Optical Communication Engineering Simulation Laboratory for Effective Undergraduate Education during Era of Covid19

Shailesh Khant[a], Atul Patel[b], Pravin R Prajapati[c]

[a]Faculty of Computer Science and Applications, CHARUSAT, Changa, India, shaileshkhant.mca@charusat.ac.in
[b]Faculty of Computer Science and Applications, CHARUSAT, Changa, India, atulpatel.mca@charusat.ac.in
[c]A D Patel Institute of Technology, CVM University, New V V Nagar, Anand, India, pravinprajapati05@gmail.com

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Abstract: Corona virus pandemic COVID19 has greatly affected the education sector. All academics institutes have to shut off face to face classroom teaching and learning. Engineering education, where there is a need to understand more of the practical concepts using costly hardware is greatly affected. One such engineering course, which involves this type of hardware, it requires practical understanding, is optical communication engineering. This paper describes how effectively this course will be taught from home using simulation tool. OPTSIM 5.0TM simulation tool is used to simulate all basic and advanced optical systems. Various optical systems and experiments such as Optical receiver, Optical Transmitter, Optical fiber amplifiers, Optical MUX, Optical De-MUX etc. can be designed for various fiber parameters and performance is measured using BER analyzer, Eye diagram analyzer, Optical Monitor, spectrum analyzer etc. This paper also describes how effectively the benefits of optical system and its performance using OPTSIM 5.0TM software will be taught in the virtual environment of teaching and learning.

Keywords: LGS, mathematics, teacher, difficulty

1. Introduction

During this COVID19 era all educational sectors are greatly affected. In the engineering field experimental process needs to be studied to understand the technical and theoretical aspects. Costlier hardware is required in the engineering subjects like optical communication. It is very difficult to demonstrate the experiments online, which involve such hardware.

With the help of powerful simulation software like OPTSIM, it is very easy to demonstrate the engineering optical communication applications online. An effort is made to simulate important applications using this software where various components are modelled and graphical relationships between them are shown. Various inbuilt components available are PRBS generator, optical transmitter, optical receiver, non-linear fiber, various types of LASERs and LEDs, photo detectors, splitter and combiner (MUX and De-MUX). For analysis purpose components modelled are signal analyzer, spectrum analyzer, BER and Q-factor tester, optical and electrical power meter and eye diagram analyzer.

2. Practical Applications

Based on the syllabus of universities and importance, following applications are selected for design and development. Following applications are simulated and analyzed.

1. APD-HBT Receiver
2. SLA (SOA) Amplifier
3. Raman Amplifier
4. WDM system
5. FSO system

APD-HBT Receiver

Since the receiver can detect small, distorted signals and then make decisions, the design of an optical receiver is much more complex than that of an optical transmitter. The avalanche photodiode (APD) is the main type of optical communication detector. To establish an extremely high electric field area, it has a more sophisticated structure than the PIN photodiode [9].

There is a high field region in which holes and electrons can acquire sufficient energy to excite new pairs of electrons-holes in the depletion region where most of the photons are absorbed and the main carrier pairs are produced. This mechanism is known as impact ionization and is the phenomenon that in ordinary reverse biased diodes leads to avalanche breakdown.

Silicon Optical Amplifier (SOA) Amplifier

The semiconductor is used by SOA optical amplifiers as the gain medium intended to be used in general applications to improve the optical launch power to compensate for the loss of other optical products. In telecommunication systems, semiconductor optical amplifiers are mostly adopted in the form of fiber-pigtailed components, working at signal wavelengths between 0.85μm and 1.6μm and producing gain up to 30 dB.

The fundamental operating theory of a SOA is the same as, but without feedback, a semiconductor laser. Via stimulated emission, SOAs amplify incident light. It causes these electrons to lose energy in the form of photons and return to the ground as the light passes through the active region. Those induced photons have the same wavelength as the optical signal, so the optical signal is amplified.

Raman Amplifier

Sir Chandrasekhar Raman first discovered Raman scattering in 1928, defining a mechanism by which light photons are scattered from matter molecules to a higher wavelength (lower energy). The light photon excites the molecules of matter to a higher (virtual) energy state, and then relaxes by releasing another photon as well as vibrational (i.e. acoustic) energy back to the ground state.

