ISSN: 0974-5823 Vol. 6 No. 3 December, 2021

International Journal of Mechanical Engineering

Simulation and Analysis of Single Mode Fiber for obtaining higher Bit Rate using different Wavelengths

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Abstract-The data transmission of 22.5 Gb/s has been experimentally demonstrated using two different digital modulation formats. The wavelength has been chosen from the various optical bands. The wavelength on which the best results have been obtained are 1310 nm, 1410 nm, 1510 nm and 1550 nm over the certain distance. The performance of the system has been evaluated from the eye diagram on the basis of Q Factor and BER (bit error rate).

Keywords— RZ (Return to Zero), NRZ (Non Return to Zero), OFC (Optical Fiber Communication).

I. Introduction

The optical fiber transmission system using optical source for data transfer is a fastest way of transmission from transmitter to receiver. The basic optical transmission system comprises of optical source, medium (wired) that carries the optical signal having data to receiver (photo-detector) and finally optical receiver converts it in electrical form. The lasers are used as the transmitters in optical transmission system. The digital data from data generator is modulated using modulation techniques and pass on to the transmitting medium for the transmission. The FTTH (Fiber to the Home) turns into fact worldwide that providing broadband capability up to the doorstep of home (Koonen et al. 2010). If there is only one direction to chase for light then it is called as propagation of single mode. If there exists more than one path, then it is called multimode propagation (Winzer et al., 2006).The optical fiber is divided into two parts depending on the propagation modes SMF (Single Mode Fiber) and MMF (Multi Mode Fiber). If there is only one direction to follow for light then it is called as propagation of single mode. If more than one path exists, then it is called multimode propagation (Addanki et al., 2018) (Chhilar et al. 2011).The study will be carried out using single mode fiber, so only SMF cable is addressed in present research work. The single mode fiber allows light rays to be propagated by just one path. The SMF is ideally designed to maintain the continuity of light pulses and thus no dispersion over long distances caused by multiple modes. Ultimately, that enables more information to be transmitted per unit of time. This provides higher bandwidth to single mode fiber compared to multimode fiber.In this paper, the simulative design is constructed to obtain the higher bit rate by using the modulation techniques as discussed below in the methodology. The simulative design setup consists of three parts namely transmitter section, medium and receiver section further, the transmitter consist of PRBS bit generator, modulation type, optical source and MZM modulator. The medium consist of optical fiber (SMF) along with the optical amplifier and is controlled by loop control which elaborates the length of optical fiber used in the communication. The receiver section consist of photodiode (PIN) used to detect the optical signal which is further passed on to low pass Gaussian filter (Xie et al., 2004) and finally the output is analyzed using bit error analyzer. The complete design is comprises of various parameters which include bit rate, power of optical source, wavelength, length of single mode fiber, types of format used to modulate the signal etc.

II.Research Methodology

The methodology shown below in the figure 1 explains the complete optical fiber transmission system from source to destination. The medium used in the system is single mode fiber (SMF) cable that carries the data in the form of bits/sec. The input data in the form of bits is passed through various modulation formats. The bands such Original band (O-band) 1310 nm, Extended band (E-band) 1410 nm , Short wavelength band (S-band) 1510 nm and Conventional band (C-band) 1550 nm are used to carry data to the receiver over the certain distance.

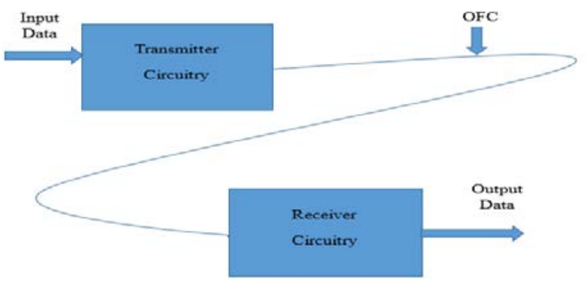

Figure 1. Design of optical fiber cable system

The modulator MZ (Mach-Zehnder) is used to combine the optical signal (CW Laser) and modulated signal and send it over the channel for the successful transmission at the receiver end. The optical amplifier is also used to regenerate the signal. At the receiver the PIN photodiode is used that convert optical signal back into electrical signal. Further, electrical signal is passed through low pass Gaussian filter for filtered output. The final output is evaluated in the terms of BER (bit error rate) and quality factor (Q-Factor) from the bit error analyzer (Soni et al. 2020).

III.Simulative Design Setup

The optical fiber communication design set up consists of CW laser, modulation formats (NRZ, RZ), PRBS generator and Mach-Zehnder modulator at the transmitter side which is used to transmit the signals at the various wavelengths which includes1310 nm, 1410 nm, 1510 nm and 1550 nm over the distance as explained in the table 1. At the receiving end, optical signal is converted backinto electrical form by using PIN photodiode. The layout parameters used for the simulative design setup is shown below in the table 1.

