Comparing Free Space Optical Communication using LED and LASER under Low Turbulence Region

Md. Farhan Memon
Student
Dept. of Electronics & Telecom.
AI's Kalsekar Technical Campus
New Panvel, 410 206

Vishal Mahadik
Student
Dept. of Electronics & Telecom.
AI's Kalsekar Technical Campus
New Panvel, 410 206

Awab Fakih
Lecturer
Dept. of Electronics & Telecom.
AI's Kalsekar Technical Campus
New Panvel, 410 206

ABSTRACT
Free Space Optical (FSO) Communication is preferred over the radio frequency communication and microwave systems for about three decades. Next generation FSO communication systems use fiber-optic technology for unseamed and better data propagation rates. Besides license-free long-range operations, it has many other advantages like high bandwidth, small size, cheap and easy installation [1]. However, atmospheric turbulence highly influences the optical waves. As a result, it has few limitations like scintillation, dispersion of beam, etc. [2]. Such challenges are overcome by using different mediums and wavelengths. This paper considers the wavelength of 1550 nm with PRBS generator at bit rate 1.25 Gb/s using both LASER and LED. These two optical sources are then compared on the grounds of Q-factor, Bit Error Rate (BER), wavelength spectrum and eye diagrams for the analysis of the sources that can be used in the FSO systems.

General Terms
Design, Verification, Comparison.

Keywords
Free Space Optics, LASER, LED, Bit Error Rate (BER), Eye diagram, ISI, Q-factor, Wavelength spectrum.

1. INTRODUCTION
Communication, when thought of, speed has been one of the major factors to be simply depend upon and rely. The faster the means of communication is, the more effective it will be. As a wireless communication technology, Wireless Optics is the most probable approach that has the ability to even up the rapid growth in wireless network devices. Another name for this technology is Free Space Optics (FSO) which simply means that this type of communication uses light propagating in free space to transceive data between two nodes which provides high bandwidth and is highly directional between the two devices. It can provide data rates as that of optical fiber over short distances with low probability of interference [3]. FSO communication has particularly found its applications in high altitudes, for example space communications, and building top metro-area communications. Although it was not realised to a greater extent in the past, but lately due to recent commercialization successes it has received a growing attention. As a result of which a wide variety of applications for wireless cellular networks (from last-mile access to back-haul) are used today [3], [4].

Optical systems work in the infrared or near infrared region of light (430 THz down to 300 GHz). Optical communication is basically a form of telecommunication which uses light as a medium with the help of optical transceiver using either LASER or LED. FSO and fibre equipment can be combined without intermediate conversions, since both the air and the material used for fibre cables have a good transmittance at the established wavelengths, namely 850 nm and 1550 nm [5]. Thus, it is a line-of-sight technology with a cost-effective alternative to fibre-optics avoiding digging, delays, and associated costs with fibres that transmits data, voice or video at speeds capable of reaching 2.5 Gbps - 10 Gbps. 1550 nm wavelength is undoubtedly better than 850 nm wavelength, we are considering the former wavelength as the basis for comparing FSO Communication through LASER and LED. The quality of the transmission line is characterized by the realized bit-error rate (BER), quality factor (Q), eye diagram and wavelength spectrum.

2. PARAMETERS
2.1 Bit Error Rate (BER)
The performance of any communication system for the various spatial modulation techniques is characterised in terms of the probability of errors also called as bit error rate (BER) [1], [3]. To have maximum protection against fading, BER should be minimised. However, a sharp increase in the BER of free space optics is noticed due to air pockets which act like lenses with time-varying properties [6], [7]. BER can be said to be the ratio of the number of bit errors detected in the receiver to the number of bits transmitted. Thus Bit error rate *BER* can be estimated as:

$$\text{BER} \approx \frac{n_e}{N_B}$$

Where n_e indicates the number of the received error bits, and N_B is the number of all transmitted bits for a sufficiently long period of time.

2.2 Quality Factor (Q Factor)
Bit error occurs when the receiver makes incorrect decisions because of the presence of noise in the received signal, whereas the measurement of signal quality is termed as Q-factor [2], [6]. It is proportional to the system's signal to noise ratio. The Q-factor representing the receiver's SNR is given by:

$$Q = T_0 \frac{(I_1 - I_0)}{\sigma_0 + \sigma_1}$$

Where T_0 stands for the maximum transmittance (which is equal to the unity). I_1 and I_0 are the average detected signal currents while σ_0 and σ_1 are the standard deviations of the noise values for bits '1' and '0' respectively. Since BER is too small to measure Q-factor is widely used [8], [9].

