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Improving the Efficiency of FSO Communication System with Multi-laser Beams

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Abstract

Free Space Optical Communication (FSO) is the Communication System which uses optical signal to establish a direct link between two points. With increase in the use of digital data and requirement of high speed Communication System it has become necessary that the reliable and high speed Communication System should be developed in order to provide uninterrupted service. Use of wireless signals in every type of Communication System has crowded the space and often results in increased interference. These all issues can be solved with the development of an efficient FSO. This paper focuses on the development an efficient FSO system for short range Communication System purpose using multi-laser beams and efficiency of FSO network under different weather conditions.

Keywords— FSO, Communication System, Free space.

I. INTRODUCTION

Free-space optical communication (FSO) is a point to point optical communication technology that uses optical signal propagating in free space to wirelessly transmit data for telecommunications or computer networking. Free space - means air, outer space, vacuum, or something similar. Despite efforts of more than a decade it has been very difficult to develop a FSO Communication system which can offer high speed data rates as well as range and 24X7 up time. Though at short ranges it has been possible to develop efficient free space optical communication system at speeds of up-to 10 Gbps, but this also degrades rapidly if ideal condition is not available [1]. All the difficulties faced in the development of a free space optical communication system are because of the weather fluctuations (fog, temperature, rain, snow, etc.), terrestrial scintillation, IRT (Index of Refraction Turbulence), beam strength, pointing and tracking issue.

Generally in OWC/FSO transmission is done through the use of optical carriers like visible, infrared (IR), ultraviolet (UV)[5]. In early time sunlight was used to signal for long distances. Since, light is used as the optical carrier and we know that the speed of light is extremely fast and nothing can go faster than the speed of light. So, it's evident that light has been used for a long-long time for large distance transmission in case of urgent situations.

In our modern era OWC/FSO uses different types of LEDs, LASERs, as the transmitter device. Because of difficulty faced in the development of the FSO system it was earlier used only in military applications, inter-satellite communication links, chip to chip communication in sophisticated instruments which demands very high speed as well as without loss. But, with increase in the user consumption of data after the twentieth century, FSO has been highly favored and focused upon technology to attain unimaginable speeds of data transmission which is not possible by the conventional use of wireless communication.

Initially FSO was thought of technology reserved for the last mile solution i.e. to connect the end points of a communication system. But it's no longer the same situation. We need such high efficient data transmitting technology in our day to day life to achieve on par performance.

Currently the demanded applications or areas for FSO communication system are Enterprise/Campus connectivity, video surveillance and monitoring, back-haul for cellular system, redundant link and disaster recovery, security, broadcasting, etc.[1]

II. FSO CHANNEL MODELLING

A. Atmospheric Loss

Atmospheric loss is the measure cause for the transmission loss for any free space optical communication system, and also it is variant in nature and hard to predict which makes it even harder to design FSO. Most common atmospheric factors affecting the FSO channel are snow, rain, fog, pollution, dust, aerosol, smoke, etc[3]. Generally for estimating the visibility of the optical signal, meteorological parameter of visibility is used to predict somewhat approximated distance of transmission. Near IR radiation is used as the optical carrier for the FSO channel and it is most affected by the water particles. These causes the scattering of light and which is defined as the deflectionof incident light from the direction of initial incidence causing spatial, angular and temporal spread[4]. For smaller distances the rain attenuation is taken as 3dB/km.

Atmospheric Turbulence

Under clear weather condition the atmospheric loss is almost negligible. But atmospheric turbulence induced fading results in greater loss of optical signal[2]. Because of the atmospheric turbulence it affects the amplitude and phase of an optical signal thus causing loss of important data and it is termed as channel fading. Atmospheric turbulence is caused because of the difference in the refractive index of air pockets that exits or are encountered by the optical carrier path to its destination[2].

III. FSO MODELLING AND SIMULATIONS

In this paper we have developed a FSO Communication system starting from the very basics of the FSO links development and further modifying it by using multiple laser beams [7].

In the first step as shown in Fig: 1.01 we developed an almost ideal FSO communication channel it eye diagram shows its Q-factor in Fig: 1.02.

Gradually the above design is modified to simulate the practical condition faced by any FSO communication placed in a real environment.

