INTERNATIONAL JOURNAL OF RESEARCH CULTURE SOCIETY
Monthly Peer-Reviewed, Refereed, Indexed Journal
Volume - 7, Issue - 11, November - 2023

ISSN(O): 2456-6683
[Impact Factor: 6.834]
Publication Date: 20/11/2023

IJRCS

DOIs:10.2017/IJRCS/202311004 --:-- Research Paper / Article / Review

Tools for Enhancing the transmission efficiency and range of Li-Fi

Akshita Modi
Electronics and Communication Engineering
Marudhar College of Engineering, Bikaner (Rajasthan) (India)
modi.akshita27@gmail.com

Abstract **:** *Li-Fi which is an optical version of Wi-Fi uses simple LED light as a source .The advantages of Li-Fi are also accomapnied with some limitations like high initial investment and installation cost . The losses associated with the transfer of data by light fidelity and the limitations of limited range and less efficiency can be increased by applying 'Lens Correction'.This paper describes the tools and equipments required for enhancing the transmission efficiency and range of Li-Fi .*

Key Words : *Li-Fi, LED, Lens Correction, Transmission efficiency.*

1. INTRODUCTION :

In the communication system "Li-Fi" is an economical technology. In general terms "Li-Fi" is light based Wi-Fi (Wireless Fidelity) technology .It is the optical version of Wi-Fi. Li-Fi is a type of wireless communication that employs visible light to communicate between devices . This technology uses simple LED light as a source to transmit and receive the information. The two highly power consuming needs of human beings is lighting and internet or data transmission. LED can full fill both these needs at the same time. This leads to explore new domains of research opportunities in view of the immense popularity of LED bulbs which is slowly replacing the conventional lighting sources.

Li-Fi has many advantages such as High Speed , Low Maintenance, greater security, greater privacy , safe for human body and it also overcomes the issues of insufficient RF Bandwidth. However, it suffers from some limitations viz. high initial investment and installation cost, interference from opaque objects, reuires unobstructed line of sight and limited renage communication. Also , there are various losses associated with the transfer of data by light fidelity such as path loss and energy loss.

This work aims to extend the range and decrease the Bit Error Rate (BER) of a LI FI system by applying 'Lens Correction'. A convex lens is used to concentrate light on photo detector and Li Fi system is build using low cost microcontroller Arduino UNO. This is followed by testing the developed system with two LED's of different diameters (5mm and 10mm) to probe into the effect of LED's shape on BER of the system. The system will then be tested by placing a convex lens in the optical channel and observe the effect on BER , on both the LED's.

2. REVIEW OF LITERATURE AND SIGNIFICANCE OF THE WORK:

Literature reveals [1-7] that various efforts are done by researches for improving the communication by Visible Light. However the research efforts seem to remain concentrated on developing new techniques and topologies for enhancing the VLC. Much less attention is focused on improving the range and accuracy of VLC especially in an LED spectrum. The different ways by which the spread of spectrum of LED can be prevented is also not adequately studied. In view of this it is befitting that the deficiencies in the existing system were improved by way of implementation of the following theoretical concepts so that the range and accuracy of VLC is increased. This would further lead to designing a methodology of VLC interface which would explain the working concept of the system based on lens correction scheme.

3.THEORETICAL CONCEPTS AND RELATED TOOLS AND TECHNIQUES :

The theoretical concepts involved in improving the tramsmission efficiency and range of Li-Fi alongwith the tools which are required to bring in that efficiency are explained below [8-15]

3.1 VLC (Visible Light Communication):

In VLC, Visible light is utilized as an optical carrier for the data transmission or illumination between the range 400 THz to 800 THz (780mm - 375mm). A white LED act as a component of communication source and silicon photo diode is used to show response to the Visible Wavelength Region. LED light appears continual to the human eye and due to fast flicker rate of LED. And we can get high data rate by using the high-speed LEDs. Every LED can transmit different data rate and it is possible by using the LED array. Availability, Capacity, Efficiency and Security is the major concern regarding Radio waves where light is a part of the electromagnetic spectrum. Radio waves can be used for the communication but it can be dangerous or harmful for human body. Infrared is harmful for the human eyes, so it can be used at low level. Ultra violet is suitable for getting sun-light but it can be more dangerous when it is exposes for long time or duration. X-rays are suitable used in the medical science not for the communication. Gamma Rays are very harmful, so it can't be used for the communication purpose.

