ISSN NO: 2770-4491
Date of Publication:21-09-2023

An Analysis of Performance in Free-Space Optical Communication Using Eight Wavelength Division Multiplexing

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Abstract: This article's main goal is to carry out an in-depth analysis of the free space optic channel's performance. The ultimate goal is to address the various obstacles associated with terrestrial infrastructure and channel leasing. In this article the four channels provided by the wavelength-division multiplexing (WDM) transmitter and transmitted to the Free-space optical communication (FSO) transceiver, resulting in successful reception of output signals at a speed of 10 Gbps, with a free channel range of 200m. The best iteration achieved an attenuation of 25dB/km. The optisystems software simulation package conducted 10 iterations, and the average total power was measured to be -34.22 dBm, while the maximum average Q-factor was 114.43. These results are considered satisfactory for the entire project, as they indicate low data error rates. (9 pt) .

Keywords: Free space, fiber optics, communication systems.

1. Introduction

Advanced positions in optical fiber communication technologies have been developed, including fiber communication and mobile communication [1]. Extensive research has been conducted on delivering standard data using emerging technological advancements , such as Wavelength Division Multiplexing (WDM), which utilizes dense division of the length of the wave, multi-modulation formats like QPSK and 16QAM, Space-Division-Multiplexing (SDM) that utilizes multiple basic fibers, and division multiplexing in the way, which uses a few fibers modes. Furthermore, there are growing demands for high-quality communication [2].

The architecture of the opposite post data center involves using fiber optic cables or coaxial cables for short-range communication between racks. When wireless connections are utilized for interconnecting shelves, the system offers good scalability, low latency, and flexibility [3].

One of the primary objectives of implementing Free Space Optics (FSO) is to eliminate water demand management for data centers and reduce expenses by mitigating Wavelength Division Multiplexing (WDM's). This phrase can be rephrased in two ways:

• Tolerance intervals for optical alignment were established to optimize the optical link's dependability between the receiver and transmitter.

• The aim was to optimize the reliability and validity of the optical link between the transmitter and the receiver by defining tolerance intervals for optical alignment.

As a result, active Ray systems installed for EOS monitoring receivers should be removed [4]. The ability to split waves in beam Wavelength Division Multiplexing Free Space Optics (WDM-FSO) is an important function of matrix waveguides, such as Arrayed Waveguide Gratings (AWGs). However, there are issues associated with this approach. One proposed solution is Wavelength Division Multiplexing Fiber Optic Ethernet (WDM-FOE), which employs a high-speed two-dimensional photodetector array (2D-PDA) [5].

The ultimate design for WDM-FSO entails the incorporation of a high-speed two-dimensional photodiode array (2D-PDA) with a Micro-Filter (MFA) and Micro Lens Array (MLA) on the receiver's end [6].

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2. Optical communication system

Traditionally, binary optical coding schemes like OOK or BPSK have been used in optical communication systems. These schemes provide two states for each code, conveying partial information [7].

Modern systems utilize QPSK, which increases the constellation size to four and enables two bits per character. By enlarging the constellation size, more bits per symbol can be achieved [8].

The telecommunications industry employs various technologies; examples of modulation techniques commonly used in communication systems include phase shift keying (PSK) and amplitude shift keying (ASK), and a range of PSK and ASK schemes collectively referred to as quadrature amplitude modulation (QAM) [9]. Examples of commonly used higher modulation schemes are shown in Figures (1-4). The number of bits per character is determined by the number of schemes used, which is equal to 2 raised to the power of that number. The selection of modulation schemes depends on multiple factors, as for receiver sensitivity of the receiver practical and receiver limits of reception with transmission complexity. [10].

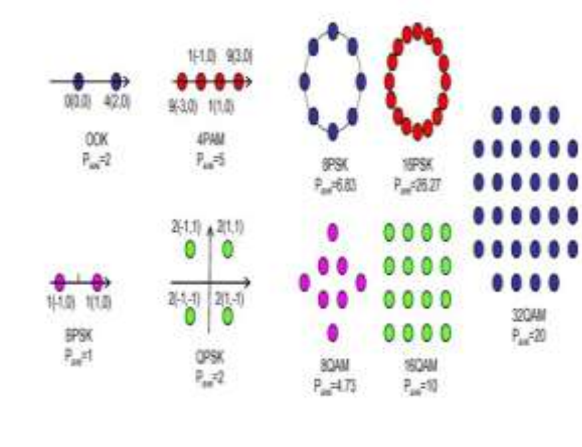

Figure 1: Constellation diagram and average symbol energies for some popular higher order.

