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# LIGHT FIDELITY WIRELESS COMMUNICATION

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***Abstract :*** This paper explores the implementation of LiFi technology for the transmission of diverse data types, including images, audio, and text, through a straightforward LiFi system designed for interaction between two PC systems. The proposed setup consists of two Arduino boards connected to the PCs, with one board functioning as the transmitter equipped with a laser module, while the other serves as the receiver connected to an LDR sensor, with the aid of the online tool to facilitate encoding and decoding data, processing ide which effectively manages the reading and storing substantial binary data. The Arduino IDE commands and operates the Arduino boards. To ensuring synchronized functionality, the Processing IDE operates in conjunction with the Arduino IDE. This integrated approach not only enhances the efficiency of data transfer but also demonstrates the practical application of LiFi technology.

***Keywords*** **- LiFi technology, data transmission, Arduino, laser module, LDR sensor, Processing IDE, Arduino IDE, binary data encoding, data decoding, high-speed communication, wireless communication, image transmission, audio transmission, text transmission, secure communication systems, visible light communication (VLC), integration of technologies, real-time data transfer, alternative to RF systems.**

## I. INTRODUCTION

The advent of LiFi (Light Fidelity) technology marks a significant evolution in wireless communication, utilizing visible light to transmit data at unprecedented speeds. Unlike traditional wireless systems that rely on radio frequency (RF) signals, LiFi employs light-emitting diodes (LEDs) to facilitate high-speed data transfer, enabling the transmission of diverse data types such as images, audio, and text. This innovative approach capitalizes on the vast bandwidth of the visible light spectrum—approximately 10,000 times greater than that of radio waves—allowing for rapid and efficient communication. The integration of LiFi technology into existing infrastructures presents numerous advantages, including enhanced security due to its limited range and reduced susceptibility to electromagnetic interference.

This study focuses on the practical implementation of a LiFi system designed for interaction between two PC systems, utilizing two Arduino boards: one functioning as a transmitter equipped with a laser module and the other as a receiver linked to an LDR (Light Dependent Resistor) sensor. The methodology involves encoding data into binary format using an online tool, which is then transmitted through modulated light signals. The Processing IDE operates in conjunction with the Arduino IDE to facilitate real-time reading and transmission of signals from the transmitter while simultaneously receiving and storing data at the receiver end. This integrated approach not only demonstrates the feasibility of LiFi technology in practical applications but also highlights its potential as a robust alternative to conventional RF communication systems, addressing the growing demand for faster and more secure data transmission methods in an increasingly connected world.

## II. LITERATURE SURVEY

**G. Devi; N. Jayanthi; S. Rahul; M. Saran Karthick; S. Gokul Raghavendra; M. Anand,"A critical review on Li-Fi technology and its future applications", March 24 2023, Published in AIP Conference Proceedings 2690, 020061, India.** This paper presents a thorough survey of Li-Fi technology, detailing its operational principles and advantages over traditional Wi-Fi systems.[1] The authors explain how Li-Fi utilizes visible light communication (VLC) to transmit data through modulation of LED light sources, which can achieve significantly higher data rates than radio frequency systems. They discuss the security benefits of Li-Fi, as its signals cannot be intercepted, thus reducing the risk of unauthorized access. The paper also addresses practical challenges such as the need for line-of-sight communication, ambient light interference. Furthermore, it outlines potential applications in various fields including healthcare, transportation, and smart homes. The authors conclude by suggesting future research directions that could enhance the technology's scalability and performance, making it a viable alternative to Wi-Fi in specific scenarios.

**"LiFi (Light Fidelity) & its Applications", Published in Telecommunication engineering centre, Department of Telecommunications ministry of communications, Government of India.** This paper focuses on Li-Fi, its applications, features and comparison with existing technologies like Wi-Fi etc. [2] Wi-Fi is of major use for general wireless coverage within building, whereas Li-Fi is ideal for high density wireless data coverage in confined area and especially useful for applications in areas where radio interference issues are of concern, so the two technologies can be considered complimentary. Li-Fi provides better bandwidth, efficiency, connectivity and security than Wi-Fi and has already achieved high speeds larger than 1 Gbps under the laboratory conditions. By leveraging the low-cost nature of LEDs and lighting units, there are lots of opportunities to exploit this medium. Li-Fi is the transfer of data through light by taking fibre out of fibre optics and sending data through LED light bulb.

