International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 13, Number 12 (2020), pp. 5182-5189


# Exploring the future of Li-Fi

**Vilma Fernandes[1], Jivan Parab*[2], Gourish Naik[3]**

*[1]Research Scholar, Electronics Programme, School of Physical and Applied Sciences, Goa University, Taleigao Pleateau, Goa -403206, India.*

*[2]Associate Professor, Electronics Programme, School of Physical and Applied Sciences, Goa University, Taleigao Pleateau,Goa -403206, India.*

*[3]Retired Professor, Electronics Department, Goa University, Taleigao Pleateau,Goa -403206, India..*

** (Corresponding author ORCID: 0000-0002-7462)*

**Abstract**

Wi-Fi is everywhere and yet it is impossible to imagine connectivity without an Wi-Fi. In the recent past the technology Li-Fi is making a way to replace Wi-Fi. Li-Fi is a superfast wireless communication system for data transmission. Till date, for short distance wireless communication Wi-Fi is used because of its speed. Li-Fi on the other hand gives better bandwidth efficiency and security. As Li-Fi uses Optical light for communication, the source is LEDs , that are rapidly replacing incandescent light bulbs for their energy savings and durability — to transmit data so it provides illumination and wireless data communications at the same time and with the same device. The lighting panes used for illuminating buildings, streets, medical centres, malls etc., allow us to transfer huge volumes of data simultaneously and concurrently and that too at very high speeds. The paper presents the use of Li-Fi communication technology in various applications such as Smart city, Healthcare, Education, Smart homes, Internet, Aviation, Automotive, Industrial. We have experimentally demonstrated the transmission of data through the use of Li-Fi. This paper also discusses about the selection of Light source (Transmitters), Detector (Receivers), modulation techniques, orientation and alignment to improve the efficiency of Li-Fi system.

**Keywords:** Light Fidelity (Li-Fi), Wireless Fidelity (Wi-Fi), Visible Light Communication (VLC), IR LED, smart city, wireless

## I. INTRODUCTION

Light Fidelity (Li-Fi) is an upcoming and futuristic branch of optical wireless communication used as an alternative to Wireless Fidelity (Wi-Fi) used for indoor communications [1][2]. Since, Li-Fi has a much larger spectrum bandwidth than the radio frequency spectrum, which is used by Wi-Fi, Li-Fi provides a dual characteristic of transmitting data at a very high rate and also provides a higher bandwidth to allow more users to utilize this large bandwidth. Professor Harald Hass, from University of Edinburg is the first person who coined the term Li-Fi. Li-Fi Light emitting diodes (LED) are not only energy efficient, but also help in reducing carbon footprints (reduction in green-house gases, like $CO_2$ emission in the atmosphere).

Using Li-Fi, scientists have been able to achieve data speeds of 224 GB/Sec in the laboratories in 2013[3]. The ability to make huge advances and to use the internet efficiently is possible using the Li-Fi. Researchers have experimented with the Li-Fi technology, not only in the laboratories, but also in the offices and industrial units and have been able to achieve very high data transmission speeds of about 1GB/Sec. Hence, Li-Fi transmits data at speeds which are hundred times faster than Wi-Fi speeds[4]. Also, there exists evidence of several other platforms on which Li-Fi can be implemented. Some have also designed a smart lighting solution for an industrial environment where the data communication was done through light. They have also done a private project with a private client by setting up a Li-Fi network to access the Internet in their office space.

The obvious benefits of Li-Fi over Wi-Fi are:

1) High data rate.
2) Higher security.

While, Li-Fi will probably not completely replace Wi-Fi in the coming years, the two technologies could be used in tandem to achieve more secure and efficient networks [5]. Since, our homes, offices, industry and buildings have already been fitted with infrastructure to provide Wi-Fi and ripping all of this first to replace it with Li-Fi technology is not particularly feasible. Li-Fi experts reported that Haas and his team have launched a company(Pure LiFi) ,that offers a plug and play application for a secure wireless internet access with a capacity of 11.5MB/sec which is comparable to the first generation Wi-Fi. A French tech company OLED Comm is in the process of installing its own Li-Fi technology in local hospitals. Due to this, many applications would be successful like providing internet through the lighting LED bulbs, thus, communication and illumination taking place simultaneously. We just must replace them with an Integrated Chip (IC) to every LED illuminating device, thus providing high wireless data transmission and illumination, and hence the world will be a cleaner, with less carbon footprint and even have a brighter future.

