LiFi Towards 5G: Concepts, Challenges, Applications in Telemedecine

Pascal Lorenz and Louiza Hamada

August 25, 2020

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Pascal LORENZ
IUT Colmar
University of Haute Alsace
Colmar, France
pascal.lorenz@uha.fr

Louiza HAMADA
IUT Colmar
University of Haute Alsace
Colmar, France
louiza.hamada@uha.fr

***Abstract*—In recent years, the number of devices, applications and services based on a wireless connectivity has grown exponentially resulting in deep changes in our ways of living. New concepts such as the Internet of Things (IoT) associated with the connectivity of sensors and machines will amplify this phenomenon. The term "wireless" refers primarily to radio frequencies (30KHz to 300GHz), the main challenge is the saturation of the spectrum electromagnetic. In this paper, we give a survey of the most significant issues Li-Fi (Light Fidelity) systems that operate at short ranges. We consider the challenging issues facing these systems: link design and system requirements, transmitter and receiver structures, challenges and possible techniques to mitigate the impairments in these systems, applications in medicine and open research issues. In Li-Fi, the data are transmitted in several bit-streams flickering of the LED bulb and decoded on the receiver side. This happens in the form of a binary transmission of data, where '0' is the LED in its 'off-state' and '1' is the LED in its 'on-state' [1]. We use this concept to transmit data (audio signal) to demonstrate the use-cases and the possible impact it can have in the ever growing field of communication.**

Keywords—Data transmission;Visible Light Communication; Li-Fi; 5G; Telemedecine.

I. INTRODUCTION

To cope with the increase in connectivity, many solutions and techniques advanced [1] are envisaged in future standards (5G) while trying to limit the cost energy and indirectly the carbon impact. An alternative solution to overcome problematic is to use complementary technology to radio frequencies beyond 300 GHz. This area is that of wireless optics.

Li-Fi (Light Fidelity) or VLC (Visible Light Communication) is a new visible light data transmission technology; there are waves between 390 nm (blue) and 780 nm (red). While Wi-Fi (Wireless Fidelity) uses the radio part of the electromagnetic spectrum (frequency of 2.4 and 5 GHz), the Li-Fi uses is the optical spectrum (frequency between 385 and 790 THz). Existing for several years in unidirectional low-speed version this smart and connected light takes a new dimension via new generation Li-Fi luminaries, bidirectional and high-speed allowing access to the internet by light. Fig. 2.

Compared with RF (Radio Frequency) technologies, the Li-Fi technology has several advantages; a bandwidth available for this technology unlike radio-frequency technologies, the Li-Fi has a theoretical transmission potential much higher than wireless radio. This technology exploits the high frequency modulation capabilities of LEDs used in commercial lighting. It reaches speeds up to 10 Mbit / s at a distance of three meters, allowing fast Internet browsing, and even suitable for viewing online videos, using a luminous flux of less than 1,000 lumens with direct lighting or indirect. [2]

LEDs can withstand micro-intensity variations that make them switch up to several million times every second. The use of LED semiconductor technology allows a theoretical switching of state (On-Off) of a billion times per second, which gives a theoretical flow of 1 Gb/s. Each light source (LED) can therefore be converted into a Li-Fi transmitter and allows the sending of information at high speed. [3]

Machine-to-machine (M2M) technology Fig. 1. connects machines, devices and appliances wirelessly via a variety of communications channels, including IP (Internet Protocol) and

SMS (Short Message Service), to deliver services with limited direct human intervention. The number of devices connected to IP (Internet Protocol) networks will be more than three times the global population by 2022. There will be 3.6 networked devices per capita by 2022, up from 2.4 networked devices per capita in 2017[4]. There will be 28.5 billion networked devices by 2022, up from 18 billion in 2017[4].

In some cases, users would really like to directly communicate with one another at high speed, without routing messages through a network, such as machine-to-machine (M2M) and device-to-device (D2D) communications [5]. Two VLC transceivers such as smart phones or laptops can realize point-to-point communication directly [5]. Light communication becomes a feasible solution as well [5].