The emitted photon has less energy than the incident photon, and therefore a greater wavelength, because of the vibrational energy. A similar process is represented by Stimulated Raman scattering, whereby a higher wavelength photon stimulates the scattering process. Absorption of first photon results in emission of second photon.

Wavelength Division Multiplexing (WDM) system

The optical multiplexer is the basic part used here. The user will share the channel in terms of wavelength. Each consumer may be assigned a different wavelength. Here, on any single wavelength, data transfer rate and organizations can be selected autonomously. Based on the fiber attenuation window, where the attenuation is minimal, it is possible to choose independent wavelengths.

The best wavelength that can be chosen is 1300nm or 1550nm. Variations of this wavelength may be used by a larger number of users. For example, wavelengths of 1550nm, 1551nm, 1552nm and 1553nm can be used for four users. Multiplexer modules such as fiber grating may be used to combine different wavelengths. The DWDM is a variation of WDM [10].

Free space Optics (FSO) system

The wireless communication system is a system that can use this optical and wireless system together to reach more areas. The Free Space Optics design Fi-Wi system is used to incorporate and model the concept of Optical Wireless in a combination of both fiber and wireless systems. Using Fi-Wi covers more users and more regions. Free space is a communication medium between the FSO transmitter and receiver and should be in a straight light association (LOS) for successful optical flag transmission. Air, space, or vacuum may be the preferred medium for this form of correspondence.

Similar to high transmission capacity and no range permit requirement, there are multiple FSO points of interest over a single optical or wireless device. In view of the fact that the proximity of the outer components such as downpour, mist, and fog, physical power, dispersion, and climatic disruption are a portion of these elements that we have to consider when transporting, the transmission in FSO depends on the medium.

Free space optics, in comparison to broadband, is an adaptable device that provides higher speeds. It's easy to install and it takes a few minutes to incorporate in traditional areas. It has low speculation. It is a system that is implemented straight ahead. Range permit or recurrence cooperation between clients is not needed as it has been required in radio and microwave frameworks in recent years.

3. Words From Literature

Kuan-Chang Chen et. al. (2018) has described working of APD and how it is useful in optical receiver. A burst mode is introduced and energy efficiency is calculated. Results in terms of Bit Error Rate (BER) also analyzed [3].

Vladimir Shulyak et. al. (2020) have calculated sensitivities of high speed optical receivers using APD as an optical detector. A simulation model is developed. The output of this mathematical model is shown. The effects on gain, bandwidth, dark current and sensitivity with respect to APD reverse bias is measured and analyzed [4].

Ipsita Sengupta et. al. (2012) have designed and demonstrated SOA with adjustable gain for the optical burst receiver. Gain analysis in terms of output power, control current, clamping current. Multiple SOAs are used to improve the performance [5].

Xiaobin Hong et. al. (2007) have focused on SOA based burst mode receiver and designed a model of it. SOA in combination with PIN diode is used. It is proved that SOA with PIN detector gives almost same performance as an APD detector [6].

T. N. Nielsen (1999) has designed WDM system using Raman amplifier. Basic Raman amplifiers, discrete Raman amplifiers and hybrid Raman amplifiers are discussed. In hybrid Raman amplifier EDFA and Raman both amplifiers are used. Performance is measured in terms of OSNR and quality factor [7].

S. H. Wang et. al. (2010) have enhanced the gain using a Raman amplifier. A method is proposed for hybrid fiber raman / parametric amplifiers. Operations of Fiber optics parametric amplifier and Raman fiber optics parametric amplifier are explained. Results of gain vs length and contours between Raman pump power and parametric pump power is measured [8].

Kwang Ryong Oh et. al. (2007) has designed and implemented various optical devices for WDM-PON systems. PON requires OLT and ONU.OLT and ONU is designed for PON system by authors. R-SOA is employed with 16 channel WDM-PON network [9].

Decai Wang et. al. (2019) has analyzed WDM based transmission system on OFDM. The performance is measured by simulation experiments on a WDM based transmission system. Frequency spectrum for DPSK, DQPSK and CO-OFDM is shown and compared [10].