The projected annual growth rate for the Li-Fi market for the years from 2013 to 2018 was 82%. And, its net worth would be $6 billion per year by the year 2018 [6]. Since Li-Fi provides illumination, it doesn't mean that the transmission will take place only during the emission of the bright light emitted by the

LED, but rather, we can configure the light bulbs to transmit the data effectively even by dimming the LED lights to a very low value efficiently. We can also use IR LED's to transmit light effectively and efficiently even in pitch darkness. Since Li-Fi is not susceptible to Electromagnetic radiations, the Li-Fi signals will not interfere with the signals in the electromagnetic sensitive areas and hence has the advantage of being used in such areas effectively, like nuclear plants, hospitals, aircrafts etc. The Wi-Fi technology transmits data over the electromagnetic spectrum whereas the Li-Fi technology transmits data over the Visible light, Ultraviolet light and the InfraRed lights. There is a possibility of the Wi-Fi spectrum to reach its maximum capacity limits soon [7]. The visible light spectrum is ten thousand times higher than the electromagnetic radio frequency spectrum. The Li-Fi technology is also much cheaper than the Wi-Fi technology in terms of cost and implementing the infrastructure. The drawbacks of Li-Fi are its short range and low reliability of data at greater distances.

## II. LI-FI V/S WIRELESS TECHNOLOGIES & IT'S CHALLENGES

There are so many wireless technologies are existing such as Wi-Fi, Bluetooth, IrDA ,NFC etc. To compare these technologies in terms of data transfer rate and Bandwidth, Li-Fi outperforms all others with speed of up to 1Gbps followed by Wi-Fi ,IrDA , Bluetooth and NFC. The main advantage of Li-Fi technology is to provide wireless communications with high data rates. Other advantages include efficiency, security and safety. Also, this technology uses free unlicensed spectrum, and it is cost-effective. Additionally, unlike RF systems, no multipath fading and the transmitter and receiver circuits are not complex. Since. Li-Fi does not interfere with the radio frequency spectrum, it can be safely used in hospitals, nuclear plants, aircrafts, and other electromagnetic sensitive areas. Since in these areas such electromagnetic devices and equipment are used, which can interfere with the operating frequencies, if we use Wi-Fi here. Li-Fi has several restrictions, which are as follows:

1. In order to use internet with the Li-Fi technology, it has to use LED's as a light source
2. To set up a communication data network using Li-Fi, it will result in high installation costs.
3. In order to transmit data reliably and for a higher range, Li-Fi requires a synchronized and perfect line of sight between the transmitter and the receiver.
4. The various factors that detriment the data transmission speed in Li-Fi are sunlight and electric candescent lights which are sometimes introduced in addition to our illuminating LED source.
5. If there are obstacles in the path of the line of sight of the Li-Fi transmission, the signal will not be able to transmit the signal reliably.
6. Since light cannot pass through walls or opaque objects, Li-Fi is confined to indoors and also has a shorter range.
7. Since Li-Fi is in its initial stages of development, experimentation and implementation, it is yet to be used by the masses on a large scale.

Li-Fi also has several Challenges to tackle such as :

1. To improve the reception range.
2. To use the best modulation technique to improve the range as well as to control the dimming of light and also to send the signal with the highest S/N ratio at a very fast rate.
3. In order to establish a peer to peer connection, the Li-Fi transmitter and receiver must be perfectly aligned.
4. Due to the interferences coming from natural sources into a room like sunlight and also from artificial sources like normal electric bulbs or incandescent light, the Li-Fi communication can be restricted. It also gets restricted due to the obstruction by walls or other opaque materials or obstacles present in its line of sight, path transmission.
5. The installation costs involved in implementing Li-Fi initially is high as compared to the radio frequency Wi-Fi system [8].

## III. LI-FI – THE FUTURE OF WIRELESS NETWORK

No doubt, that Wi-Fi is used a lot nowadays, but sooner or later Li-Fi will be used extensively due to its numerous advantages and will replace Wi-Fi. Radio frequency (RF) that is used for wireless communication today has a limited spectrum, and with the rise of smart home and smart city technology the abundance of connected devices are placing strain on our current networks. Li-Fi can help solve this problem. As the light spectrum 10,000 times larger than the radio spectrum it can be utilized to connect devices and assist in taking the strain off current networks.The Li-Fi finds its applicability in following.

**Internet of Things**– with Li-fi Internet is achievable at a very high data rate even in dense environments like tunnels or interiors of a building etc. This will open up an way for thousands of IoT devices to be connected [25]. have the capacity to transport data to and from various terminals without the need for interaction between human and human or human and computer. In the present-age tech-driven world where digitalization has become the buzzword for businesses, the Internet of Things has evolved as a revolutionary advancement that is fostering connectivity, communication, and information sharing between various on-premise and remote terminals. Researchers are focusing on LiFi as a viable solution for the rapid growth of IoT and Big data, and are working on developing smarter, faster and more reliable methods of data transmission.

**Smart city** – The street lights, malls and the buildings can be fitted with the Li-Fi technology, and internet can be made accessible to customer. The street lighting can also be made intelligent by implementing LED's and the Li-Fi technology to the street lamps.