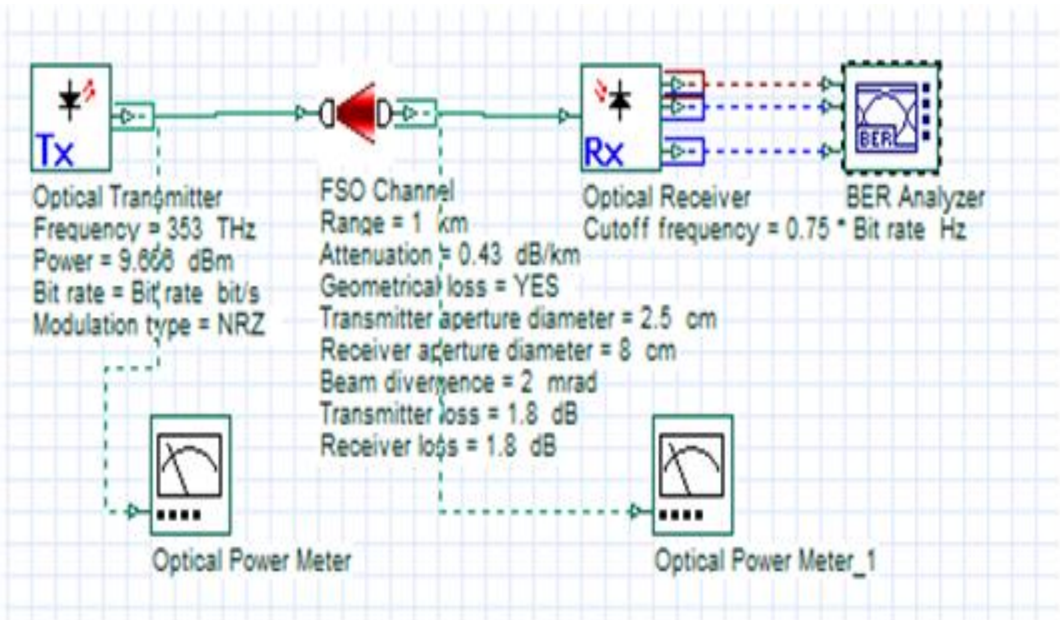


Fig: 1.01 Basic FSO Design

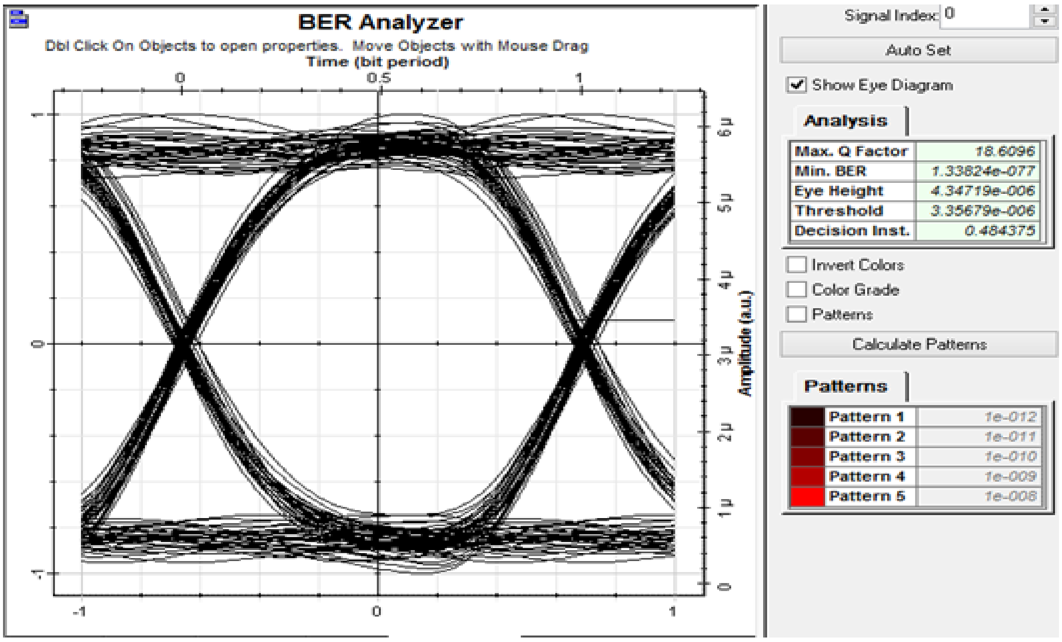


Fig: 1.02 Eye Diagram for Basic FSO

Step 2:
Here the no of channels are increased between the transmitter and receiver i.e. multi-laser beams are used by transmitter and is coupled back to a single channel at the receiver end. Since, any optical signal goes through multitude of change in path, it is possible that the signal might deviate from its original path miss the receiver aperture since the FSO deployed transmitter and receiver has small aperture unlike in wireless communication where large aperture antennas are used.