Table 1. Simulative Design Setup Parameters

The name of the parameter used	The value of the parameter
Bit Rate	22.5 Gb/sec
Power	1mW
CW Laser Frequency	1310nm, 1410nm, 1510nm and 1550nm
Fiber Length	10Km
Type of Filter	Low Pass Gaussian Filter
Photo Detector	PIN
Modulator Formats	RZ and NRZ
Attenuation	0.3dB/Km, 0.2dB/Km

The low pass Gaussian filter permits the low frequency signal to pass. The BER analyzer is used to analyze the output in terms of quality factor and bit error rate. The simulative design setup for the RZ modulation formats at optical wavelengths 1310 nm (Jawla and Singh, 2013) is shown below in the simulative design figure below.

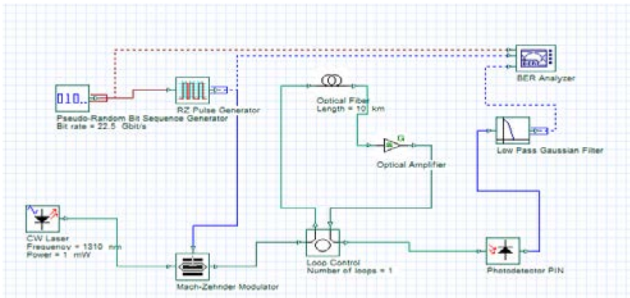

Figure 2. Simulation layout of optical fiber transmission system at 1310 nm

The figure 2 shows above the simulation layout for the OFC system in which the optical wavelength 1310 nm is used. The RZ modulation format is used to here along with the MZ modulator for the transmission of data (Gonda et al., 2019). The optical fiber of length 10 Km is used to send data rate 22.5 Gbps from sender to receiver. Further, the simulative setup has been simulated for other optical wavelengths like 1410 nm, 1510 nm and 1550 nm.

IV.Result and Discussions

The output is analyzed from the bit error analyzer in the form of eye diagrams.The figure 3 below shows the eye diagram with maximum quality factor 5.749 and the BER $4.469e^{-009}$. It also indicates that the maximum data transferred from the sender to receiver with minimum losses. Similarly, the output in terms of bit error rate and quality factor are obtained from the BER analyzer for various optical bands NRZ and RZ formats.

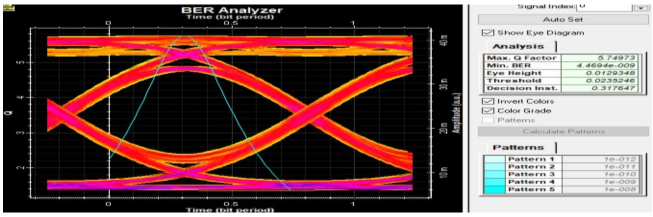

Figure 3. Eye diagram at optical wavelength 1310 nm using RZ format

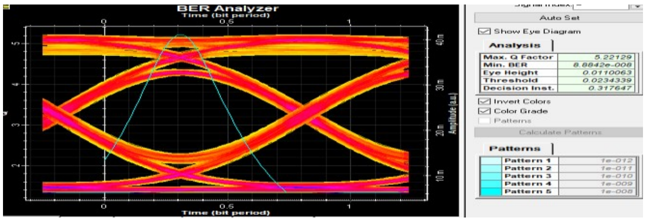

Figure 4. Eye diagram at optical wavelength 1410 nm using RZ format

The figure 4 above shows the eye diagram at the optical wavelength 1410 nm using RZ format.The maximum quality factor achieved here is 5.221 and minimum bit error rate is $8.884e^{-008}$. The results from the RZ modulation format are shown here in the figures.

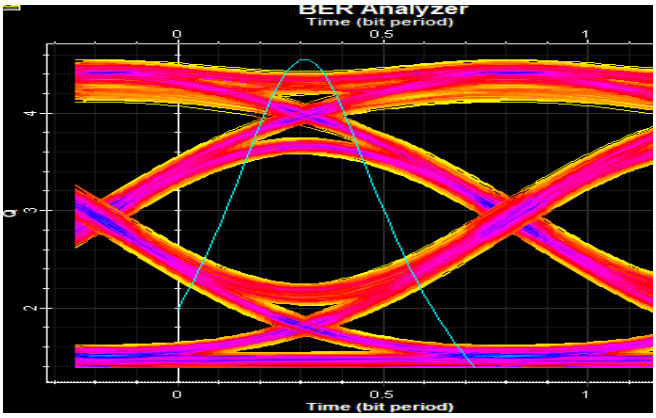

Figure 5. Eye diagram at optical wavelength 1510 nm using RZ format

The figure 5 above shows the eye diagram at optical wavelength 1510 nm using RZ format and the figure 6 shows the eye diagram at the optical wavelength 1550 nm.