TABLE I. DIFFERENCE BETWEEN LIFI AND WIFI

Parameters	LiFi	WiFi
Standard	IEEE 802.15.xx	IEEE 802.11.xx
Frequency	Band 1000 times of THz	2.4 GHz
Bandwidth	Unlimited	Limited
Data Transmission	Bits	Radio waves
Transmitter	LED	Antenna
Cost	Low	High
Topology	Point to point	Point to multipoint
Electromagnetic Interference	No	Yes
Broadcast	Limited to the lighting zone	Long range
Applications	Operation theatres in the hospitals airlines, undersea explorations, , office and home premises for data transfer and internet browsing	Internet browsing with the help of Wi-Fi hotspots
Privacy	Light is blocked by the walls and hence will provide more secure data transfer	RF signal cannot be blocked by the walls and hence need to employ techniques to achieve secure data transfer.

IEEE 802.15.7 [6] provides for the use of dimmers that regulate lighting intensity and electrical energy consumption. The use of a dimmer and the Li-Fi transmission circuit must guarantee the lighting efficiency of the lamps. In terms of infrastructure, the replacement of light bulbs for new LED bulbs will create a dual network functionality: lighting and communications. Visible light is so far from the RF band that no interference is possible with other equipment running on the RF, allowing the use of Li-Fi in hospitals and airplanes, safely. Li-Fi has a communication area that is limited to the lighting zone, which limits its reach to this area, but it can

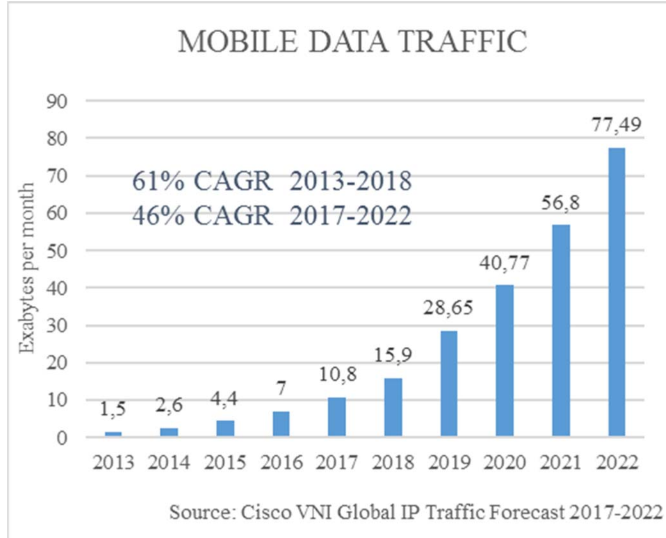

Fig. 1. Global M2M traffic growth.

also be a security advantage. RF is, however, significantly less sensitive to noise than Li-Fi. Li-Fi comes in addition to RF communications, it does not replace them. Table 1 presents a brief comparison between Wi-Fi communications and Li-Fi.

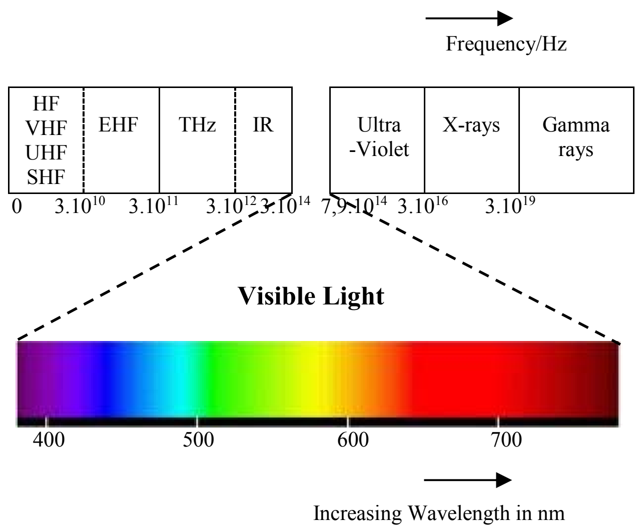

Fig. 2. Electromagnetic spectrum [7] [3].

II. BACKGROUND

The wireless communication based on electromagnetic waves dates back to the photophone -a telecommunications device invented by Alexander Graham Bell in the late 19th- that allows transmission of speech on a beam of light. The development of the wireless communication leads to advance research in Li-Fi technology [8]. This Visible Light Communications (VLC) technology is very new and was proposed by the German physicist Harald Haas in 2011[8].

The idea is to transmit wireless data from each light bulb: « cleaner, greener, bright, ».