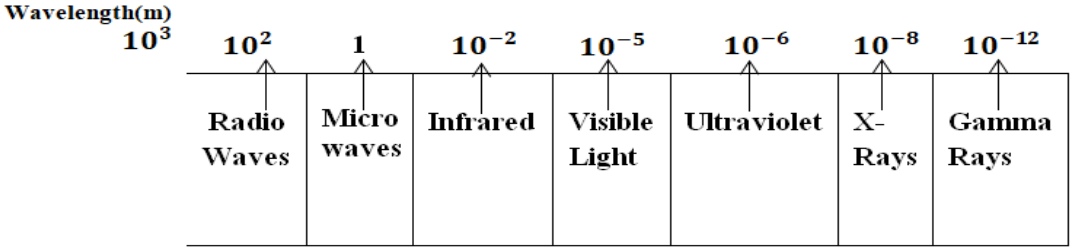

Fig 1: Electromagnetic Spectrum

3.2 Arduino Uno

- Arduino Uno is a circuit board utilized by ATmega328P. In the year of 2005, it was developed by Massimo Banzi and David Cuartielles. There are 14 I/O digital pins on the Uno board. From these 14 pins, 6-pins can be utilized for Pulse Width Modulation (PWM) outputs. There are 6-pins which are reserved for analog inputs. Also, the board consists of Reset button, Power Jack , A USB Connection, Quartz Crystal of 16 MHz ,An In Circuit Serial Programming (ICSP) Header, A USB Connection. Arduino are powered by making a connection of Arduino board with computer through a USB cable. Else, it can be powered using a battery or an AC-to-DC adapter.

3.2.1 Features of Arduino Uno Board:

It allows interface with USB such as a serial component. There are many hardware characteristics such as interrupts (both external and internal), output Pulse Width Modulation (PWM) pins, different sleep modes and timers. For many applications, it has a sufficient fast 16 MHz clock which does not accelerate the microcontroller. It has a design which is an open source outline and there is leverage of being open source which makes it easy to help in debugging projects. The flash memory required for storing program is of about 32KB.It has a feature of implicit voltage control. Up to 12v is required to interface extrinsic power source and this regulates it on 5V as well as 3.3V. To bypass USB port there exist an ICSP connector which is important to re-boot load your chip in the event that it defiles and can never again used to your PC. For simple debugging process, on-chip LED is integrated with digital pin 13. There exists a reset button to reset the code burned in the microcontroller.

3.2.2 Arduino Uno Specification:

- Arduino Uno has ATmega328 Microcontroller.
- It has an Operating Voltage of 5V
- The recommended Input Voltage lies in the range 7-12V.
- The Input Voltage must be limited in the range 6-20V.
- There are 14 I/O digital pins on the Uno board. From these 14 pins, 6-pins can be utilized for Pulse Width Modulation (PWM) outputs.
- There are 6 Analog Input pins.
- Each I/O Pin can carry 40 mA of DC current.
- 3.3V Pin provides a DC current of 50 mA.
- ATmega328 has on chip 32 KB of flash memory.
- ATmega328 has on chip 2 KB of Static RAM.
- ATmega328 has on chip 1KB of EEPROM.
- It has a 16MHz of Clock Speed.

