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High Speed 10 Gbps WDM-RoF for Free Space Optical Communication System

R. Prithvi Raj[1*], S. Robinson[2]
[1]*Student, Department of Electronics and Communication Engineering, Mount Zion College of Engineering and Technology, Pudukkottai, India*
[2]*Professor, Department of Electronics and Communication Engineering, Mount Zion College of Engineering and Technology, Pudukkottai, India*
*Corresponding author: prithviraj8694@gmail.com

***Abstract*: Free-space optics (FSO) is a communication technology that uses lasers in free space between transmitter and receiver units to transmit data. It has many merits such as low maintenance, no spectrum license, high bandwidth, high data rate and ease. To have high data rates, 5G technology is deployed with millimeter waves by employing in WDM-Ro-FSO system. Two, four, eight and sixteen independent channels are used and each carrying 10 Gbps-100 GHz of radio signals. With the help of BER and eye diagrams, the output signal is received for two, four, eight and sixteen independent channels. The simulation and design of WDM-Ro-FSO system are presented in this paper. The successful transmission of 2 × 10 Gbps, 4 × 10 Gbps, 8 × 10 Gbps and 16 × 10 Gbps of data along a link range of 18 Km are analyzed.**

***Keywords*: Free-space optics, WDM (wavelength division multiplexing), Ro-FSO (radio over free space optics).**

1. Introduction

FSO offers several communication techniques over wired communication such as optical fiber and gives wireless broadband services to last mile [1], [2]. FSO uses different modulation format to transmit data between from one point to another point and it is a secured communication [3], [4]. FSO links have many advantages such as secured data, high data rate, high security, free license, modulation techniques, low cost, high performance, easy installation and immunity to electromagnetic interference [5]-[9]. FSO links can be deployed for inter-satellite communication, military and inter-aircraft links [10], [11]. FSO communication links have many parameters such as data rates, launch power, transmitter aperture diameter, receiver aperture diameter, bandwidth and operating wavelength [12]. For achieving better performance, WDM has been introduced in FSO links and it is widely used in free space optics [13]-[15].

WDM is one of the techniques for FSO which uses a different wavelength of laser light over the same medium [16]. WDM technique provides higher bandwidth as compared to other technique to meet the demand of multimedia applications such as live streaming and video calling [17]. 5G technology is designed to provide higher data rates than LTE and to support more traffic and highly utilization of a network coverage area. To meet these objectives, millimeter wave is introduced as a potential carrier [18], [19]. 24-26 GHz faces high attenuation over a metallic wire which limits the coverage area. RoF was introduced with millimeter wave to have a high data rate with low distortion and it replaced with Ro-FSO for cells [20]-[23]. Two independent channels with a data rate of 5 Gbps for 5G applications over a link range of 5,000 m [24]. In this paper, 2, 4, 8, 16 channels carrying 10 Gbps and 100 GHz of radio signal is transmitted over a link range of 18 Km.

In this paper, 2, 4, 8, 16-channel WDM-based FSO link has been proposed with each channel transmitting at 10Gbps data rate and 100 GHz of radio signal transmitted over 18 Km of free space channel.

2. System Description

At the light source, a pseudo-random bit sequence (PRBS) is a binary sequence that generates information and it sends to return to zero (RZ) pulse generator which creates a sequence of return to zero from the user data. Mach-Zehnder modulator (MZM) modulates these signals into an electrical signal with a laser of 1550nm wavelength of spacing 1nm. A CW laser (continuous wave laser) is used with 10 dBm of input power. Lithium Niobate (LiNb) modulates the output signal of Mach-Zehnder modulator with 100GHz of radio signal. Direct current (DC) is used for bias stabilization. WDM multiplexes the optical signal together and optical amplifier is used to amplify the optical signal. This optical signal is propagated over 18 Km of free space link. In the receiver side, Avalanche photo detector (APD) converts the optical signal into electrical signal. To remove any noise, low-pass filter is used. Furthermore, BER analyzer is used to analyze bit error rate. In this work, 2, 4, 8, 16- channels WDM-Ro-FSO system is proposed to encode 10 Gbps-100 GHz data.

In this work, 2, 4, 8, 16-channel WDM-Ro-FSO system with each channel transmitting at 10Gbps rate and 100 GHz of radio signal has been designed using optisystem simulation software. The transmission power is set to be 10dBm, and the transmitter and receiver antenna aperture diameter are taken to be 5 and 20 cm, respectively. The wavelengths for designed two channels

are 1550nm, 1551nm, and for four channels are 1550nm, 1551nm, 1552nm, 1553nm. The wavelengths for designed eight channels are 1550nm, 1551nm, 1552nm, 1553nm, 1554nm, 1555nm, 1556nm, 1557nm, and for sixteen channels are 1550nm, 1551nm, 1552nm, 1553nm, 1554nm, 1555nm, 1556nm, 1557nm, 1558nm, 1559nm, 1560nm, 1561nm, 1562nm, 1563nm, 1564nm, 1565nm. The simulation parameter of the proposed system is listed in Table 1. Figure 1 shows the proposed WDM-Ro-FSO system and figure 2 shows the transmitter section.