**Monica Leba; Simona Riurean; Andreea Lonica et al., "LiFi — The path to a new way of communication", Published in: 2017 12th Iberian Conference on Information Systems and Technologies (CISTI), Lisbon, Portugal, Electronic ISBN:978-9-8998-4347-9.** This conference paper presents a detailed summarizes most of the research, developments and applications achieved so far and looks at the different aspects of the strengths and weaknesses, implementations, challenges, VLC IEEE standard and data modulation techniques of the VLC and specific LiFi's new coined optical wireless communication technology.[3] The paper exploring alternative parts of the electromagnetic spectrum that could potentially offload a large portion of the network traffic from the overcrowded radio frequency (RF) domain. Due to the latest improvements, the optical wireless communication (OWC) proves to be a viable alternative solution to the issues of forthcoming radio frequency RF spectrum crisis, especially in certain places and situations. Currently, most mobile data traffic is consumed indoor, where light fidelity (LiFi) which is related to visible light communication (VLC) offers lots of specific advantages, and effective solutions to the many issues of wireless communication.

**V Manikanta Sanjay, Ankith Indra Kumar, "A Review on Li-Fi: The Next Generation Wi-Fi", Published in *International Journal for Research in Applied Science and Engineering Technology*, November 2021, India, ISSN: 2321-9653.** In this comparative study,[4] Light Fidelity (LiFi) is a Visible Light Communication (VLC) based technology that making a light as a media of communication replacing the cable wire communication. LiFi is evolved to overcome the rate speed in Wi-Fi, while using LiFi the rate speed can reach until 14 Gbps. This paper includes an introduction of the LiFi technology including the architecture, working, performance, and the challenges Li-Fi, its applications, features and comparison with existing technologies like Wi-Fi etc. Wi-Fi is of major use for general wireless coverage within building, whereas Li-Fi is ideal for high density wireless data coverage in confined area and especially useful for applications in areas where radio interference issues are of concern, so the two technologies can be considered complimentary.

**Kanchan Tiwari Swami; Asmita A. Moghe et al., "A Review of LiFi Technology", Published in: December 2020 5th IEEE International Conference on Recent Advances and Innovations in Engineering (ICRAIE), India, Electronic ISBN:978-1-7281-8867-6.** This paper explores the basic need of LiFi over WiFi. It describes the working methodology of LiFi and briefly discusses the various modulation techniques used in LiFi technology for data transmission. [5] It also gives an overview of journey of visible light communication technology from ancient time to LiFi era. In this paper we have described the applications of LiFi in different domains which will help us to magnify the new research area in this technology. Which also answers the challenges of 5G.

**SOMESH KUMAR SINGH, SAKAR GUPTA, "A Review Paper on LI-FI", Published in IRE *Journal, April 2018,* India, Volume 1 Issue 10 | ISSN: 2456-8880.** This paper focuses on exploring this new communication technology and give relative study on Li-Fi.[6] In Li-Fi, from the electromagnetic (EM) frequency spectrum the visible light portion is used for information interchange which is analogous to conventional forms of wireless communication such as Bluetooth and Wireless- Fidelity (Wi-Fi), in which data or information is transmitted over the wireless medium using radio frequency (RF) signals. By modulating the intensity of light sources like LED is used as a transmitter and a photosensitive detector like Photodiodes (PD) is used for demodulation of the light signals to convert back into electrical form as a receiver. The intensity of light sources is modulated in such a way that which is unnoticeable to the human eyes. There is a crucial need of Li-Fi technology, to overcome the problem faced by the conventional wireless communication system. In this paper wide overview of need of Li-Fi, applications of Li-Fi, design challenges for Li-Fi, future scope and recent development in Li-Fi are provided.

**Nischay, "A Review Paper on Li-Fi Technology", Published in IJERT, April 2018, India, VIMPACT – 2017 (Volume 5 – Issue 23), ISSN (Online): 2278-0181.** This study paper focuses on Li-Fi, its applications, features and comparison with existing technologies like Wi-Fi etc. [7] Wi-Fi is of major use for general wireless coverage within building, whereas Li-Fi is ideal for high density wireless data coverage in confined area and especially useful for applications in areas where radio interference issues are of concern, so the two technologies can be considered complimentary. Li-Fi provides better bandwidth, efficiency, connectivity and security than Wi-Fi and has already achieved high speeds larger than 1 Gbps under the laboratory conditions. By Leveraging the low-cost nature of LEDs and lighting units, there are lots of opportunities to exploit this medium. Li-Fi is the transfer of data through light by taking fiber out of fiber optics and sending data through LED light bulb.