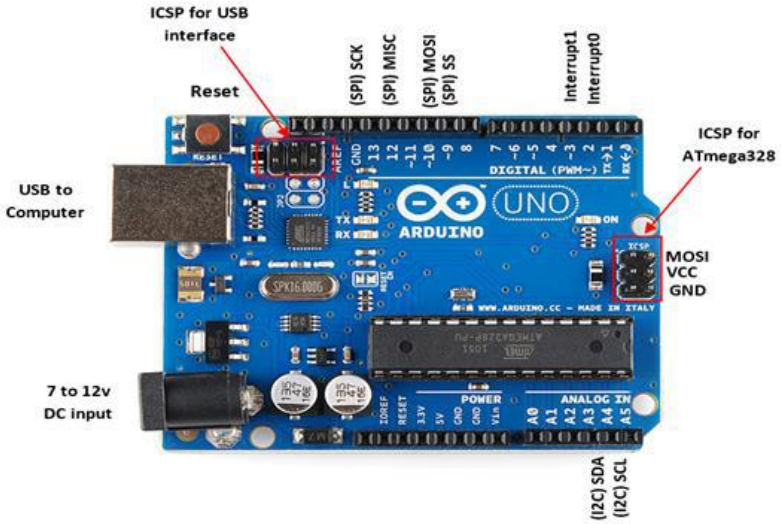

Fig 2: Arduino Board Description

Pins	Function
RX	Receiver: This pin is used to collect TTL serial bits.
TX	Transmitter: This pin is used to send TTL serial bits.
Digital I/O(PWM)	.14 digital input /output pins are present on Arduino UNO board. From these pins 16 pins have capability of Pulse Width Modulation. The pins can be configured to read digital input I.e. logical input in 0 ,1 format. The pins can also be configured for providing digital output.The PWM pins are preceeded by ~ sign.
GND	Ground
Analog pins	The analog pins of Arduino UNO are numbered from A0 to A5.These can be configured as input to read continuous values from analog sensors or for displaying analog output.
Vin	Used to obtain supply if Arduino UNO board is powered exernally
5V Pin	The external components connected to Arduino UNO with rating of 5V draws power from this pin.
3.3V Pin	The external components connected to Arduino UNO with rating of 3.3V draws power from this pin.
IORef	This is acronym for input voltage reference .

3.3 Hyper terminal Software

The most widely used communication and terminal emulation software is the hyper terminal software. It allows two network applications to communicate with each other. In Fig 3 Hyper Terminal New connection window is shown.

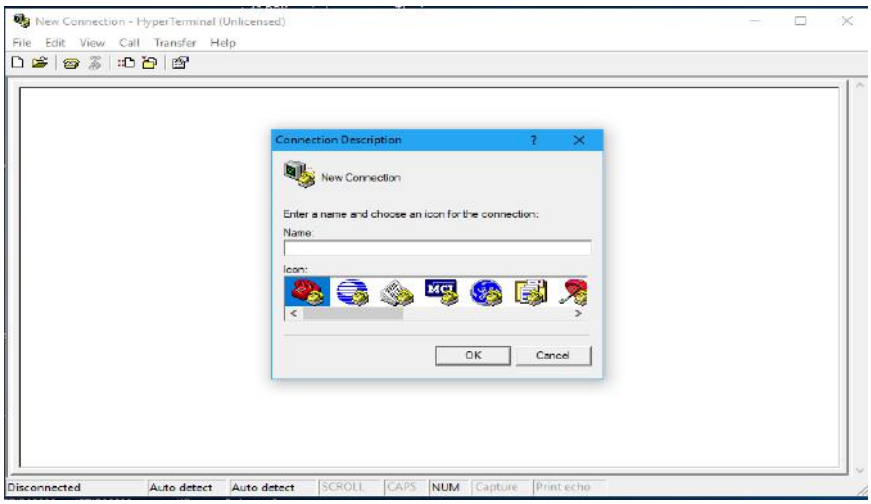

Fig:3 Hyper terminal window

3.4 Li-Fi Communication

3.4.1Phototransistor:

A Phototransistor is an electronic exchanging device which can detect light levels .The luminance is proportional to the reverse current which moves the junction when light falls on it. The main application of phototransistors is determining the light heartbeat or light pulses and converting them into electrical signals. Phototransistors are actuated by light rather than electric current.