2. 1. WDM Transmitter

The WDM transmitter, which is the first component of the system, generates eight distinct optical channels at specific frequencies: (381.9, 382., 382.1, 382.2, 382.3, 382.4, 382.5, and 382.6) THz. The transmitter's features include an input optical power of 36mW, The parameters specified are a frequency spacing of 100 GHz, an extinction ratio of 10 dB, a line width of 10 MHz, and an NRZ modulation format. The transmitter type is an externally modulated laser, and these optical channels are then fed into an 8x1 WDM[10]. The results of these enhancements exhibit the following characteristics**:**

Table 1: (8×1) WDM transmitter properties

Name	Values	Unite
Ports number	8	-
Frequencies	785	Nm

Table 2: The WDM multiplexing (8×1) main properties

The name	The values	The unite
The depth	100	dB
The filters order	1.9	-

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Table 3: The WDM multiplexing (8×1) main Channels

The name	**The values**
CH1	381.9THz
CH2	382THz
CH3	382.1THz
CH4	382.2THz
CH5	382.3THz
CH6	382.4THz
CH7	382.5THz
CH8	382.6THz

2. 2. Optical Receiver Simulation

The final component of the setup is the optical receiver, which is comprised of an (8x1) Demultiplexer that separates each received channel depending on its wavelengths. Each output channel is then processed by the optical receiver's built-in subsystem, which functions as a photo-detector with positive intrinsic negative (PIN) characteristics[11]. This subsystem also includes the low pass filters with cut-off frequencies of (0.75 x bitrate), an insertions loss of 0 decibels, a filter depth of 100 decibels, and a filter order of CH 4.

After the signal completes its round-trip journey, it is regenerated electrically using 3R, which generates modified electrical signals and the original bit sequences for BER analysis[12]. The bitrate of the signal is 5 gigabits per second, the sequence length is 128 bits, and there are 64 samples per bit, resulting in a total of 8192 samples [13]. The proposed layout of the experiment is illustrated in Figure (2).

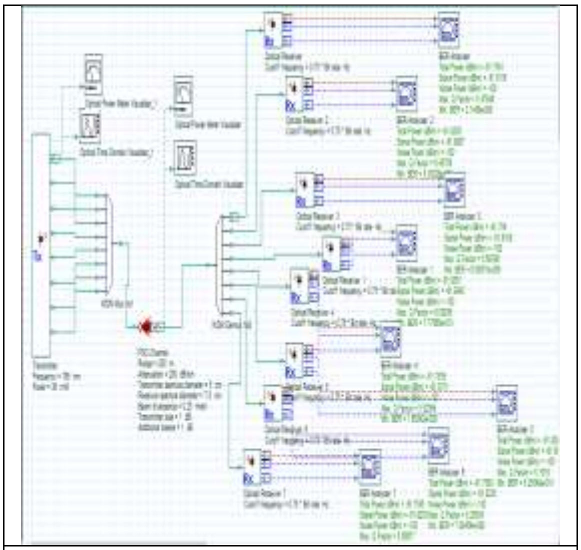

Figure 2: The main layout screenshot of the simulation.

Unsatisfactory as no output is observed due to the decline in attenuation value. To analyze the performance of the Wavelength Division Multiplexing (WDM) based Free Space Optics (FSO) system, the attenuation was considered as an optimization parameter. This was done through 10 iterations of attenuation ranging from 25 to 100 decibels per kilometer [14]. The attenuation is a crucial parameter in setting up an FSO system as it plays a vital role in the free space channel by affecting factors such as fog, rain, and moisture [15].

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To make the most of a single channel, we utilized an (8x1) WDM as an active component to multiplex four input channels into one output channel that would be sent to the FSO components[16]. This allowed for better utilization of the available channels in the FSO system.
The degradation in attenuation value will negatively impact the output signal, resulting in noise and inter-symbol interference (ISI) being present in the output signal [17].
The ability to split waves in beam Wavelength Division Multiplexing Free Space Optics (WDM-FSO) is an important function of matrix waveguides, such as Arrayed Waveguide Gratings (AWGs). However, there are issues associated with this approach [18]. One proposed solution is Wavelength Division Multiplexing Fiber Optic Ethernet (WDM-FOE), which employs a high-speed two-dimensional photo-detector array (2D-PDA) [19].
The proposed WDM-FSO system incorporates a high-speed two-dimensional photodiode array (2D-PDA) in conjunction with a Micro-Filter (MFA) and Micro Lens Array (MLA) on the receiver's end [20].