So, with the use of multi-laser beam (Fig: 1.03) it is possible that some beams might deviate from their original path but at the same time some beams will be accurately received by the receiver.

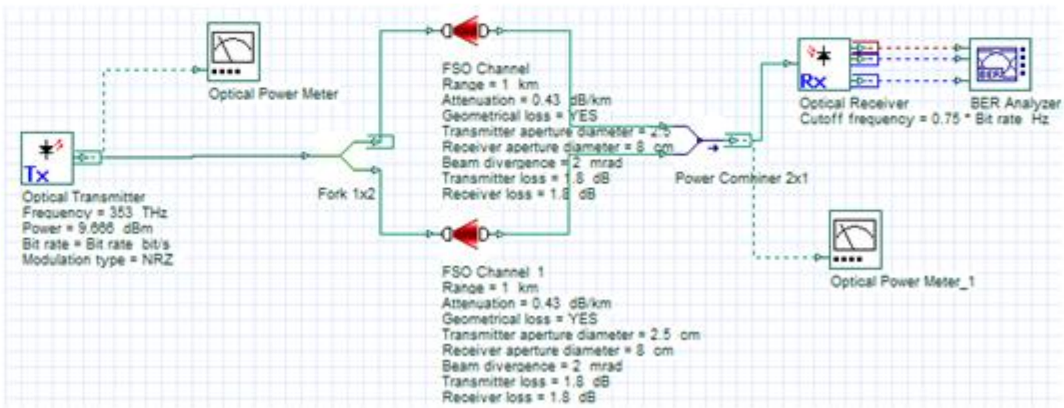


Fig:1.03 FSO with multiple channels

Step 3:
Since above we implemented multi-laser transmitter, we can see that the result obtained is far superior to the previous one.

Now we will use couplers and de-couplers as shown in Fig: 1.04 to input the power at the transmitting end and divide it into multiple power sources amplifying it then again combining all of them to give the final power to the FSO transmitter. Again this improves the Q factor even further than the previous one.

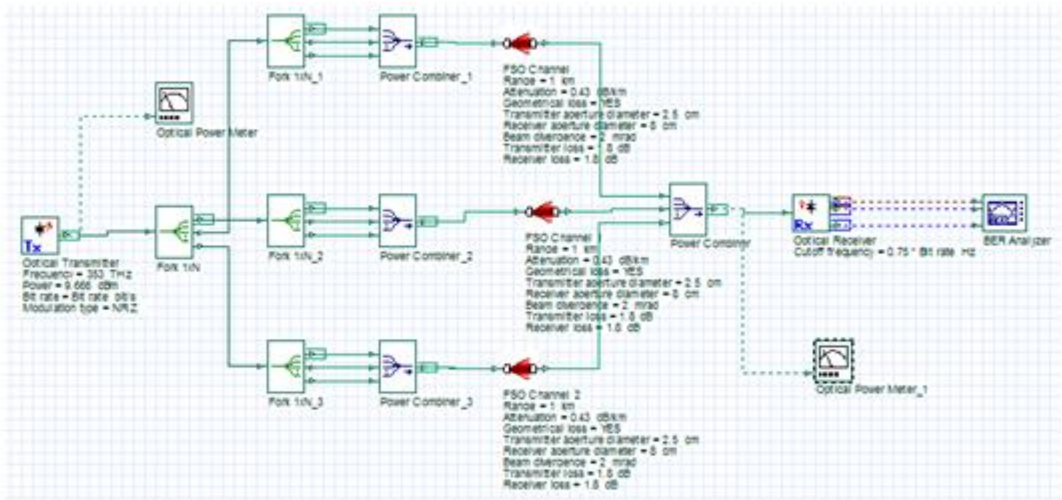
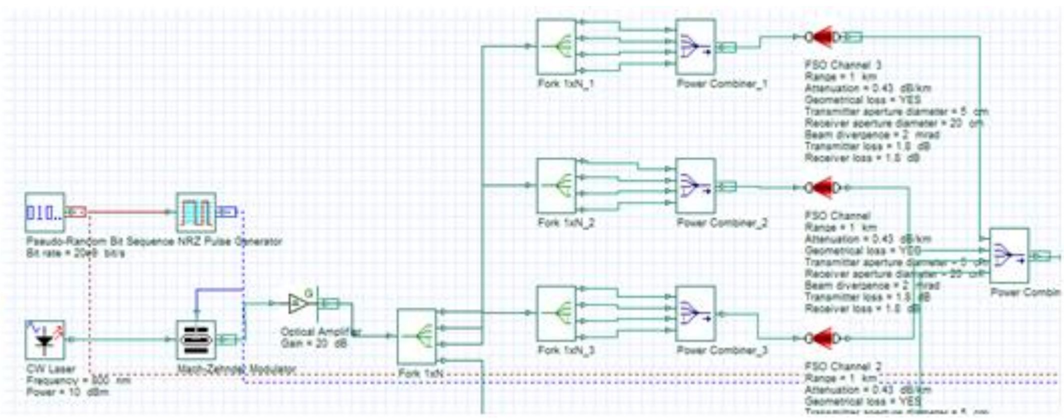


