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Design and Experimental Analysis of a Laser-Based Li-Fi Communication System

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Abstract: Light Fidelity (Li-Fi) is an emerging optical wireless communication (owc) system that employ light-emitting diodes (LEDs) to acheive medium to high speed transmission using optical signals. Li Fi is a form of Visible light communication(VLC) technology i.e. lifi provides secure communication connectivity for under water communication,smart home, smart cities, classrooms and hospital,medicial equipment,traffic and vehicle communication. It strengthens security compared to modern radio-frequency (RF) communication systems. RF-based systems are sensitive to jamming, and the available spectrum is heavily occupied due to multiple devices operating on the same frequency band. This results in issues such as low data quality, collisions, and interference, particularly in indoor environments.In this work, a low-cost Li-Fi communication system is implemented to address these limitations while keeping the system affordable and simple. The proposed approach uses microcontrollers such as ESP8266 and ESP32 as the transmitter and receiver, respectively. At the transmitter side, text data are entered from a phone or laptop into the ESP8266 through a serial interface and transmitted using a laser diode.The laser diode is controlled via On-Off Keying (OOK) modulation, in which the light source alternates between ON and OFF states to represent binary data. By streamlining the encoding and decoding process, this method facilitates the receiver's detection and interpretation of the transmitted text. At the receiver side, an ESP32 microcontroller is used to handle the received data, process it, and display the decoded text on an OLED screen. A high-sensitivity light dependent resistor (LDR) sensor module is used to sense the incoming light signal in real time, and threshold-based detection is applied to distinguish between logic levels. The system was tested indoors under normal lighting conditions, and successful text transmission was observed without noticeable interference during communication. The experimental result of Li-Fi demonstrate the high speed data transmission upto 100 Gbps.

Index Terms: Li-Fi, OWC ,VLC ,LED, ESP8266, Laser Diode, LDR Sensor, OOK

I. INTRODUCTION

A prospective wireless communication method that can either supplement or replace traditional radio-frequency (RF) communication systems is Light Fidelity (Li-Fi). By using light as the transmission medium, Li-Fi offers advantages such as high data rates, improved security, and reduced electromagnetic interference, making it suitable for sensitive and interference-prone environments [1], [2].Optical communication (OC) systems operate over the largely unregulated optical spectrum, enabling reliable data transmission without contributing to RF congestion. Among many approaches,laser based technology has gained high attention due to its high intensity and extended communication range [3]. Environmental conditions,line of sight are the major challenges in VLC communicatinon[4],[5].In recent years, research efforts have focused on developing simple and low-cost optical communication systems to overcome these limitations while maintaining practical feasibility [6], [7]. Such systems aim to improve adaptability and robustness without relying on complex signal processing techniques or expensive hardware. Optical communication is particularly suitable for indoor environments, where lighting conditions can be controlled to minimize interference and improve communication reliability [4].In this paper,the adaptive optical communication has been taken into consideration using the On-off keying modulation(OOK). The system employs ESP8266 and ESP32 microcontrollers for the transmission and reception of text data. A laser diode is used as the transmitting source, while a light-dependent resistor (LDR) is used at the receiver to detect variations in light intensity. A threshold-based decision mechanism is implemented to enhance signal reliability under varying indoor lighting conditions. The proposed design emphasizes simplicity, low cost, and practical implementation. It is suitable for indoor scenarios where conventional RF communication may suffer from interference, congestion, or security concerns. The experimental evaluation demonstrates that the suggested design is appropriate for affordable indoor optical communication applications by confirming that stable data transmission can be accomplished over short and moderate distances.

Unlike conventional visible light communication systems that employ photodiodes and complex signal processing, the proposed implementation focuses on a simplified and low-cost architecture using an LDR-based receiver and threshold-based decoding, making it suitable for educational and experimental applications.

II. SYSTEM ARCHITECTURE

The system depicted in fig.1. is essentially a short-range data transfer system built over a simple and inexpensive architecture. The system is fundamentally divided into three parts: data transmission, optical communication through free space, and data reception and display as text. At the transmitting end, the microcontroller ESP8266 is implemented, and at the receiving end, the microcontroller ESP32 is used for data decoding and output handling. Apart from this, some other low-cost optical wireless communication architectures for short-range applications have been reported in previous papers [6]. Text data is transmitted by On-Off Keying (OOK) modulation using a laser diode, and an LDR sensor module is placed at the receiving end to respond to changes in laser light intensity, which is a very common method in simple optical wireless systems [8].