4. Experimental Results

The applications mentioned in the above section are simulated using OPTSIM 5.0™ software. Experimental results are shown and analyzed for various applications or practical listed as follows.

These results are useful for students in understanding fundamental aspects of the subject. Various parameters which are involved in results are BER and Q-Factor. Eye diagram is also used to show whether transmitted signals are correctly received or not. Performance of systems is measured by varying input parameters like received power and length of fiber and getting the effect on Bit Error Rate and Quality Factor.

APD-HBT Receiver

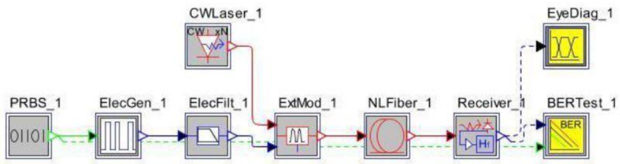

Fig 1: APD Transmitter and Receiver

Fig. 1 shows a schematic diagram of APD receiver with the transmitter. Various blocks involved are Pseudo random bit sequence generator which generated binary sequence. It is converted into an electrical signal by means of the electrical signal generator. This signal is intensity modulated using continuous wavelength LASER. The light signal is transmitted through fiber to APD receiver. BER tester and eye diagram analyzer blocks are used to get various relationships between BER and Q factor versus received power for various bitrates. Relationships are also obtained for BER and Q factor versus fiber length for various bitrates and fiber length.

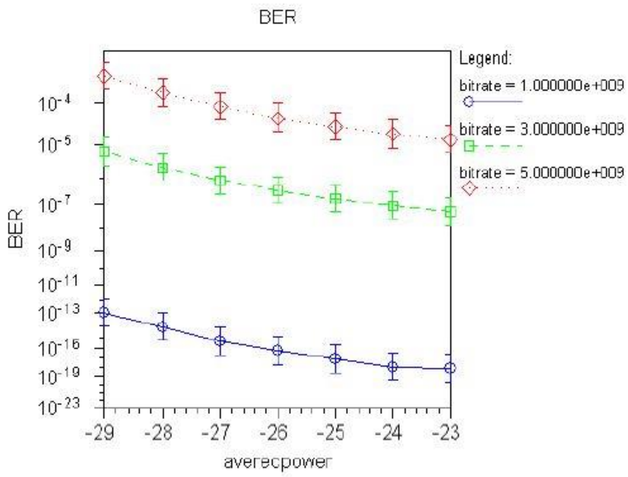

Fig 2: APD: BER versus Power versus Bitrate.

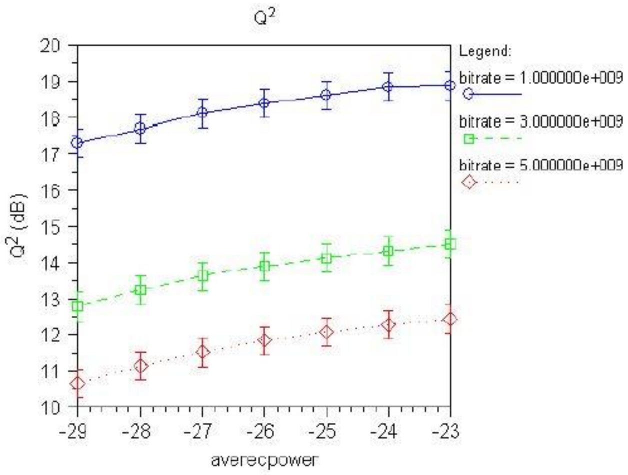

Fig 3: APD: Q factor versus Power versus Bitrate.

Fig. 2 shows variations in BER with respect to received power for various bit rates. It has been proved that as received power increases the BER decreases. Also, as bit rate increases the BER increases because due to a higher rate, there will be more chance of errors.

Fig. 3 shows variations in Q factor with respect to received power for various bit rates. It has been proved that received power increases the Q factor increases.

