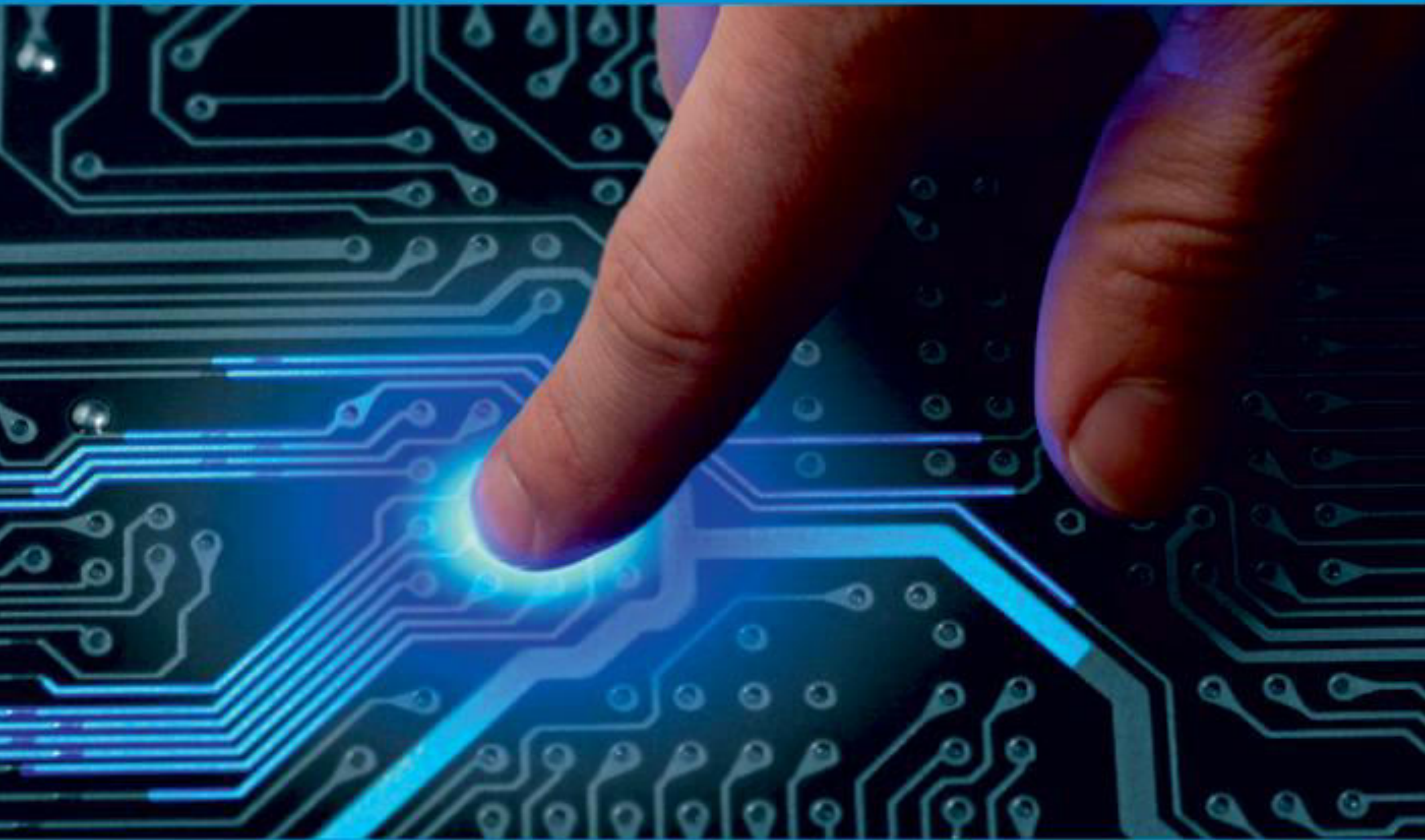
IJIRCCE

e-ISSN: 2320-9801 | p-ISSN: 2320-9798



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

Volume 10, Issue 8, August 2022

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.165

International Journal of Innovative Research in Computer and Communication Engineering

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.165|| A Monthly Peer Reviewed & Referred Journal |

|| Volume 10, Issue 8, August 2022 ||

| DOI: 10.15680/IJIRCCE.2022.1008044 |

FPGA based DWDM Multiplexed Optical Communication System using Various Modulation Technniques

Satheesh Kumar J, Rasna K B Das

PhD Scholar, Department of Electronics and Communication Engineering, Karunya Institute of Technology and Science, Coimbatore, Tamil Nadu, India

PhD Scholar, Department of Electronics and Communication Engineering, Karunya Institute of Technology and Science, Coimbatore, Tamil Nadu, India

ABSTRACT: The communication of information has contributed to the advancement of human life. Communication has significantly evolved for both wired and wireless systems. The amount of data traffic on these networks will continue to increase dramatically and gradually, based on past performance. The only method to achieve this high bandwidth and speed is through optical fiber connections. Long-distance data transmission, fiber-to-the-home, cable television, communication, entertainment, building, decorating, medical, health care, research, and development are just a few of the uses for optical fibers. Different multiplexing strategies have been applied in order to boost data rate and capacity. This article covers the features of optical communication as well as recent developments that enhance bandwidth, spectrum efficiency, information transmission rate, and other aspects. These developments include WDM, OFDM, PDM, and SDM. Using FPGA, parallel computing is feasible.

FPGA is perfect for digital signal processing and high-performance optical data transmission systems because of all these advantages. Hardware design can also be facilitated using an FPGA chip.

KEY WORDS: DWDM, FPGA, SDM, PDM.

I. INTRODUCTION

Newer than other integrated circuit types are digital integrated circuits, or ICs. Field Programmable Gate Arrays, or FPGAs, are a class of integrated circuit that may be designed to carry out particular tasks and implement digital circuits. It has developed into a vital part of optical communication and signal processing systems that link to computers, cutting costs and power usage. Numerous students are interested in utilizing FPGA for their projects due to its dependability.

This paper's primary goal is to highlight current trends, new research areas, and areas of prospective future study for an FPGA-based DWDM multiplexed optical communication system using various modulations such as CSRZ/RZ/NRZ/ DPSK/QAM with LED/ laser/source.

An explanation of the writing process for this paper may be found below. System block diagrams are covered in Section I, and recent optical communication technologies, and modulation schemes are compared and discussed in Section II. Section III has the conclusion.