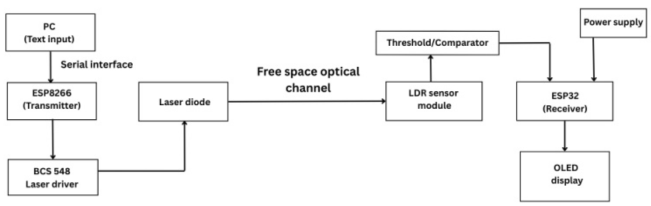

Fig. 1. Schematic diagram of optical communication system

A. Transfer of data

Text information is initially converted into an optical signal at the transmitter side and then transmitted. The ESP8266 microcontroller is utilized in this case as the control unit primarily due to its small size, low price, and suitability for transmitting simple text data in short-range communication systems [6]. The binary digit "1" in On-Off Keying (OOK) modulation is represented by switching the laser diode ON, and the binary digit "0" is represented by switching it OFF. This is a modulation technique that is commonly used in optical wireless communication because it is straightforward and requires very little computational power [8], [9]. The ESP8266 produces the necessary digital signal that corresponds to the encoded text data, which in turn directly controls the laser diode.

B. Receiving of Data

The receiving point acts as the signal receiver, which receives the data signal sent through the air and converts it back into the original message text. The ESP32 microcontroller on the receiving side is used to perform both signal processing and decoding operations.The laser beam is detected by the LDR sensor module, which varies its resistance according to the received laser light intensity. When the LDR is pointed toward the laser beam, its resistance changes with the amount of light it receives. The change in resistance is detected from the microncontroller and changed into electrical signal and gets processed using the logic for threshold to obtain the required digital output,[9] [10]. After that, the ESP32 decodes the digital signal to obtain the text data that was transmitted.

III. METHODOLOGY

The proposed system handles both short- and long-distance messages, and you do not need any fancy hardware or complicated signal processing. It just keeps things simple.On the receiving side, there is an LDR sensor module. It reacts to changes in light. It is not the fastest thing out there, so the system uses basic threshold logic to make sense of the signal. If you want to see exactly how it comes together, check out Fig. 2.

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A. Text Data Encoding and Transmission

The system uses On-Off Keying for each bits. when it receives a 1 then laser turn ON, . For it detects a '0', then laser turns OFF. The ESP8266 handles all the switching through a power circuit, so it stays quick and accurate. Once it is modulated, the light signal travels straight through the air to the receiver.

B. Optical Signal Detection Using LDR

On the receiver side, the LDR sensor detects any changes in the laser beam' s intensity. When light hits the LDR, its resistance changes. This change turns into an electrical signal that reflects the incoming light. However, the LDR's raw output is not ready for the ESP32 embedded controller yet. firstly It needs some signal conditioning first. The system relies on changes in ambient light to recognize when a signal comes through, and it does this effectively.

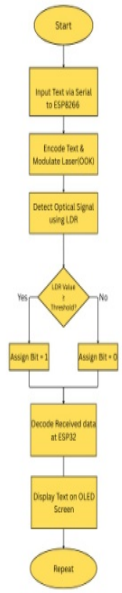

Fig. 2. Overall data flow of the proposed system methodology

C. Threshold-Based Decision Logic

To interpret those optical signals, the system uses a threshold-based decision logic. It compares the incoming voltage to a set threshold, V_{th}.If the signal is above the threshold, it is counted as valid. If it is not, the system ignores it. It is straightforward and effective. The received binary signal D(t) is determined as follows:

$$D(t) = \begin{cases} 1, & V_{LDR}(t) \geq V_{th} \\ 0, & V_{LDR}(t) < V_{th} \end{cases}$$

where $V_{LDR}(t)$ is just the voltage from the LDR, and it shifts depending on how much light hits the sensor. There's a set threshold to figure out when the laser's on or off, which helps block out extra light from the room.

D. Data Decoding and Display

That is easily accomplished with the ESP32, it just has to grab these bits as they arrive and decode them, putting everything back where it belongs. It only takes collections of bits and groups them into ASCII codes, making it simply perform bit operations and get the text out at some point. And with the OLED screen on the ESP32, we can show this text and you guys might actually be able to understand what that was.