2.3 Eye Diagram

Eye diagram is a tool useful for qualitative analysis of a signal in high speed transmission. When the multiple bits of data are transmitted at high rate, it can potentially lead to errors in the interpretation at the receiver which is termed as Inter-Symbol Interference (ISI), this is visualised with the help of eye diagrams [4].

It is generated in an oscilloscope by superimposing sweeps of different time domain signals of a long data stream which results in an image similar to the opening of an eye. The time interval at which the received signal needs to be sampled with fidelity is determined by the opening of the eye, where the ideal time of sampling is when the height of the eye opening is largest [10], [11]. Thus the eye diagram is a common indicator of the signal quality where the closing of the eye is proportional to the sensitivity of the timing errors of the whole system.

3. SYSTEM DESIGN

Fig 1 and Fig 2 shows the basic concept and devices that have been used in designing. FSO link consisting of a transmitter, FSO channel, and receiver has been put together [6]. The only difference between the two block diagrams is that an LED has been used in Fig 1 and a LASER (VCSEL) in Fig 2 for analysis with external modulation or directly modulated. Receivers can feature detectors based on either PIN or APD. There is a simple FSO link design under study with link parameters reported as stated above considering weak turbulence region. Transmitter consists of a PRBS generator at bit rate 1.25 Gb/s, NRZ Driver, and directly modulated at 1550 nm. Optical power out of the transmitter is 1.3 dBm. FSO link has a 500 meters range with a beam divergence angle of 3 mrad. The environmental additional attenuation is specified by its mean value of –4.92 dB and standard deviation (sigma) of 1.9 dB. Receiver is a PIN/TIA (with Bessel-Thompson electrical filter with 1 GHz bandwidth) and is followed by BER Tester. There are also Optical Meter, Spectrum, Eye Diagram, and Optical Waveform Analysers.