I.1 The FPGA-based DWDM Multiplexed Optical Communication System's components employing Different Modulation Techniques

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.165|| A Monthly Peer Reviewed & Referred Journal |

|| Volume 10, Issue 8, August 2022 ||

| DOI: 10.15680/IJIRCCE.2022.1008044 |

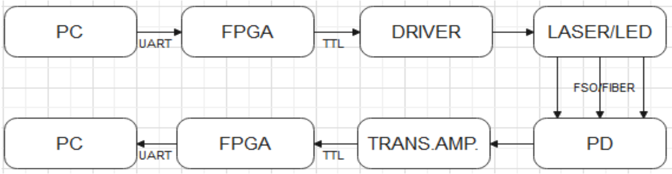


Figure 1. Shows a DWDM multiplexed optical communication system built on FPGA and employing a variety of modulation techniques.

The suggested system comprises a computer, an FPGA board, a photo detector, a transimpedance amplifier, an LED/laser source, a FIBER DWDM multiplexed channel, and an LED/laser driver.

The data server function is carried out by the computer. Documents and text are two instances of data that is transmitted over a channel. Three files: a picture, a PDF, and a digital audio file. The Universal Asynchronous Receiver Transmitter (UART) interface is used to send the data to the FPGA development board at first. This interface enables real-time data transmission and reception. The development board is configured to transform incoming data into information that is helpful. The serial data is then used to extract the modulation and conversion.

The TTL logic of the transistor is compatible with modulation of binary levels between 0 and 1. The LASER or LED driver receives the output from the FPGA board. Depending on the incoming TTL signal, it is in charge of turning on and off the laser or LED. The optical ray passes through the channel on its way to its final location. photodetector that is aligned properly. And then in the optical detector, the trans-impedance system is employed. Incoming current level of the photodetector is transformed by the amplifier stage to the corresponding voltage level. It's boosted as well. To demodulate the signal, an FPGA board is utilized.

Following reception, the signal is transformed from TTL to serial format. Lastly, the computer gathers serial data via the UART interface[2]. Performance and flexibility constraints have currently been overcome by FPGA, ADC, novel modulation techniques, and multi-channel DWDM. Scholars have observed these innovative methods for creating a FIBER structure based on FPGA for enhanced modulation techniques in multi-channel DWDM optical communication. The FPGA was chosen as a MODEM due to its capacity for both serial and parallel processing, as well as its adaptability to optical to binary signal processing, which enables the ADC to adjust the resolution of the data it provides.

II. CURRENT TECHNOLOGIES AND AN ANALYSIS OF DIFFERENT FPGA-BASED OPTICAL COMMUNICATION SYSTEM AND WITH MODULATIONS SCHEMES

Rising bit rates in telecom applications are the first step toward the development of more advanced fiber structures and communication mechanisms that are required for increasing transmission capacity. These have been developed gradually over the previous few decades [3]. A higher bit error rate is achieved through highly secure, fast transmission with low radiation and noise levels, which is the primary goal of all new improvements in the digital optical communication system. The wired and wireless optical communication system has drawn a lot of interest lately. It combines several modulation schemes, such as RZ, NRZ, CSRZ, DPSK, DQPSK, and QAM technologies, with DWDM, PDM, and SDM multiplexing methods [4].

II.1. Recent studies in VLC Technology-Optical data transmission through visible light for fiber and fso.

Because of its benefits, such as being license-free and having a huge spectrum resource, visible light communication (VLC) is employed in a wide range of applications. VLLC provides a far larger bandwidth than standard LED-based VLC technologies, allowing for quick outdoor and indoor point-to-point fso and fibre Optical data transfer.

In the year 2020,Sarkar et al.[2] interpreted the development of a half-duplex terrestrial FSO communication system based on FPGAs and a 100 mW DPSS (diode-pumped solid-state) LASER source at `808 nm (IR). The distance of communication is 40 feet in line of sight (LOS). The Serial Communication Protocol (SCP) was utilised, with a data rate of 115.2 Kbps and the modulation technique On-off Keying (OOK).In 2019, Yufeng Zhang et al. [1] described how an FPGA was used to design a real-time VLC system that uses differential phase shift keying (DPSK). The study found that the system performed well in all of its operations, including real-time transmission, transmission distance, and bit error rate (BER). The driving module receives data from the random number generator (PRBS) and then drives the LED to perform intensity modulation. A LED(red) with an optical power of 0.5w serves as the transmission light

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.165|| A Monthly Peer Reviewed & Referred Journal |

|| Volume 10, Issue 8, August 2022 ||

| DOI: 10.15680/IJIRCCE.2022.1008044 |

source. An optical lens was placed behind the LED to collect the light beam. The transmission distance can exceed 66m at a real-time data rate of 10Mbps and a BER of less than $10^{-5.}$ In the same year,J. Kang et al.,[3]VLLC technology was particularly appealing for cellular backhaul, transitory communication links, and underwater communication. A video can be sent in real time at a data rate of 500 Mbps over a distance of 2 metres using the suggested technique. 8B/10B encoding and the NRZ-OOK modulation technology were employed on the FPGA platform.In the year 2017 T,Adiono et al.,[5]. A system that transmitted visible light communication of baud rate 115200bps for a length of 9.6 metres was developed with the help of features and investigation results of white LED and photodiode current, amplitude-frequency characteristics, and reaction time. The work was carried out by Intensity Modulation and Direct Detection (IM/DD) principles, with a design of link of LOS and a modulation code of a 16 X 8 lighting array of white LED. In the same year A. Al Safi and B. Bazuin[6] The notion of transferring data using light waves utilising an LED light bulb that adjusts the light intensity quicker than the human eye can follow is referred to as Described Light Fidelity /Optical Wi-Fi.The VLC based data communication medium that uses visible light in the range of 375nm to 780nm LED producecs lights to transport data in one direction at a data rate of 10Gbps while also lighting the room. Using IR technology, University of Oxford researchers have achieved 224 Gbps bi-directional speed across 3 metres. This speed will enable the download of 18 nos. of 1.5 GB movies in a single second. Leeds University researchers also used laser diodes to achieve 20 Gbps indoor VLC.Table1.shows a comparison of VLC and VLLC Technology for FPGA based DWDM-OFDM multiplexed Optical data transmission.