**J. P. M. G. Linnartz, C. R. B. Corrêa, T. E. B. Cunha et al., "ELIoT: enhancing LiFi for next-generation Internet of things", Published in *EURASIP Journal on Wireless Communications and Networking, September 2022.*** This paper investigates Future IoT applications such as flexible manufacturing, augmented reality and self-driving vehicles rely on sophisticated real-time processing in the cloud to which mobile IoT devices are connected. High-capacity links that meet the requirements of the upcoming 6G systems cannot easily be provided by the current radio-based communication infrastructure. Light communication, which is also denoted as LiFi, offers huge amounts of spectrum, extra security and low-latency transmission free of interference even in dense reuse settings. [8] The paper also discusses results from a distributed multiple-input multiple-output topology with a fronthaul using plastic optical fibre. And evaluate seamless mobility between the light access points and also handovers to 5G, besides low-power transmission and integrated positioning. Future LiFi development, implementation and efforts towards standardization are addressed in the EU ELIoT project.

**Mohammad Reza Ghaderi, "LiFi and Hybrid WiFi/LiFi indoor networking: From theory to practice", Published in Science Direct**, ***21 July 2022*****, Tehran, Iran, Volume 47, ISSN: 1573-4277.** This paper provides a comprehensive overview of how [9] Li-Fi technology holds the key to solving the challenges of 5th and higher generation mobile networks. LiFi is a two-way wireless communication technology that enables high-speed transmission on both up and down links simultaneously. Although LiFi provides high-speed data transfer capability, it has some weaknesses such as coverage. So, hybrid WiFi/LiFi network can uses fast data transfer from LiFi and wide coverage from WiFi. Their integration can complement the shortcomings of each of these technologies and increases the network performance. In this work, while describing LiFi theory, the recent studies in this field are presented. Theoretical and practical concepts of LiFi-based indoor networks, issues such as network structures, cell deployment models, modulation techniques, multiple access schemes, criteria for measuring network performance, and scenario-based architectures for implementing a real LiFi-based indoor network based on up-to-date equipment manufactured by some LiFi manufacturers are discussed in detail.

**Omar Faruq, Kazi Rubaiyat Shahriar Rahman et al., "Li-Fi technology based long range free-space communication data transmit system evaluation", Published in** ***Ak Journals*****, October 2023, Volume 14: Issue 3, Online ISSN: 2063-4269.** This review paper is an in-depth study and analysis of Light Fidelity (Li-Fi), [10] The research fields that are pertinent to Li-Fi networks are thoroughly analyzed and categorized in this paper: high speed data transmission, receiving, sharing, broadcasting through light in free space optical communication system by Li-Fi technology. They also followed some methods and developed a unique method to develop this study: VLC, OOK, a Lambertian discharge mechanism, LOS, NLOS, or a CMOS optical receiver. The proposed model tested transmits and receives audio, video, and other data, which is very high-rated and near the 2 GB/s range To address the numerous issues of Wi-Fi which is related to power supply, availability, efficiency, and security as a result of the various access points.

## III. OBJECTIVE

**1.Utilization of a practical Li-Fi system:** The objective is to effectively implement a functional Li-Fi communication system that leverages visible light for data transmission between devices. This involves constructing a system that demonstrates the core principles of Li-Fi technology, showcasing its ability to transmit data reliably and efficiently in real-world scenarios. By utilizing commercially available components such as LEDs and photodetectors, the aim is to validate the practicality of Li-Fi systems in various applications, including indoor communication, thereby contributing to the understanding of how optical wireless communication can be integrated into existing infrastructures.

**2.To implement simpler Li-Fi system for minimal scaling:** The goal is to design a straightforward Li-Fi system that minimizes complexity while maintaining essential functionalities. This approach focuses on creating a scalable architecture that can be easily expanded or adapted for different use cases without introducing significant overhead. By employing basic components and clear modular designs, the system can be scaled up or down based on specific requirements, making it accessible for educational purposes, prototyping, or small-scale commercial applications.

