Sistem LiFi / VLC - Implementare practică

LiFi / VLC system - Practical implementation

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Abstract: Articolul prezintă modul de realizare și testare a unei platforme experimentale LiFi realizată în scopul demonstrării modalităților de integrare a comunicației optice wireless în rețele de acces eterogene. Sunt măsurate ratele de bit, latența și factorul BER pentru diverse scenarii de utilizare și este indicată modalitatea de interconectare cu rețelele pe cupru – Ethernet sau radio. De asemenea sunt puse în evidență avantajele și dezavantajele tehnologiei optice comparativ cu celelalte tehnologii.

Abstract: The article presents the way of realization and testing of a LiFi experimental platform designed to demonstrate ways to integrate wireless optical communication into heterogeneous access networks. Bit rates, latency, and BER factor for different usage scenarios are measured, and interconnection with copper networks - Ethernet or radio is indicated. It also highlights the advantages and disadvantages of optical technology compared to other technologies.

1. INTRODUCTION

The emergence of real-time multimedia applications, digital Internet services and other business and personal applications required the development and deployment of broadband network access technologies. Wireless broadband access technologies facilitated high-speed access to fiber-based backbone infrastructure. Some of the services commonly used in need of high-speed network access can be classified as follows [1], [2]:

1. Broadcast, multicast services - digital television and PPW channels;
2. Interactive interactive video services, interactive games, home shopping and telemedicine;
3. Internet - Internet browsing, download and banking transactions;
4. Services - home work, video conferencing and video telephony;
5. Small Office / home Internet web design page, Internet server;
6. Others - streaming video, audio, fax, e-mail and file transfer.

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The potential market for fixed broadband wireless technologies is very high. These technologies will soon replace local telephony companies, classical on-line telephony is a non-economic and outdated appearance in the current context. Also, HFCs for distribution of television signal will be redesigned. With the help of new combined technologies (radio-optic), a single access point in the dwelling will provide the three basic services: telephony, internet and television [3].

Services such as telephony, TV broadcasting, signage, SMS, MMS, e-Health (DES), e-commerce, bank transfers and video on demand are among others expected to change as a share of traffic in the world market at a different pace during the following years. The biggest increase in Internet traffic worldwide will come from advanced video services (resolution, interactivity). On the other hand, it is anticipated that service providers will continue to provide services, differentiating by making their quality consistent with service agreements with end-users. Network operators are therefore faced with the challenge of providing a range of services with different requirements in terms of quality assurance (QoS) services as well as transit of transmission networks using different transmission technologies in aspects such as multiplexing, coding and modulation formats, or aggregation of data transmission speeds.

Table 1 Developments in optical technology development for the next 10 years [3], [4]

Technology	**2015**	**2020**	**2025**
Physical level	A/D and D/A photonic converters	60% of components and electronic blocks will converge to the optical	80% of components and electronic blocks will converge to the optical
"Ultra" wide band networks	1 Gbps, 20% FTTH	10 Gbps, 50% FTTH	100 Gbps, 80% FTTH
RoF cognitive protocols	Transparency, energy efficiency	Partial optical signal processing, optical cognitive technologies	Total optical signal processing
Power consumption	Deploy "sleep" features at the network level	Replacement of switches and routers with their optical variants	All the critical components of the network will be optical. Total transparent networks. Only the management elements will work electrically.
Unmanaged optical comm. (new optical interfaces including femtocells and home networks)	New types of optical network interfaces. Use POF .	Large POF use	POF Generalization. Wireless and Wireless-Optic Integration New types of optical network interfaces. Use POF.c.

A review of the most significant issues related to infrared communication technology, which will enable the realization of future high performance and cost-effective indoor optical wireless systems. Several possible configurations for indoor optical wireless systems, modulation, and multi-access techniques are presented in [5] as well as their advantages and limitations discussed in detail.

In [6] is proposed „a new communication infrastructure which uses the existing heavy public infrastructure and simultaneously attaining the high bandwidth facility using Li-Fi technology. This new architecture uses two levels of communication. At core level, the existing communication infrastructure is used, whereas, at the terminal level the Li-Fi system is used. This type of architecture has many advantages that include low cost, high bandwidth facility. On the other hand, the usage of Li-Fi systems reduces the scarcity of radio spectrum, which is very important in the present communication system".