**Healthcare** – Since, in hospitals and operation theatres, the use of mobile phones (Wi-Fi) is not allowed, as Wi-Fi can cause interference with the patient's equipment or other medical equipment in the hospital, which run on electromagnetic radiations. Also, these electromagnetic radiations can pose a huge risk for the patients. Li-Fi uses light and thus, this lighting in the hospital can be fitted with Li-Fi light panels, hence, providing a dual application of Lighting, internet and communication functionalities without any interference.

**Education**–Computer laboratories and classrooms can be connected with fast internet and also provide lighting to the classrooms.

**Smart homes**– A House can be interconnected with continuous fast internet connectivity. And also the appliances can communicate through the already existing Led lighting fixtures in the house meant for illumination and communication.

**Aviation** – We are aware that Wi-Fi cannot be used inside the aircraft, once the aircraft has taken off, more specifically in the passenger seating area, since the Wi-Fi signals used by the passengers may interfere with the aircrafts navigational signals. Hence, the passengers are allowed low speed internet onboard and that too at very specific times and at a high cost. We know that LED's are used for illuminating the individual passenger compartments. Hence, we can exploit this feature by providing media and internet services using Li-Fi internet and that too at quite a fast speed without interfering even with the aircrafts navigational signals. The seats of the passengers are fitted with the Li-Fi receivers and the passenger seat lights, placed above the passenger seat are the Li-Fi transmitters, thus allowing streaming of data and internet.

**Smart Street lighting** – The streetlights can be made smart. Smart lighting will be provided, which in turn will be used for illumination as well as communications. Street lights are the Li-Fi transmitters, thus streaming of data and internet within that zone or area. Various types of controlling can also be done using this concept. Energy consumption and wiring incorporated will also be reduced as lights are already on for illumination, so no additional energy is required for data transmission. Its use can be extended in Projection Display Systems [9]. Lamp Technology, which is electrode free using Li-Fi, has been created for projection display applications. An optics set is used to convert light into an output which is efficiently accepted by the projector. It offers flexibility in the type of output. It allows the system integrator to convert between collimated and focused output. This flexibility helps in the use of the same lamp for many projector types.

**Automotive** – The vehicles can be fitted with the Li-Fi devices to allow communication between vehicles specially when there exist a bottleneck or traffic, so that the drivers can divert the traffic route and avoid the traffic route. The street lights Li-Fi devices and the vehicles Li-Fi devices will be synchronized.

**Industrial**–Li-Fi technology can be used when data has to be communicated between sites in a factory, to the supervisor periodically without physically visiting the sites and obtaining the required specific data.

**Underwater explorations** – The vehicles which are remotely operated underwater for ocean bed, sea environment and marine life explorations, use very long power supply and data cables. These data cables are used to transmit and receive signals from the divers in the ocean and the pilots aboard the ship for communication between them. But, normally, these cables are not very long enough for the divers to explore the ocean beds. Hence, if the Li-Fi technology is introduced here, using very high power LED lights with cable waterproofing, it would be convenient for the dover to explore the ocean bed with ease even at such great depths. The divers could communicate with one another using their headlights in the oceans and also send their findings immediately to the processors on board the ship on the surface. Hence, the Li-Fi technology which uses light makes communications and exploration underwater possible even to such great depths whereas radio frequencies used by Wi-Fi fails miserably at such great depths.

**Military applications –**Since, Li-Fi technology is secure and reliable it will be difficult for the enemies to eavesdrop. In order for the enemy to tap on, intercept or eavesdrop on our private messages, they have to be within our vicinity, which is difficult for the enemy in danger of being shot at or captured. Hence, Li-Fi technology can be used efficiently for military applications.

**Advertisement and Disaster Management –** Li-Fi can be used as significant means of communication during disasters, since it uses light signals. During disasters like earthquakes, floods or landslides, the power and internet cables could be disrupted and hence, Li-Fi technology could be used then.

**Radio broadcasting:** Traditionally, in order to broadcast radio signals from a radio station, a large amount of power is required to be supplied to the radio masts and hence due to this, a large amount of power, which is being utilized for the transmission, makes this traditional way of broadcasting highly inefficient. But, by using the Li-Fi technology, which makes use of the LED's, utilizes very low powers to transmit or broadcast these same signals, thereby making them power efficient.

## IV. METHODOLOGIES TO TACKLE CHALLENGES FACED BY LI-FI

The major challenge faced by Li-Fi is reception range and improving S/N i.e data rate to overcome come this selection of Light source, receiver, modulation technique and alignment plays a vital role.

### Modulation

The Li-Fi system provides several special modulation formats and techniques for fast speed transmissions during communication for efficiently transferring the signal over larger distances. Dimming based modulation schemes are required to efficiently and reliably transmit the same signals even in dimmed conditions. The dimming based modulation schemes are carrier based transmissions. In these carrier based

transmissions, LED's are turned ON & OFF at a particular rate to achieve the desired data rate [10][11][12].