SLA (SOA) Amplifier

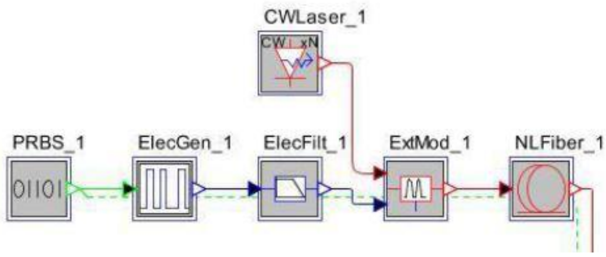

Fig 4: SOA Transmitter.

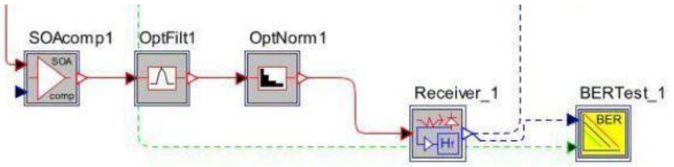

Fig 5: SOA Receiver.

Fig. 4 shows a transmitter setup for measuring SOA performance. It also includes PRBS generator, Electrical signal generator, CW Laser, Intensity modulator and nonlinear fiber.

Fig. 5 shows the input signal at SOA from the transmitter, Optical filter and Optical normalizer. Normalized output is given to SOA receiver where PIN detector is used as photo detector. BER tester is used for measuring various graphical relationships.

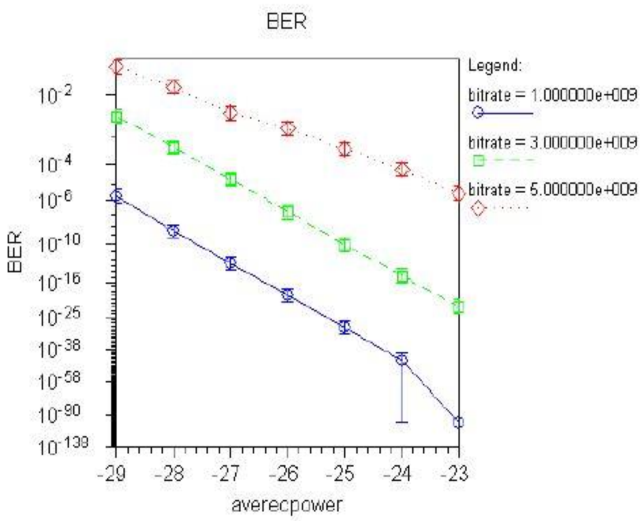

Fig 6: SOA: BER versus Power versus Bitrate.

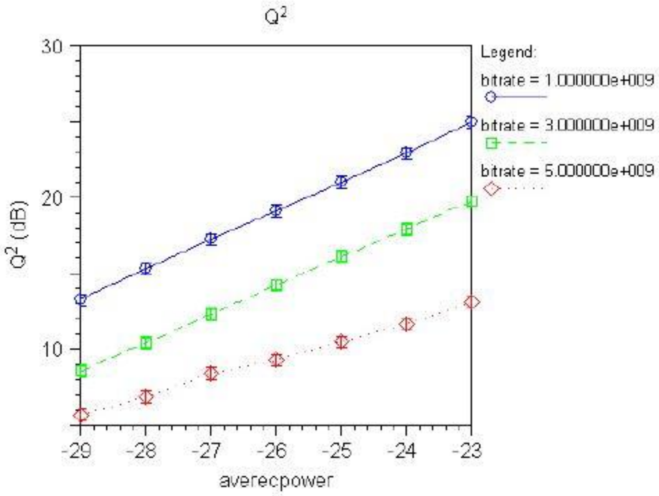

Fig 7: SOA: Q factor versus Power versus Bitrate.

Fig. 6 shows variations in BER with respect to received power for various bit rates. It has been shown that as received power increases, the BER decreases. Also, as bit rate increases the BER increases because due to a higher rate, there will be more chance of errors.

Fig. 7 shows variations in Q factor with respect to received power for various bit rates. It has been proved that received power increases the Q factor increases.