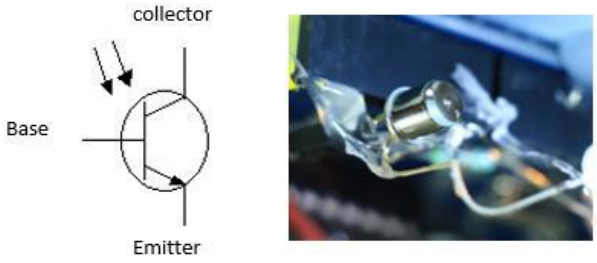

Fig. 4: Phototransistor

The base terminal is comprised of by the material which is delicate to light. The two arrows pointing towards the phototransistor shows that the phototransistor is activated by the light episode on it. Phototransistor can be of three terminals or two terminals we can discard base according to our requirement. It can be worked in three regions that are the cut-off region, active region, and the saturation region. The active region is utilized for creating current. The produced current by phototransistor relies upon different factors separated from luminance force, for example,

- **DC Current Transistor:** The higher the DC current pick up of the transistor, the higher will be the force of photocurrent created.
- **Time Constant:** Response time of the transistor additionally affect the effectiveness of phototransistor to create photocurrent
- **Luminous Sensitivity:** The luminous sensitivity affectability can be dictated by the proportion between the photoelectric current and incident luminous flux of transition.
- **Area of the collector-base junction:** The region of collector-base junction is vital for the generation of photocurrent, the higher the region of the area of the collector-base junction the higher will be the size of photocurrent created by the phototransistor.
- **Wavelength of the incident light:** The wavelength of the light fed on phototransistor controls the measure of photocurrent produced. The higher the wavelength the lower will be the recurrence.

3.4.2 Source LED:

Led is utilized as a part of Li-Fi as an information source all the more proficiently to produce information streams. Ordinary IR LED can generate single data streams with speed of 10-20 Kbps. On the other hand source LED used in Li-Fi communication generates thousands of information streams at a much faster rate. Micro LED's are utilized on the grounds that miniaturized scale LED's can flash 1000 times quicker than commercial LED and can transmit million times speedier than that of a business LED. It can impart on communication speedier than Wi-Fi.

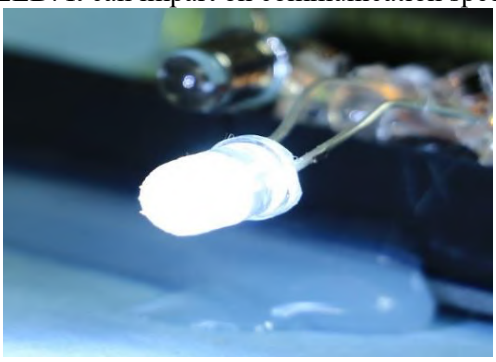

Fig. 5: Source Led

3.5 RS 232 Standard

RS-232 is a standard protocol which is utilized for Serial Communication amongst PCs and its peripherals. RS232 chooses the voltage way for the trading of data amongst various devices and furthermore it characterizes the common pin wire setup and control signs to be used. This, standard was fundamentally intended for electromechanical typewrites and was additionally adjusted for correspondence amongst PCs and their peripherals. A few highlights like character encoding, mistake discovery conventions, character confining, and so on which are fundamental for information transmission between two devices, are not characterized by the RS232 protocol.

Normally a few devices dodge the negative voltage level i.e. they acknowledge zero voltage level as an OFF state. What's more, in zero voltage level, the yield voltage flag ranges from +12v to - 12v [31].

3.6 Virtual Serial Port

There are relevant reasons behind the need of Virtual Serial Port. In order to create a serial port connection between the computer and devices like data transmission system, Serial port data capture, System debugging, GPS data replication and many more, as the serial port cannot be connected directly with the null-modem cable due to remote location. Thus, there is a need of a driver called Virtual Serial Port which creates an application using TCP/IP stack to communicate with the remote serial port. Virtual serial port might be used for the testing and debugging of distinct applications which uses the null-modem cable. We connect to modem while writing a program and send “AT” commands. For this, there is a need to imitate connection by establishing a virtual serial port to send and receive command on it.

3.7 Proteus

Proteus is a simulation tool developed by **Lab center Electronics** limited for Electrical and. It is used for Board designing, circuit simulation and PCB layout designing. It is used to draw a complete designing circuit which is based on the microcontroller system. In circuit simulation two important aspects are:

ISIS : The concept of ISIS architecture allows us to integrate graphical simulation and present along with Proteus VSM collaborative circuit simulation in the design environment.