A prototype to demonstrate a full-duplex wireless (VLC - visible light communication) system based on Universal Serial Bus (USB) port is shown in [7]. „Combing with a USB 2.0 port on one board, it can achieve up to 2 Mbps bit rates error free, which is mainly limited to the USB bridge circuit, between two computers for data transmission, such as text, audio and video".

An overview of LED-based VLC with an comprehensive survey on advances and research activities in this technology, focusing on several aspects such as main elements of VLC systems, potential applications and challenges for practical implementation, integration and commercialization is described in [8]. In addition, VLC is compared with radio frequency (RF) systems and future directions in the field of high-speed LED-based VLC systems are considered. In this paper, [8], the author focus on „three main aspects of VLC: components of VLC systems, potential applications and challenges for practical implementation, integration and commercialization". Also, is provided a brief comparison of VLC with RF systems, and discussed the research in the field of ordinary LED-based VLC systems.

An extensive report about this technology is maded in [9]. This report, give an overview of the LiFi technology, discuss its benefits and challenges, and summarize research actions and standardization activities in the field, including commercially available products.

LiFi systems have a lot of possible applications. The most common application is the need for a wireless connection to the Internet for all devices located in a location (residential or office). Every living room or office room has a number of bulbs. If ordinary bulbs were replaced by LEDs, then it would be possible to deploy a LiFi system, the entire room would benefit from Internet access through the light. Due to this reason, LiFi technology has the potential to become very popular with local indoor networks. The author of [10] discusses about all key component technologies required to realize optical cellular communication systems referred to here as optical attocell networks. „Optical attocells are the next step in the progression towards ever smaller cells, a progression which is known to be the most significant contributor to the improvements in network spectral efficiencies in RF wireless networks" [10].

Figure 1 shows an experimental setup for implementing a LiFi system. The article presents the ways of interfacing the systems using radio and optical technologies (optical fiber) with LiFi / VLC systems. This "interfacing", which some call aggregation, has several aspects. Firstly, hardware aggregation between equipment (connectivity, signal types, signal levels, transmission speeds) must be achieved. Then follows the "software" aggregation, which consists of "interconnecting" the equipment in terms of modulation, multiplexing, signal compression / decompression formats. The term software has here the meaning of the structure of the signal, the interface having, among other things, the role of changing the signal format to the minimum speed imposed by the system.

A hybrid system consists of different communications networks and subsystems in terms of the technology used that can use different protocols for communication at its different points and may need transient aggregation devices.

Due to the increasing demand for access to high-speed internet services, radio-based infrastructures and copper-in-copper networks can not cope especially with dense urban environments.

With this versatile module, it is possible to verify and demonstrate how to "connect" LiFi to other technologies and communications (wireless radio, Ethernet, etc.).

2. EXPERIMENTAL SETUP

The article presents an experimental model using MOD-IRDA + and ESP32 Gateway optical modules in an infrared-assisted assembly. Both the transmitting and receiving devices (MOD-IRDA + modules) operate according to the IRDA / IRDA + standard, the device being used only to validate theoretical considerations, being adapted for interconnection with other technologies and transmission environments.
Figure 1 shows the experimental model - consisting of two ESP32 Gateway modules and two MOD-IRDA + modules connected via a UEXT interface [11].

A few characteristics of the ESP32 Gateway module:

- Contains an ESP32-WROOM32 module;
- Contains a MicroUSB connector;
- Has a USB CH340 serial converter;
- Built-in developer for Arduino and ESP-IDF;
- Has WiFi technology implemented, BLE connectivity;
- It is equipped with 100Mb Ethernet Interface;
- MicroSD memory card;
- 20-pin GPIO connector with all ESP32 ports;

With this versatile module, it is possible to verify and demonstrate how to "connect" LiFi to other technologies and communications (wireless radio, Ethernet, USB, etc.).

