University of Asia Pacific

Department of Computer Science and Engineering

CSE 312: Data Communication and Computer Networks Lab

LAB REPORT 1

Course Report Title: Basic Optical Network Model

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1. Introduction

Optical communication is a technology that transmits data using light as the carrier signal. It offers high bandwidth, low attenuation, and is immune to electromagnetic interference, making it the backbone of modern telecommunication networks.

A basic optical communication system has three main components:

- **Transmitter (Tx):** Converts electrical signals into optical form using a light source such as a laser diode or LED.
- **Optical Channel (CH):** Typically an optical fiber that carries the modulated light signal over a distance.
- **Receiver (Rx):** Converts the received optical signal back to electrical form using a photodetector.

In this lab, we designed and simulated a basic optical communication system using optical system simulation software. Our aim was to analyze system performance in terms of Bit Error Rate (BER), eye diagrams, oscilloscope readings, optical power, and Optical Spectrum Analyzer (OSA) results before and after fiber transmission.

2. Literature Review

Optical communication has rapidly evolved as a cornerstone technology for high-speed data transmission, owing to its immense bandwidth and low loss characteristics. Many researchers have contributed to understanding the fundamental components and challenges of optical communication systems.

Agrawal (2012) comprehensively describes the core structure of fiber-optic communication systems, emphasizing the roles of transmitters, optical fibers, and receivers, along with impairments like attenuation, dispersion, and nonlinear effects that limit system performance [1]. Keiser (2010) also elaborates on the physical principles underlying optical fiber transmission and details key design parameters to optimize signal quality [2].

Kumar et al. (2017) provide a review of optical communication technologies, highlighting advancements in modulation techniques and system architectures that have improved data rates and transmission distances [3]. Ellis and Sillard (2006) focus on the importance of coherent detection and digital signal processing, which enable higher sensitivity and spectral efficiency in modern optical systems [4].

Agrawal's work on nonlinear fiber optics (2010) delves into the effects of fiber nonlinearity on signal propagation, offering insight into mitigation strategies necessary for long-haul communication [5]. Winzer and Neilson (2016) discuss scaling challenges and innovations such as space-division multiplexing and integrated parallelism to meet increasing bandwidth demands [6].

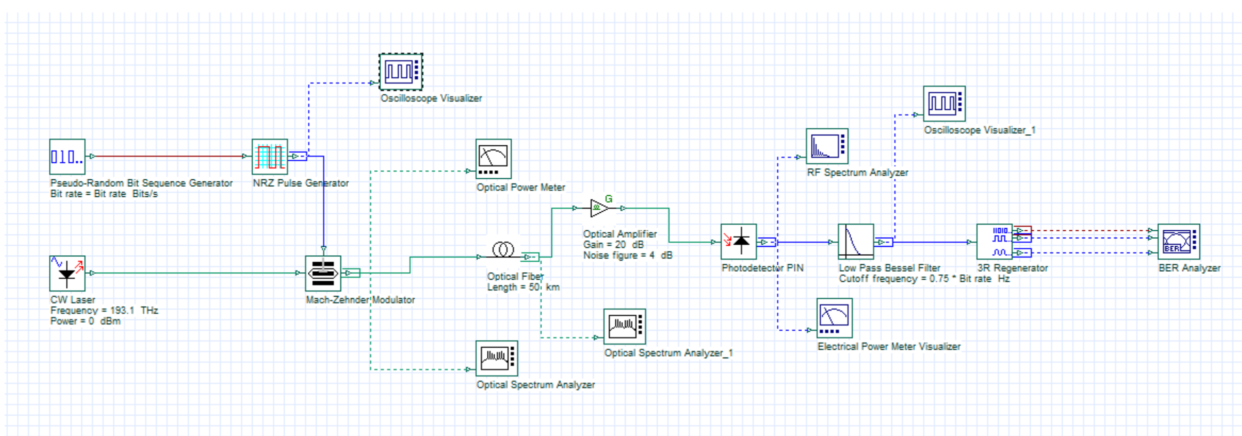
Mollenauer and Gordon (2006) study soliton transmission in fibers, a nonlinear optical phenomenon that can maintain pulse shape over long distances, contributing to reducing dispersion-related impairments [7]. Winzer (2018) reviews high-spectral-efficiency modulation formats that maximize data throughput while maintaining signal integrity [8].

Ellis and Ponting (2015) highlight the promise of coherent detection combined with advanced digital signal processing to further push the limits of optical communication performance [9]. Finally, Roberts et al. (2018) explore the emerging role of machine learning in optical networks for tasks such as performance monitoring, fault detection, and dynamic resource allocation, illustrating the trend toward intelligent communication systems [10].

Together, these studies form a comprehensive foundation for understanding and designing basic and advanced optical communication systems, guiding the simulation and analysis performed in this lab.