**3.To Develop a cost-effective Li-Fi system:** The aim is to create an economical Li-Fi communication system that demonstrates the feasibility of using optical wireless technology without incurring high expenses. By selecting affordable components and optimizing the design for cost-effectiveness, this project seeks to make Li-Fi technology more accessible to a broader audience. The low-cost system will serve as a proof of concept for potential applications in areas where traditional wireless communication may be limited due to infrastructure constraints or high operational costs.

## IV. SYSTEM DESIGN

The proposed LiFi system design focuses on the efficient transmission of diverse data types—including images, audio, and text—between two PC systems using Arduino-based components. The system consists of two primary units: a transmitter unit and a receiver unit. The transmitter unit features an Arduino board functioning as the central controller, equipped with a laser module to modulate light signals that represent encoded data. The user inputs data through a PC interface, which is processed by the Processing IDE to encode it into binary format. This encoded data is then transmitted as modulated light signals via the laser module. Conversely, the receiver unit also employs an Arduino board connected to an LDR (Light Dependent Resistor) sensor that detects incoming light signals.

As represented in the fig 1. The Arduino converts these light signals into electrical signals, which are decoded back into binary format using the Processing IDE. The decoded data is subsequently stored in a text document on the connected PC for further use. This design not only enables high-speed data transmission but also enhances security by confining light signals within physical boundaries, thus reducing the risk of unauthorized access. Additionally, it operates without electromagnetic interference, making it suitable for sensitive environments such as hospitals and aircraft. Overall, this integrated approach demonstrates LiFi's potential as a secure and efficient wireless communication methods while effectively facilitating real-time data transfer between two PC systems.