Table 1
Simulation parameters of WDM-RO-FSO system

S. No.	Parameters	Values
1	Data rates	10 Gbps
2	Launch power	10dBm
3	Channel spacing	1nm
4	Attenuation	0.2 dB/km
5	Transmitter aperture diameter	5cm
6	Receiver aperture diameter	30cm
7	Dark current	10NA
8	WDM bandwidth	20GHZ

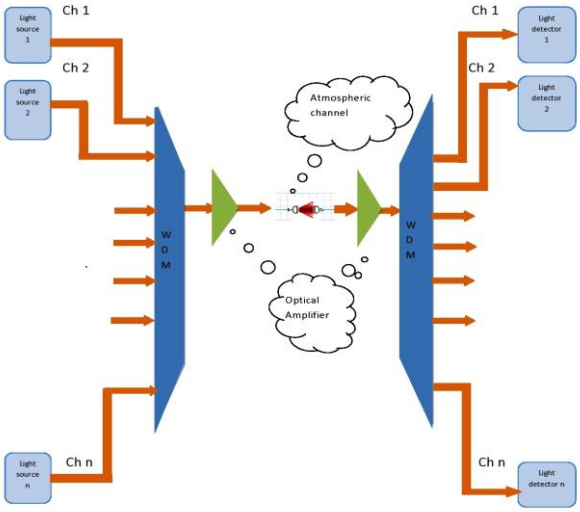

Fig. 1. Proposed WDM-Ro-FSO communication system

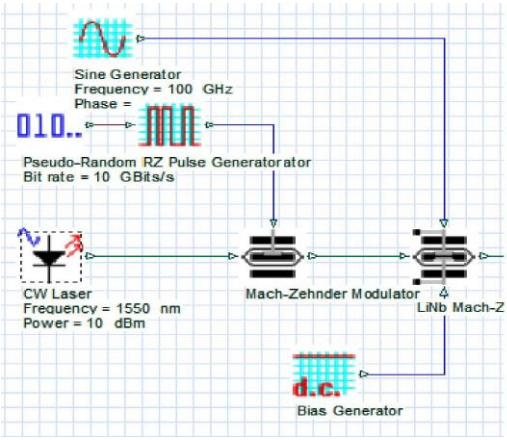

Fig. 2. Transmitter section

3. Results and Discussion

The simulations of proposed WDM-Ro-FSO system has been performed and discussed. Figure 3 characterizes the measure of BER values and max quality factor values with respect to link range for 2 channels WDM-Ro-FSO system. Minimum BER for channel 1 is figured as $5.16e^{-14}$ and $3.14e^{-9}$and for channel 2 is detected as $2.63e^{-15}$ and $3.39e^{-10}$ at a distance of 15 and 18.5 Km as shown in fig 3(a). Similarly, maximum quality factor for channel 1 is observed as 7.41 and 5.78 and for channel 2 as 7.80 and 6.14 at a range of 15 and 18.5 Km as shown in fig 3(b). Figure 4 characterizes the measure of BER values and max quality factor values with respect to link range for 4 channels WDM-Ro-FSO system. Minimum BER for channel 1 is figured as $1.86e^{-13}$and $1.90e^{-9}$; for channel 2 as $1.30e^{-17}$ and $2.26e^{-12}$; for channel 3 as $1.34e^{-13}$ and $1.65e^{-9}$ and for channel 4 as $5.01e^{-13}$and $3.55e^{-9}$ at a distance of 15 and 18 Km as shown in fig 4(a). The maximum quality factor for channel 1 is observed as 7.24 and 5.86; for channel 2 as 8.44 and 6.89; for channel 3 as 7.28 and 5.88 and for channel 4 as 7.10 and 5.75 at a distance of 15 and 18 Km as shown in fig. 4(b).