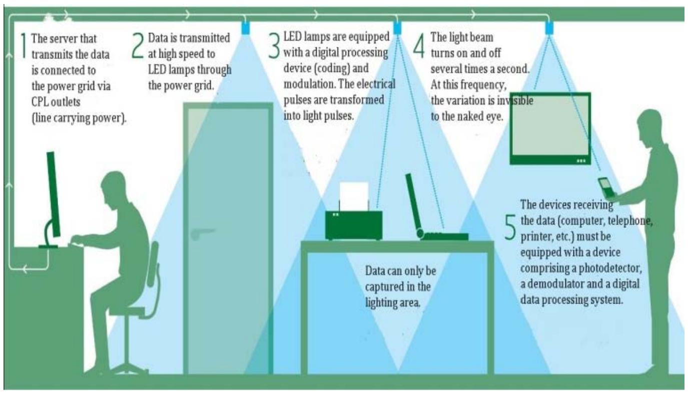

Fig. 3. Light Fidelity technology [8].

This technology consists of insert a microchip in the LED lamp connected to an up-stream collection transmission source (optical fiber, CPL or DSL ...). Fig. 3.

III. Li-Fi Networking

The operation is based on a transmission block and a reception block in which is intercalated, in between, an optical channel the light-emitting diode is used, which can be switched on and off several thousand times per second imperceptibly by the eye; it can be used to transmit information according to the computer binary system. On, the LED transmits a bit (1); off, it produces a bit (0) [9].

These extremely fast frequency changes (0 or 1) make it possible to transfer all types of video or audio data over a broadband connection. The transmission unit (central unit, Fig. 3) is a Li-Fi router which supplies the lighting system with electricity and data, while the reception block is a mobile terminal (cellular telephone or conventional tablet) which decrypts the signal bright thanks to a sensor that modulates it into a very high frequency Internet signal [9].

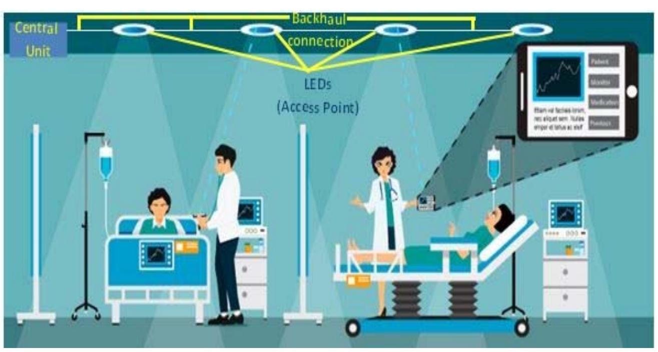

Fig. 4. Design of a Li-Fi architecture within the hospital [9].

According to the IEEE 802.15.7 [10] standard, the low bit rate for a PHY I layer is modulated with OOK (on off keying) or VPPM (variable pulse position modulation) modulation. The rate reaches 100 kb / s in the first case for a frequency a clock rate of 200 kHz and 266.6 kb / s with a clock rate of 400 kHz for VPPM modulation. When uses a PHY II layer, a 120 MHz clock OOK modulation allows to transmit 96 Mb / s. The use of a VPPM modulation with a clock frequency of 7.5 MHz makes it possible to reach 5 Mb /s. The PHY III layer is reserved for color modulation shift keying (CSK) that requires multi-chip LEDs; it can transmit 96 Mb/s in 16-CSK mode with a clock frequency of 24 MHz. Rates higher values have been experimentally established with quadrature amplitude modulation (QAM). This one is accompanied by a process of coding digital signals by distribution in orthogonal frequencies in the form of multiple sub-carriers (OFDM: orthogonal frequency division multiplexing).
Other schemes, such as amplitude modulation and carrier less phase (CAP), have achieved data rates greater than 1 Gb / s [11]. It remains to orient research on reception optics to widen the scope of detection.

IV. Example of implementation

This personal work consists of developing a circuit capable of transmitting an audio signal via visible light, the objective here is to highlight the potential of the visible spectrum in the field of information transmissions. This system combines two sections, the section emitting an audio signal applied to the base that will be emitted as light by light emitting diodes as for the receiving section it allows to receive this message using a phototransistor to convert it into an electrical signal.
We try to explain through this work, how to design a simple visible light audio link that is used to transmit wireless audio signals. This visible light audio connection makes it possible to transmit audio signals up to 4 meters. An 8ohm speaker or headphone is connected to the receiver section to listen to the transmitted signal.