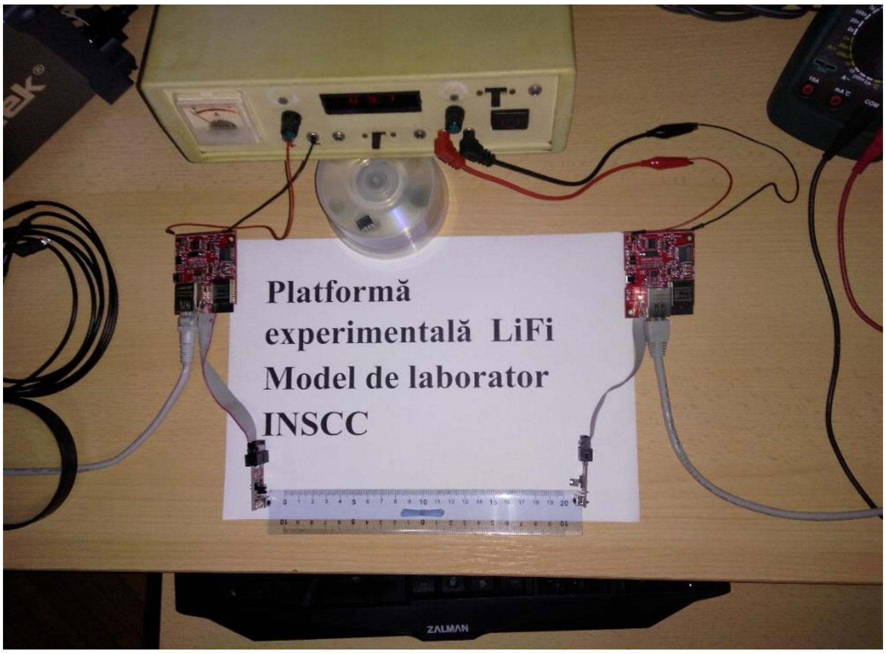

Fig.1 Experimental model – Optical gateway/modules (Ethernet coupling with ISP)

Figure 2 depicts the experimental electronic module (gateway board) that contain UEXT, IR MCU and ICSP modules [11] and figure 3 shows the power supply for this modules [11].

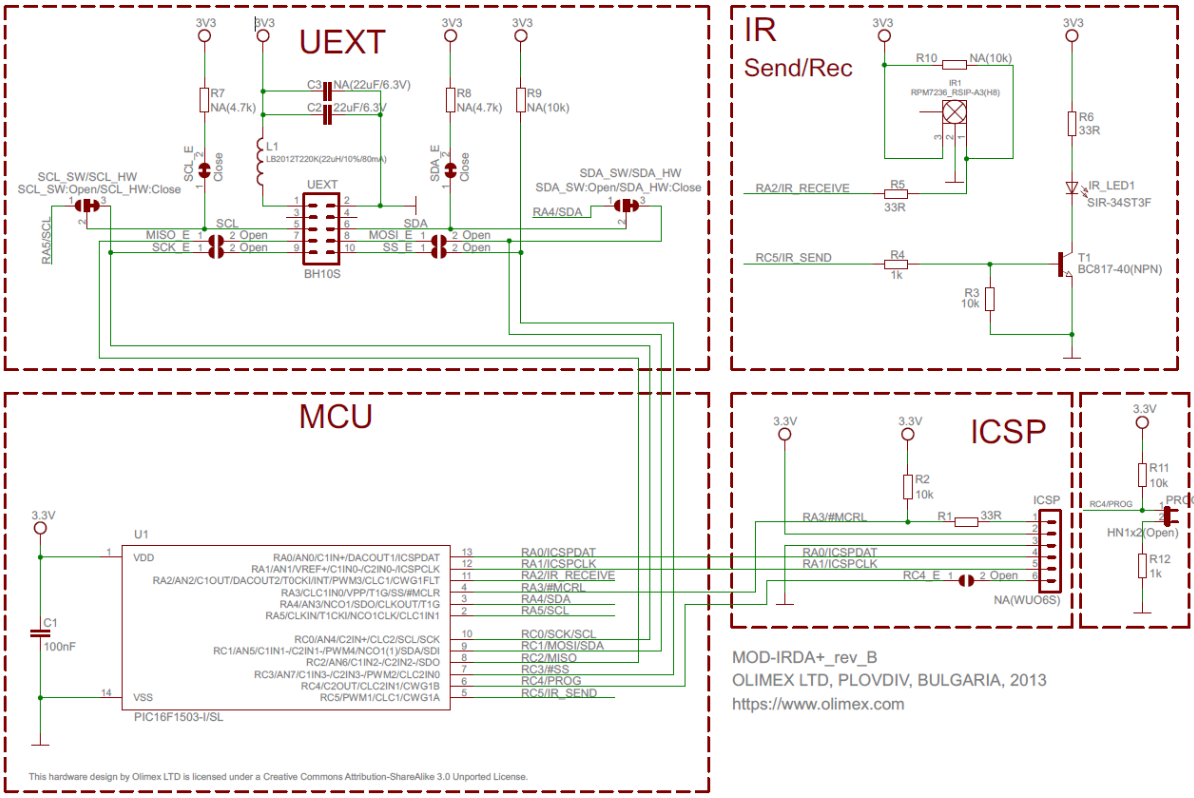

Fig. 2 Experimental Model – Gateway (contain UEXT, IR MCU and ICSP modules) [11]