The dimming based modulation schemes implemented in indoor Li-Fi based systems are OSM (Optical Spatial modulation), PPM (Pulse Position modulation), VPPM (Variable Pulse Position modulation), OPPM (Overlapping Pulse Position modulation), PWM (Pulse Width modulation), OOK (On Off Keying) [13][14].

Some of the dimming based modulation schemes are explained in Table 1. The multicarrier modulation schemes used in Li-Fi are OFDM (Orthogonal Frequency Division Multiplexing), ACO-OFDM (Asymmetrically-Clipped Optical Orthogonal Frequency Division Multiplexing), DCO-OFDM (DC-biased Optical Orthogonal Frequency Division Multiplexing), etc. But, the multicarrier modulation schemes have their advantages and disadvantages. The advantage of multicarrier modulations is that, it helps to achieve high data rates and decreases the effect of distortion, noise and interference, thereby, decreasing the bit error rate. The disadvantage of the multicarrier modulation scheme is that they are a bit energy inefficient. But, the advantages outweigh the disadvantages and hence they are used. The most common and widely used multicarrier modulation scheme is the OFDM (Orthogonal Frequency Division Multiplexing). The OFDM based signal transmission is complex and bipolar in nature [15][16][17].

For better performance as compared to the conventional techniques, some modifications are required to be implemented in the OFDM scheme for a Li-Fi system [18]. In ACO-OFDM (Asymmetrically-Clipped Optical Orthogonal Frequency Division Multiplexing) scheme, only the odd sub-carriers are modulated [19][20], whereas in the DCO-OFDM (DC-biased Optical Orthogonal Frequency Division Multiplexing) scheme, all the sub-carriers are modulated and an unipolar signal is generated by adding a positive direct current. The energy efficiency of ACO-OFDM is more than the DCO-OFDM. It is well known that the equation between the light that is emitted by an LED and the current generated by it, is non-linear. Hence, this non-linear behaviour of the LED affects the execution of the OFDM based modulation scheme. Multicoloured LED's are designed to provide dual purposes, that is for illumination as well as for communication. The modulation schemes which fall under this category are CSK (Colour Shift Keying), MM (Metameric modulation), CIM (Colour Intensity modulation), etc.

In the CSK modulation scheme, the signals are encoded into colour intensities emitted by the Red, Green and Blue LED's (RGB-LED) [21][22][23].

To ensure a constant luminous flux, the constant colour intensities emitted by the Red, Green and Blue LED's are maintained, by mapping the transmitting bits into instantaneous chromatics of the LED. Due to the constant luminous flux that has been maintained in the CSK, this modulation scheme is highly reliable, when it comes to the LED's performance and also gives a flicker free effect over all the frequencies. The MM (Metameric modulation) schemes also can modulate data signals in the visible light spectrum and also provides a constant lighting signal or luminous flux. It also has a higher energy efficiency and provides a good colour quality control.

**Table 1:**The Dimming based modulation schemes:

| **Sr. No.** | **Modulation scheme** | **Working Principle** | **Advantage** | **Disadvantage** |
|---|---|---|---|---|
| 1 | ON-OFF Keying (OOK) | It is a dimming based modulation scheme which transmits data by sequentially turning the LED's ON and OFF. | It provides a good trade-off between implantation complexity and system performance. | Decreasing or increasing the brightness of the LED from 50% dimming level would cause the data rate to decrease. |
| 2 | Pulse Width Modulation (PWM) | In PWM signals, the pulses carry the modulated signal in the form of a square wave and the pulse widths are adjusted based on the desired level of dimming. | PWM achieves the dimming, without changing the intensity levels of the pulses. | Data rate is low |
| 3 | Pulse Position Modulation (PPM) | PPM allows one pulse per symbol duration. The symbol duration is divided into time-slots of equal durations and a pulse is transmitted in one of the time-slots. | PPM is more power efficient as compared to OOK. | PPM has a lower spectral efficiency and a limited data rate. |
| 4 | Variable Pulse Position Modulation (VPPM) | VPPM is a combination of PWM and PPM. In VPPM, the width of the signal pulses is changed according to a specified brightness level to support dimming. | It displays a better spectral efficiency as compared to PPM. | VPPM lacks power efficiency. |

| | | | | |
|---|---|---|---|---|
| 5 | Overlapping PPM (OPPM) | OPPM allows more than one pulse to be transmitted during the symbol duration and the different pulse symbols can be overlapped. | OPPM can achieve a higher spectral efficiency as compared to PPM and VPPM. | Wide range of Dimming levels can be obtained due to overlapping. |
| 6 | Optical Spatial Modulation (OSM) | It is a single carrier transmission modulation technique in which input bits sequence is mapped and corresponds to a certain LED index. | Displays efficient power and bandwidth. | Performance can be deteriorated due to the high optical channel correlation because it depends upon the transmitter and receiver. |

**Orientation Aligning**

In this paper, experimental results are being presented using a protocol for OWC and the geometrical orientation of the LED's namely, circular and hexagonal and also the optimum placement of the LEDs within the receiver's scope, are implemented to maximize the transmitter's foot prints. Various orientation are shown in figure 1.