3. System Design

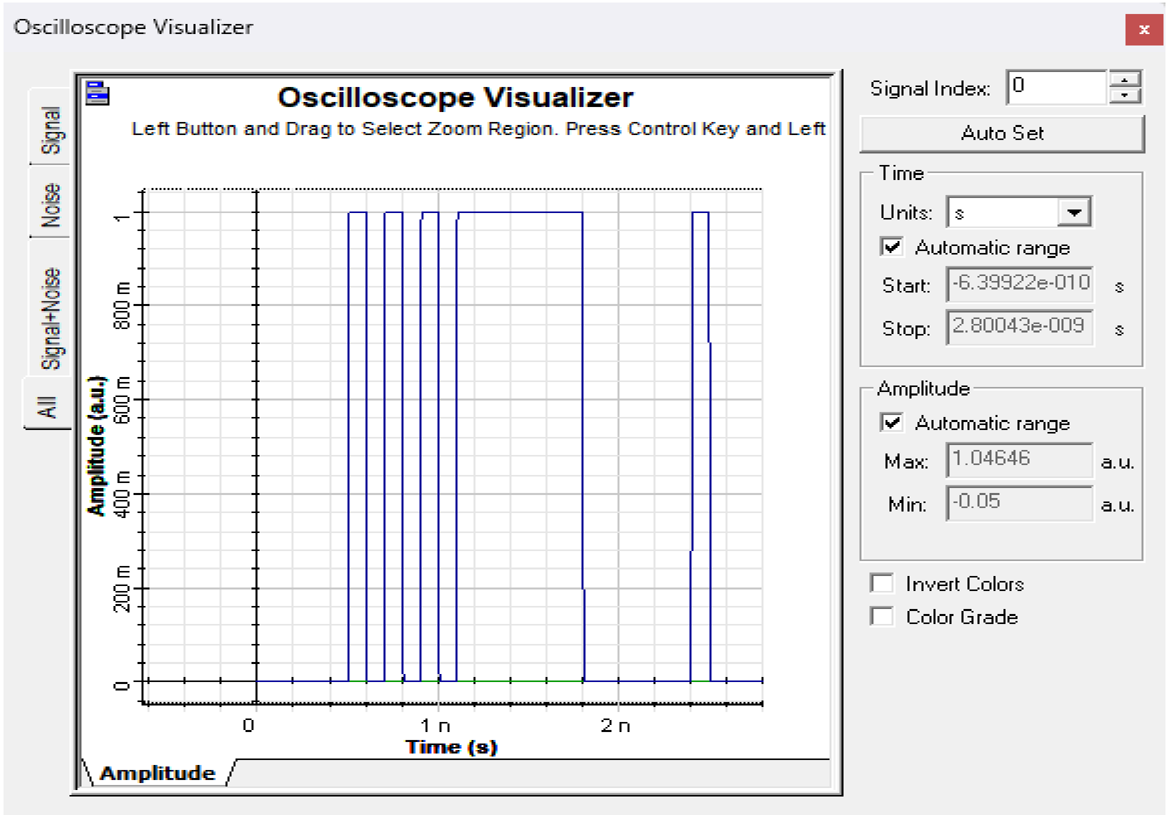
- Pseudo-Random Bit Sequence Generator - 1
- NRZ Pulse Generator - 1
- Oscilloscope Visualizer - 2
- CW Laser - 1
- Mach-Zehnder Modulator - 1
- Optical Fiber - 1
- Optical Power Meter - 1
- Optical Spectrum Analyzer - 1
- Optical Amplifier - 1
- Photodetector PIN - 1
- RF Spectrum Analyzer - 1
- Low Pass Bessel Filter - 1
- Electrical Power Meter Visualizer - 1
- 3R Regenerator - 1
- BER Analyzer



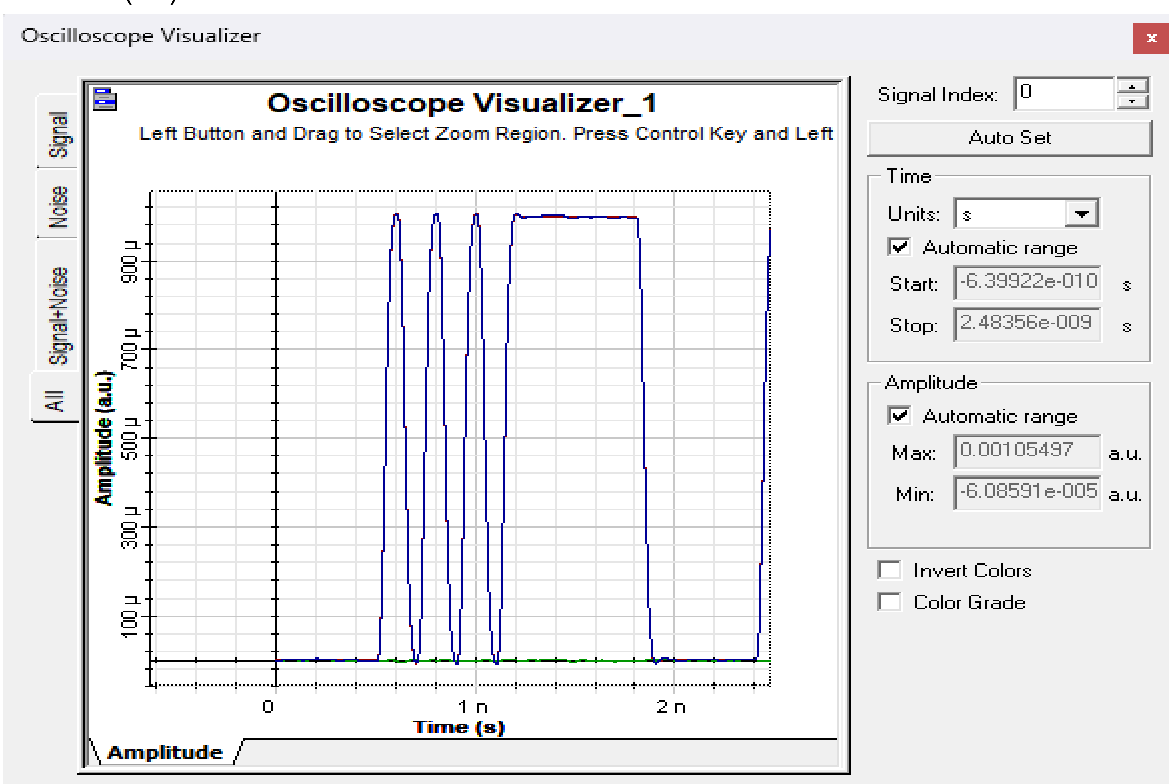
4. Results

- **Oscilloscope of (Without Fiber)**

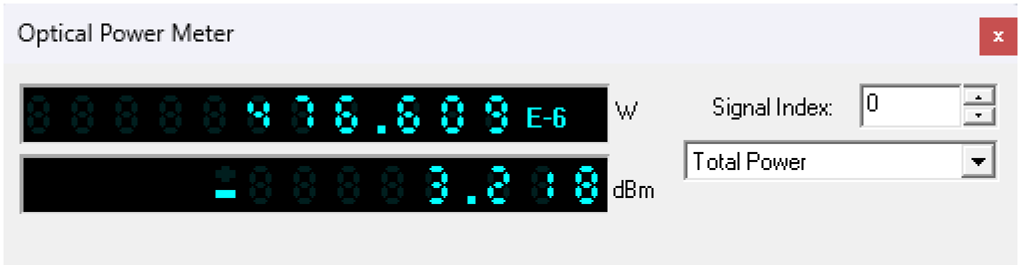
- Transmitter(Tx)



- Receiver (Rx)