The principle in this circuit is visible light communication. It is used only for short-range line of sight communications. In the electromagnetic spectrum, the rays of light are wavelengths longer than the wavelengths of normal light. These light beams are visible to the human eye, and we can visualize them.
Li-Fi uses light to transmit data unlike Radio waves [12]. Li-Fi can be defined as [19] "Li-Fi is high speed bi-directional networked and mobile communication of data using light. Multiple light bulbs form a wireless network, offering a substantially similar user experience to Wi-Fi except using the light spectrum [18]".
Every LED lamp should be powered through a LED driver [12], this LED driver will get information from the Internet server and the data will be encoded in the driver [12]. Based on this encoded data the LED lamp will flicker at a very high speed that cannot be noticed by the human eyes [12]. But the photo detector on the other end will be able to read all the flickering and this data will be decoded after amplification and processing [12]. The data transmission will be faster than RF. Here we are using Solar panel, photodiode or photo transistor at the receiving end to sense light. [5]

The work consists of two parts:

- **Main idea:** deals with the problem of the transmission by visible light of a functional approach.

The Li-Fi technology unlike the radio-wave technology is still appreciated because of its significant security advantages, since it is not possible to intercept data from outside the room or building. In terms of electromagnetic disturbances, in itself, the optical light does not cause any electromagnetic disturbance. LED lamps must, however, be installed correctly to avoid any disturbance.

- **Identification of the blocks and realization of the prototype:**

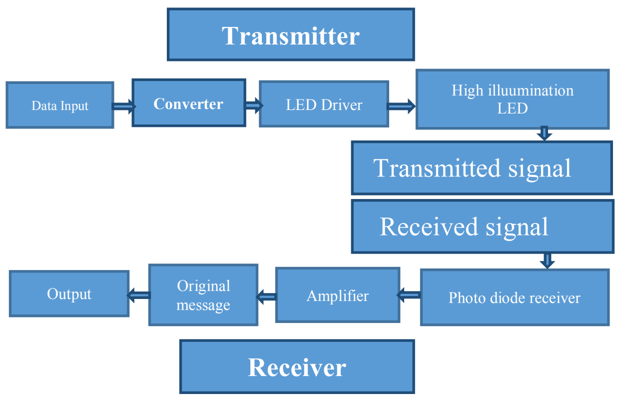

Fig. 5. Basic block diagram of Li-Fi system.

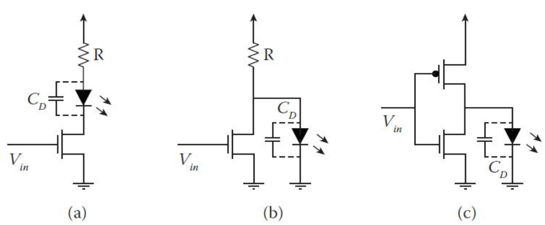

Fig. 6. Digital drivers: (a) single transistor, (b) single transistor inverter, and (c) complementary inverter

a) The emission block: Digital LED drivers allow the LED modulation in the digital domain (on–off). The common applications require the LED current control from an input signal that usually has a fixed voltage and low current capability. Thus, an active circuit is needed to drive the required current through the LED. Fig. 6. depicts three configurations used in digital LED drivers. The metal-oxide-semiconductor field-effect transistor (MOSFET) is the preferred active device in the digital domain for its low conduction resistance, RDS_ON. Thus, at low RDS_ON values, the MOSFET can simultaneously handle high currents and achieve low-power dissipation: [15].

The circuit in Fig. 6.a uses a transistor in series with the LED. As Vin increases, the current in the transistor rises, thus the LED current also rises. The current is limited by the resistor R, according to Ohm's law, which is given by:

$$I_{\mathrm{LED}} = (V_{+} - V_{\mathrm{LED}})/R \qquad (1)$$

b) The reception block: the receiver will have the task of capturing the light signal emitted by the LEDs by means of the phototransistor which will then be translated into an amplified electrical signal by means of a Darlington transistor which is the combination of two bipolar transistors of the same type.