Fig: 1.04 FSO with multiple copies of Input data

Step 4:
As the designs presented in Fig: 1.05 shows that the Q factor improving and we are getting close to the practical condition of our environment gradually making it practically possible to implement.

Now here the previous step design is improved by the use of optical amplifiers at first at the transmitter end and then at the receiver and again at both ends.



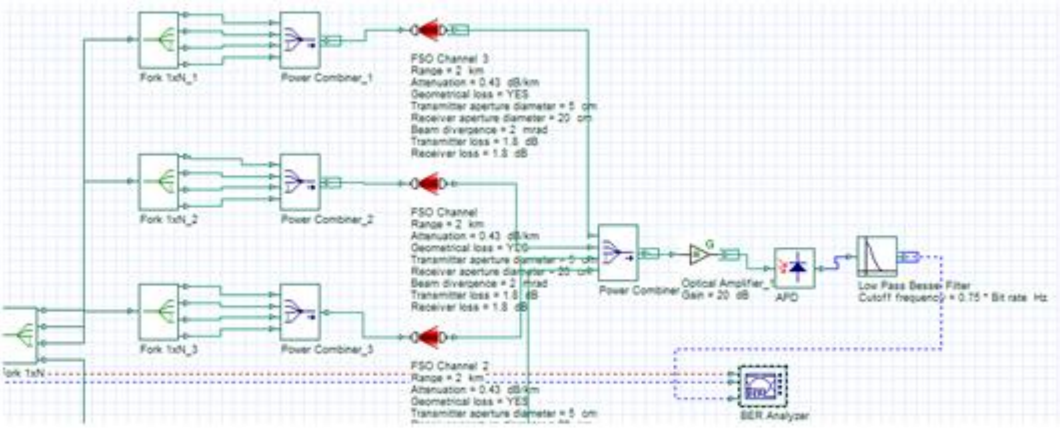


Fig: 1.05 Multiple FSO channels with optical amplifiers at Transmitter as well as Receiver

Step 5:
Now the use of different wavelengths will be shown here and the results are compared between 800nm wavelength and 1550nm wavelength. (Clear Sky; A=0.43dB/km)

Fig: 1.06 shows the FSO running at 1550nm while Fig: 1.07 shows the use of wavelength 800nm and contradicting to other papers where 1550nm was used, 800nm gives better results.