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E. Performance Evaluation

For an indication of whether everything is working, watch the Bit Error Rate (BER). This serves to validate the transferred data. You just take the number of bits you received that were wrong N_e and divide it by how many you took in total N_t.

$$\text{BER} = \frac{N_e}{N_t}$$

BER was tested by transmitting an identical textual report and examining errors with distance. That helped us see how reliable the system is as you take it farther.

IV. EXPERIMENTAL SETUP

The suggested system's trial setup was carried out in an indoor setting with typical illumination. The main goal of this experiment was to see if it is possible to send text data over distances using the proposed system and to observe its ability to adapt to receiving signals. The proposed system was tested to validate its feasibility in this setup. The experiment was conducted to check the proposed system and its hardware architecture in an environment. The experimental evaluation focuses on verifying correct end-to-end data transfer, signal detection reliability, and real-time text display at the receiver. All tests were carried out in a controlled indoor setting to observe system behavior under practical operating conditions rather than ideal laboratory isolation.

A. Test Experiment

We did all the experiments in a room where we could control everything. The laser and the sensor were placed so the laser and the sensor faced each other.This way, we could make sure the laser and the sensor had a clear path to communicate with each other. We made sure the laser beam from the transmitter went directly to the sensor that received the signal. This helped us obtain a continuous signal from the laser. When we were performing the experiments, we kept the regular room lights on along with the laser and the sensor. We did this to see how the system works in real situations when all the lights are on. This allowed us to observe how the system behaves indoors under normal lighting conditions. The system was tested to see if it could work properly with the lights that are usually on, such as the lights in homes and offices, and not only when it is dark. We wanted to know if the system could work well under normal lighting conditions. The system was tested with the lights on to observe whether it operates properly under such conditions. Sometimes, systems are tested under different environments. The sensor works differently when there is background lighting present. The sensor does not behave the same all the time because of the background lighting. This helps us see how well the sensor works with the threshold-based reception approach. Background lighting makes a difference in the sensor output. Both the sensor and the threshold-based reception approach are affected by background lighting. This helps us understand how well the sensor and the threshold-based reception approach work together.

Both the transmitter and receiver were placed on stable platforms to avoid movement or vibration during operation. Maintaining physical stability ensured that any observed variations in performance were due to system behavior rather than mechanical misalignment. This setup enabled repeatable experiments and consistent observation of system performance.

B. Hardware Configuration

The transmitter section of the system consists of an ESP8266 microcontroller, an NPN transistor, and a laser diode. The ESP8266 is responsible for receiving the input text data and generating the digital control signal required for optical modulation. The system is powered through a laptop USB connection, which provides both power and serial communication for input data transmission during experimentation. The NPN transistor is used as a driver circuit to regulate the laser diode. Since the output current of the ESP8266 is limited, the NPN transistor guarantees that the necessary current multiplication is obtained to properly drive the laser diode. The laser diode is modulated using on-off keying based on the digital signal produced by the microcontroller, where the laser is turned ON and OFF according to the binary data to be transmitted. An ESP32 microcontroller, an LDR sensor module for optical signal detection, and an OLED display that shows the decoded text data make up the receiving unit. The LDR sensor detects the incoming optical signal and converts variations in light intensity into corresponding electrical signals. These signals are processed by the ESP32 using threshold-based logic to distinguish between logic '1' and logic '0'.The ESP32 takes the information it gets from the LDR sensor and puts it back together into the original message. The ESP32 displays the decoded message on the OLED screen as it happens so you can immediately see if it worked. The whole setup receives power from a power supply, allowing standalone operation without dependence on a computer system. Fig. 3 shows the entire hardware configuration of the suggested system.

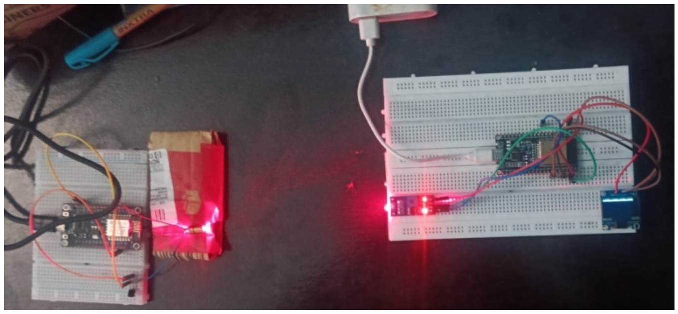


Fig. 3. Experimental setup for Li-fi system

C. Operating Conditions

The experiment involved sending the text strings repeatedly from the transmitter to the receiver. This was done to make sure the communication process was consistent and reliable. The receiver got the signal and turned it back into text. Then it showed the text on the OLED screen as it happened. The receiver did this with every signal it got. The text strings were sent multiple times to test the system.