LiFi systems must also be analyzed through the security of the transit data. A unique feature of LiFi systems is the increased security of data transmitted by the use of visible light, access to data being possible only from devices located in the same room with the system and in the light beam of the optical emitter. Depending on the purpose and nature of the communication, as well as on the importance of the transit data, it is possible to ensure a very low divergence of the optical beam, providing an extremely secure point-to-point connection.

Current LiFi systems operate in the 750-960nm (infrared) range, and even over (there are laboratory tests with wavelengths of 1310 and 1550nm). It is a question of choosing the wavelength ranges where the attenuation has low values for these types of applications using common and cheap components. The common feature for the optical transmitter and photodetector is the spectral range. In the wavelength range of 400-950nm we have some features:

- small specific attenuations;
- operating at relatively high power;
- components with features that allow high-speed modulation techniques with reduced size and power consumption;
- mature manufacturing technologies, materials and structures with low technological dispersion, increased amplification and low noise;
- ability to operate in a wide range of temperatures without major performance degradation;
- passive components represented by couplings and filters;
- high reliability - MTBF for at least 10 years (some manufacturers provide lifetime warranty on transceivers equipped with these types of components).

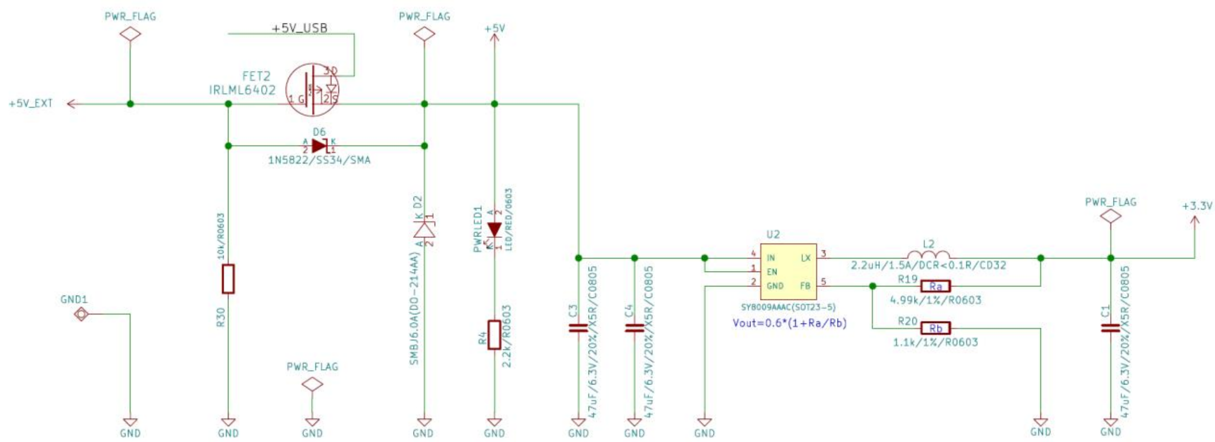

Fig. 3 Experimental module – power supply 5V – 3,3V [11]

Figure 4 shows the schematic of the Ethernet module used for the experimental model. Figure 5 describes the UEXT module used to interconnect the ESP32 board with IRDA+ module, as shown in Figure 6.