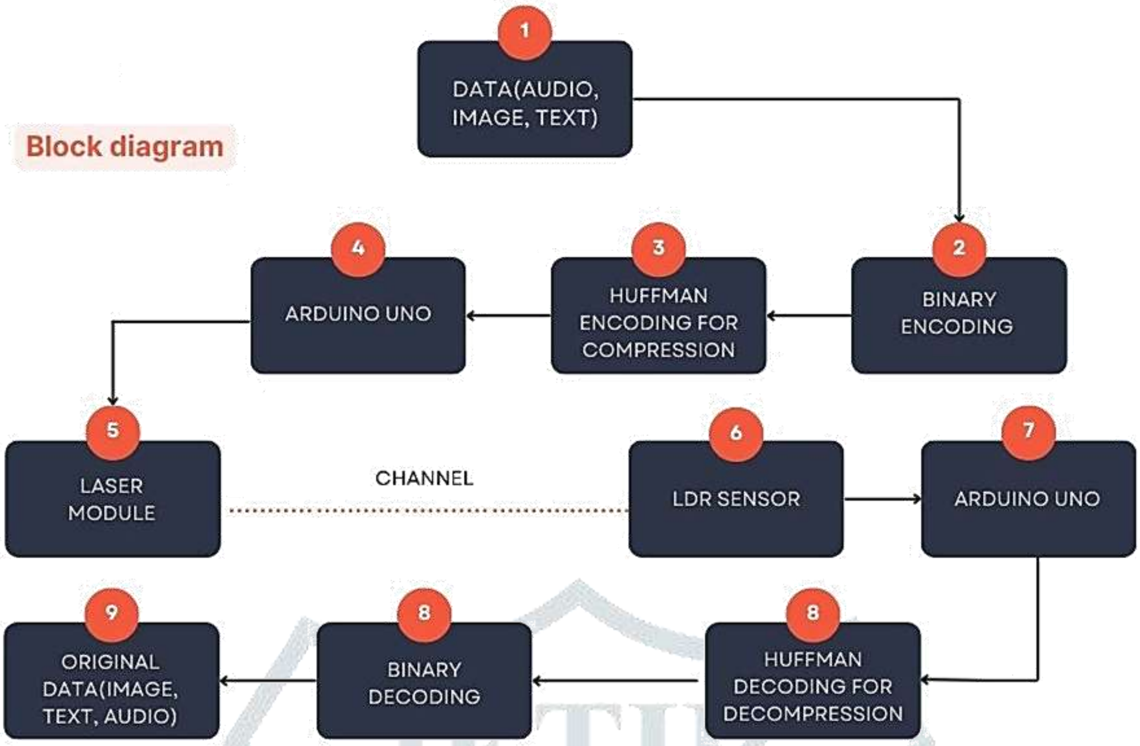


**Fig 1.** Block Diagram for system design.

## V. COMPONENTS USED

**Arduino Uno:** The Arduino Uno is a widely-used microcontroller board based on the ATmega328P chip, as shown in fig 2 designed for ease of use in electronics projects. It features 14 digital input/output pins, of which 6 can be utilized for Pulse Width Modulation (PWM), and 6 analog input pins. The board operates at a voltage of 5V and can be powered via USB or an external power supply ranging from 7 to 12V. With a clock speed of 16 MHz, it provides sufficient processing power for various applications. The Arduino Uno also includes built-in LED indicators, a reset button, and an ICSP header for programming. Its compatibility with the Arduino Integrated Development Environment (IDE) allows users to easily write and upload code. This board is favored by beginners and professionals alike due to its versatility and extensive community support.

**Fig 2.** Arduino Uno.

**Laser module:** it is a compact device that emits a coherent beam of light as shown in fig 3, typically used in applications requiring precise targeting or measurement. These modules can vary in wavelength, often emitting red or green light, and are commonly used in alignment tasks, optical communication, and even in Li-Fi systems. The laser module consists of a laser diode, which generates the light, and a housing that focuses the beam into a narrow point. Many laser modules also include a lens to enhance beam quality and distance. They are powered by low voltage sources (usually between 5V to 12V) and can be easily integrated with microcontrollers like the Arduino Uno for projects involving distance measurement or light-based communication. Safety precautions are essential when using laser modules to prevent eye damage or unintended reflections.


**Fig 3.** Laser Module.

**Light Dependent Resistor (LDR) sensor**: it is a type of resistor as shown in fig 4 whose resistance decreases with increasing incident light intensity. It is widely used in light-sensing applications such as automatic lighting systems, solar garden lights, and alarm systems. The LDR operates on the principle of photoconductivity; as light falls on the sensor, it allows more current to flow through it, thus reducing resistance. Typically made from cadmium sulfide (CdS), LDRs are sensitive to visible light wavelengths and can be connected to microcontrollers like Arduino for real-time monitoring of ambient light levels. In practical applications, they are often used in conjunction with other components like transistors or operational amplifiers to create more complex circuits that respond to changes in light conditions. For the current setup we used a three pin LDR sensor where A0 was absent.

**Fig 4.** LDR Sensor.

.**Jumper wires**: they are essential components in prototyping and circuit building that allow for easy connections between different electronic components on a breadboard or an Arduino board. As shown in fig 5 These wires come in various lengths and are available with male or female connectors at either end, making them versatile for different applications. Jumper wires facilitate quick assembly and modification of circuits without the need for soldering, which is particularly beneficial during the development phase of projects. They can be used to connect sensors, actuators, microcontrollers, and other electronic devices seamlessly. Available in both solid core and stranded varieties, jumper wires provide flexibility in design while ensuring reliable electrical connections. Their ease of use makes them indispensable tools for hobbyists and engineers alike when creating temporary setups or experimenting with circuit designs.

**Fig 5.** Jumper wires.

## V. METHOLOGY

**Hardware setup:**

the hardware setup consists of two Arduino Uno boards, a laser module, an LDR sensor, and jumper wires, all of which are for establishing a simple Li-Fi communication system. The **Arduino Uno** serves as the central control unit for both the transmitter and receiver. For the transmitter side, one Arduino is connected to a **laser module** (that emits modulated light signals) as shown in the fig6. Specifically, pin 3 of the Arduino is connected to the signal pin of the laser module, while the GND and 5V pins connect to the GND and VCC pins of the laser module, respectively. This configuration pin 3 can be changed to any digital pin and should be reflected the specific pin in the transmitter code.

On the receiver side, the second Arduino Uno interfaces with an **LDR (Light Dependent Resistor)** sensor as shown in the fig 6, We used a three pin LDR sensor so A0 was absent, The LDR pin D0 is connected to analog pin A0 of the Arduino, with its VCC and GND pins connected appropriately to power the sensor. The LDR detects variations in light intensity emitted by the laser module and converts these light pulses into electrical signals that can be interpreted by the Arduino. The configuration of pin A0 can be changed to any other analog pin and should also be reflected same in the receiver code. Jumper wires facilitate all necessary connections between components, ensuring reliable communication pathways. To enhance light reception and minimize ambient interference, a small paper tube can be used to align the LDR directly with the laser beam. This careful arrangement of hardware components is for achieving effective data transmission through visible light.