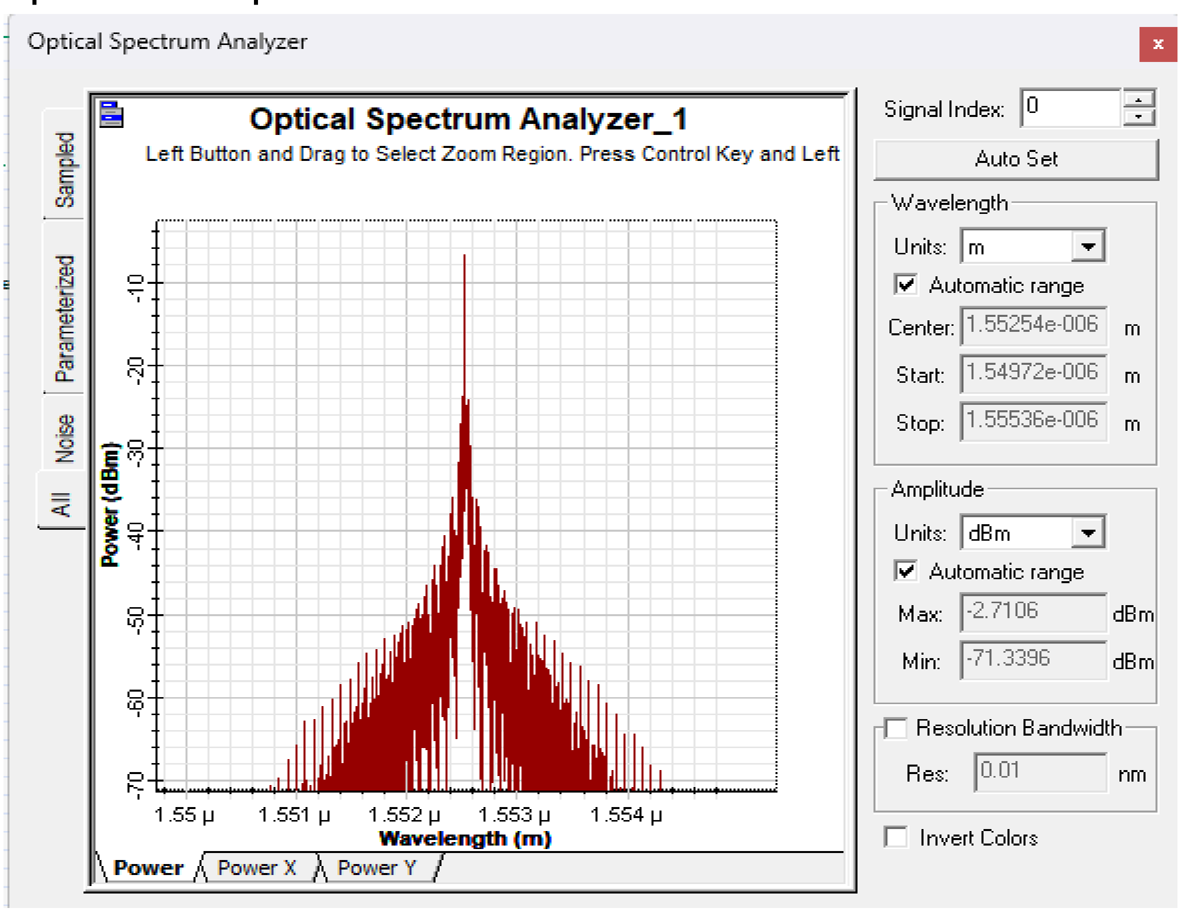


- **Power**
  - Transmitter(Tx)



  - Receiver (Rx)