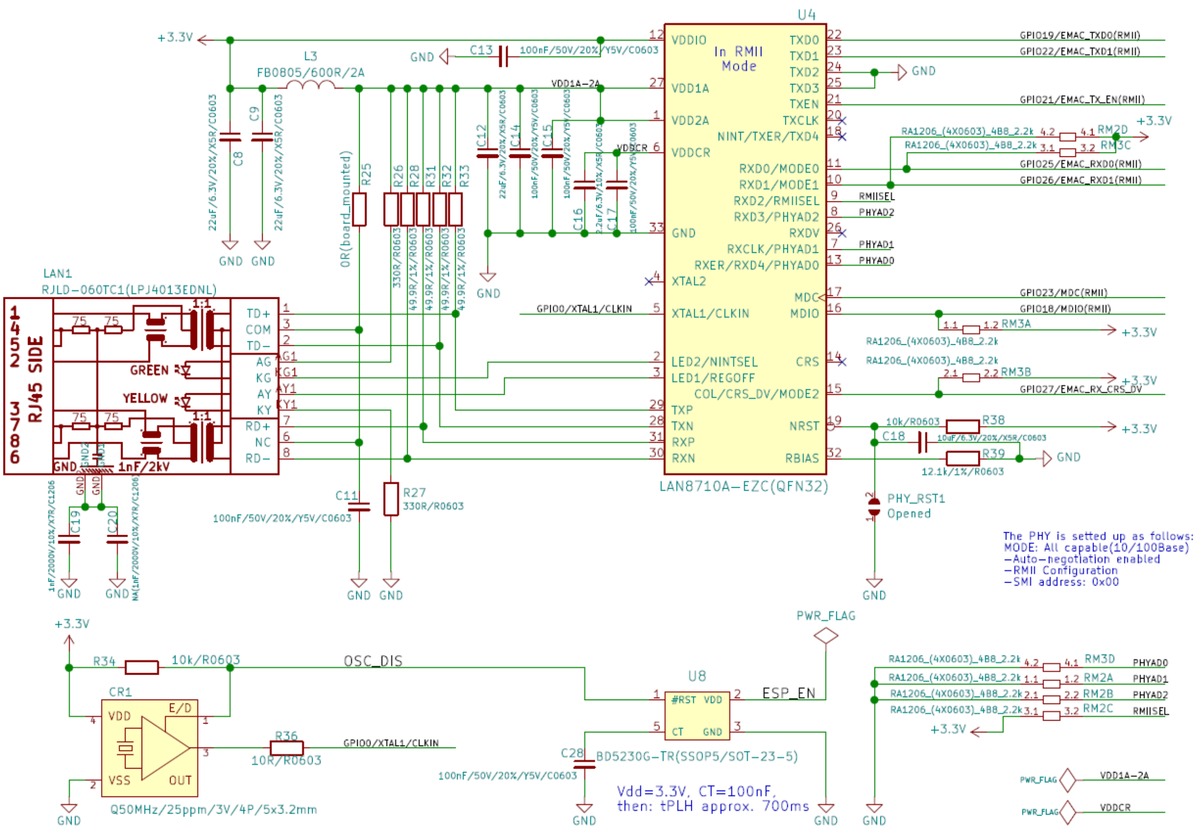

Fig. 4 Experimental model - Ethernet communication sub-system [11]

Pin #	Signal Name
1	3.3V
2	GND
3	TXD
4	RXD
5	SCL
6	SDA
7	MISO
8	MOSI
9	SCK
10	SSEL

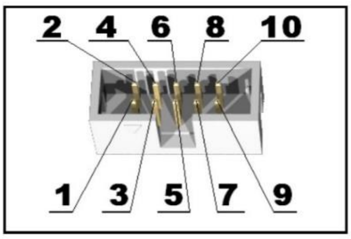

Fig.5 Experimental model – UEXT module [11]

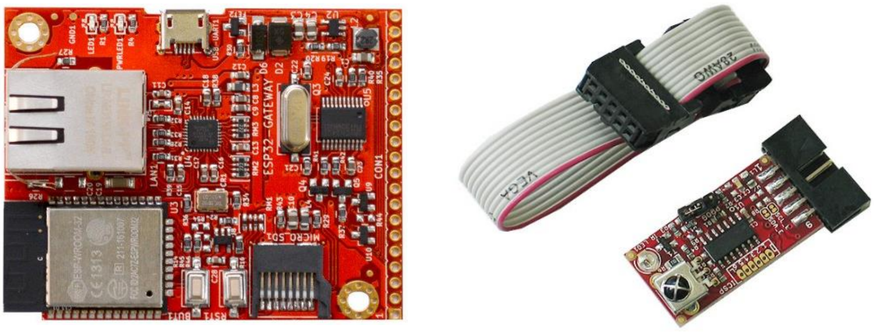

Fig.6 ESP32 Board with IRDA+ module [11]

3. RESULTS

The article presents the methods of interconnection, signal aggregation, transfer modes as well as considerations related to the design of hybrid systems using LiFi technology. LiFi / VLC communication between compatible devices and data transfer via the Gigabit-Ethernet (RJ-45) interface to the Internet is studied. This was made possible by choosing a versatile ESP32 module that contains all the commonly used interfaces currently in use. Even if the transfer rates are small, the purpose of the laboratory experiment is to demonstrate certain operating principles of the LiFi/VLC system and to validate the compatibility and signal aggregation with existing networks and technologies. Table 2 shows internet access speed for the experimental model.