Ref.	Year	Source	Data Rate	Distance	Technology
[2]	2020	LASER	115.2 Mbps	40 Feet	VLLC
[1]	2019	LED	10 Mbps	66 Meters	VLC
[3]	2019	LASER	500 Mbps	2 Meters	VLLC
[5]	2017	LED	115.2 Mbps	9.6 Meters	VLC
[6]	2017	LED	224 Gbps	3 Meters	VLC

Table1.VLC and VLLC Technology with data rate and distance

Visible light communication(VLC) and visible laser light communication (VLLC) are sophisticated, highly developed optical data transmission systems that provide light as well as fast fiber and fso optical data transmission.The regions of infrared light and visible light (700 nm-1 mm), (400-700 nm) in the spectrum for electromagnetic are used in this new technology. Because they provide excellent illumination performance, light-emitting diodes (LEDs) have been considered the best choice for VLC systems. Micro-LEDs and laser diodes (LDs) are being considered as new ideal light sources to overcome bandwidth and other transmission related issues. The wavelength range 1260nm to 1625nm has the lowest dispersion, lowest signal distortion, and low loss, making it ideal for optical fibre transmission. The C-band (Conventional Band) ranges from 1530 nm to 1565 nm and represents the conventional band. Optical fibre has the lowest loss in the C-band and thus it has a significant advantage in long-distance transmission systems. When the C-band is insufficient to meet bandwidth requirements, the L-band (1565nm - 1625nm) is frequently used.

II.2. Review on recent studies in various modulation schemes for FPGA based DWDM-OFDM multiplexed Optical data transmission.

The digital modulation formats such as differential phase-shift keying (DPSK), amplitude shift keying (ASK), and quadrature phase-shift keying (QPSK), QAM, BASK, BFSK, BPSK, NRZ, RZ, CSRZ are used in fiber-optic communications .Researchers have been employing various techniques to lower the power need, optimise the area, and achieve shorter propagation delay since the advent of FPGA technology. Line coding modulations (NRZ, RZ, CSRZ) combined with DWDM multiplexing are critical components of a communication system in which 1s and 0s are converted into a voltage and current pulse sequence that may be transmitted. The benefits of OFDM can be combined with the above-suggested modulation techniques(QAM, DPSK, QPSK) to improve Optical data transmission speed and bandwidth efficiency. Table 2.shows the review on different modulation schemes based on FPGA with year

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.165|| A Monthly Peer Reviewed & Referred Journal |
|| Volume 10, Issue 8, August 2022 ||
| DOI: 10.15680/IJIRCCE.2022.1008044 |

Review on different Modulation schemes based on FPGA		
Ref	**Modulations**	**FPGA board and year**
[7]	Coded Mark Inversion format, Manchester coding, Pseudo ternary encoding, AMI, Polar RZ and NRZ, Uni polar RZ and NRZ.	Xilinx Spartans-6 XC6SLX45 FPGA(2014)
[8]	BASK-BFSK-BPSK	Altera DE2 FPGA Board(2017)
[6]	QAM	Virtex-4 FPGA Zynq-7000 FPGA(2017)
[1]	DPSK	Xilinx-ML605 Evaluation Board(2019)
[1]	Adaptive LDPC code with 8,16,32,64 QAM	FPGA BOARD(2014)
[12]	SDM-Sigma Delta	FPGA PLATFORM (2021)
[14]	RZ-DPSK	NON-FPGA(2011)
[10]	Adaptive 64 QAM	FPGA BASED BOARD (2021)
[13]	NRZ,RZ,CSRZ,DB,DPSK,DQPSK, RZ-AMI	NON-FPGA(2020)

Table 2. different modulation schemes based on FPGA with year

According to Yufeng Zhang et al.,[1] in 2019, This article shown that DPSK performs better than OOK in terms of bit error rate when the signal power and system bandwidth are equal. When using an FPGA to develop a real-time VLC system based on DPSK, the findings showed that the system performs well in terms of real-time transmission rate, distance, and bit error rate (10^{-6} BER) and the results revealed that system can effectively transmit at 10Mbps for 66 metres distance. Better indices are expected to be achieved in the future as device performance improves. This paper only proposed a wireless optical data transfer system. According to A. Al Safi and B. Bazuin, in 2017 [6] This research proposed new methods for creating various types of Amplitude Shift Keying and Quadrature Amplitude Modulation using FPGA. On-Off Keying (OOK), Binary ASK (BASK), and 4ASK (M-Array ASK) are the implemented ASK modulators, whereas 4QAM and 16QAM are the implemented QAM modulators. In this paper,creating the sine wave carrier is one of the most important effort in the implementation of any digital transmitter, including ASK. To implement QAM modulators, two sinusoidal carriers are required, and a 24-bit phase accumulator and Look-Up Table (LUT) based on Direct Digital Synthesizer (DDS) technology were used. Two 24-bit accumulators acting on the rising and falling edges of the main system clock were used to generate the two carriers with 90-degree phase changes. In the year 2014, V. Singh and B. Mishra [7], The following categories can be used to categorise line coding techniques. Line encoding schemes such as Unipolar RZ and NRZ (non-return-to-zero), Polar RZ and NRZ, AMI (alternate mark inversion) and Manchester coding, and Pseudo ternary encoding, CMI (Coded Mark Inversion) format are used in this paper. All the codes mentioned above are in the stage of generation and not in the field of application level of communication.According to B. R. Jammu et al.,in 2017[8], BASK, BFSK, and BPSK digital modulators were demonstrated using FPGAs. The implementation's key advantages were the small number of digital blocks required for

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.165|| A Monthly Peer Reviewed & Referred Journal |