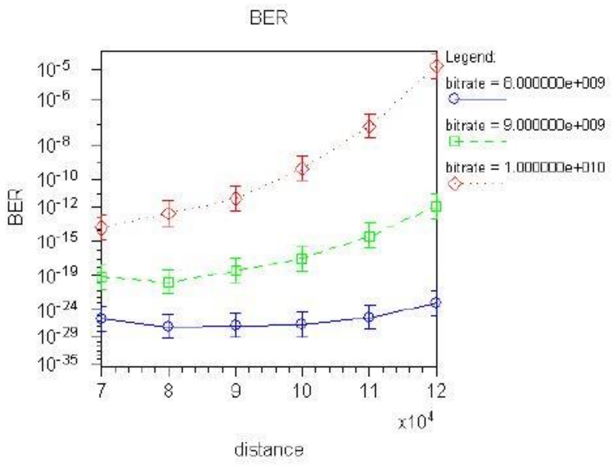

Fig 8: SOA: BER versus Distance versus Bitrate

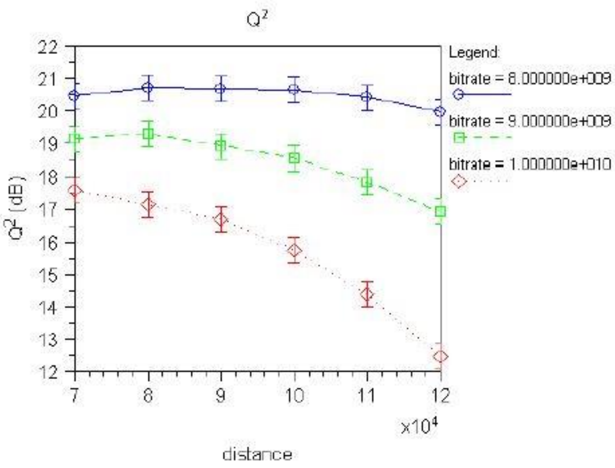

Fig 9: SOA: Q factor versus Distance versus Bitrate.

Fig. 8 shows the relationship in BER with respect to fiber length for various bit rates. The fiber used here is nonlinear fiber means it used all types of fiber non linearity like cross phase modulation and others. The results are shown for various bit rates. From the graph it has been clear that as the fiber length increase BER increases because of longer length there is more attenuation in light signal. Even as bit rate increases, there is more erroneous output.

Fig. 9 shows the relationship in Q factor with respect to fiber length for various bit rates. It has been proved that received power increases the Q factor increases.

Raman Amplifier

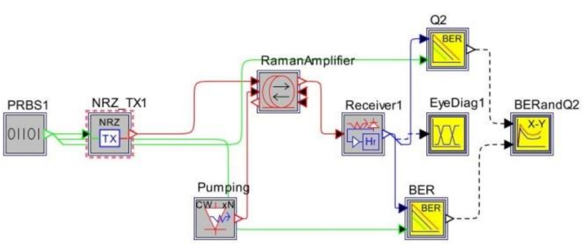

Fig 10: Raman Amplifier Transmitter and Receiver

Fig. 10 shows the schematic or setup using a Raman amplifier. NRZ transmitter is used to transmit light signal. Raman amplifier requires pumping from another source. The pumping can be bidirectional. Laser pumping is used here from transmitter side. Students can perform simulation using pumping from transmitter side as well as receiver side. The output of Raman amplifier is directly fed to the receiver, which can be PIN receiver or APD receiver.

To measure the performance of a system BER tester, Q factor analyzer and eye diagram analyzer can be used. Using XY plotter relationship between Q factor and BER can also be shown. Improvement in the performance due to Raman amplification can be shown using this analyzer block.

