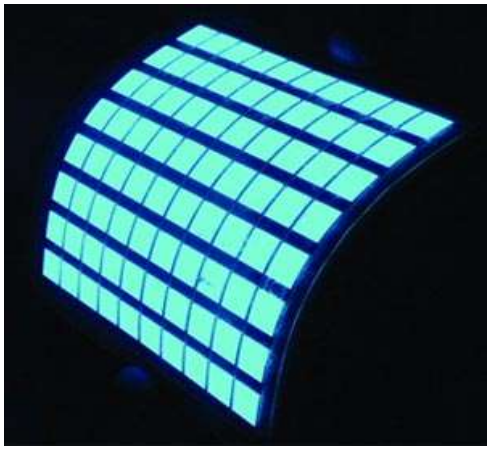

Fig 4. OLED

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A typical OLED is composed of a layer of organic materials situated between two electrodes, the anode and cathode, all deposited on a substrate. A voltage is applied across the OLED such that the anode is positive with respect to the cathode. A current of electrons flow through the device from cathode to anode, as electrons are injected into the conduction band of the organic layer at the cathode and withdrawn from the valence band at the anode.
An exciton is formed by the recombination of the holes and electrons due to the electrostatic force. This happens closer to the emissive layer, because in organic semiconductors holes are generally more mobile than electrons. The decay of this excited state results in a relaxation of energy levels of the electron, accompanied by emission of radiation whose frequency is in the visible region.
A drawback of OLEDs is that it emits a fairly broad spectrum of light, and different wavelengths will pass through the grating at different angles, forming a rainbow. Research is still ongoing to get the narrow width characteristics.

Limitation of LI-FI

Even though Li-Fi is one of the best technologies so far, it faces the following problems:

1. Light can't pass through opaque objects, so if the receiver is inadvertently blocked in any way, then the signal will be immediately cut out. As a result, it is applicable to mainly - Line Of Sight (LOS) communication. If the light signal is blocked we can switch over to radio waves.[6]
2. Interference from external light sources(eg: sunlight, normal bulbs), which may be present in the path of transmission can affect the reliability of the entire system.

Applications

1. Operation theatres (OTs) do not allow Wi-Fi due to radiation concerns as it may be hazardous to patients. Usage of Wi-Fi in the hospitals interferes and at times blocks the signals of the monitoring equipment. To overcome this and to make OT tech savvy, Li-Fi can be used for accessing internet and controlling medical equipment.[2]
2. This technology can provide speedier internet access. Hence, it can replace Wi-Fi at educational institutions and at companies.
3. Li-Fi can be used to communicate with the LEDs of the cars, thereby managing traffic in a better manner. Furthermore, a "smart" LED car light can also alert drivers when other vehicles are too close.
4. Power plants need fast, inter-connected data systems so that demand, grid integrity and core temperature can be monitored efficiently. Wi-Fi isn't recommended for the sensitive areas, surrounding the power plants and so Li-Fi can offer safe, abundant and cost effective connectivity atsuch sensitive locations.
5. In aircrafts, Li-Fi can be used for data transmission at a high rate. It can easily provide high speed internet using light sources such as overhead reading bulb, etc. Also, it does not interfere with the navigational systems of pilots.

Conclusion

In the near future, data for laptops, smart phones etc. can be transmitted using the light in the room, as a carrier. By virtue of this technology, we can enter into a new era of a greener and cleaner future. Micron sized LED's being developed, will acknowledge the growth of Li-Fi. It has a brighter chance to replace traditional Wi-Fi because of the growing population and the increase in need for wireless internet. It promises to resolve bandwidth limitations and usage restrictions. The possibilities of applications are numerous and can be explored further.

Acknowledgment

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