- **Optical Laser Output**

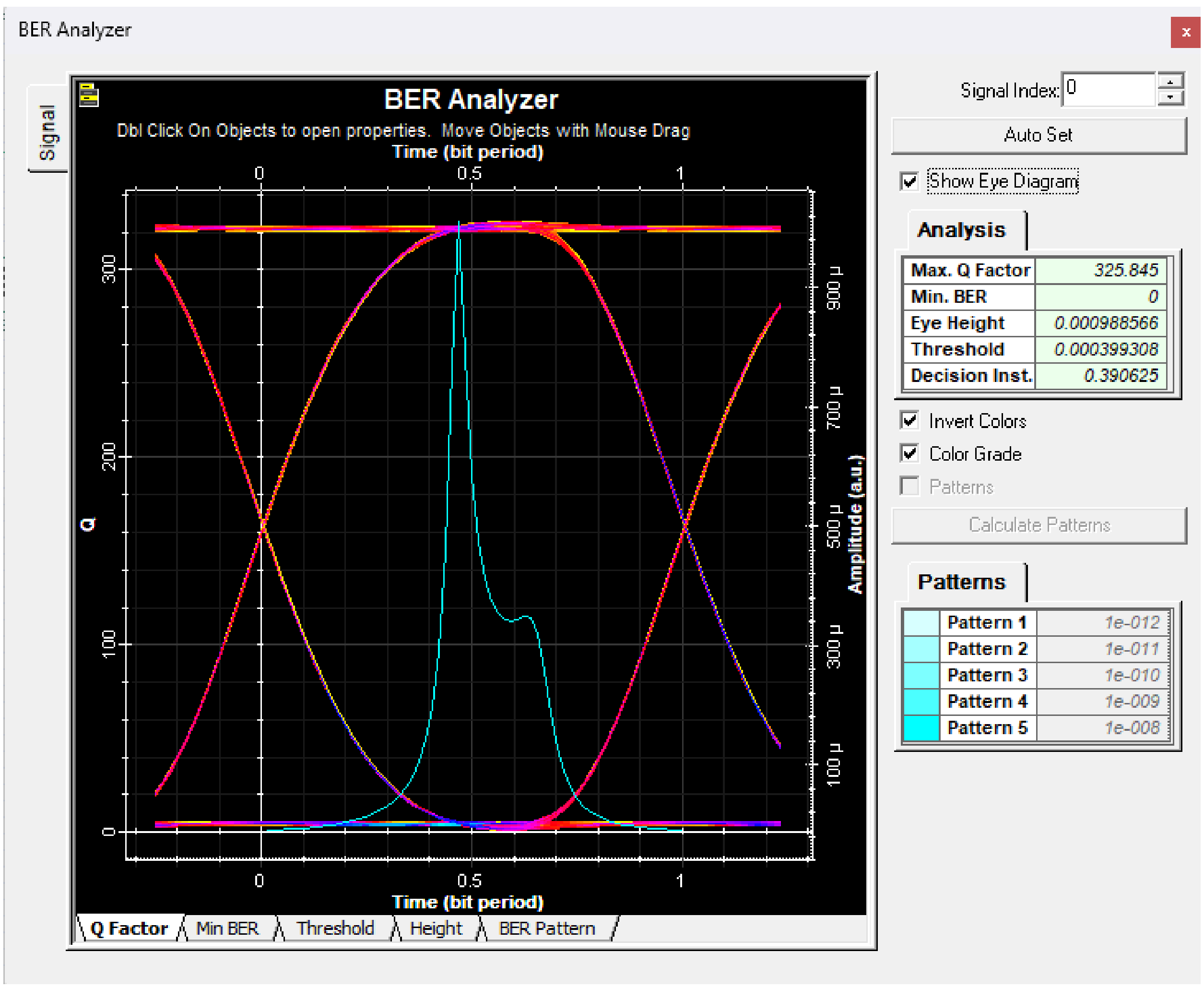


- **BER & Q Factor**

Analysis

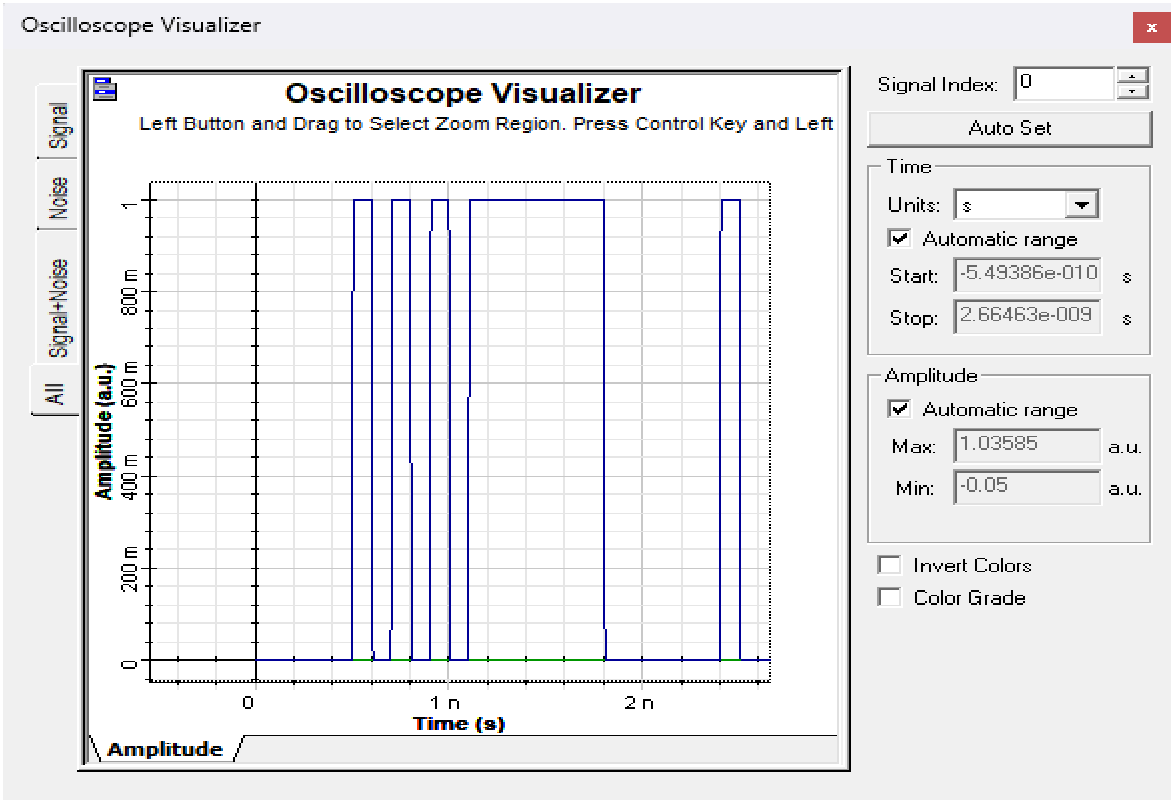
Max. Q Factor	325.845
Min. BER	0
Eye Height	0.000988566
Threshold	0.000399308
Decision Inst.	0.390625

- **Eye Diagram**

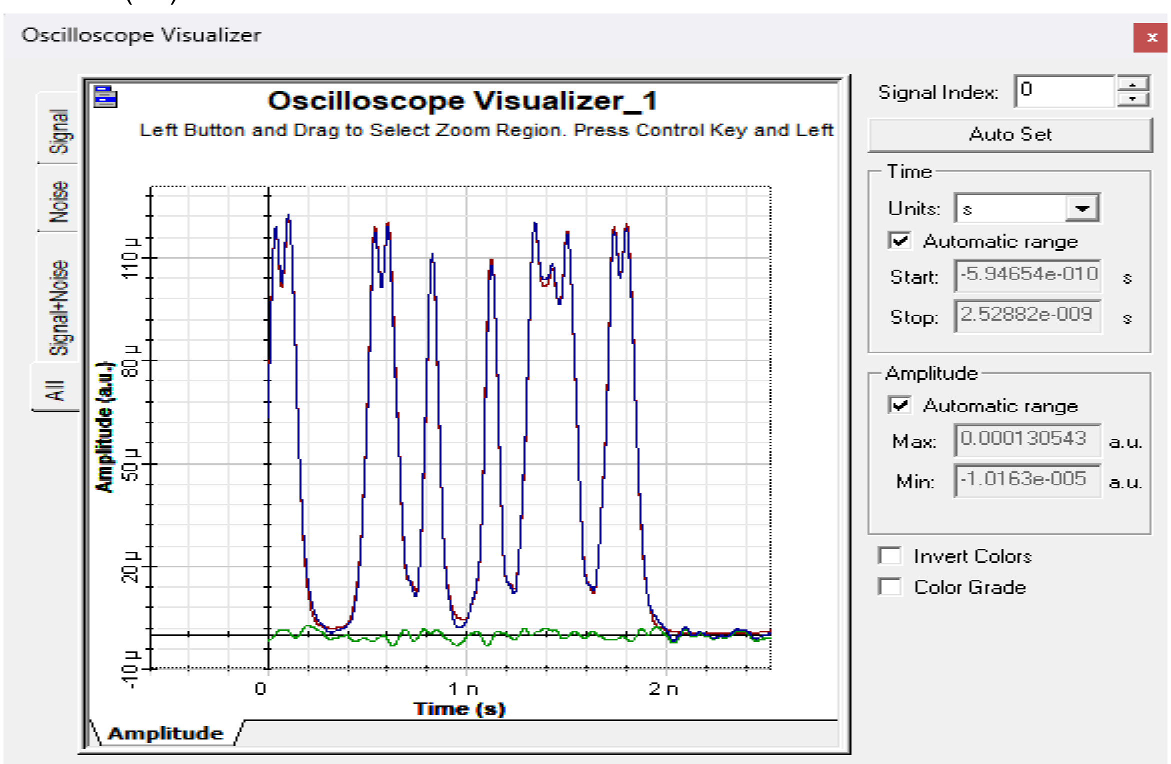


- **Oscilloscope of (With Fiber 50km)**

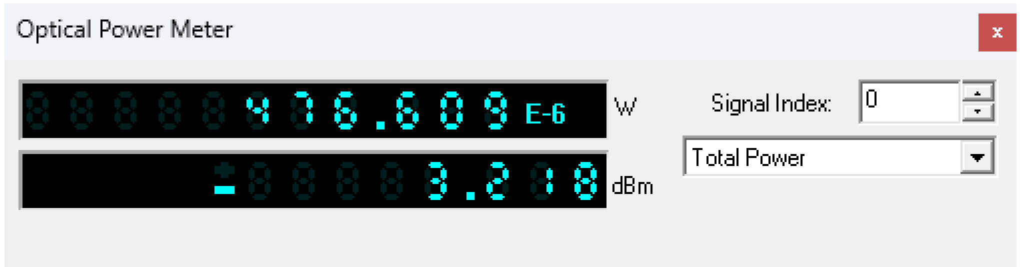
- Transmitter(Tx)