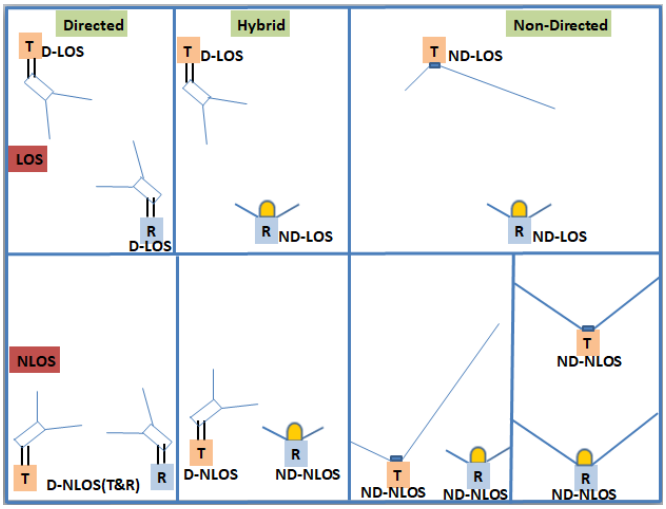


**Fig.1.** Orientation layout

D –> directed

LOS –> Line of Sight

ND-> Non directed

NLOS –> Non Line of Sight

***Directed*** – Focuses in a particular direction consisting of a combination of D-LOS Transmitter and a D LOS Receiver

- A Combination of a D-NLOS Transmitter and Receiver.

***Hybrid*** –A combination of D-LOS Transmitter and ND-LOS Receiver.

- A combination of D-NLOS Transmitter and ND-NLOS Receiver

***Non Directed*** – A combination of ND-LOS Transmitter and Receiver

- A combination ND-NLOS Transmitter and Receiver

**Transmitter and Receiver**

We have used an single LED, which behaves as the transmitter of an Indoor Li-Fi based system. These LED's provide an incoherent solid state illumination and also have a low cost. If the LED's are arranged and oriented in an array pattern consisting of a group of LED's the intensity of Light can be increased [26]. Further, if we add an optical lens to the array of LED's, we get a better directed radiation pattern from the transmitter. Also, if the geometrical arrangement of the LED array is in a circular or hexagonal shape, we can expect a better response from the receiver. We can use Intensity based modulation schemes for the LED's, in which the data is encoded by using the intensity of the emitted light. We can also use colour based modulation schemes, in which different colour LED's can be used in the Li-Fi Communication system. The phosphor coated white LED's provide data rates of about 1GB/Sec [27]. The RGB LED's provide a high data rate of about 3.4GB/second. The LED lighting panels normally use the white light emissions. This white light performs both the functions of the desired illumination as well as the communication. There are different ways of producing this white light. White light is a combination of various colours in the right proportions. One technique of producing white light is to use a blue LED with a yellow phosphor coating. Hence, when a beam of this blue light passes through this yellow phosphor coating layer, the given LED light emits white light. Another technique of producing white light is to properly balance and mix the correct proportions of Red, Green and Blue (RGB) coloured LED's.

LED's are cheap and the light emitted by the LED's is incoherent and therefore, Intensity modulation (IM) is employed. In Intensity modulations, the input signal is modulated into an optical signal of the instantaneous power. Then, this optical signal is received by a receiver by using the Direct Detection method. In the Direct Detection method, a light sensing device like a photodiode is used to convert this sensed optical signal power into a corresponding proportional current which is followed by a transimpedance amplifier to obtain the required gain. The original input signal is thus reconstructed at the receiver.

## V. SYSTEM IMPLEMENTATION & TESTING

The entire system is designed using Arduino Board. The implemented system block is shown in figure 2.