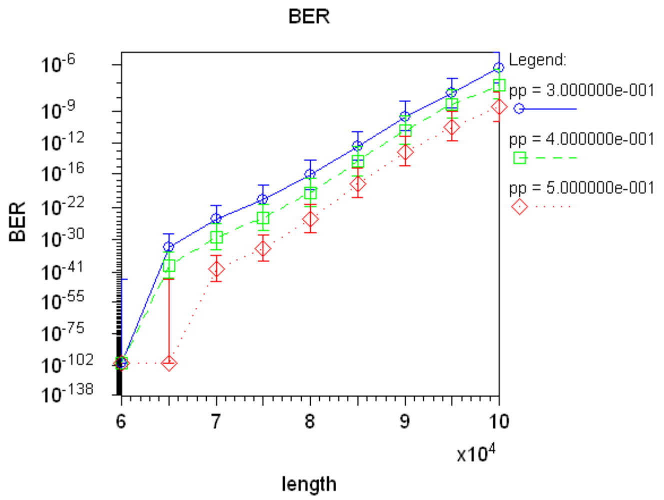

Fig 11: Raman: BER versus Distance versus Bitrate

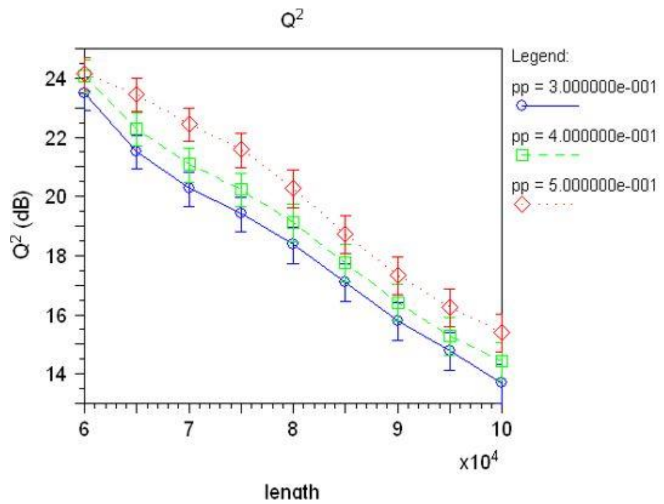

Fig 12: Raman: Q factor versus Distance versus bitrate.

How BER is reduced and Q factor improves using Raman amplification is shown in Fig. 11 and Fig. 12. In these relationships it is clear that due to amplification, we can send the signal for long distance without distortion. BER versus distance versus bit rate relationship is shown in Fig. 11 and Q factor versus distance versus bit rate relationship is shown in Fig 12. Students can vary other parameters like electrical power, received power, bit rate etc.

WDM system

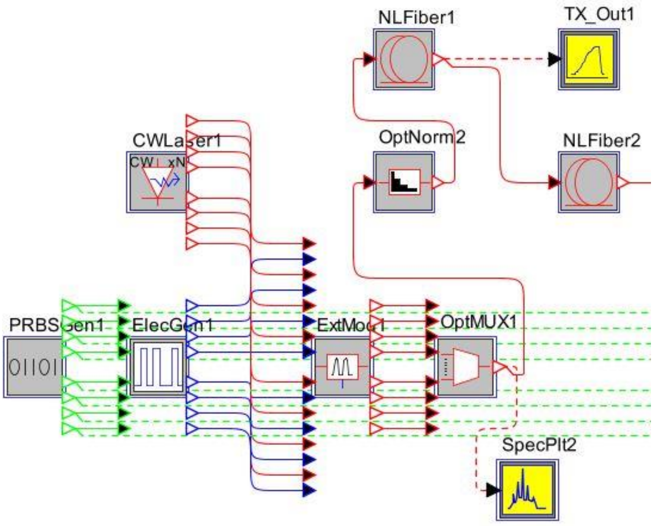

Fig 13: WDM Transmitter.

WDM transmitter is shown in Fig. 13. From PRBS generator eight channel signals are generated. All eight signals are converted to light signal using electrical signal generator, CW Laser and modulator. The output signals are multiplexed using optical multiplexer. All eight signals are converted to a different wavelengths light signal. This multiplexed signal is travelled to optical fiber. A spectrum analyzer is used at input side as well as the output side to view the wavelength spectrum. WDM receiver contains splitter block or de-multiplexer block which separate out all eight signals and send it to the receiver which further converts this light signal into an electrical signal using photo detector, preamplifier and low pass filter block. Fig. 14 shows the wavelength spectrum of eight multiplexed signals having different wavelength starting from 1550nm to 1557 nm.

Figs. 15 and 16 show the relationship between BER versus power and Q factor versus power.