- Receiver (Rx)

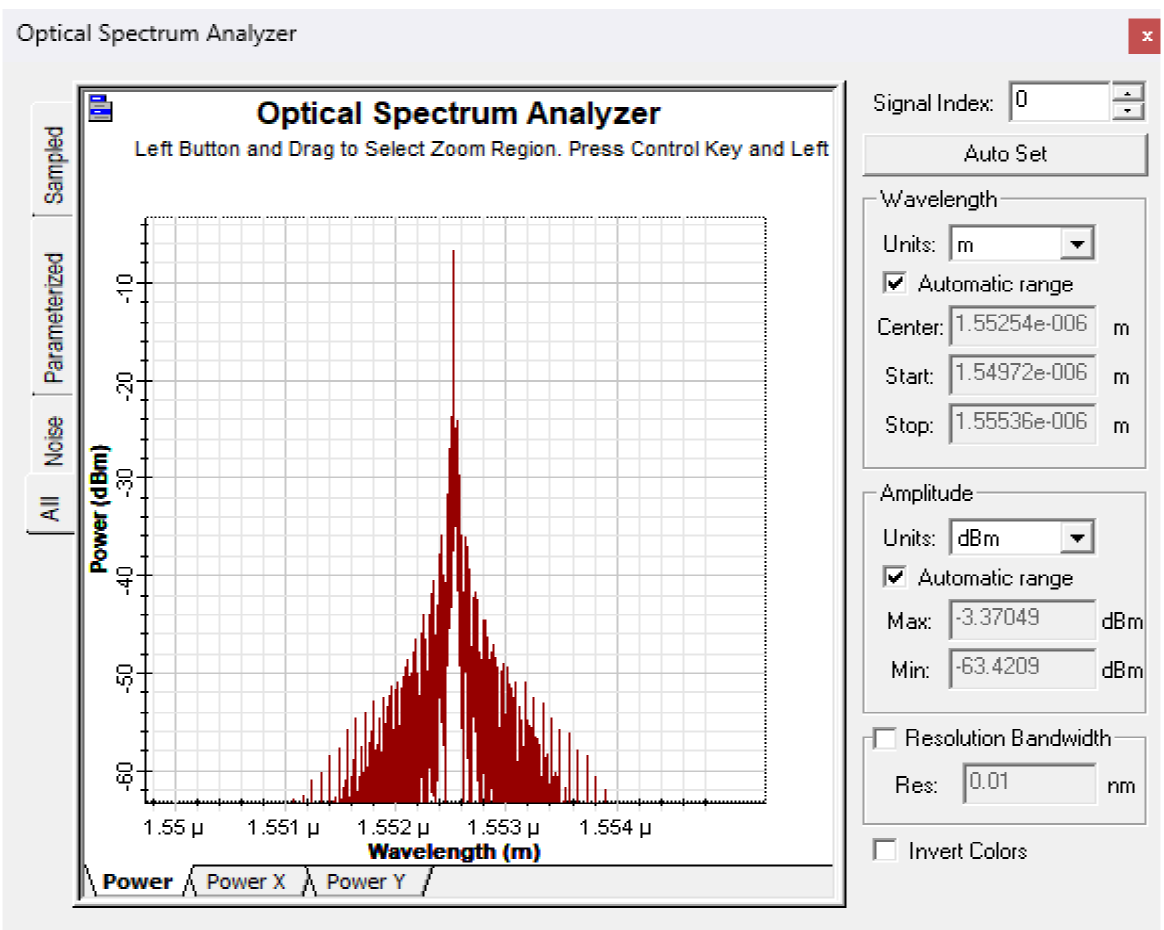


- **Power**
  - Transmitter(Tx)



  - Receiver (Rx)