3.7.1 System Requirement

- Intel Pentium processor (AMD processors) with processing speed greater than or equal to 1GHz.
- Operating System: Windows 10/8/7/Vista/XP.
- Graphics card supporting with OpenGL Version 2.0 or higher and multi-sampling ant aliasing (MSAA).
- 256Mb or above RAM (However recommended RAM is 512Mb) Intel HD Graphics 3000. GPU: 512 MB NVidia or ATI graphics card.
- If the system does not meet these requirements then system run in the windows GDI mode. That means the display handled by the windows not by the graphics hardware then some of the important features automatically will be hidden or will not be available.
-

3.7.2 Simulation and Overview:

ISIS has the development environment for the interactive system simulator with Proteus VSM. It provides the facility for the microcontroller-based design simulator. In the ISIS simulator each object and source code are related to each other in the different project.

Important features of Proteus VSM:

- Supportable to both Interactive and graphical simulations.
- Numerous Interactive peripheral like switches, lamps, LED’s etc.
- Open source architecture for ‘plug in’ component code in C++ and other languages.
- Terminal mode includes input, output, power, Bus and Ground.
- Virtual instruments include virtual terminal, voltmeters, signal generator, ammeters, dual beam oscilloscope and 240 channel logic analyzers etc.
- Graph of On-screen graphing are placed directly on the schematic like another object. And it includes Digital, analogue, audio, frequency, noise etc.
- Digital simulator used BASIC programming languages for testing and modelling vector generation.

3.8 COMPIM:

The serial port's physical interface model is known as COMPIN, which allows a physical device to communicate data with the devices used in simulation process. The serial information is received by circuit in form of digital signal produced by UART or CPU. COMPIN enables communication between physical and virtual sides of program with different baud rates. Physical COM ports are supplied with COMPIN in addition to Bluetooth and USB.

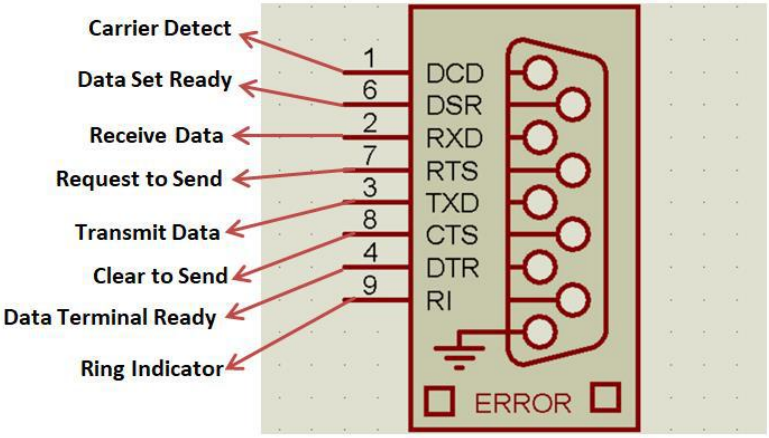

Fig. 6: DB-9 Connector

4 DESIGNING OF METHODOLOGY ON THE BASIS OF THEORETICAL CONCEPT AND MATHEMATICAL MODELLING:

A VLC system is constructed using Arduino UNO, LEDs, phototransistors and other components. The Bit Error Rate of the developed system is tested in two experiments. In the first experiment the BER is tested by using LED's of different diameters, to test the effect of shape of LED on VLC.

In the second experiment the VLC channel medium is changed .A spherical convex lens is placed in the path between transmitter and receiver and consequent decrease in efficiency is noted. The aim of this research is to apply the Lens Correction in VLC system to decrease the BER and extend the range. Mathematical modeling is discussed below.