The OLED screen showed the text in real time, which meant it displayed the text as soon as the receiver got it.The system was tested in indoor lighting conditions. This included changes in the surrounding light to see how it affected the detection and decoding accuracy. The system was also tested with the transmitter and receiver at different distances from each other, but still close enough to observe how stable the system was. The goal was to test the system under various conditions to see how well it worked. The system and its signal detection and decoding accuracy were the focus of the test and its performance under different separation conditions. The threshold value used for signal detection was adjusted according to the adaptive reception strategy. This adjustment was performed to ensure reliable differentiation between the presence and absence of the laser signal under changing environmental conditions. Proper threshold selection played an important role in maintaining consistent signal detection and minimizing decoding errors.

D. Data Observation

Validation of the transmitted text was checked by comparing the transmitted text with that shown on the OLED terminal screen using an independent viewing receiver. The transmitted text was attempted to be received for decoding when the received text was block-wise the same as the transmitted input (containing no missing and incorrect characters). Differences were noted and explained in terms of alignment precision, surrounding light conditions, and the threshold used during testing. This monitoring framework is used for experimenting with the behaviour of the system and investigating the limitations of the proposed laser-based Li-Fi system.

V. RESULTS AND DISCUSSION

The results and discussion are mainly centered on assessing the dependability of short-range text data transmission under indoor illumination by employing the adaptive thresholdbased reception method. This work aims at examining system performance in real operating conditions and also at determining the factors affecting the stability and accuracy of the communication. Experiments were conducted at various transmitter-receiver distances under controlled indoor conditions. At closer ranges, the strength of the received optical signal was high enough to allow accurate threshold-based detection that led to the proper decoding of the transmitted text.

The received text in fig.4. was shown on the OLED screen in real time, thus confirming the successful communication from end to end [11]. When the transmitter and the receiver are far apart, the signal does not always remain strong. The further the distance between the two points of communication the less the optical power recieved. This is because the light beam spreads out and it becomes difficult to keep it aligned. When this happens, it is harder to decode the signal. That means the distance plays an important role in optical system,in case of simple optical receivers.The transmitter and the receiver can also be affected by light sources, which can cause problems with the optical link in some cases. Indoor lighting caused background illumination at the receiver, which in turn affected the sensor output and resulted in variations in the signal level. This effect was more pronounced at longer distances, where the intensity of the laser at the receiver was lower. The adaptive threshold mechanism was very helpful in dealing with this issue. It allowed us to adjust the detection level based on the environment.

Table I summarizes the observed system performance at extended transmission distances under outdoor line-of-sight conditions.We noticed that the Bit Error Rate (BER) was low when we were transmitting over short distances, when everything was properly aligned and the signal was strong. The BER stayed low as long as we had a good signal and proper alignment. When we increased the distance, the BER started to increase. This happened because the received signal was weaker and more easily affected by surrounding light.

TABLE I

LONG-DISTANCE PERFORMANCE OF THE PROPOSED SYSTEM UNDER OUTDOOR LINE-OF-SIGHT CONDITIONS

Distance (m)	BER	Success (%)	Observation
100	0.05	90	Stable reception with clear decoding
200	0.09	85	Slight signal attenuation observed
300	0.14	78	Minor decoding errors present
400	0.20	70	Reduced signal strength at receiver
500	0.26	62	Weak detection with frequent errors
600	0.31	56	Intermittent reception under alignment
700	0.36	50	Highly sensitive to alignment
800	0.40	46	Unstable reception with high noise
900	0.44	42	Partial decoding only
1000	0.48	38	Limited reliability, near system limit