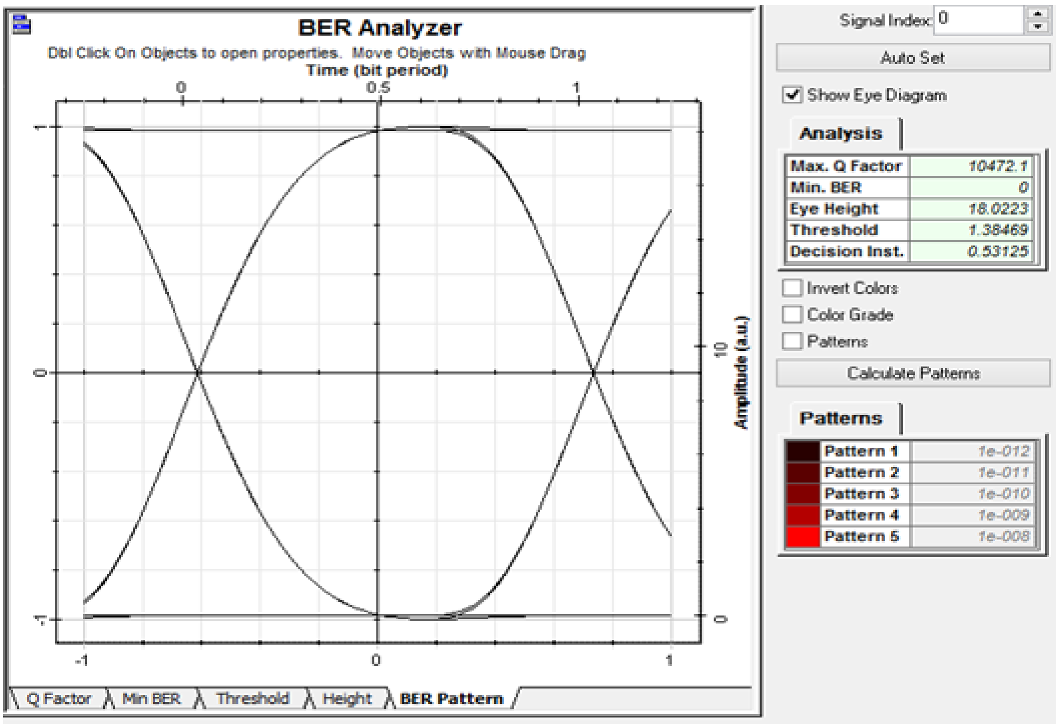


Fig:1.06 Eye Diagram for 1550nm with Q-factor-10472

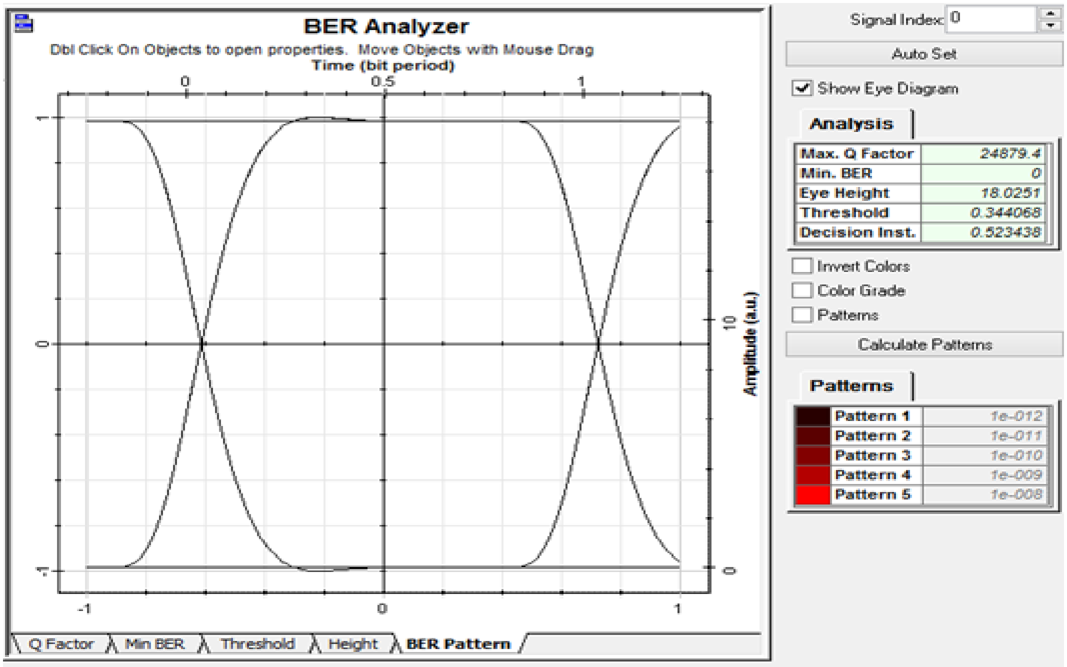


Fig: 1.07 Eye Diagram for 800nm with Q-factor-24879

Results and Graphs

i) Eye Diagram after Step 3 (Clear Sky; A=0.43dB/km)

This eye diagram in Fig: 1.08 shows the FSO Q-factor in a clear sky condition where atmospheric loss is very insignificant.