Table 2 Internet access speed for the experimental model

Transmission distance [m]	Transmission speed [kbps]		BER	Latency [ms]
	Download	Upload		
0,2m	4900	4450	10^{-14}	14
0,5m	4100	3800	10^{-13}	16
1m	2800	2460	10^{-12}	16
2m	2600	2200	10^{-9}	24
5m	780	621	10^{-6}	42
10m	-	-	-	-

4. CONCLUSIONS

Unlike Wi-Fi systems, LiFi systems have limited coverage coverage on the surface of the camera in which they are deployed, the light not having the propagation property through walls and massive obstacles as in the case of radio frequencies. This feature has increased interest in the implementation of LiFi systems in the groups concerned with ensuring a high level of security of communication. For the experimental model access speeds can be increased by using switching (dedicated) components (infrared LEDs and photodiodes). Modules used in the experiment use common (very slow) components.

LiFi has a major potential because it can transform any conventional LED lighting system (residential / household or public) into an integral part of a Gbps network. Operates in the field of visible or even infrared wavelengths and avoids interference with radio spectrum requiring licensing.

Signal formats for video transmissions should include video encoding at different levels of digitization accuracy, video compression, high definition video, and high-speed data (internet). Understanding the issues of optical emission and reception, optical beam propagation, optical detection as well as multiplexing issues and the correct choice of modulation schemes is important for the practical implementation of a LiFi-based transmission system.

5. REFERENCES

[1] Viorel Manea, Sorin Pușcoci ş.a. „***Comunicații LiFi pentru aplicații SmartHome/SmartCity***”, PN 16 17 03 02 program nucleu – I.N.S.C.C., ian-dec. 2017.

[2] Olivier Bouchet, Pascal Besnard, Adrian Mihaescu, ***Indoor Free Space Optic: A new prototype, realization and evaluation***, 2013

[3] Kamsula P., ***Design and implementation of a bi-directional visible light communication testbed***, University of Oulu, Department of Electrical and Information Engineering, 2015

[4] Volker Jungnickel, Jelena Vucic, Klaus-Dieter Langer, ***High-speed Optical Wireless Communications***, Optical Fiber Conference (OFC), Fraunhofer (Heinrich Hertz Institute), March 13, 2014, San Francisco, CA, Tutorial Th1F.5

[5] Chaturi Singh, Joseph John, Y.N.Singh, K.K. Tripathi, ***Review on Indoor Optical Wireless Systems***, Ajay Kumar Garg Engineering College, Ghaziabad-2017

[6] D. Satyanarayana, Alex Roney Mathew, and Sathyashree S., ***An Architecture for Wireless Communication Systems using Li-Fi technology,*** 8th International Conference on Latest Trends in Engineering and Technology (ICLTET'2016) May 5-6 2016 Dubai (UAE)

[7] Liwei Ding, Fang Liu, Yingjie He, Hongbo Zhu, Yongjin Wang, ***Design of Wireless Optical Access System using LED***, Liwei Ding, Fang Liu, Yingjie He, Hongbo Zhu, Yongjin Wang, Optics and Photonics Journal, 2013, 3, 148-152

[8] Carlos Medina, Mayteé Zambrano, Kiara Navarro, ***LED based visible light communication: technology, applications and challenges – a survey***, International Journal of Advances in Engineering & Technology, Aug., 2015

[9] Ivica Stevanović, ***OFCOM-Report, Light Fidelity (LiFi)***, Federal Office of Communications OFCOM, Licences and Frequency Management Division, Radio Technology Section, April 10, 2017

[10] Dobroslav Tsonev, Stefan Videv and Harald Haas, ***Light Fidelity (Li-Fi): Towards All-Optical Networking,*** Institute for Digital Communications, Li-Fi R&D Centre, The University of Edinburgh, EH9 3JL, Edinburgh, UK, 2016
[11] https://www.olimex.com/

Disclaimer: All practical applications and experimental evaluations are made using Olimex modules and schemes (downloaded from https://www.olimex.com, reference [11]). The software for the ESP-32 module is a freeware (developer community download) with small modifications adapted for the needs of the proposed experimental model.