This behavior is expected in a wireless communication system that relies on having a clear line of sight. The adaptive threshold mechanism and the Bit Error Rate are important parts of such systems. Proper alignment between the laser diode and the receiver sensor was found to be critical, especially for longer transmission ranges. Due to the limited response time of the LDR sensor, the achievable data rate was limited to a few hundred bits per second. Since the laser diode produces a narrow and highly directional beam, even small misalignments resulted in a noticeable reduction in received signal strength. Accurate alignment is therefore necessary to control the flow of light from the transmitter to the receiver and to ensure stable data reception. The results show that using a laser diode is very effective for short-range communication because it sends the signal in one direction [12]. This helps prevent the signal from spreading out and improves performance over distance. One of the advantages of this system is that it is simple and does not cost much to set up. It can be made simple and low-cost by using basic components and simple signal processing methods. The laser diode system also has some limitations. Using an LDR sensor makes the system respond slowly, which limits the achievable data rate and makes it unsuitable for high-speed transmission . In addition, the LDR sensor requires a strict line-of-sight with the transmitter, which makes the system difficult to use in many situations and less reliable when obstacles are present. Despite these restrictions, the current study effectively illustrates the operation of Li-Fi using low-cost and easily available components, which is consistent with the fundamental concepts of Li-Fi communication systems [11],[12].The observations validate the feasibility of implementing basic optical wireless communication systems using simple and low-cost components, and the results provide a foundation for future enhancements and performance improvements.

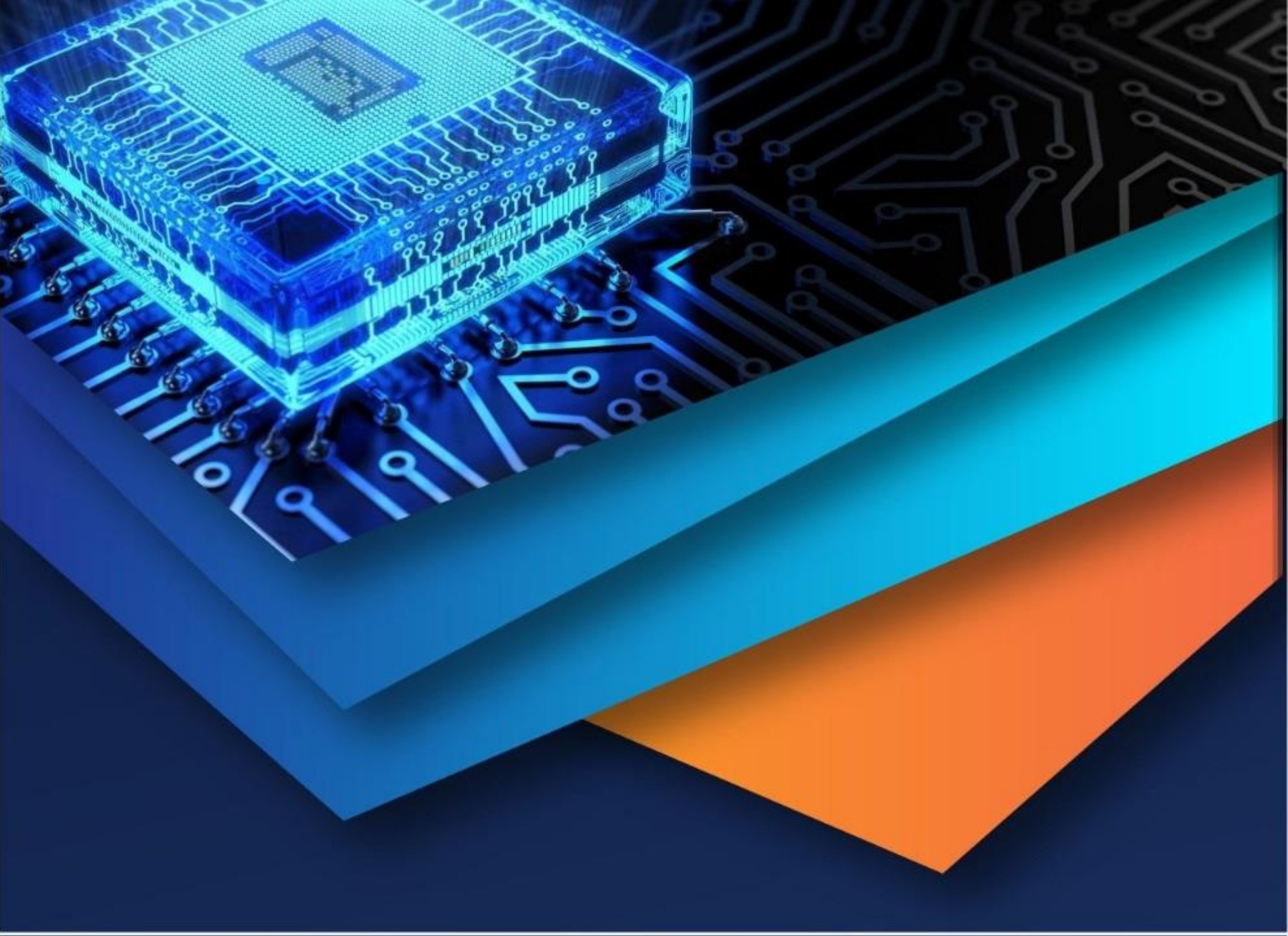
Fig. 4. Received text displayed on the OLED screen during experimentation.