4.1 Mathematical Model

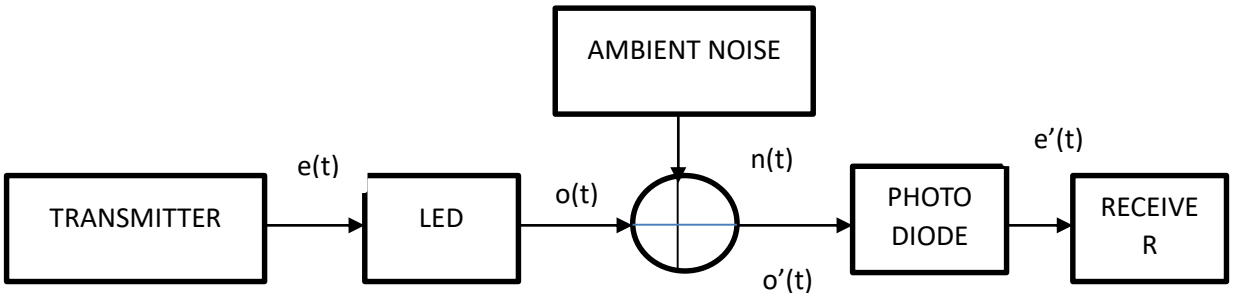

Fig 7: Block model

Fig. 7 shows the block model of VLC system. Here e(t) is the electrical signal to be transmitted. The LED brings out an electro optical conversion and convert the electrical signal(e(t)) into optical signal (o(t)). The optical signal when propagates through the visible light communication channel, it gets interfered by ambient noise from surrounding (n(t)). Now the resultant signal is (o'(t)), which reaches the photodiode. At photo transistor opto electrical conversion takes place and the signal (o'(t)) gets converted into received electrical signal (e'(t)).

The photo transmitter or LED can be described completely by two parameters

Full Width Half Maximum Angel: The Full Width Half Maximum Angel denotes the angel after which the intensity of light emitted from LED falls to fifty percent of the full intensity.

Lambertian parameter: The pattern of the escaping light is defined by Lambertian parameter and depens upon FWHM by equation given below:

$$m = \frac{-\ln(2)}{\ln(\cos(FWHM))}$$

The above mentioned parameters completely define the optical coverage of the LED.

The power loss in a visible light channel can be determined by the following equation

$$G_i = \frac{P_R}{P_T} = \frac{(m+1)A_{pd}cos(\theta)^m \cos(\varphi)}{2\pi d^2}$$

Here P_R is emitted flux from receiver's input.

P_T is flux received at transmitter

A_{pd} is area of photo transistor

θ is radiation angel

φ is angel of incidence.

Thus it can be seen that the power loss in visible light communication channel depends on three important factors namely distance between receiver and transmitter(d), angel of incidence(θ) and angel of radiation(φ).

It can be seen that with decrease in angel of incidence the path loss will decrease. The poer of a converging lens is defined as the extent or angle to which the lens converges beam of light falling on it.

$$P = \frac{1}{f}$$

Where P is power of converging lens in Dioptre or m^{-1}

And f is the focal length of lens.

Thus a lens having a focal length of 15 cm , has power of 6.6 D .

As shown in Fig 4.2 and 4.3,a convex lens converges the Field Of View(FOV).When such a lens is placed between LED and photo diode it converges the beam of light falling on its surface by LED so that angel of incidence increases. The increase in angel of incidence leads to less loss in the channel. The results presented in the later sections confirm the outcome.

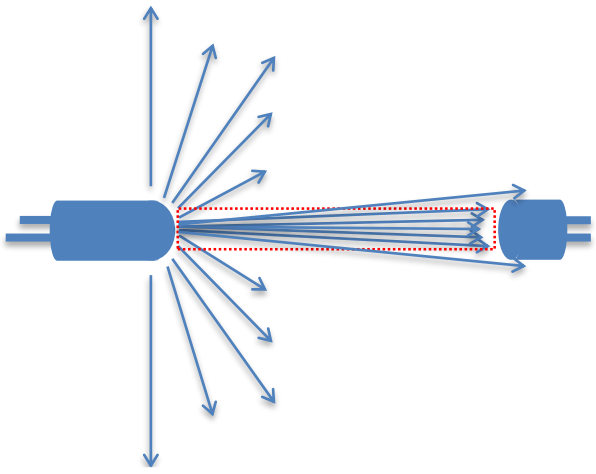

Fig 6: Divergence of spectrum in absence of lens.