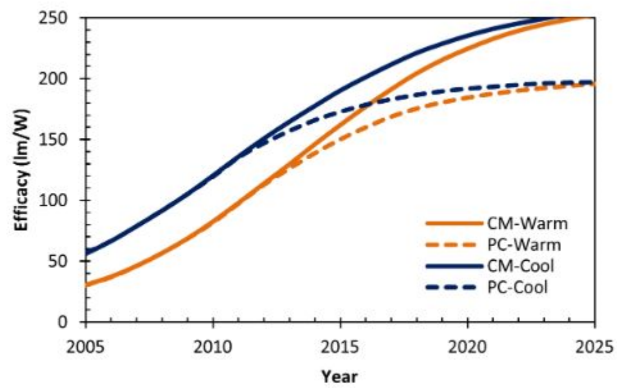

Fig. 7. LED efficacy improvement [14].

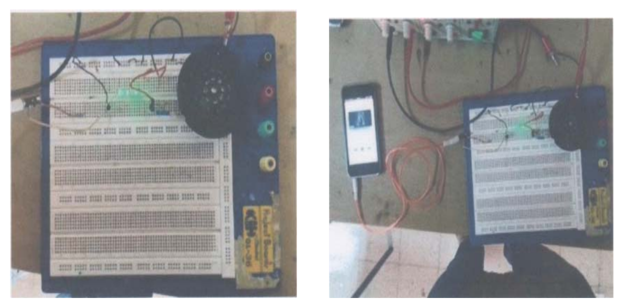

Fig. 8. The experimental setup

LED lighting constraints: LED lighting constraints are crucial to modulation and signal processing for VLC systems, which include dimming control, chromaticity control, and flicker-free communication [5]. LEDs are also the main source of nonlinearity in optical systems, and it has to be taken into account when modulating as amplitude distortion occurs, having a significant impact on the performance of the optical system [5] [10].

Interference and Noise. Other artificial and natural light sources such as fluorescent, incandescent and sunlight create background noise and interference as it shares the same wavelength band as the VLC transmission [5]. This interference must be removed at the receiver. Optical filters are a simple method to eliminate the majority of interference from natural and artificial sources.

Levels of illumination. Since VLC is based on an illumination source, there is an important task in minimizing the degradation of information transmission performance when the level of illumination changes [5], up to the point of being able to transmit even in those situations when lights are usually off the transmission within acceptable performance, which require techniques to control the LED power and the data transmission and dimming control functions Line of sight (LOS (line of sight)). [10]

Indoor VLC is built for LOS. Receivers are expected to have a clear LOS to the lighting system [5]. Visible light signals can be reflected but does not penetrate most of objects which can be a disadvantage and distributed lighting sources must be provided to maintain a high SNR (signal to noise ratio) throughout [5]. If light levels are low and VLC receivers do

not have LOS, communication is greatly limited and hence the data rate reduces [5]. Therefore, it is also important to analyse the shadowing effect and find possible solutions to it [19]. Mobility. OWC (Optical Wireless Communication) systems are required to allow for user mobility [19]. If the receiver or transmitter is mobile, the link can be lost due to movement or rotation of the terminal [5]. Hence, it is necessary and important to have link recovery [5], rate adaptive techniques and handover mechanisms to maintain the communications. Such problems are challenging and need to be investigated [5].
Besides generating and capturing the light signals, additional hardware is needed to filter and interpret these signals. For example, a suitable band pass filter can be used to filter out incoming signals with frequencies other than those desired; an optical filter can be a good way to filter out light of other wavelengths; a lens to focus incoming light can be suitable if the light intensity is low [19]. In the case of digital data transmissions, a digital signal processor at both ends of the system is required to process incoming and outgoing data.

V. CONCLUSION

The main future use of Li-Fi seems to be the relief of different networks namely: 3G, 4G, Wi-Fi. In this perspective, there is a technology currently under study: 5G This technology will use these 4 kinds of networks so as not to clutter them. For example, if someone picks up Wi-Fi or Li-Fi at home, goes out and travels to their place of work, the most powerful and appropriate network will take over. In this case, surely that once outside it will capture 3G or 4G. [16]

Visible light communication technologies currently in development can overcome some of these shortcomings, and even create new ones opportunities. The technological bases used by these new means of communication, like LED, are maturing [5]. This will allow good performance technical and energy as well as a cost of deployment content. Many applications are possible: from Li-Fi communication between computer to geolocation through the communication between cars. However, the visible light communication technology seems for the moment be better suited for professional use due to lack of consumer equipment compatible. The establishment and democratization of Li-Fi will be a real challenge, its many advantages will make it a technology of the future, but its disadvantages will not make it a total replacement technology of the communication systems based on radio waves. Its place will be to take among these radio technologies for particular uses [13] [16].