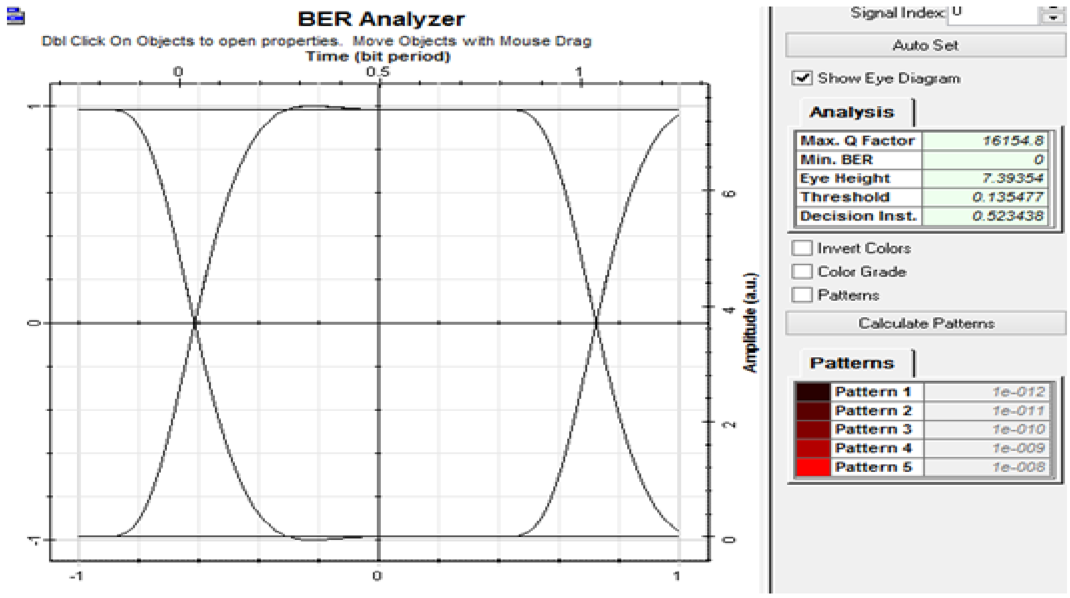


Fig: 1.08 Eye Diagram for normal rain (A=.43 dB/km)

ii) Eye Diagram after Step 4 (Rain; A=4.3dB/km; 800nm)

Here the eye diagram in Fig: 1.09 shows that in case of mild weather loss the FSO is not much affected and eye diagram moves towards almost perfect shape. This shows the design efficiency of our FSO model.