VI. CONCLUSION AND FUTURE SCOPE

The work of the research concludes the design and testing of a laser-based optical network for short range text data communication. The experimental results demonstrated that the proposed system was capable of performing optical data transmission under indoor lighting conditions. Using on–off keying modulation and adaptive threshold-based reception, the system was operated. The results of the trials verify that it is feasible to transmit text reliably at short distances if the alignment between the transmitter and receiver is properly maintained. The laser diode used to supply the light provided high directionality, which facilitated focused signal transmission, and the adaptive threshold method allowed detection to be more stable even in the presence of ambient lighting. The use of high-speed photodiodes and optical lenses can significantly increase the distance over which transmission can take place with a higher degree of reliability. The use of an LDR sensor results in a slow response; thus, the achievable data rate is limited. In addition, the need for strict lineof-sight alignment reduces the degree of freedom and the communication range. These disadvantages highlight a tradeoff between system simplicity and performance. Despite these limitations, the present work convincingly demonstrates the operation of Li-Fi using very cheap and readily available components. The system can be considered a proof of principle optical wireless communication setup, which sets the scene for the use of faster optical sensors and higher data rates or audio transmission in the future[14].

REFERENCES

[1] M. A. Z. Chowdhury, M. T. Hossan, A. Islam, and Y. M. Jang, “Visible Light Communication and LiFi: Recent Advances and Future Trends,” IEEE Access,2024.
[2] A. M. Khalid and H. Elgala, “Optical Wireless Communication: Recent Progress and Challenges,” IEEE Photonics Journal, 2024.
[3] A. Gomez, K. Shi, and S. Wang, “Laser-based optical wireless communication systems: Recent trends and applications,” IEEE Access, 2023.
[4] P. Sikder, R. Islam, and M. R. Hossain, “Advancements and challenges of visible light communication for indoor applications,” Photonics, 2025.
[5] S. Vappangi and R. Mitra, “A survey on integration of visible light communication with wireless systems,” Displays, 2022.
[6] A. Petrosino and L. Rugini, “Li-Fi for Internet of Things: Recent developments and open challenges,” Optical Switching and Networking, 2023.
[7] M. G. Al-Hamiri and A. Abd, “Performance enhancement techniques for Li-Fi communication systems,” Optical Wireless Communications, 2024.
[8] B. G. Lee, S. Y. Jung, and S. H. Kim, “Threshold-based signal detection techniques for optical wireless communication,” IEEE Photonics Technology Letters, 2022.
[9] J. Islim, D. Tsonev, and H. Haas, “Optical wireless communication systems beyond RF limitations,” IEEE Communications Magazine, 2023.
[10] R. Perez-Jimenez, J. R. Perez, and F. J. Lopez-Hernandez, “Lowcost optical receivers for short-range optical wireless links,” Optical Engineering, 2022.
[11] S. Dimitrov and H. Haas, “Optical wireless communication principles for indoor Li-Fi systems,” IEEE Communications Surveys & Tutorials, 2022.
[12] H. Haas, L. Yin, Y. Wang, and C. Chen, “What is LiFi?,” Journal of Lightwave Technology, vol. 34, no. 6, pp. 1533–1544, 2016.
[13] S. Rajagopal, R. D. Roberts, and S. K. Lim, “IEEE 802.15.7 Visible Light Communication: Modulation Schemes and Dimming Support,” IEEE Communications Magazine, vol. 50, no. 3, pp. 72–82, 2012
[14] Y. Wang, Z. Li, and H. Haas, “Recent Developments in LiFi Technology for High-Speed Indoor Wireless Communication,” IEEE Open Journal of the Communications Society, 2025.



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