|| Volume 10, Issue 8, August 2022 ||

| DOI: 10.15680/IJIRCCE.2022.1008044 |

digital modulation, the flexibility to interface with modules on FPGA boards, and the user's frequency controllability of the input signals.This paper used all the above codes to implement radio transmission[9],. In the year 2021 Ivan B. Djordjevic et al.[10], Rate-adaptive LDPC (Low-Density Parity Checking) codes based on shortening with an overhead ranging from 25% to 42.9% yield a coding gain of 13.08 dB to 14.12 dB with a post-FEC BER of 10^{-15} for the Binary phase shift keying system. Furthermore, the proposed rate adaptive LDPC coding has been demonstrated with higher order modulations of QAM covering a wide range of SNR(signal to noise ratio).Moreover , in 16-QAM and 64-QAM, use different LDPC codes on different bits to implement unequal error protection. At the same coding rate as the comparable LDPC code, this results in an additional 0.5 dB gain over typical LDPC coded modulation. In high-order modulation formats with more than 64 QAM bits, adaptive LDPC codes cannot be used to bridge the gap between them. M. Yoshida et al. In the year 2014,[11], They demonstrated the first real-time adaptive 4-64 QAM optical coherent transmission system using OPLL technology and an FPGA-based transmitter and receiver. With an optical bandwidth of 6 GHz, polarization-multiplexed 5 G symbol/s, 4-64 QAM (20-60 Gbit/s) signals were transported over 320 km. Using a polarisation multiplexing approach at 5 G symbol/s, rate-variable transmission (2060 G bit/s) was achieved over 320 km, with OSNR margins raised by 9 and 17 dB, respectively, by altering the modulation level from 64 to 16 and 4 G symbol/s. When the on-line system's 7% FEC overhead is taken into account, the theoretical spectral efficiency approaches 9.3 bit/s/Hz. Several tones are used in this paper for OPLL, polarisation, and clock recovery, which adds to the system's complexity when compared to normal digital coherent optical transmission system.In year 2021, Haolin Li et al.[12], a radio over fibre link can be implemented in three ways: digital radio through fibre (DRoF), analogue radio through fibre (ARoF), and sigma delta through fibre, as described (SDoF). Digital signal processing is pushed as far as feasible into the transmission chain using an all-digital radio through fiber approach based on the sigma-delta modulator (SDM). This paper described a 100-GS/s single-bit and fourth-order SDM for digital radio in the high-frequency band via fibre transmission without the need for real-time analog/optical up-conversion. This is the most fastest sigma-delta modulator, as well as the first real-time demonstration of sigma-delta-modulated radio through fibre at 24 GHz. 256-QAM can be received even in a back-to-back optical arrangement. At runtime, the carrier frequency, which ranges from 22.75 GHz to 27.5 GHz, can be digitally modified. Furthermore, the delay introduced by this high-speed sigma-delta modulator in transmit chain is less than 1 s. Its all-digital design allows for network virtualization, making the transmitter compatible with a variety of current protocols. The outstanding performance validates the SDM based RoF approach which provided excellent competitiveness in high frequency RoF 5G communication. In this paper,the existing wireless approach, the suggested system is confined to a certain application and verified for 20 km distance ssmf. In 2020, K H ShakthiMurugan et al.[13], Using a bit error rate (BER) of 10^{-12} .as a benchmark, this study looked at the performance of different formats at 40 Gbps in terms of the received OSNR (Optical Signal Noise Ratio) penalty after transmission via a cascade of ten optical filters and a fibre length. Using Optisytem 9.0 the Non return to zero and Return to zero formats, On Off keying, Duo binary, Alternate Mark Inversion, Carrier suppressed return to zero, Differential Phase Shift Keying, and Differential Quadrature Phase Shift Keying formats were investigated.This proposed work is not employed with the FPGA board.W. Jia et al. in the year 2011[14], this paper proposed and demonstrated the generation of a 10 Gbps return-to-zero differential phase-shift keying (RZ-DPSK) signal using a direct modulated chirp-managed laser (CML) without the usage of a differential encoder or optical phase modulator. The proposed CML-based 10-Gb/s RZ-DPSK signal demonstrated 3dB greater receiver sensitivity after 70-km transmission over standard single mode fibre (SSMF) without chromatic dispersion compensation. This study focused solely on CMLK.

II.3. Review recent studies in various multiplexing techniques based on FPGA for Optical data transmission systems.

Because of the introduction of new communication systems, communication has increased in the digital world compared to past eras. Fiber optic communication is one of the most important communication technologies in the modern period since it meets all of the challenges. This makes use of many types of multiplexing techniques to maintain a reasonable level of service in the absence of traffic and simpler instruments that make efficient use of available resources. One of them is Wavelength Division Multiplexing (WDM), which is highly successful. [15]. By making greater use of the spectrum, Orthogonal Frequency Division Multiplexing (OFDM) enables high-speed data transfer.[16]. Space division multiplexing (SDM) is now possible using multicore fibres (MCF) or multielement fibres due to recent advances in fibre technology (MEF) [17].Among the many different multiplexing methods, mode-division multiplexing (MDM) is one of the most rapidly growing[18].The polarisation multiplexing approach is another spectral-efficient multiplexing technique (PDM)[19].

II.3.1.WDM Technology

A new approach in wavelength-division multiplexing (WDM) systems is used[20]. WDM is a wavelength multiplexing technique in which many optical carrier signals are multiplexed into a single optical fibre using different wavelengths

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.165|| A Monthly Peer Reviewed & Referred Journal |

|| Volume 10, Issue 8, August 2022 ||

| DOI: 10.15680/IJIRCCE.2022.1008044 |

of laser light.This technology offers bidirectional communications and capacity multiplication via a single fibre strand, with each wavelength carrying adifferent channel. WDM divides the optical spectrum into several channels that simultaneously transmit and receive data. WDM systems are classified into three types: dense wavelength division multiplexing (DWDM), ultra-dense wavelength division multiplexing (UDWDM), and coarse wavelength division multiplexing (CWDM).The DWDM is a solution for communications networks with high data consumption. DWDM connects users' devices to the router directly, resulting in increased bandwidth. By decreasing wavelength space, DWDM can boost transmission capacity and distance. The cost-effective CWDM is another sort of WDM. For short transmission distances of less than 50 km, CWDM is used because it is more cost-effective than DWDM [21]. Design of a coherent ultra-dense wavelength division multiplexing passive optical network (UDWDMPON). This system's optical distribution network power budget was calculated using 40 downlink UDWDM channels in the C band with a channel spacing of 5 GHz. The experimental demonstration, data transmission via a 40-kilometer field-installed fibre connection at 10 Gbps employing dual polarisation quadrature phase-shift keying formats power budget of 29 dB was obtained..[22].Figure 2 depicts the optical WDM Technique in which wavelength transmits by transmitters with different wavelengths j where j = 1, 2, 3,n

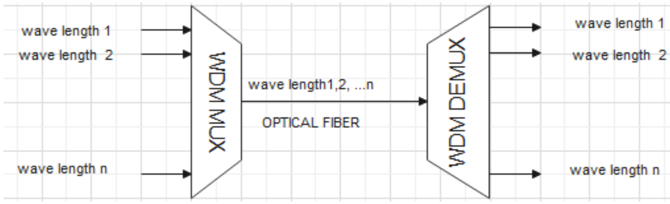


Figure2. WDM Technology

II.3.2. SDM Space Division Multiplexing

To boost optical communication capacity, space-division multiplexing (SDM) employs a multiplicity of space channels. It can be used for both free space and guided wave optical communication. The primary new components are space-multiplexer to link light from distinct cores or modes into SDM fibres, SDM optical amplifiers to amplify SDM signals, spaced de-multiplexer, and optical connectors for SDM[18].