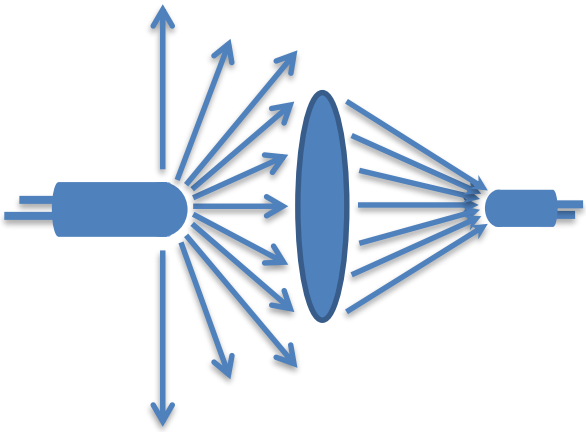

Fig 7 Convergence of spectrum in presence of a convex lens.

5. CONCLUSION:

Using the above theoretical concepts and tools /equipments mentioned above, the limitations of existing system are eliminated and the Li-Fi can be implemented with more transmission accuracy and efficiency and the range of VLC can be extended by lens correction.

REFERENCES :

1. Haas H., Yin L., Wang Y. and Chen C. (2016), What is LiFi? Journal of Lightwave Technology, 34(6) 1533-1544.
2. Mahendran R. (2016), Integrated LiFi (Light Fidelity) for smart communication through illumination, 2016 International Conference on Advanced Communication Control and Computing Technologies (ICACCCT), Ramanathapuram, 53-56.
3. Albraheem L. I., Alhudaithy L. H., Aljaser A. A., Aldhafian M. R. and Bahliwah G. M., (2018) Toward Designing a Li-Fi-Based Hierarchical IoT Architecture, IEEE Access, 40811-40825.
4. Mahendran R. (2016,) Integrated LiFi (Light Fidelity) for smart communication through illumination, 2016 International Conference on Advanced Communication Control and Computing Technologies (ICACCCT), Ramanathapuram, 53-56.
5. Kulkarni S., Darekar A. and Joshi P. (2016), A survey on Li-Fi technology, *2016* International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), Chennai.
6. Wang J., Jiang C., Zhang H., Zhang X., Leung V. C. M. and Hanzo L., Learning-Aided (2018), Network Association for Hybrid Indoor LiFi-WiFi Systems, IEEE Transactions on Vehicular Technology, 67(4), 3561-3574.
7. Sangeetha A., Sardar S., Rao S. and Kumar K. S. (2017), Performance Analysis of Different OFDM Techniques in DD-SMF Systems, *2017* International Conference on Technical Advancements in Computers and Communications (ICTACC), Melmaurvathur, 77-79
8. Kalaiselvi V. K. G., Sangavi A. and Dhivya (2017), Li-Fi technology in traffic light, 2017 2nd International Conference on Computing and Communications Technologies (ICCCT), Chennai, 404-407.
9. https://www.zdnet.com/article/scottish-school-claims-world-first-for-using-light-based-li-fi-networking/
10. Cogalan T., Haas H. and Panayirci E. (2015) , Power Control-Based Multi-User Li-Fi Using a Compound Eye Transmitter, *2015 IEEE Global Communications Conference (GLOBECOM)*, San Diego, CA, 1-6.
11. Adwani A. and Nagtode S. (2016) , LI-FI: Information transferring through LED's," *2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT)*, Chennai, 2125-2127.
12. Wu S., Wang H. and Youn C. (2014), Visible light communications for 5G wireless networking systems: from fixed to mobile communications, IEEE Network, 28(6), 41-45.
13. Tran N. T. and Shi F. G., LED package design for high optical efficiency and low viewing angle, 2007 International Microsystems, Packaging, Assembly and Circuits Technology, Taipei, 10-13.
14. K. Behera , A. Lenka , P. Karmakar , G.Mati , “Li-Fi Transreceiver Using Low Power Low Cost Laser Link”, IEEE,2018.
15. Abdalla Iman, Rahaim M. B. and Thomas D.C, (2019), Little Journal, IET Communications, 13(7) 822.