- **Optical Laser Output**

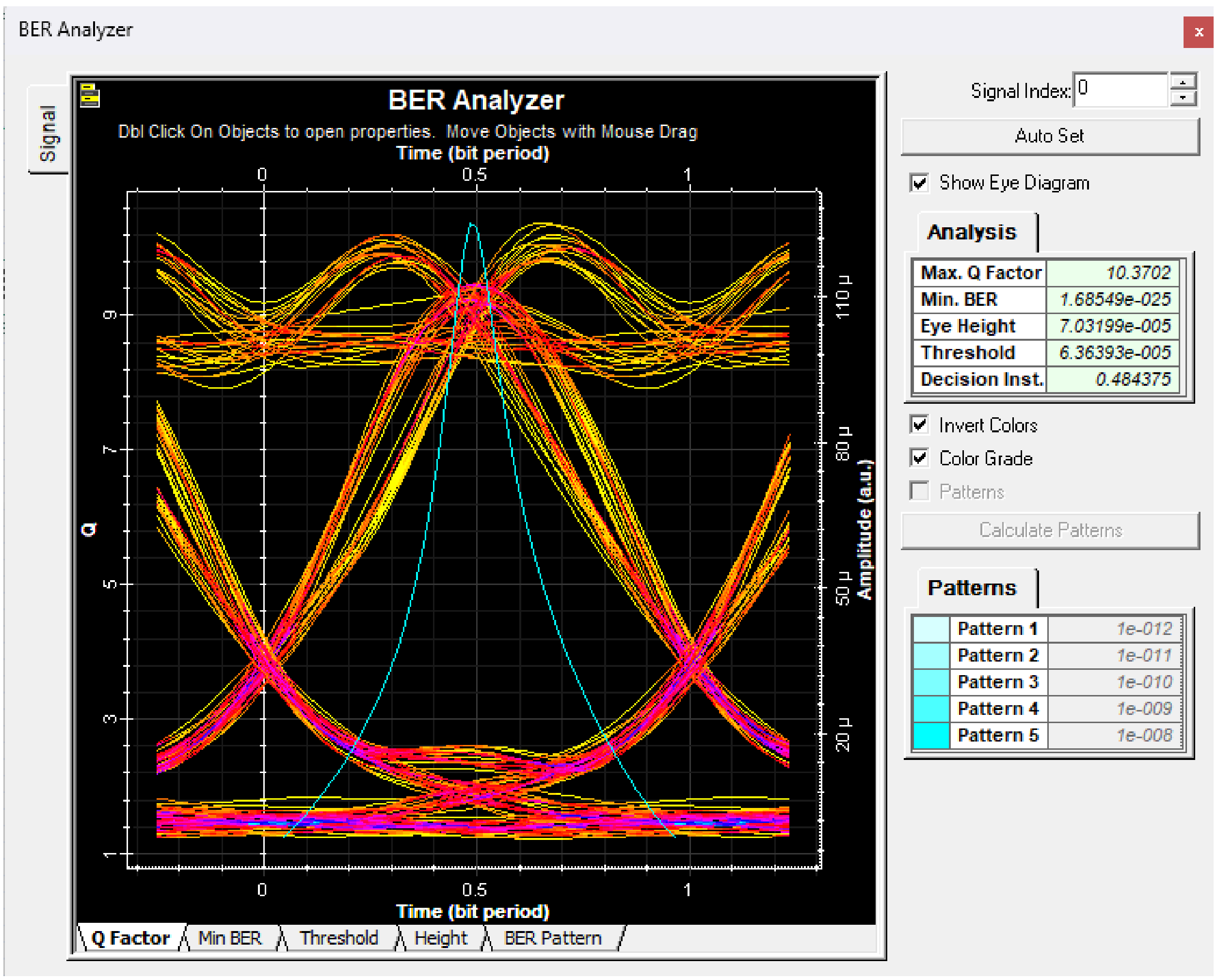


- **BER & Q Factor**

Analysis

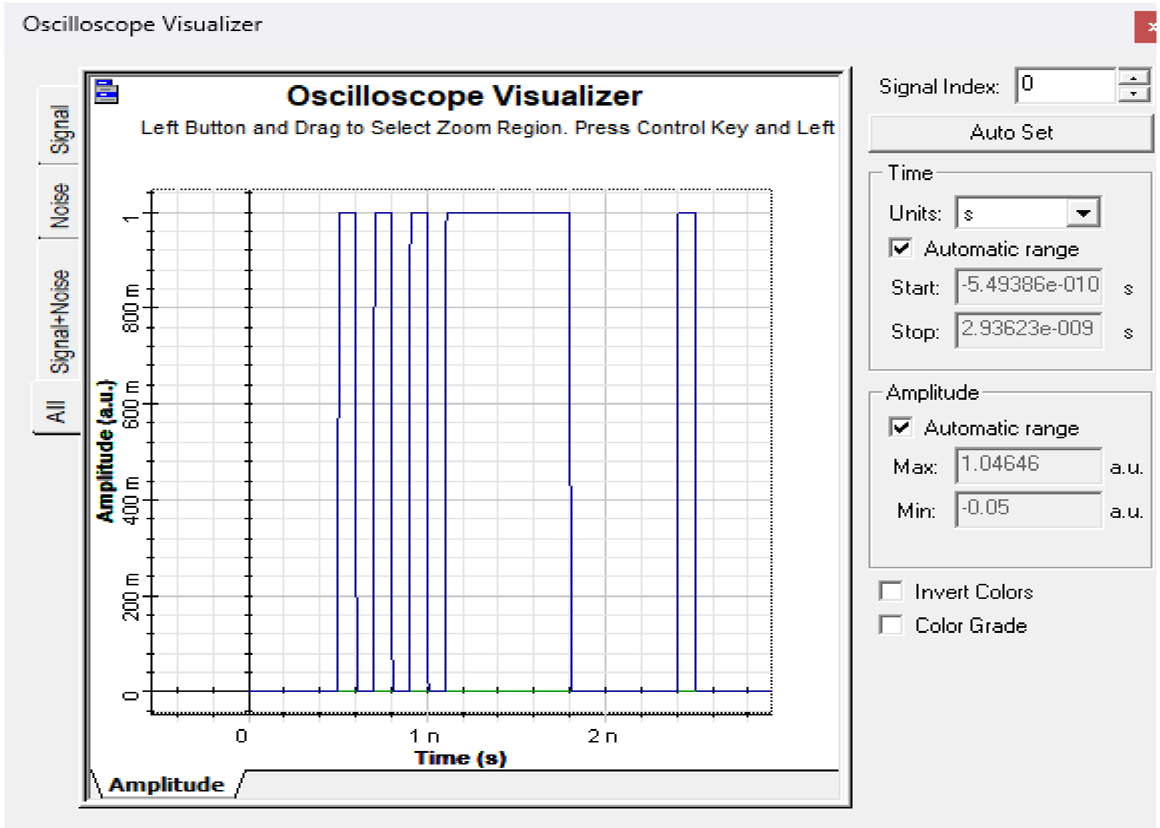
Max. Q Factor	10.3702
Min. BER	1.68549e-025
Eye Height	7.03199e-005
Threshold	6.36393e-005
Decision Inst.	0.484375