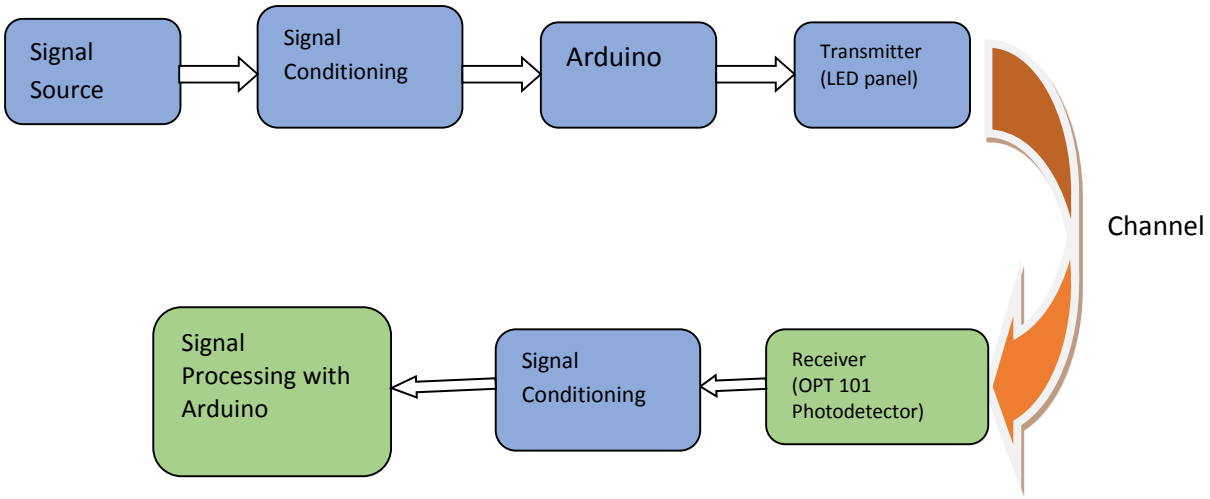


**Fig. 2.** System Implemented Block

The signals from the source are first signal conditioned and given to A/D converter of Arduino board, which then converts them into Digital form. These signal is then transmitted as light (White LED or IR-LED). On the other side, OPT 101 Photo detector is place in line with transmitter. OPT 101 is very sensitive to light and it has inbuilt transimpedance amplifier. Detected output is then filtered and given to Arduino for further processing and original signal recovery.

The experiment was conducted in order to analyse the performance of visible and IR light in an Optical wireless communication system to transmit data reliably as shown in figure 3.

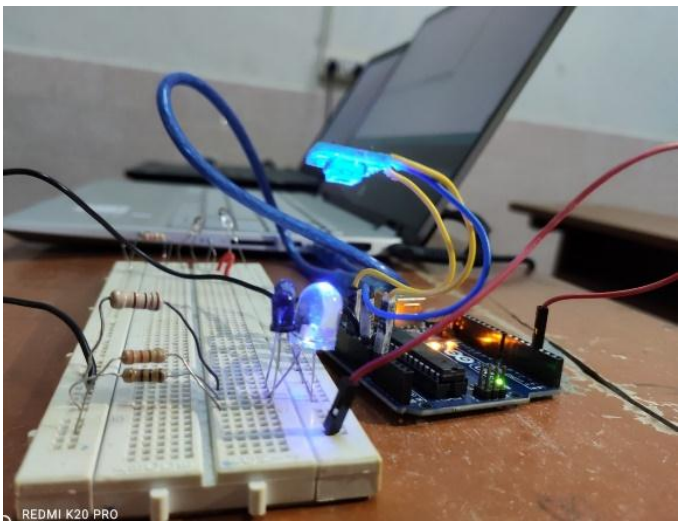


**Fig. 3:** Experimental setup

Initially, in the experiment, the transmitter was kept stationary and the receiver was moved from 1 meter to 4 meters distance and data transmission accuracy was recorded. The alphabets characters, A till z in ASCII were sent repeatedly by the Arduino and transmitted through the LED display and these characters were received by the OPT 101 photodiode receiver.

The experiment was carried out under three conditions which are shown in Table 2:

**Table 2:** conditional cases

| Case | Ceiling Lights | Sunlight |
|---|---|---|
| 1 | ON | YES |
| 2 | ON | No |
| 3 | OFF | NO |

Case 1: Ceiling lights are ON and sunlight is also allowed to enter the room partially and it is measured using a White LED and an IR LED separately.

Case 2: Ceiling lights are ON and no sunlight is also allowed to enter the room and it is measured using a White LED and an IR LED separately.

Case 3: Ceiling lights are OFF and no sunlight (pitch dark room) is allowed to enter the room and it is measured using a White LED and an IR LED separately.

Data was generated using an Arduino code. This experiment focuses on the successful transmission of data from the transmitter and its accurate reception at the receiver.

## VI. RESULTS & DISCUSSION

Li-Fi uses the light to send data wirelessly compared to Wi-Fi which uses RF signals. Thus, it works within the ambit of light source and within the allowed radius[28]. Moreover, Li-Fi networks finds it extremely difficult to pass through opaque objects, such as walls due to the nature of the light waves. Li-Fi also requires precision alignment of light transmitter to receiver to ensure effective transmission [29].

We have performed the experiments to transmit data using Li-Fi for different data links and measured the transmitter and receiver distance of separation to achieve respective data links. The results are depicted in Table 3.