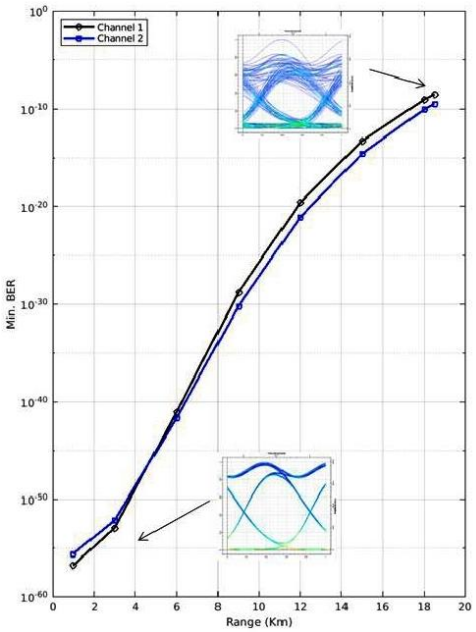

Fig. 3(a). BER versus link range

The figure 5(a) shows Minimum BER for channel 1 is figured as $3.77e^{-9}$; for channel 2 as $2e^{-8}$; for channel 3 as $4.67e^{-10}$; for channel 4 as $3.26e^{-8}$; for channel 5 as $9.94e^{-9}$; for channel 6 as $3.72e^{-10}$; for channel 7 as $2.57e^{-10}$ and for channel 8 as $9.74e^{-11}$ at a distance of 18 Km. The maximum quality factor for channel 1 is observed as 5.74; for channel 2 as 5.45; for channel 3 as 6.1; for channel 4 as 5.37; for channel 5 as 5.57; for channel 6 as 6.12; for channel 7 as 6.18 and for channel 8 as 6.33 at a distance of 18 Km as shown in fig. 5(b).

The figure 6(a) shows Minimum BER for channel 1 is figured as $5.87e^{-9}$; for channel 2 as $9.11e^{-11}$; for channel 3 as

1.13e^{-9}; for channel 4 as 3.75e^{-9}; for channel 5 as 5.35e^{-11}; for channel 6 as 2.93e^{-9}; for channel 7 as 4.50e^{-9}; for channel 8 as 3.08e^{-9} ; for channel 9 is figured as 4.03e^{-13}; for channel 10 as 1.76e^{-10}; for channel 11 as 3.56e^{-13}; for channel 12 as 3.04e^{-9}; for channel 13 as 1.61e^{-8}; for channel 14 as 1.93e^{-9}; for channel 15 as 1.06e^{-8}and for channel 16 as 4.96e^{-9} at a distance of 18 Km. The maximum quality factor for channel 1 is figured as 5.67; for channel 2 as 6.35; for channel 3 as 5.95; for channel 4 as 5.75; for channel 5 as 6.43; for channel 6 as 5.78; for channel 7 as 5.71; for channel 8 as 5.78; for channel 9 is figured as 7.13; for channel 10 as 6.25; for channel 11 as 7.16; for channel 12 as 5.78; for channel 13 as 5.49; for channel 14 as 5.86; for channel 15 as 5.57 and for channel 16 as 5.70 at a distance of 18 Km as shown in fig. 6(b).