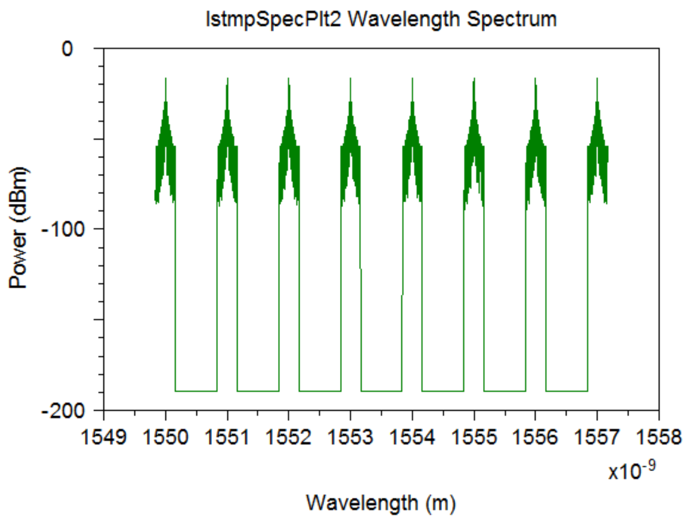

Fig 14: WDM spectrum at input side.

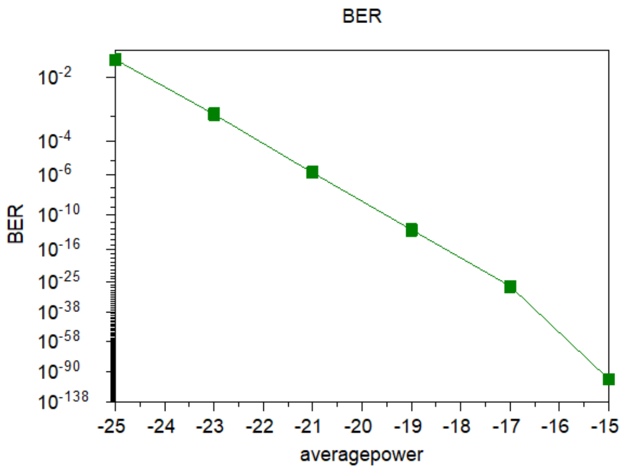

Fig 15: WDM: BER versus Power.

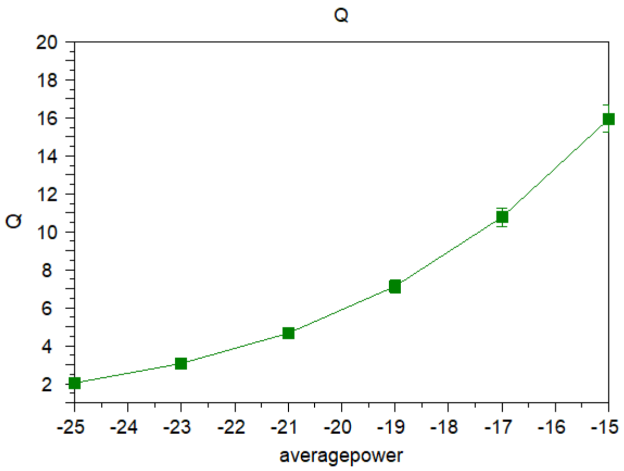

Fig 16: WDM: Q Factor versus Power.