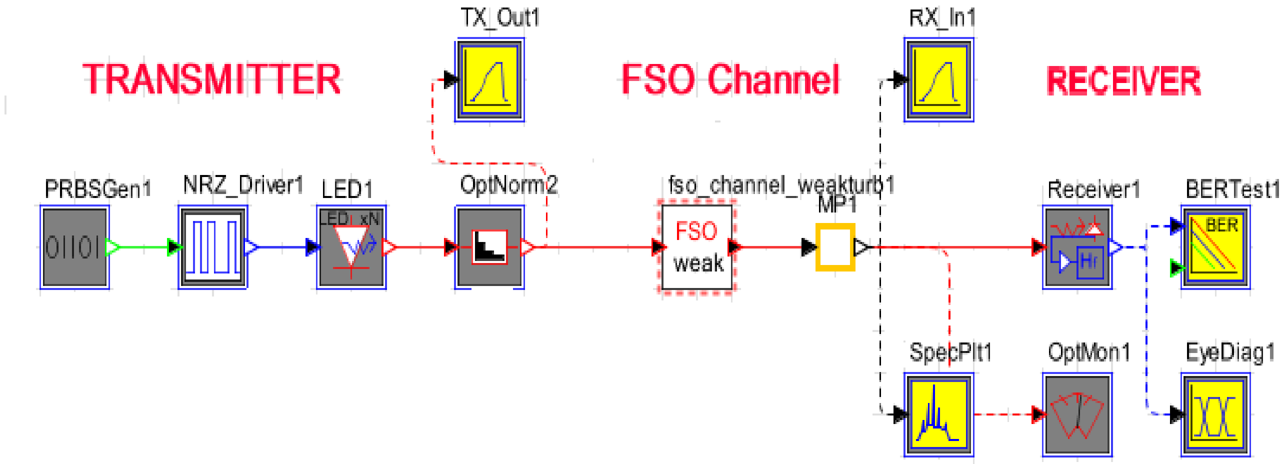

Fig 1: LED System

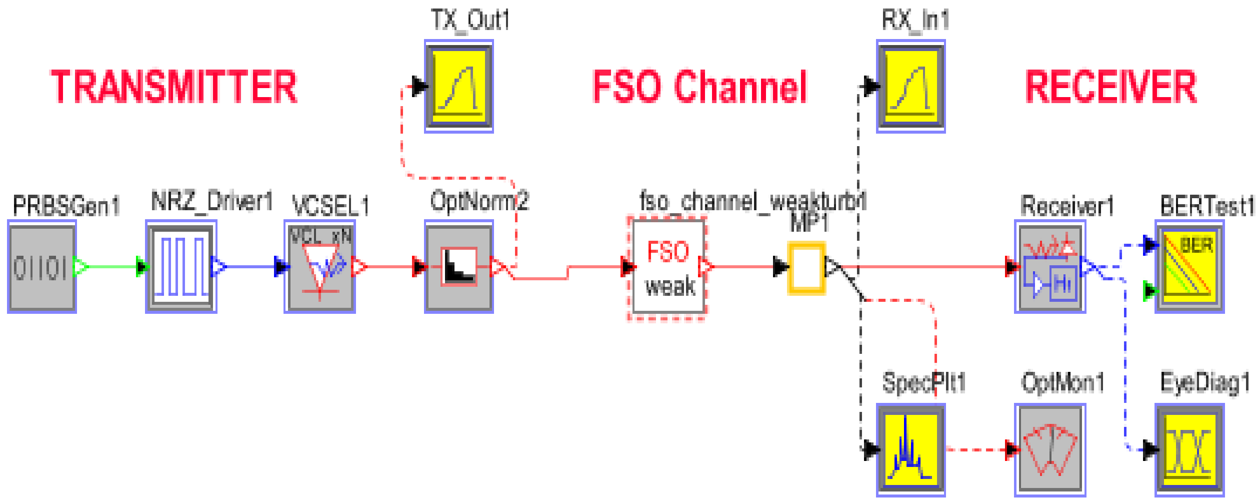

Fig 2: LASER System

4. RESULTS

4.1 Bit Error Rate

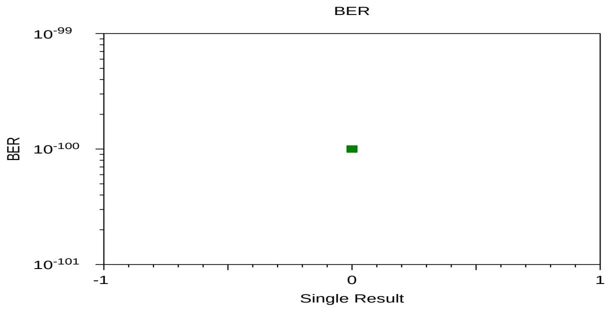

Fig 3: BER output for LED system

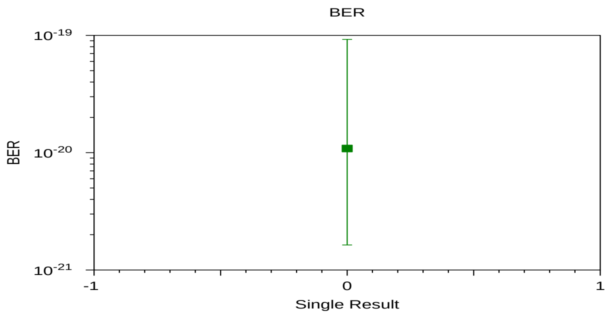

Fig 4: BER output for LASER system

4.2 Q Factor

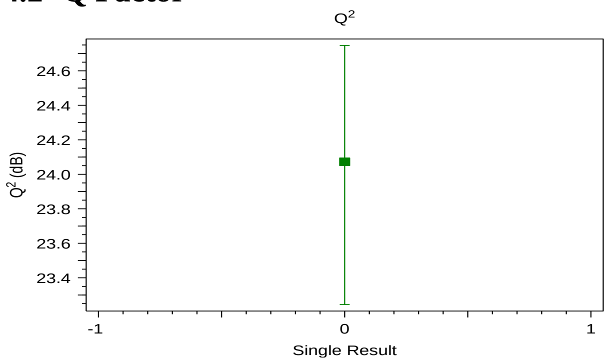

Fig 5: Q factor output for LED system

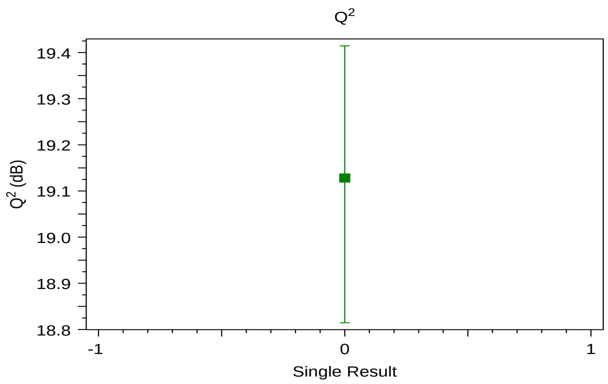

Fig 6: Q factor output for LASER system

4.3 Eye Diagram

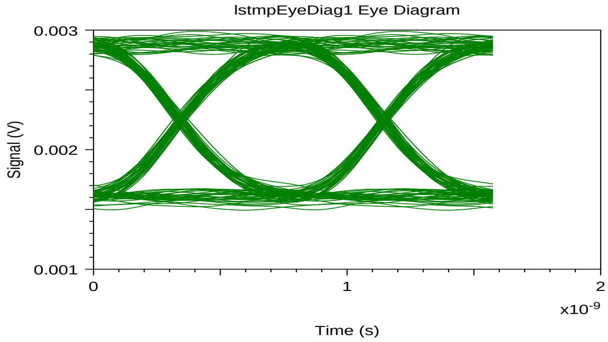

Fig 7: Eye diagram output for LED system

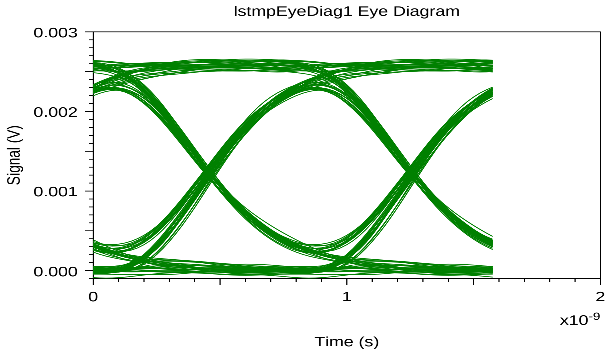

Fig 8: Eye diagram output for LASER system

4.4 Wavelength Spectrum

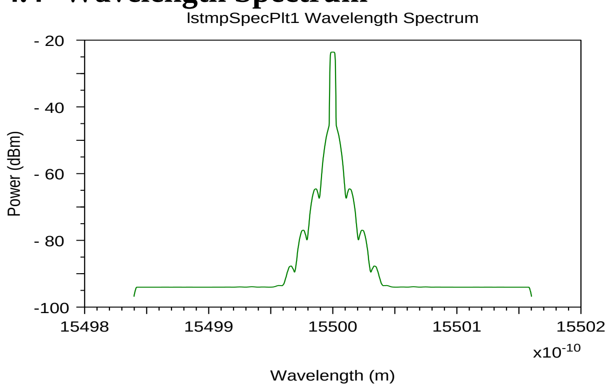