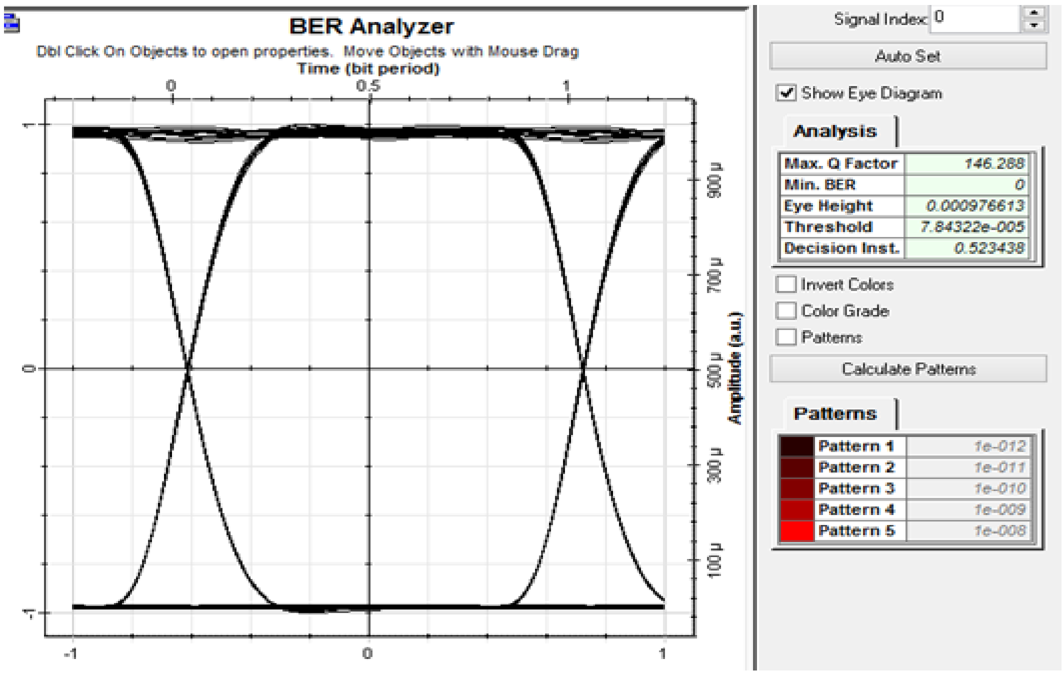


Fig: 1.09 Attenuation 4.3 dB/km

iii) Eye Diagram after Step 4 (Fog; A=43dB/km; 800nm)

As the eye diagram in Fig: 1.10 shows that in case of worst weather condition how the optical signal degrades because of the increased atmospheric loss, like rain and fog.

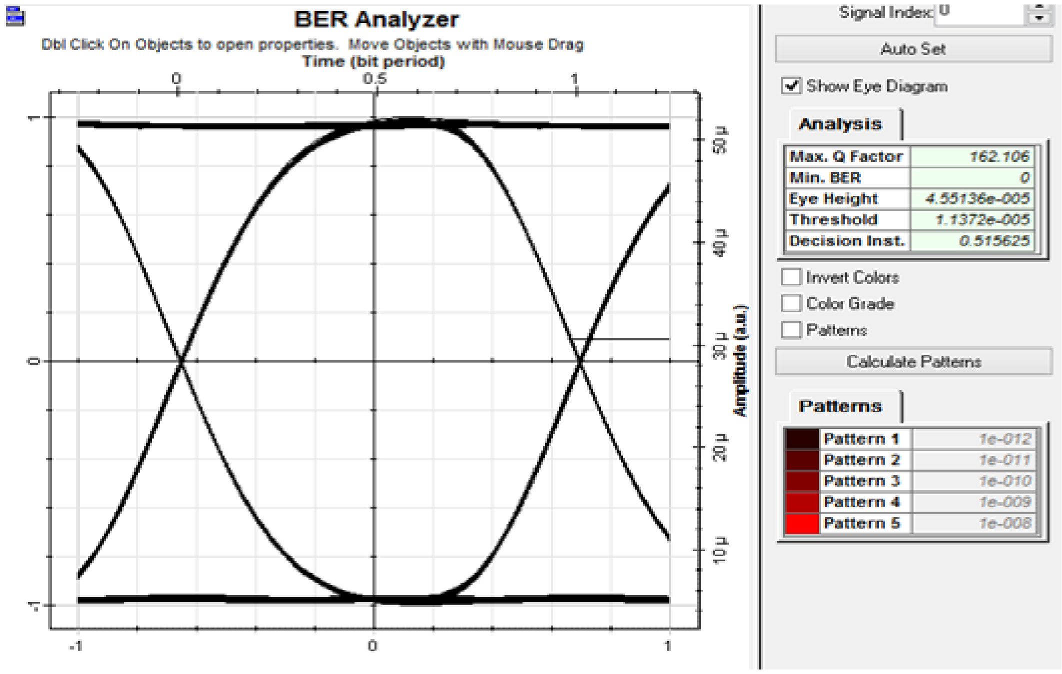


Fig 1.10 Attenuation 43 dB/km

IV. CONCLUSION

After decades of effort in FSO technology it is still difficult to produce a single FSO communication system sufficient for all kinds of different conditions. It is essential that we develop a efficient heterogeneous communication system that can support all of our data needs for different types of services and different types of traffic are easily transmitted over it. FSO is more favored because it does not require any type of bandwidth allocation, thus reducing its deployment cost dramatically. It can be setup anywhere very quickly and can be started using it right afterwards. It is promising in case of disaster situations where after any natural calamity we face severe disruption in communication system. It is necessary that we overcome all difficulties faced by OWC in order to leap to a next generation communication technology, as we can't depend on our currentwireless communication system as it has already reached its limits. The main problems that needs to be focused upon are the modulation schemes used for optical carrier as, we are still using the same modulation schemes as we were using for wireless communication system [6]. But FSO communication system demands a different and effective type of modulation schemes. Also use of incoherent lasers will dramatically improve the distance of communication, as some amateur radio operators in 2012 achieved a distance of approximately 250 km's, which is of the utmost importance.

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