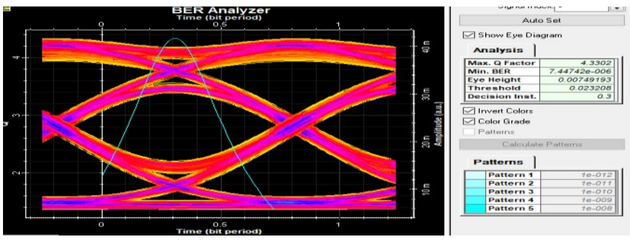

Figure 6. Eye diagram at optical wavelength 1310 nm using RZ format

Table 2. Output from BER analyzer for the RZ and NRZ format

Optical Wavelength	Using RZ format		Using NRZ format	
	Q-Factor	BER	Q-Factor	BER
1310 nm	5.749	4.469e-009	4.755	9.921e-007
1410 nm	5.221	8.884e-008	4.595	2.159e-006
1510 nm	4.550	2.681e-006	4.396	5.501e-006
1550 nm	4.330	7.447e-006	4.306	8.276e-006

The table 2 provides the output from the bit error analyzer in terms of Q-Factor and BER for different formats RZ and NRZ. The best result is obtained at wavelength 1310 nm with Q-Factor 5.749 and BER is $4.469e^{-009}$ with constant bit rate of 22.5 Gbits/s.The value of Q factor achieved at the wavelength 1310 nm is maximum with NRZ modulation format over the distance 10 Km.

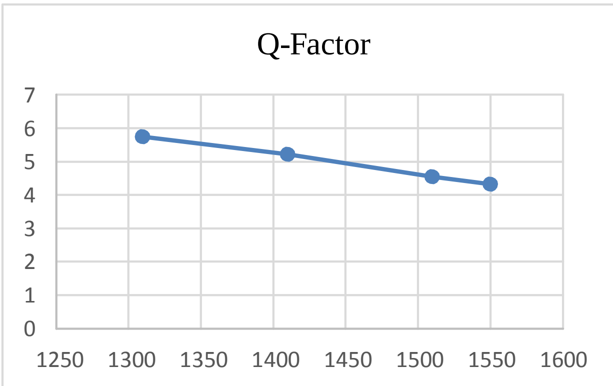

Figure 7. Graph between the optical wavelength and Q-Factor

The figure 7 shows the graphically representation of optical wavelength vs Q-Factor. The x-axis represents the values from the different optical wavelength bands and the y-axis represents the different values obtained in terms of quality factor from the simulative design setups. In this the maximum quality factor is achieved at optical wavelength 1310 nm with RZ modulation format.The best result is obtained at wavelength 1310 nm with Q-Factor 5.749 and BER is $4.469e^{-009}$.

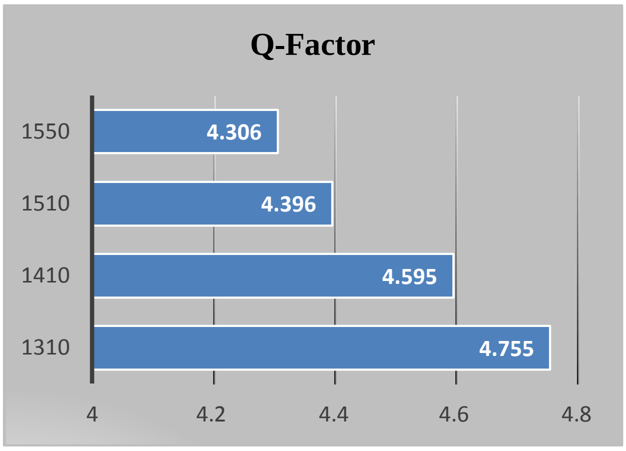

Figure 8. Optical wavelength vs Q-Factor

The graphical representation of the figure 8 shows the optical wavelength vs Q-Factor. The different values at the different optical wavelength bands are shown above in the figure using NRZ modulation format. The maximum Q-Factor is achieved at optical wavelength 1310 nm with NRZ modulation format which is 4.755.

Conclusion

The optical fiber transmission system discussed in this paper is used to transmit data at bit rate 22.5 Gbits/sec. The single mode fiber of length 10 Km is used in the above design setup. In the simulation designs NRZ and RZ modulation formats are used over the various bands with wavelength 1310 nm, 1410 nm, 1510 nm and 1550 nm respectively which is used to send the data over the distance discussed above. In the above designs with different wavelengths the maximum quality factor obtained at the wavelength 1310 nm is 5.749 and the bit error rate obtained is $4.469e^{-009}$. From the above results, it is concluded that the suitable results are obtained only at some specific wavelengths. The best suitable wavelength from the above set of wavelengths is 1310 nm for transmitting the data rate of 22.5 Gbps over the distance 10 Km with RZ modulation format with minimum power.In the future work, more data rate can be send over the longer distances by varying the different parameters.

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