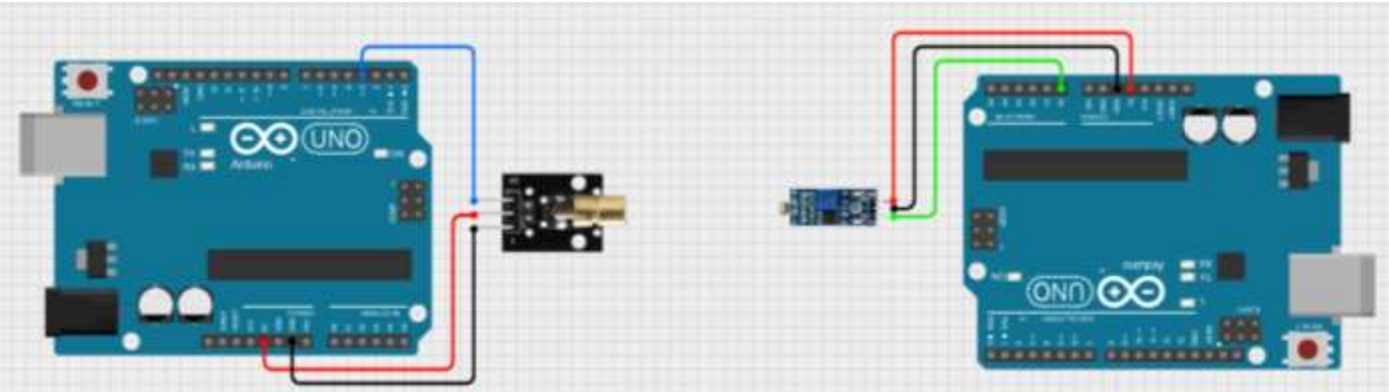


**Fig 6.** Jumper wires.

**Software Setup:**
The software setup involves programming both Arduino boards using their respective Integrated Development Environments (IDEs). The transmitter Arduino is programmed using the **Arduino IDE**, where code is written to transmit binary code in light signal form at a higher baud rate for efficient transmission. The binary code text file is generated using an online tool that encodes any data into binary sequences that are then downloaded and stored. This code controls the laser module to emit light pulses corresponding to each binary digit—where a '1' is represented by an illuminated laser and a '0' by its absence. Also, the **Processing ide** is coded to read and display the binary code from the online sourced encoded text file. It is connected to Arduino ide through the baud rate the code should also set the baud rate similar to Arduino ide to ensure synchronization. If the data is huge then compress the data using Huffman encoding method

On the receiving end, the second Arduino Uno runs a complementary program that reads input from the LDR sensor via analog pin A0. The software continuously monitors light intensity levels and translates these readings back into binary data. This data is then displayed in real-time on the Serial Monitor within the Arduino IDE. Additionally, a **Processing IDE** application is employed to read this binary data and store it in a text file for further analysis. Once data transmission is complete, If the data has been compressed with Huffman encoding then decode it. Online tool can be utilized to convert the received binary data back into its original data format.

## VI. RESULTS & DISCUSSIONS

The project highlights the remarkable versatility and effective use of Li-Fi technology, showcasing its ability to facilitate seamless transmission and reception of encoded information through light signals as shown in Fig 7 and Fig 8 the LDR sensor will blink both led only when laser light is transmitted. By utilizing visible light as a medium for data transfer, Li-Fi enables high-speed wireless communication that is both secure and reliable. Unlike traditional wireless technologies that rely on radio frequencies, Li-Fi operates without electromagnetic interference, making it particularly advantageous in environments where data integrity is critical. also ensures that sensitive information can be transmitted securely, mitigating the risks associated with unauthorized access. However, due to limited hardware capability there are certain setbacks such as ram, and higher baud rate, which lead to inefficient use of Li-Fi technology.

Replacing with a more versatile component and a set up on simpler design, the lifi communication can be made more practical and efficient compared to the traditional RF system. And can also co-exist to compensate for each other's drawbacks. Li-Fi's potential as a transformative solution in modern communication systems is vast. Its ability to integrate seamlessly with existing infrastructure while providing high-speed connectivity positions it as a key player in the evolution of wireless communication technologies. As research and development continue to advance, the future of Li-Fi looks promising, paving the way for innovative applications that leverage its unique capabilities.