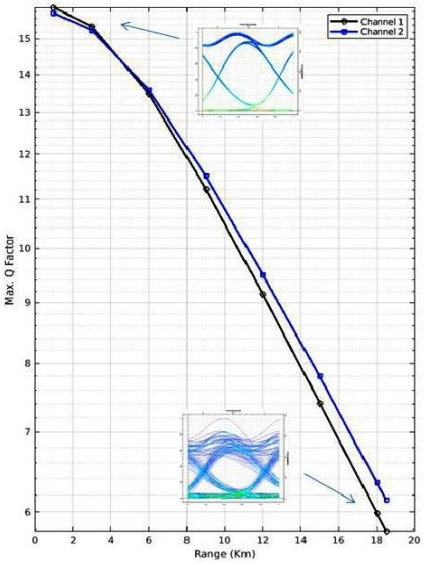

Fig. 3(b). Quality factor versus link range

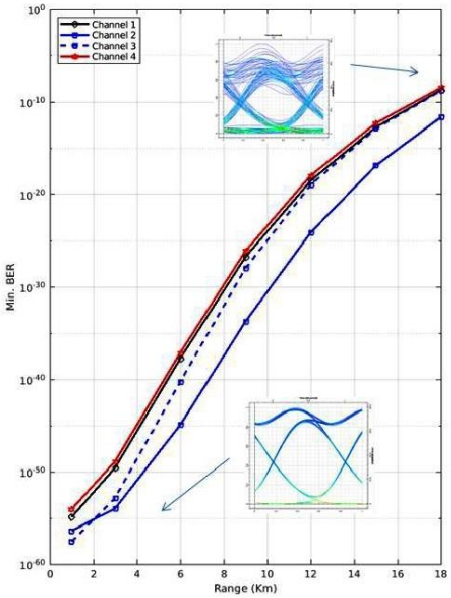

Fig. 4(a). BER versus link range

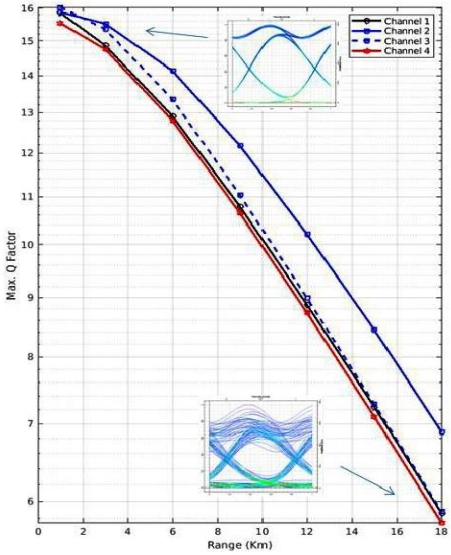

Fig. 4(b). Quality factor versus link range

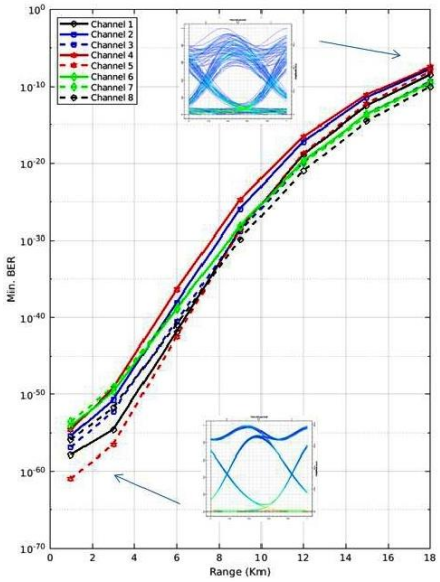

Fig. 5(a). BER versus link range

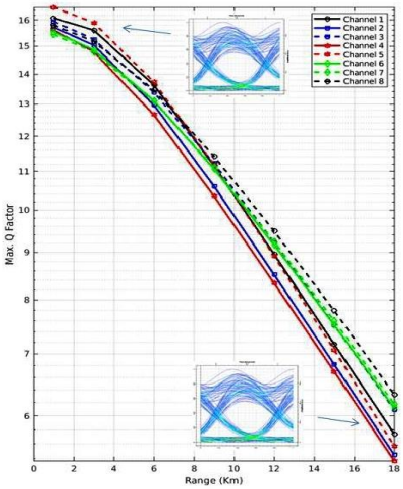

Fig. 5(b). Quality factor versus link range

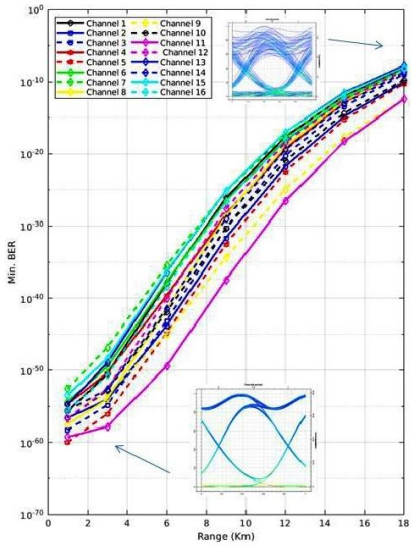

Fig. 6(a). BER versus link range

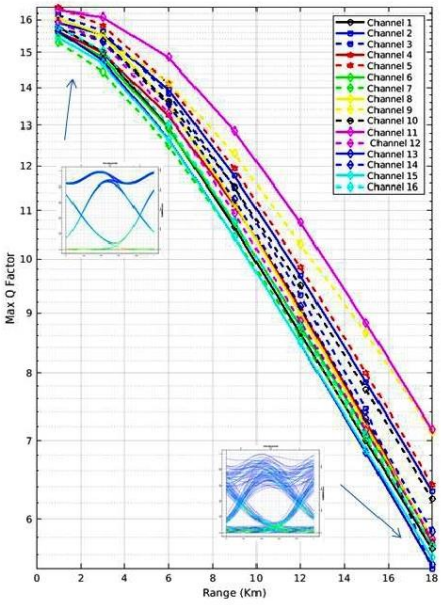

Fig. 6(b). Quality factor versus link range

4. Conclusion

In this paper, the performance of high speed WDM-Ro-FSO system was proposed to support 5G technology with millimeter waves. 2,4,8,16-channels are transmitted at a link range of 18 Km of free space, each carrying 10Gbps-100 GHz is analyzed on the basis of quality factor (Q), bit error rate (BER) and eye diagrams. The result shows successful transmission of 2, 4, 8, 16-channels of WDM-Ro-FSO system.

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