II.3.3. PDM Polarization Division Multiplexing

Polarization-division multiplexing is a physical layer approach for multiplexing signals carried on electromagnetic waves that use the polarisation of the electromagnetic waves to discriminate between orthogonal signals. Polarization-division multiplexing is commonly used with phase modulation or optical 16-QAM to achieve transmission speeds of up to 112 Gbit/s across a single wavelength[19].

II.3.4.OFDM OrthogonalFrequencyDivisionMultiplexing

Figure 3showsthe optical OFDM Technique, which delivers numerous symbols through a network of subcarriers.

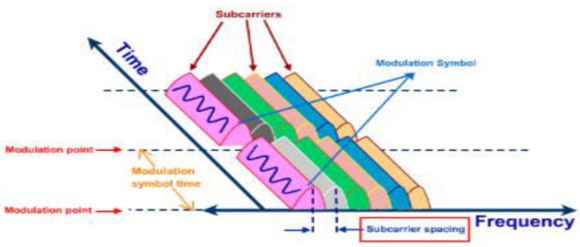


Figure 3 optical OFDM Technique

OFDM (Orthogonal Frequency Division Multiplexing) has become a common optical communication technology. OFDM is an acronym for Frequency Division Multiplexing (FDM). Signal modulation based on OFDM has been widely used in mobile communications, including digital audio and video broadcasting. Compared to other communication technologies, this is due to its fast speed, significantly low attenuation, and resilience to frequency selective fading. Even with such advanced features, today's world craves greater speed and data rate with the least data loss[16].This ever-increasing need has resulted in significant advancements in optical communication and modulation. OFDM accomplishes this by delivering numerous symbols through a network of subcarriers. Each symbol is modulated

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.165|| A Monthly Peer Reviewed & Referred Journal |

|| Volume 10, Issue 8, August 2022 ||

| DOI: 10.15680/IJIRCCE.2022.1008044 |

using a unique combination of in-phase (in phase with the carrier) and quadrature (90 degrees out of phase with the carrier) components to ensure orthogonality across a bit period.

These components are distributed so that they provide optimal spectral efficiency throughout a symbol period while being less influenced by fading[23].Table3. Show the comparison of various multiplexing techniques with data rate, distance and modulation schemes for fso/fiber optical data transmission system.

REF	YEAR	MULTIPLEXING	DATA RATE	DISTANCE	MODULATION
[22]	**2019**	**UDWDM**	**40x10 Gb/s**	**40 Km**	**DP-QAM**
[24]	**2014**	**UDWDM**	**10 Gb/s**	**80 Km**	**QPSK**
[25]	**2011**	**UDWDM**	**12 Gb/s**		**PROTOTYPE**
[26]	**2014**	**DWDM**	**40 Gb/s**	**63 Km**	**RZ-DQPSK**
[27]	**2014**	**DWDM**	**4x10 Gb/s**	**26 Km**	**QKD**
[28]	**2020**	**DWDM**	**40 Gb/s**	**42 Km**	**NRZ-OOK**
[29]	**2020**	**DWDM**	**10X80 Gb/s**	**10 Km**	**256 QAM**
[30]	**2021**	**WDM**	**165X10 Tb/s**	**160 Km**	**128 QAM**
[31]	**2015**	**UDWDM**	**12X 10 Gb/s**	**80 Km**	**16 QAM**
[19]	**2015**	**PDM**	**112 Gb/s**		**16 QAM**
[11]	**2014**	**PDM**	**20-60 Gb/s**	**320 Km**	**64 QAM**
[17]	**2014**	**SDM**	**320 Gb/s**	**100 Km**	**PM-16QAM**
[18]	**2013**	**SDM**	**120 Gb/s**	**16.8 km**	
[32]	**2016**	**OOFDM**		**25 Km**	**256 QAM**
[33, p. 4]	**2014**	**OFDM**	**10.4 Gb/s**	**20 Km**	**256 QAM**
[34]	**2013**	**OFDM**	**2.8 Gb/s**	**10 Km**	**16 QAM**
[35]	**2013**	**OFDM**		**100 Km**	**QPSK**
[36]	**2015**	**CO-OFDM**	**100 Gb/s**	**495 Km**	**QPSK**

Table3. Comparison of various multiplexing techniques

Some of the advantages of OFDM systems are as follows. spectral efficiency is high , ISI reduced, longer symbol duration against ISI effect, resistance to frequency selective fading than single carrier systems is more, due to the frequency selectivity of the channel it is possible to recover lost symbols by appropriate channel coding and interleaving, With single-carrier systems, channel equalisation is easier than using adaptive equalisation techniques, The process of channel equalisation is less complicated than that of impulsive equalisation. Because of advantages such as adaptive bandwidth usage and the ability to use multiple modulation styles per subcarrier, CO-OFDM has grown in popularity for access network applications.

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.165|| A Monthly Peer Reviewed & Referred Journal |

|| Volume 10, Issue 8, August 2022 ||

| DOI: 10.15680/IJIRCCE.2022.1008044 |

II.4. Review recent studies in FSO and Fiber optical communication systems based on FPGA.

Fibre optics is a fundamental building component in telecommunications due to more bandwidth capacity and minimal attenuation, hence it is suitable for beyond Gigabit communications.[37]. The free-space optical link (FSO) uses an optical beam travelling through the atmosphere for wireless data transmission. The possible bandwidth of light communication is substantially higher than that of radiofrequency (RF), allowing for more data through a single channel.[38].

II.4.1. FSO communication system based on FPGA

In the year 2020, H.B. Jeonet al.[39], A prototype FPGA-based free-space optical (FSO) communication system was used to examine visual signal transfer. For processing sent and received video data, use an FPGA-based real-time prototype and a channel emulator to replicate the FSO channel's turbulence, scintillation, and power attenuation. Change the turbulence and wind speed in the channel emulator's setup environment. In the same year,ZunHtayet al.[40] The researchers applied tiny form particles to transceivers which installed on an FPGA as an FSO transmitter and receiver to validate the experiment. The performance of a single FSO connection with high-speed under turbulence and fog conditions was investigated used a specialised indoor chamber of atmospheric . With a scintillation index of 0.35, the proposed system provides the same data rate as a clear channel link under turbulence, while the bit error rate increased from 10^{-12} to $5X10^{-4}$. AbirTouatiet al.[41],in the year 2017, described that the research offered an experimental test setting for the performance of FSO and RF links in terms of PDR during the summer season in Qatar. The FSO link is substantially affected, according to the study, compared to the RF link, which is regarded as stable. Given the high temperatures and sun irradiation measured throughout the summer, it is reasonable to conclude that these two elements have the greatest impact on FSO performance.In the year 2016,according toM. Luet al.[42], This article described the first field demonstration of real time Raptor coded FSO communication over a 1.87 kilometer urban link. The hardware design of a Raptor 10 decoder implemented in an FPGA platform using a novel resource and time efficient matrix inversion method. Over an 8hour period in real-world weather circumstances, the Raptor coded FSO link's throughput is assessed experimentally and numerically.