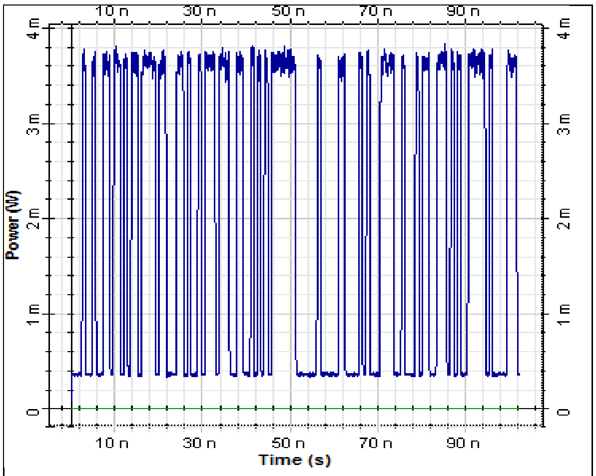

Figure 3: The power versus time signal befor the FSO channels, the distance is (200m).

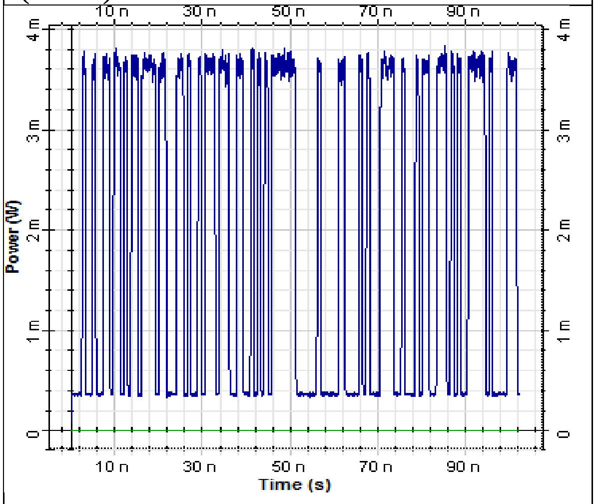

Figure 4: The power versus time signal after the FSO channels, the distance is (200m).

The signals before transmission through the optic channel free space and those received at the receiver end appear similar, which is attributed to the proper system parameter settings [21].
Figures 5 and 6 demonstrate excellent eye-opening for a data rate of 5 Gb/s over a 200 m FSO link. The signals received from the transmitting end are of high quality, as no interference or inter-symbol interference

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(ISI) is observed[22]. The x-axis of the figure indicates the bit-time values, which represent the necessary interval between transmitted bits [23].

The bit time represents the duration of the ellipse required for each bit of the network to be affected [24]. It also measures the amplitude of individual waves, while the Q factor denotes its value [25]. The Q-factor iteration curves with high peaks are indicated by the color red.

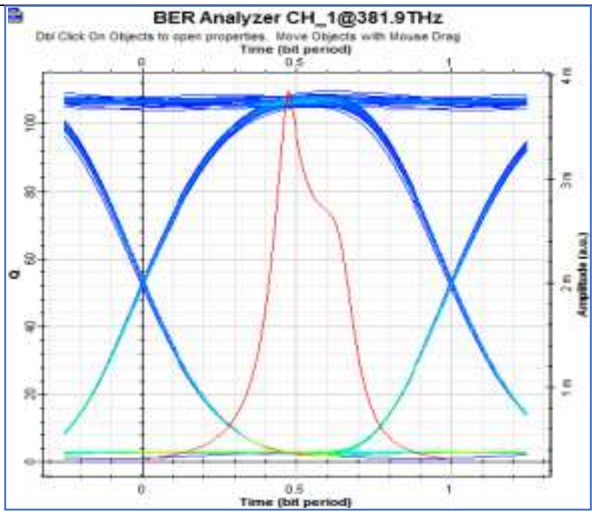

Figure 5: The eye diagram when the range of distance is (200m) and Q-factor versus time from BER Analyzers channel 1 attenuation is equal to 25 dB/km.

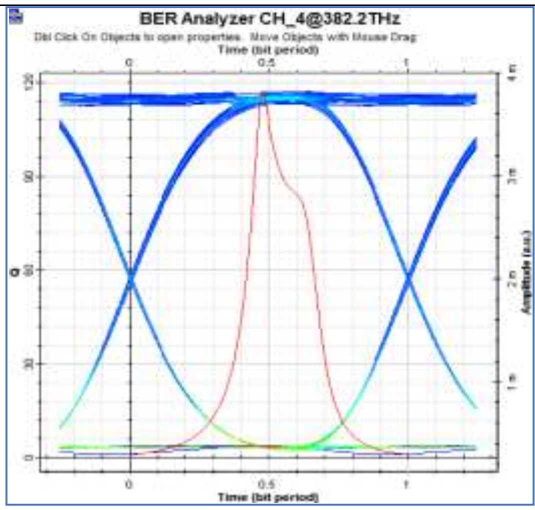

Figure 6: The eye diagram when the range of distance is (200m) and Q-factor versus time from BER Analyzers channel **4** attenuation is equal to 25 dB/km.

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