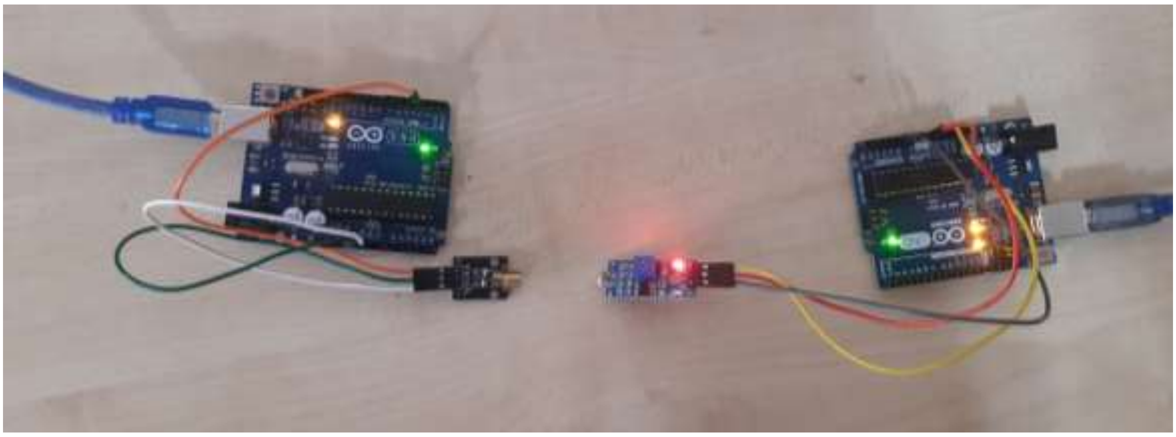

**Fig 7.** Li-Fi system when the binary code has 0's symbol.

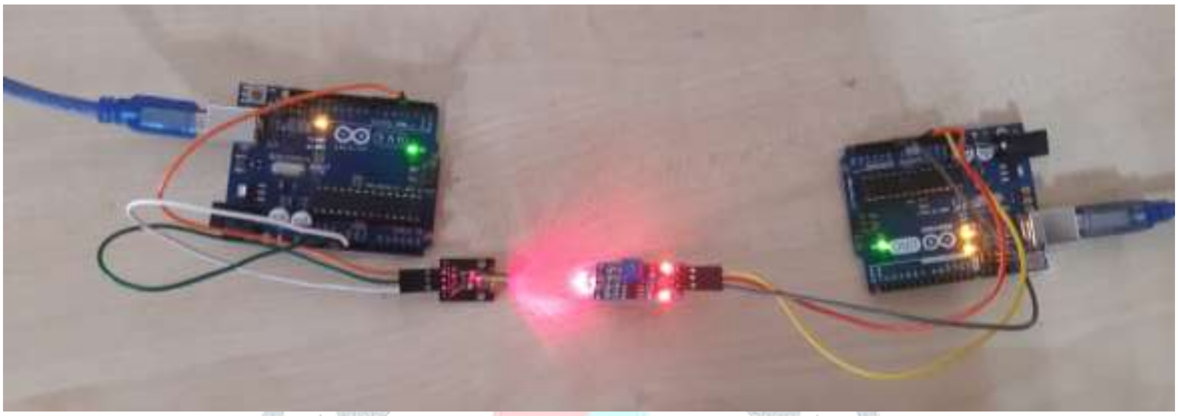

**Fig 8.** Li-Fi system when the binary code has 1's symbol.

## VII. CONCLUSION

The advent of Light Fidelity (Li-Fi) technology marks a significant paradigm shift in the domain of wireless communication, leveraging the vast and underutilized spectrum of visible light for data transmission. As a complementary system to traditional radio frequency-based networks, Li-Fi promises to alleviate the congestion faced by existing Wi-Fi infrastructures, offering data rates potentially exceeding those achievable via conventional methods by several orders of magnitude. The inherent characteristics of Li-Fi, such as its immunity to electromagnetic interference and enhanced security—due to the confinement of light within physical boundaries—position it as an ideal solution for high-stakes environments like military operations and healthcare facilities. Looking ahead, the trajectory of Li-Fi development appears robust.

## VIII. REFERENCE

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