II.4.2. Fiber Optical Data communication system based on FPGA

In 2015, Masato Yoshida et al.[43] , The first real time 10 G bps QAM (2.5 G symbol/s, 16 QAM) QSC broadcast across 320 kilometres was demonstrated using a transceiver by FPGA. After a 320-mile broadcast, maintaining a detection fault chances of more than 99.93 percent for Eve may result in error free operation for a efficient receiver (Bob). The number of masked signals was increasedto 2500 from 50 as produced with a normal QSC using amplitude and phase noise. There was updated of encryption random number sequence pattern by online recently, which is favourable to system security.M. Yoshida et al.,in the year 2014,[11] They used OPLL technology and transceiver made by an FPGA to demonstrate the first real-time adaptive 4x64 QAM. Signals of 6 GHz optical bandwidth, polarised multiplexing 5 G symbol/s, 4x64 QAM (20-60 Gbit/s), and 4x64 QAM (20-60 Gbit/s) were carried for a distance 320 km. Rate-variable transmission (2060 G bit/s) was achieved of distance 320 km using a polarisation multiplexing method at 5 G symbol/s. In the year 2016,J.J. Zhanget al.[32], the efficiency and high closeness of the selected minimum bit resolution map are experimentally proved in described 25km SSMF OOFDM broadcasting systems by intensity modulation and direct detection (IMDD). In 2016, A. Shahpari et al. [31] A hybrid 80 km standard single-mode fibre (SSMF) optical wireless link is used to illustrate the performance of a 12 x 10 Gb/s bidirectional UDWDM-PON. The tests used a high-density 6.25 GHz grid, Nyquist-shaped 16-array quadrature amplitude modulation (16QAM), and digital frequency shifting. Nonlinear and back-reflection effects on receiver sensitivity are also examined for bidirectional transmission in fibre.

III. CONCLUSION

Currently, High-performance ICs technologies related to FPGA have overcome the operations and flexibility limitations of optical data transmission systems because it is less complex, more secure, and more efficient in long-distance optical fibre data transmission systems and noise detection/correction than analogue modulation. Because of their high spectrum efficiency, anti-interference, and other advantages, OFDM and DWDM are widely used in optical fibre data transmission and have become a research hotspot. As a result, the VLLC system is being used to develop a more advanced FPGA-based high-speed long-distance DWDM-OFDM multiplexed optical transmission. To achieve the best results, the VLLC system provides high-power, low-cost laser sources. Researchers had to develop new technological solutions to overcome the various problems of RF and microwave wireless networks. FSO communication system is a system that merges two popular technologies, free-space optics and radio frequency (RF).Under various atmospheric disturbances, the data speed will also be boosted. As a result, the system could be applied to outside usage of building-to-building communication via a local area network (LAN) to send the

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.165|| A Monthly Peer Reviewed & Referred Journal |

|| Volume 10, Issue 8, August 2022 ||

| DOI: 10.15680/IJIRCCE.2022.1008044 |

information (video, picture), military usage where data must be transmitted securely, and long-distance data transmission via fibre communications. For FSO/FIBER optical data transmissions, researchers have been using various modulation techniques to reduce power consumption, optimise area, achieve shorter propagation, delay, minimum BER, and maximum data rate over long distancesIn this context, each of the above-mentioned modulation schemes has advantages and disadvantages in terms of their applications. Because it can provide high spectral efficiency and an efficient channel equalisation method by simple frequency domain signal processing, CO-OFDM (coherent optical orthogonal frequency-division multiplexing) has received a lot of attention as a promising technology in optical communication systems.The details of this review can be used for future research in the field of developing an FPGA based long distance DWDM-OFDM multiplexed wired and wireless Optical data transmission system using VLLC technology.

CONFLICTS OF INTEREST: Not Applicable.

REFERENCES

[1] Yufeng Zhang, (second) Minglun Zhang, (third) Hongyu Zhou, (forth) Youyuan Sun, (fifth) Chen Wei, and (sixth) Wen He, "A Long Distance Real-time DPSK Visible Light Communication System Based on FPGA | IEEE Conference Publication | IEEE Xplore," 2019 18th International Conference on Optical Communications and Networks. https://ieeexplore.ieee.org/document/8934859 (accessed Nov. 29, 2021).

[2] T. S. Sarkar, B. Sinha, S. Mukherjee, I. Joardar, and S. Mazumdar, "Development of an FPGA based Indoor Free Space Optical (FSO) Communication System using 808 nm Infrared (IR) LASER Source," in 2020 IEEE Calcutta Conference (CALCON), Feb. 2020, pp. 313–317. doi: 10.1109/CALCON49167.2020.9106422.

[3] J. Kang, L. Wang, and C. P. Yue, "Design of a Real-Time Visible Laser Light Communication System with Basedband in FPGA for High Definition video Transmission," in 2019 IEEE 8th Global Conference on Consumer Electronics (GCCE), Oct. 2019, pp. 179–180. doi: 10.1109/GCCE46687.2019.9015495.

[4] S. Srivastava and P. Hobden, "Low Cost FPGA Implementation of a SPI over High Speed Optical SerDes," in 2018 IEEE International Symposium on Smart Electronic Systems (iSES) (Formerly iNiS), Dec. 2018, pp. 146–151. doi: 10.1109/iSES.2018.00040.

[5] T. Adiono and A. P. Putra, "Hardware/software model of DCO-OFDM based visible light communication SoC using DMA," in 2017 International SoC Design Conference (ISOCC), Nov. 2017, pp. 92–93. doi: 10.1109/ISOCC.2017.8368785.

[6] A. Al Safi and B. Bazuin, "Toward digital transmitters with Amplitude Shift Keying and Quadrature Amplitude Modulators implementation examples," in 2017 IEEE 7th Annual Computing and Communication Workshop and Conference (CCWC), Jan. 2017, pp. 1–7. doi: 10.1109/CCWC.2017.7868397.