Fig 9: Wavelength spectrum of LED system

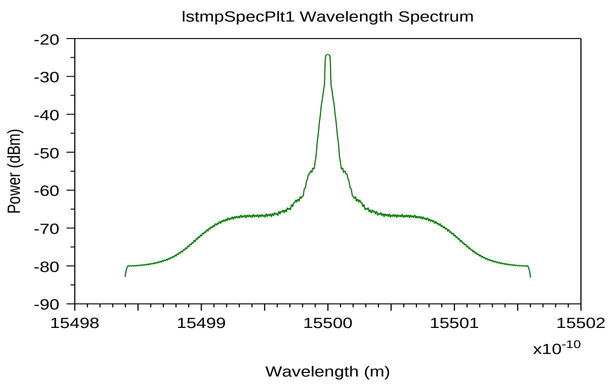

Fig 10: Wavelength spectrum of LASER system

5. CONCLUSION

Medium	BER	BER Low	BER High	Q^2 (dB)
LED	8.5274 e-058	3.8020 e-067	3.9726 e-048	2.4073 e+001
LASER	1.0854 e-020	1.6356 e-021	9.2456 e-020	1.9326 e+001

In this paper simple FSO link design has been used with transmitter consisting of PRBS Generator at the bit rate of 1.25 Gbps, NRZ Driver directly modulated at 1550 nm for both LED and LASER and found out parameters like BER rate, Quality Factor, Eye Diagrams and Wavelength Spectrum. From the above table, we can infer that on the basis of obtained results LED is better for transmission than the LASER.

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