FSO system

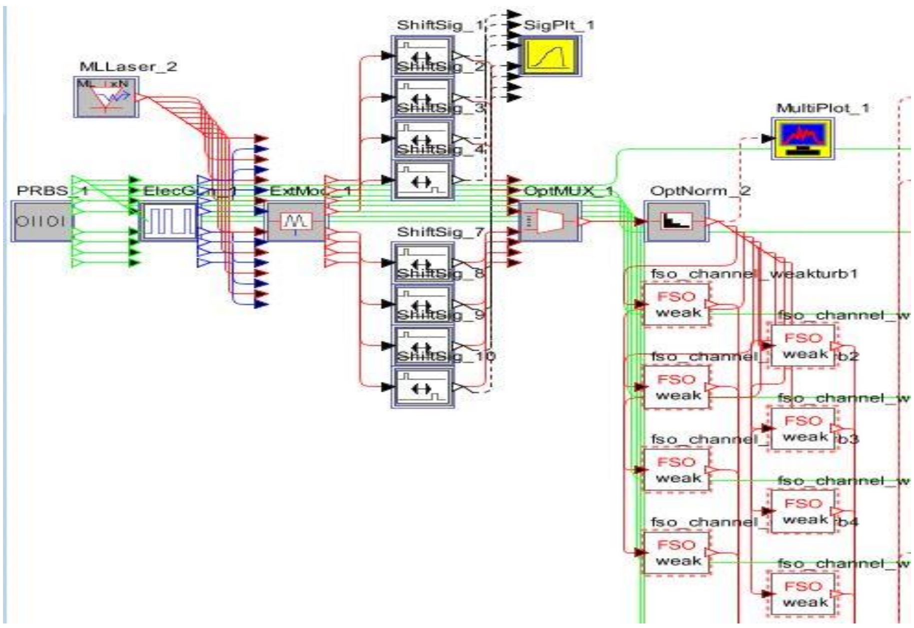

Fig 17: FSO Optical line terminal.

Fig. 17 shows the schematic of FSO transmitter using Time Division Multiplexing (TDM) Technique. Eight signals generated from the PRBS generator are converted into light energy signal by means of electrical signal generator, modulator and laser source. Eight light wave signal with different wavelengths are shifted in terms of time using time shifter block. These times shifted signals are now multiplexed using TDM technique. FSO block is used to implement and model free space optics channel.

When light signal is passed from free space or air, it has to undergo attenuation from the space and background radiation problems. To model these problems various components shown in Fig. 18 are used. It shows the detailed diagram of FSO block. Input taken from multiplexer is first fed to FSO attenuator which takes into account the various attenuations. The attenuated output is fed to another block which models various types of radiation and scattering.

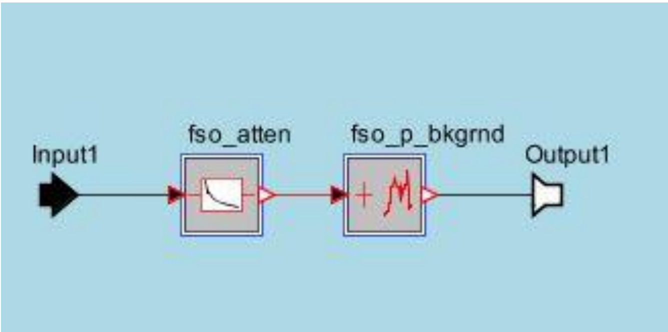

Fig 18: FSO Components

Fig. 19 shows the received signal's eye diagram from one of the time de-multiplexed signal.

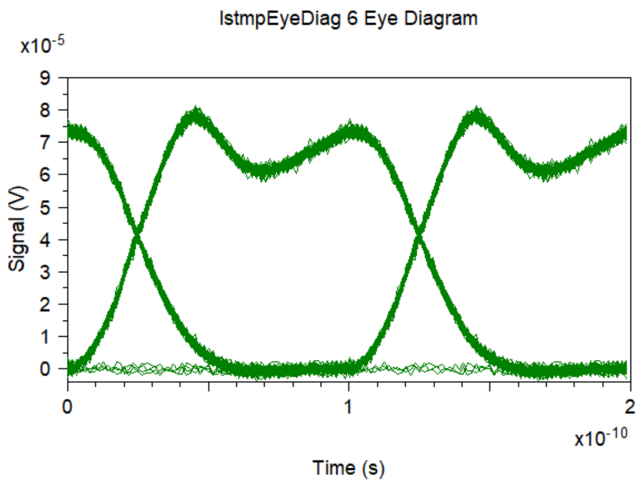

Fig 19: FSO Eye diagram

5. Conclusion

It is difficult to learn practical engineering application without hardware support in education from home in COVID19 era. Using the optsim simulation software, various optical communication applications which are there in undergraduate course syllabus like APD receiver, SOA amplifier, Raman amplifier, WDM system and FSO system are simulated. Various graphical relationships are shown between parameters like BER, Q factor, Bit rate, fiber length, Received power, transmitted power. Students will understand the fundamental concepts of these applications and able to design many such projects in online education without hardware support. In future, similar work can be carried out in the Optical Networking Laboratory.

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