[7] V. Singh and B. Mishra, "FPGA IMPLEMENTATION OF VARIOUS LINES CODING TECHNIQUE FOR EFFICIENT TRANSMISSION OF DIGITAL DATA IN COMMUNICATION," IJRET: International Journal of Research in Engineering and Technology, vol. Volume: 03, no. Issue: 04, Apr. 2014, doi: 10.15623/IJRET.2014.0304011.

[8] B. R. Jammu, H. K. Botcha, A. V. Sowjanya, and N. Bodasingi, "FPGA implementation of BASK-BFSK-BPSK-DPSK digital modulators using system generator," in 2017 International Conference on Circuit ,Power and Computing Technologies (ICCPCT), Apr. 2017, pp. 1–5. doi: 10.1109/ICCPCT.2017.8074203.

[9] N. Kikuchi, T. Yano, and R. Hirai, "FPGA prototyping of single-polarization 112-Gbit/s optical transceiver for optical multilevel signaling with delay detection," in 2015 European Conference on Optical Communication (ECOC), Sep. 2015, pp. 1–3. doi: 10.1109/ECOC.2015.7341946.

[10]Ivan B. Djordjevic, Senior Member, IEEE, and Ding Zou, Student Member, IEEE, "FPGA-based rate-adaptive LDPC-coded modulation for the next generation of optical communication systems." https://www.osapublishing.org/oe/fulltext.cfm?uri=oe-24-18-21159&id=349765 (accessed Nov. 29, 2021).

[11]M. Yoshida, T. Hirooka, K. Kasai, and M. Nakazawa, "Adaptive 4~64 QAM real-time coherent optical transmission over 320 km with FPGA-based transmitter and receiver," Opt. Express, OE, vol. 22, no. 13, pp. 16520–16527, Jun. 2014, doi: 10.1364/OE.22.016520.

[12]"Real-Time 100-GS/s Sigma-Delta All-Digital Radio-Over-Fiber Transmitter for 22.75–27.5 GHz Band | IEEE Conference Publication | IEEE Xplore." https://ieeexplore.ieee.org/document/8696567 (accessed Nov. 30, 2021).

[13]K H Shakthi Murugan1, Sudharsanam V2, Padmavathi B3, Judy Simon4, Jacintha V5, Sumathi K6, "BER analysis of 40 Gbps Ro-FSO Communication System for 5 G applications under Fog Weather Conditions | IEEE Conference Publication | IEEE Xplore," 2020. Accessed: Nov. 30, 2021. [Online]. Available: https://ieeexplore.ieee.org/document/9376490

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.165|| A Monthly Peer Reviewed & Referred Journal |

|| Volume 10, Issue 8, August 2022 ||

| DOI: 10.15680/IJIRCCE.2022.1008044 |

[14]W. Jia, J. Xu, Z. Liu, K.-H. Tse, and C.-K. Chan, “Generation and Transmission of 10-Gb/s RZ-DPSK Signals Using a Directly Modulated Chirp-Managed Laser,” IEEE Photonics Technology Letters, vol. 23, no. 3, pp. 173–175, Feb. 2011, doi: 10.1109/LPT.2010.2092761.

[15]D. Prakash and G. Sadashivappa, “ENHANCING THE CAPACITY OF DWDM OPTICAL NETWORK - A SURVEY,” p. 5.

[16]Research Scholar, Jain University, Bengaluru, Karnataka, India, V. K. T. R., and K. V. Prasad, “FPGA Based Design and Implementation of DUC/DDC Based OFDM for Data/Image Transmission,” ijeetc, pp. 199–204, 2019, doi: 10.18178/ijeetc.8.4.199-204.

[17]“First demonstration of all-optical programmable SDM/TDM intra data centre and WDM inter-DCN communication | IEEE Conference Publication | IEEE Xplore.” https://ieeexplore.ieee.org/abstract/document/6964258 (accessed Nov. 30, 2021).

[18]D. J. Richardson1, J. M. Fini2 and L E. Nelson3, “Space-division multiplexing in optical fibres | Nature Photonics”, Accessed: Nov. 30, 2021. [Online]. Available: https://www.nature.com/articles/nphoton.2013.94

[19]V. Moreira, F. Lumertz, A. Chinatto, F. Cardoso, L. Santos, and D. Arantes, “FPGA implementation of a coherent optical receiver front-end: High-level design and test methodology,” in 2015 SBMO/IEEE MTT-S International Microwave and Optoelectronics Conference (IMOC), Nov. 2015, pp. 1–6. doi: 10.1109/IMOC.2015.7369216.

[20]“A Novel Optical Frequency-Hopping Scheme for Secure WDM Optical Communications | IEEE Journals & Magazine | IEEE Xplore.” https://ieeexplore.ieee.org/document/7102675 (accessed Nov. 30, 2021).

[21]N. Muchhal and A. Bhatt, “High Speed and Spectrally Efficient Optical Communication System-Review of the Recent Advances and Emerging Trends,” Jan. 2017.

[22]M. Luo et al., “Real-time coherent UDWDM-PON with dual-polarization transceivers in a field trial,” Journal of Optical Communications and Networking, vol. 11, no. 2, pp. A166–A173, Feb. 2019, doi: 10.1364/JOCN.11.00A166.

[23]M. A. Mohamed, “FPGA Synthesis of VHDL OFDM System | SpringerLink,” Aug. 12, 2012. https://link.springer.com/article/10.1007/s11277-012-0786-0 (accessed Nov. 30, 2021).

[24]R. M. Ferreira et al., “Impact of TWDM on optional real-time QPSK WDM channels,” in 2014 The European Conference on Optical Communication (ECOC), Sep. 2014, pp. 1–3. doi: 10.1109/ECOC.2014.6964105.

[25]C. E. Gray and D. C. Keezer, “Extending a DWDM Optical Network Test System to 12 Gbps x4 Channels,” J Electron Test, vol. 27, no. 3, pp. 351–361, Jun. 2011, doi: 10.1007/s10836-011-5216-9.

[26]J. Zhou, Z. Huang, C. Liu, and S. Su, “Design of adaptive dispersion compensation and demodulation system for 40Gbps RZ-DQPSK optical fiber communication receivers,” Optik - International Journal for Light and Electron Optics, vol. 1, no. 125, pp. 370–373, 2014, doi: 10.1016/j.ijleo.2013.06.044.

[27]Iris Choi,1 Yu Rong Zhou,2 James F. Dynes, “Field trial of a quantum secured 10Gb/s DWDM transmission system over a single installed fiber,” 2014. https://www.osapublishing.org/oe/fulltext.cfm?uri=oe-22-19-23121&id=301342 (accessed Nov. 30, 2021).