- **Eye Diagram**

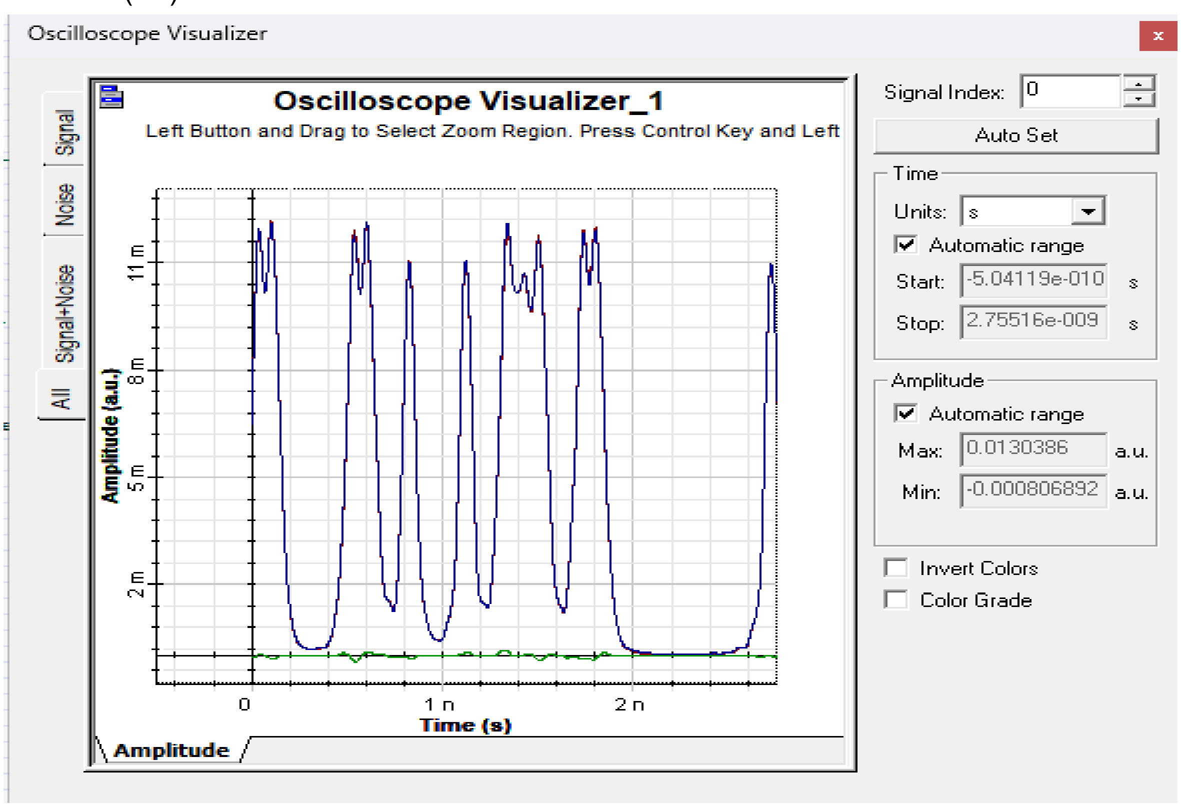


- **Oscilloscope of (With Amplifier)**

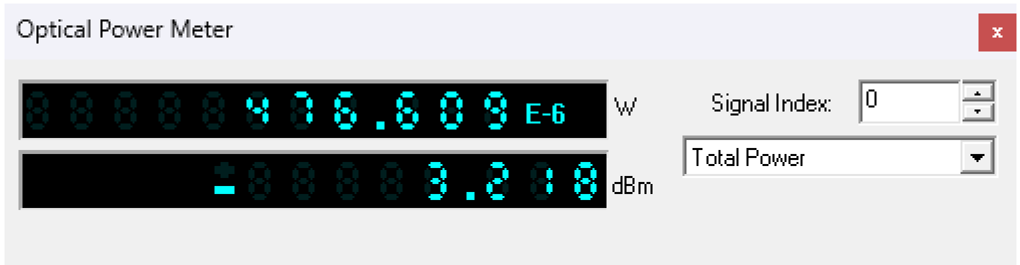
- Transmitter(Tx)



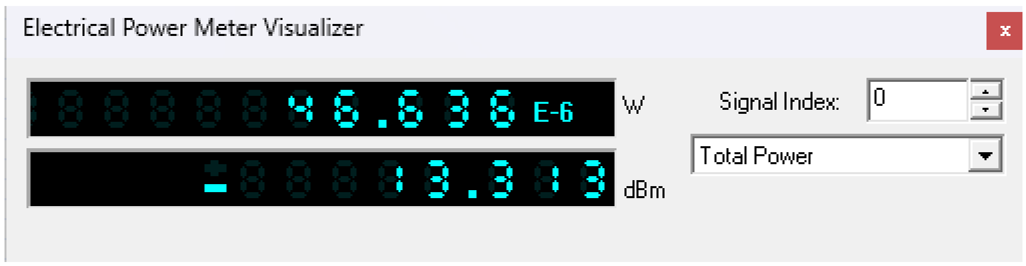
- Receiver (Rx)



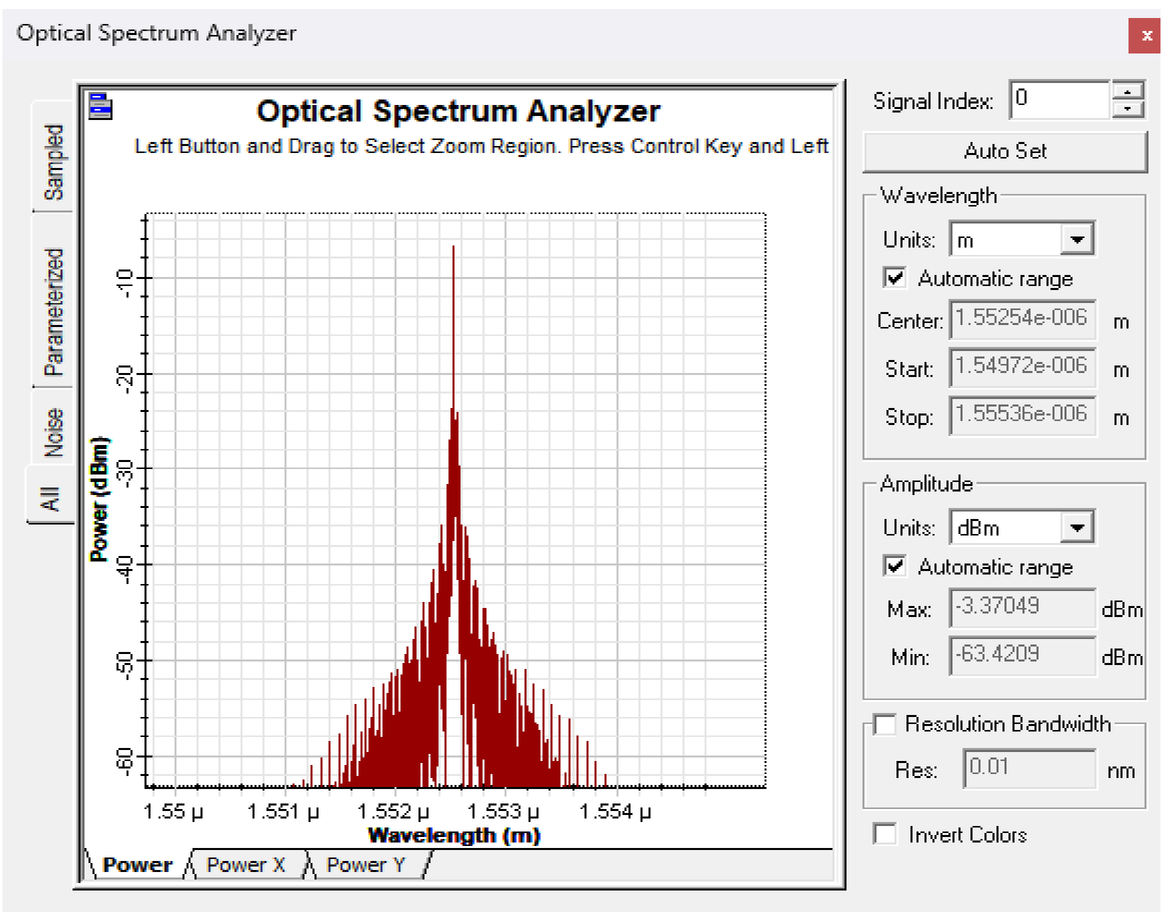
- **Power**
  - Transmitter(Tx)