**Table3:** Li-Fi T-R distance for 100%,95% & 90% Data link

| Sr. No. | Type of lighting pattern | Case Type | Distance in meter for 100% link | Distance in meter for 95% link | Distance in meter for 90% link |
|---|---|---|---|---|---|
| 1. | White LED | Case 1 | 0.2 | 0.34 | 0.5 |
| 2. | IR LED | Case 1 | 0.5 | 0.62 | 0.74 |
| 3. | White LED | Case 2 | 0.5 | 0.76 | 1.0 |
| 4. | IR LED | Case 2 | 1.0 | 1.86 | 3.0 |
| 5. | White LED | Case 3 | 0.85 | 1.26 | 1.5 |
| 6. | IR LED | Case 3 | 2.0 | 3.0 | 4.0 |

The OPT 101 Receiver was moved from zero meters to four meters to get data link up to 90 % and the reading was recorded. From the results table , it can be seen that in case 3, when only LED's (White and IR) lights are ON, the system performance is the best.

For the Case 3 with IR LED, the link is 100 %, 95% & 90% reliable at 2,3 and 4 meter respectively. Similarly, for Case 2 and case 1 with IR LED, 90% link is achieved at distance of 3 meter and o.74 meter respectively . with only white LED on for data transmission system performance goes down with 90% reliable link at 1.5 meter,1 meter and 0.5 meter for case 3, case 2 and case 1 respectively. Due to the ambient room light intensity the readings were not satisfactory.

We have conducted experiment with single white LED and IR LED which had lots of synchronization and linking problems. Synchronization between the transmitter and the receiver is a very challenging task and has to be taken care and monitored and adjusted at all times for higher response at the receiver. However, to tackle this, an array of white LED's arranged in a circular panel needs to be designed, which will perform better than with the single white LED or single IR LED.

## VII.CONCLUSION

Though Li-Fi poses some disadvantages, it shows lot of advancement in wireless technology. It has entered each and every sector and in near future definitely it will be boon for our society. Li-Fi attains good speed which helps this technology for accessing internet in near future from anywhere as these lights will be available at every corner. As Li-Fi is highly secure It will be beneficial for defence services as their data is very confidential and private and Li-Fi cannot be hacked so data is protected. From the experimentation we conducted, it can be concluded that if the receiver is in close proximity to the transmitter, all LED arrangements (single, both white and IR LED and circular arrangement of LED's) reflected at the receiver are similar. However, circular geometry transmits the light to more distance than the single arrangement of LED's, so the best results can be achieved by arranging the LED's in the circular geometry. Adding an optical lens at the transmitter to increase the range will give a better output. Modulation is quite useful to overcome the dynamic variation of light intensity at the receiver. Further investigation can be done by different orientation of LEDs, using high bright/super bright LEDs and the photodiode with faster response time.

## REFERENCES

[1] Amit Jaykumar Chinchawade, Prof. K. Sujatha, "LiFi based Audio Transmission with Home/Office Automation System", in International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), ISSN: 2347-6710, Vol. 5, Issue 7, July 2016, pp. 12533-12539.

[2] Sindhu, M. Priyanka, A.K. Swedha, R.A. Ranjana, "Cryptography based secured LiFi for patient privacy and emergency healthcare service", in International Journal of MC Square Scientific Research Vol. 9, No. 1, April 2017 pp. 86-96.

[3] V. Thayananthan, O. Abdul Kader, K. Jambi, k. A. Barnahdi, "Analysis of Cyber Security based on LiFi in green data storage environments", 978-1-5090-6644-5/17 2017, IEEE.

[4] Sonali Bhattacharya, Manish Joshi, "LiFi (Light Fidelity) Technology in 4th International Conference on System Modeling & Advancement in Research Trends(SMART) College of Computing Sciences and Information Technology(CCSIT), 2015, pp. 423-429.

[5] Yunlu Wang, "Load Balancing in Hybrid LiFi and RF networks", January 2018.(Thesis).

[6] hamza976.wordpress/category/Li-filight-fidelity/

[7] https://www.nytimes.com/2012/04/18/technology/mobile-carriers-warnof-spectrum-crisis-others-see-hyperbola.html

[8] Augustine EhiremenIbhaze, FederickObataimenEdeko, "High Capacity data rate system: Review of Visible Light Communicationstechnology", Journal of Electronic Science and Technology, 27th August, 2020, Science Direct, https://doi.org/10.1016/j.nlest.2020.100055

[9] Mark Hereld, Ivan Judson, Rick L. Stevens, "Introduction to building projection based tiled display systems", August 2000, IEEE Computer graphics &

applications, 20(4):22-28, DOI: 10.1109/38.851746, IEEE Xplore.

[10] Porselvi S., Bhagya lakshmi L., Sanjay Kumar Suman, "Healthcare Monitoring Systems using LiFi networks", in Innovare Journal of Engineering & Technology, ISSN: 2347-1573 Vol. 5, Issue 2, 2017 pp. 1-4.