OledComm in collaboration with a hospital in the south of France is being tested on this project. Also, we can think of a utility of this network in the factories of production, where at the moment one favors the wire networks rather than wireless [14]. LED is a natural transmitter and can easily broadcast information, which can be embedded in LED displays and screens in different public areas, such as waiting hall at the airports and train stations, and sent to passengers. If an image sensor in a camera is used as signal detector, optical camera communication (OCC) could receive the broadcasting information [5] [17]. In shopping malls and outlets, merchandise and advertisement information can be broadcasted to customers through lighting LEDs or signage. Exhibitions, galleries, and museums are also ideal places to use LEDs for seamless information broadcasting [5].

REFERENCES

[1] C. X. Wang et al., "Cellular architecture and key technologies for 5G wireless communication networks," in IEEE Communications Magazine, vol. 52, no. 2, pp. 122-130, February 2014.

[2] J. Garcia-Marquez and S. Topsu, LES COMMUNICATIONS par lumière visible: le Li-Fi, March 2017.

[3] Moodle, La technologie LiFi, 2017.
Website: https://moodle.lyceecolbert-tg.org/course/view.php?id=31.

[4] Internet of Things : the evolution of M2M, GSMA Intelligence. Sources: Industry estimates for IoT and total M2M connections; GSMA Intelligence for cellular M2M connections.

[5] Z. Wang, QI Wang, W. Huang and Z. XU, Visible Light Communications Modulation and Signal Processing, IEEE Pres, November 2017.

[6] LAN/MAN Standards Committee, IEEE standard for local and Metropolitan area networks Part 15.7: Short-Range Wireless Optical Communication Using Visible Light. IEEE (New York) 2011.

[7] C. Le Bas, Système de télésurveillance médicale utilisant la technologie de transmission optique sans fil, Limoges University, France, Novembre 2017, p. 14.

[8] H. Haas, LiFi is a paradigm-shifting 5G technology, Reviews in Physics 3 (2018) 26-31.

[9] A. Fauteux, Le LiFi, l'Internet sans fil à DEL, La MAISON DU 21e SIECLE, November 2017.
Website: https://maisonsaine.ca/actualites/le-lifi-linternet-sans-fil-a-del.html.

[10] Y. Wang, X. Huang, L. Tao, J. Shi and N. Chi, 4.5-Gb/s RGB-LED based WDM visible light communication system employing CAP modulation and RLS based adaptive equalization, Opt. Express, 23 (10), 13626-13633 (2015).

[11] H. Haas, Wireless data from every light bulb, TED Global, August 2011.

[12] R. Jain, Audio Transfer using Li-Fi Technology, CircuitDigest, July 2018.
Website: https://circuitdigest.com/electronic-circuits/audio-transfer-using-lifi-technology.

[13] S. Lelux, LIFI – Light Fidelity : Internet par lampe LED – 14 milliards de point LIFI d'ici 2020 ans. est-ce réaliste? LiFi – Li-Fire and Visible Light Communication – concept and reality, Tactis, April 2018.

[14] C. Handleman, LEDs Becoming the New Normal Well Played George Bush, The Handleman Post, December 2013.
Website: https://handlemanpost.wordpress.com/2013/12/17/kudos-to-george-bush/.

[15] L. N. Alves, L. Rodrigues, J. L. Cura, Lighting and Communications: Devices and Systems In Visible Light Communications (pp. 9-70). CRC Press. 2017.

[16] A. Bouarfa, Conception et implémentation d'un système LiFi, AbouBekr Belkaid University, p. 31, Algeria, June 2017.

[17] W. Huang, P. Tian, and Z. Xu, "Design and implementation of a real-time CIM-MIMO optical camera communication system," Opt. Exp., vol. 24, no. 21, pp. 24567–24579, Oct. 2016.

[18] LiFi: The Future Internet of Flight, pureLifi.
Website: https://purelifi.com/pdt-astronics-purelifi-future-internet-of-flight/

[19] Z. Ghassemlooy, W. Papoola, S. Rajbhandari, Optical Wiireless Communications: System and Channel Modelling with MATLAB, CRC Press, 2013.