  - Receiver (Rx)



- **Optical Laser Output**

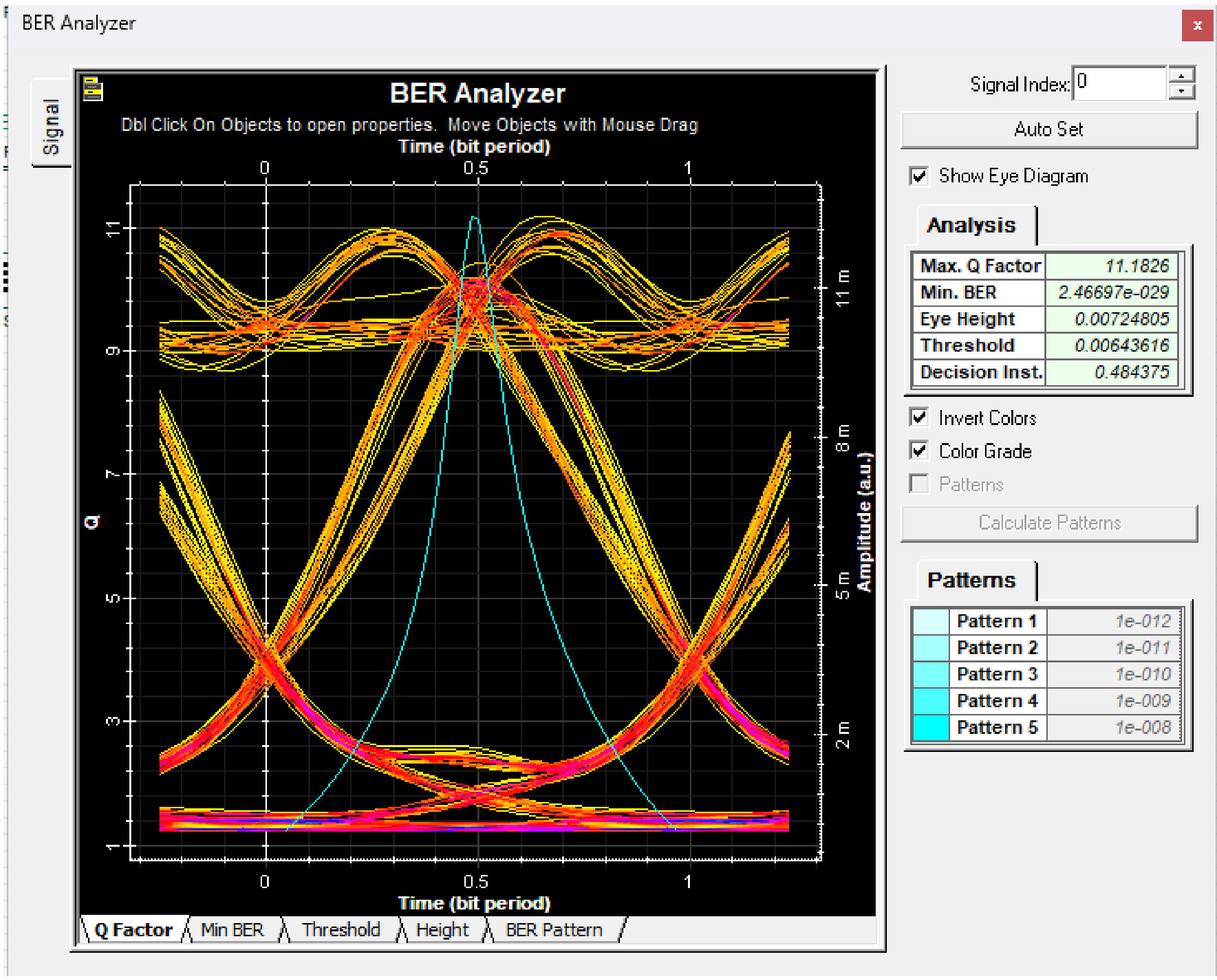


- **BER & Q Factor**

Analysis

Max. Q Factor	11.1826
Min. BER	2.46697e-029
Eye Height	0.00724805
Threshold	0.00643616
Decision Inst.	0.484375

- **Eye Diagram**



5. Discussion

Parameter	Without Fiber	With Fiber (50 km)	With Amplifier
Oscilloscope (Rx)	Clean signal, sharp transitions	Distorted signal, broadened pulses	Restored amplitude but with noise
Power (Rx)	Almost no power loss → Rx ≈ Tx.	About 10 dB loss due to attenuation → weaker signal.	Signal boosted again (positive dBm) → better performance but some noise introduced.
BER	≈ 0 (ideal)	Increased (errors due to attenuation & dispersion)	Reduced compared to fiber-only, but not zero
Q-Factor	Very high (excellent quality)	Decreased (signal degradation)	Improved vs fiber-only, but lower than ideal
Eye Diagram	Wide open (clear distinction between bits)	Narrow, partially closed	More open than fiber-only, but noisy
System Quality	Excellent (ideal condition)	Poorer performance, high error probability	Better performance, but limited by amplifier noise

Without Fiber: The system performs ideally since no transmission impairments are present. BER is negligible, Q-factor is high, and the eye diagram is wide open.

With Fiber (50 km): Attenuation reduces received power, and dispersion broadens pulses. This leads to a closed eye diagram, higher BER, and lower Q-factor.

With Amplifier: Power is restored, improving BER and Q-factor compared to fiber-only. However, amplified spontaneous emission (ASE) noise prevents full recovery, making the system better but not ideal.

6. Conclusion

This project successfully demonstrated the design and performance evaluation of a basic optical communication system under different transmission conditions. The results clearly show the influence of fiber impairments and the role of amplification in long-distance communication:

1. **Without Fiber:** The system worked perfectly with no errors and a clear signal.

2. **With Fiber (50 km):** The signal became weaker and distorted because of attenuation and dispersion, which increased errors.

3. **With Amplifier:** The amplifier restored the signal power and improved performance, but it also added some noise, so the system was better but not perfect.

Overall, the study illustrates the trade-offs in optical communication systems: while optical fibers enable long-distance, high-bandwidth data transfer, their inherent impairments must be managed through signal amplification, dispersion compensation, and advanced modulation techniques. For real-world deployment, more sophisticated methods such as coherent detection, dispersion compensation, forward error correction (FEC), and intelligent signal processing are essential to ensure reliable, long-haul optical communication.

References

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