[11] MauryaKatta, P. Ponnammal, RakeshPeddikuppa, VigneshGandham, "A secure LiFi modern healthcare system using body sensor network", in International Journal of Pure and Applied Mathematics, ISSN: 1314-3395 Vol. 119 No. 12, 2018, pp. 13135-13142.

[12] Ms.Bhagyashree M. Meshram, Dr. V. M. Deshmukh, "Image Encoding and Decoding using Base Technique and its wireless transmission using LiFi", in International Journal on Future Revolution in Computer Science and Communication Engineering, ISSN: 2454-4248, Vol. 4, Issue: 4,April 2018, pp. 541-545.

[13] Z-C. Wang, Q. Wang, W. Huang, Z-Y.Xu, "Visible light Communication: Modulation & Signal Processing", John Wiley & sons, New Jersey(2017), Google Scholar.

[14] T. Kormine, M. Nakagawa, "Fundamental analysis for Visible light communication system using LED lights", IEEE Trans. Consum. Electron, 50(1), Feb(2004), pp. 100-107.

[15] DilukshanKarunatilaka, FahadZafar, VineethaKalavaally, RajendranParthiban, "LED based Indoor Visible light communications: State of the Art", in IEEE Communication Surveys and Tutorials, Vol. 17, No. 3, Third Quarter, 2015, pp. 1649-1678.

[16] Hyung-Joon Jang, Joon-Ho Choi, Z. Ghassemlooy and Chung Ghui Lee, "PWM based PPM format for Dimming Control in Visible light communication system".

[17] Trio Adiono, AnggaPradana, SyifaulFuada, "A low-complexity of VLC system using BPSK", http://doi.org/10.3991/ijes.v6i1.8072, http://www.i-jes.org.

[18] Talha A. Khan, Muhammad Tahir, Ahmad Usman, "Visible light communication using wavelength division multiplexing for Smart Spaces", in the 9th Annual IEEE Consumer Communications and Networking Conference – Smart Spaces and Personal Area Networks", 978-1-4577-2071-0/12, 2012, IEEE, pp. 230-234.

[19] PayalSoni, Shikha Singh, A review on Matlab based Platform for the evaluation of Modulation techniques using multiuser MIMO-OFDM for VLC using Matlab", International Journal of Science and Technology & Engineering (IJSTE), Vol. 3, Issue: 9, March 2017, ISSN(online): 2349-784X, pp. 517-521

[20] HanyElgala, RaedMesleh, Harald Haas, "Indoor Optical Wireless Communication: Potential and State of the Art, in Topics in Optical Communications", IEEE Communications Magazine, September 2011, pp. 56-62.

[21] I. Stefan, H. Elgala, and H. Haas, "Study of Dimming and LED Nonlinearity for ACO-OFDM based VLC Systems," IEEE Wireless Communications and Networking Conf. (WCNC), Paris, France, 2012, pp. 990–994.

[22] H. Elgala and T. D. C. Little, "Reverse Polarity Optical-OFDM (RPO-OFDM): Dimming Compatible OFDM for Gigabit VLC Links," Optics Express, vol. 21, no. 20, 2013, pp. 24,288–299.

[23] K. Akhavan, M. Kavehrad, and S. Jivkova, "High-Speed Power-Efficient Indoor Wireless Infrared Communication Using Code Combining, I," IEEE Trans. Commun., vol. 50, no. 7, 2002, pp. 1098–1109.

[24] Anonymous, "High-Speed Power-Efficient Indoor Wireless Infrared Communication Using Code Combining, II," IEEE Trans. Commun., vol. 50, no. 9, 2002, pp. 1495—1502.

[25] Akassh A. Mishra and Neelesh S. Salian, "Internet using Visible Light Communication," IACSIT International Journal of Engineering and Technology, Vol. 3, No. 5, October 2011.

[26] FarooqAftab, MuhammedNafeesUlfat Khan, Shazad Ali, "Light Fidelity (LiFi) Based Indoor Communication System", May 2016, International Jjournal of Computer networks & communications, 8(3): pp. 21-31, DOI: 10.5121/ijcnc.2016.8302.

[27] https://www.google.com/amp/s/spectrum.ieee.org/tech/talk/semiconductors/opoelectronics/laser-lifi-could-blast-100-gigabits-per-second.amp.html.

[28] C. Robbins, "Li-Fi Security," CYBER MATTERS, 10 January 2017. [Online]. Available: https://cybermatters.info/2017/01/10/li-fi-security/. [Accessed 24 October 2018].

[29] Private Tunnel, "Benefits And Future Security Concerns Of Li-Fi Networks," OpenVPN, 15 November 2016. [Online]. Available: https://www.privatetunnel.com/news/lowfinetworks/. [Accessed 24 October 2018].