[28]Toms Salgals1, 2, *, Andis Supe1, Vjaceslavs Bobrovs1, Jurgis Porins1, Sandis Spolitis1, 2, “Comparison of Dispersion Compensation Techniques for Real-Time up to 160 Gbit/s DWDM C-Band Transmission | Elektronika ir Elektrotechnika,” 2020. https://eejournal.ktu.lt/index.php/elt/article/view/25892 (accessed Nov. 30, 2021).

[29]“10 Channel WDM 80 Gbit/s/ch, 256 QAM Bi-Directional Coherent Transmission for a High Capacity Next-Generation Mobile Fronthaul | IEEE Journals & Magazine | IEEE Xplore.” https://ieeexplore.ieee.org/document/9242232 (accessed Nov. 30, 2021).

[30]Masato Yoshida , Member, IEEE, Takashi Kan , Keisuke Kasai, Member, IEEE, “10 Tbit/s QAM Quantum Noise Stream Cipher Coherent Transmission Over 160 Km | IEEE Journals & Magazine | IEEE Xplore,” Feb. 2021, Accessed: Nov. 30, 2021. [Online]. Available: https://ieeexplore.ieee.org/document/9167410

[31]A. Shahpari et al., “Coherent Ultra Dense Wavelength Division Multiplexing Passive Optical Networks (Invited Paper),” Optical Fiber Technology, Jul. 2015, doi: 10.1016/j.yofte.2015.07.001.

[32]J.J. Zhang, Z.H. Tang, R.P. Giddings, Q. Wu, W.L. Wang, B.Y. Cao, Q.W. Zhang, and J.M. Tang, “Stage-Dependent DSP Operation Range Clipping-Induced Bit Resolution Reductions of Full Parallel 64-Point FFTs Incorporated in FPGA-Based Optical OFDM Receivers | IEEE Journals & Magazine | IEEE Xplore,” IEEE, 2016. https://ieeexplore.ieee.org/document/7498676 (accessed Nov. 30, 2021).

[33]Ming Chen, Jing He, Jin Tang, Xian Wu, and Lin Chen, “Real-Time 10.4-Gb/s Single-Band Optical 256/64/16QAM Receiver for OFDM-PON | IEEE Journals & Magazine | IEEE Xplore,” Oct. 15, 2014. https://ieeexplore.ieee.org/document/6868959 (accessed Nov. 30, 2021).

[34]L. Yu, M. Wang, L. Zhang, J. Feng, and T. Hu, “The design and implementation of OFDM-PON uplink frame synchronization based on FPGA,” in Proceedings of 2013 3rd International Conference on Computer Science and Network Technology, Oct. 2013, pp. 612–615. doi: 10.1109/ICCSNT.2013.6967188.

[35]“Real-Time Optical OFDM Long-Reach PON System Over 100 km SSMF Using a Directly Modulated DFB Laser.” https://www.osapublishing.org/jocn/abstract.cfm?uri=jocn-6-1-18 (accessed Nov. 30, 2021).

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.165|| A Monthly Peer Reviewed & Referred Journal |

|| Volume 10, Issue 8, August 2022 ||

| DOI: 10.15680/IJIRCCE.2022.1008044 |

[36]Noriaki Kaneda, Senior Member, IEEE, Timo Pfau, Member, IEEE, Huan Zhang, Jeffrey Lee, Member, IEEE, Young-Kai Chen, Fellow, IEEE, Chun Ju Youn, Yong Hwan Kwon, Eun Soo Num, and S. Chandrasekhar, Fellow, IEEE, "Field Demonstration of 100-Gb/s Real-Time Coherent Optical OFDM Detection | IEEE Journals & Magazine | IEEE Xplore," Apr. 01, 2015. https://ieeexplore.ieee.org/document/7031859 (accessed Nov. 30, 2021).

[37]M. S, A. I. Rasheed, and D. U. M. Roy, "Design Approach for a FPGA based Ethernet Bridge for Optical Fiber Communication System," International Journal of Engineering Research & Technology, vol. 9, no. 5, Jun. 2020, doi: 10.17577/IJERTV9IS050682.

[38]J. Poliak and M. Kubíček, "FPGA-based media converter for FSO links," in 2013 2nd International Workshop on Optical Wireless Communications (IWOW), Oct. 2013, pp. 157–161. doi: 10.1109/IWOW.2013.6777798.

[39]H.-B. Jeon et al., "Demo: A Unified Platform of Free-Space Optics for High-Quality Video Transmission," arXiv:2005.06954 [cs, eess], May 2020, Accessed: Nov. 29, 2021. [Online]. Available: http://arxiv.org/abs/2005.06954

[40]Zun Htay1, Nithin Mohan1, Mojtaba Mansour Abadi1, Zabih Ghassemlooy1, Andrew Burton2, Stanislav Zvanovec3, "Implementation and Evaluation of a 10 Gbps Real-time FSO Link | IEEE Conference Publication | IEEE Xplore," 2020. https://ieeexplore.ieee.org/document/9410045 (accessed Nov. 30, 2021).

[41]Abir Touati1;2, Farid Touati1, Abderrazak Abdaoui1, Amith Khandakar1, Syed Jawad Hussain1 and Ammar Bouallegue2, "An experimental performance evaluation of the hybrid FSO/RF," 2017. https://www.spiedigitallibrary.org/conference-proceedings-of-spie/10096/100961J/An-experimental-performance-evaluation-of-the-hybrid-FSORF/10.1117/12.2256792.short?SSO=1 (accessed Nov. 30, 2021).

[42]M. Lu, L. Liu, and S. Hranilovic, "Raptor-coded free-space optical communications experiment," Journal of Optical Communications and Networking, vol. 8, no. 6, pp. 398–407, Jun. 2016, doi: 10.1364/JOCN.8.000398.

[43]Masato Yoshida, Toshihiko Hirooka, Keisuke Kasai, and Masataka Nakazawa, "Real-time 10 Gbit/s-16 QAM Quantum Stream Cipher Transmission over 320 km with FPGA-based Transmitter and Receiver," OFC © OSA 2015 2015. https://www.osapublishing.org/abstract.cfm?uri=OFC-2015-W4F.4 (accessed Nov. 30, 2021).

INNO SPACE
SJIF Scientific Journal Impact Factor
Impact Factor: 8.165

doi crossref

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

निस्केयर NISCAIR

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING