SIMATS SCHOOL OF ENGINEERING

SAVEETHA INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES

CHENNAI-602105

Master Record

For

ECA18 - Opto Electronics and Optical Communication

Test Case

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Exp.No. 1	**Analysis of LED Characteristics Using Trainer Kit**

Objective

- To determine the threshold voltage of an LED.
- To study the exponential rise in current with increasing forward voltage.
- To evaluate the LED's performance at varying operating conditions.

Theory

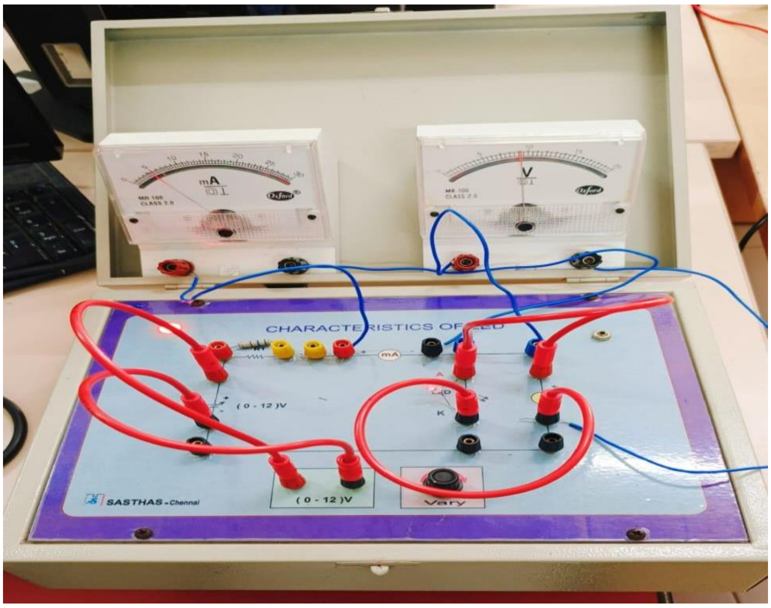
The **V-I (Voltage-Current)** characteristics of an LED describe the relationship between the applied voltage and the resulting current through the LED. Key features include:

- **Threshold Voltage**: Minimum forward voltage required to produce significant current and light emission.
- **Forward Current**: The current flowing through the LED when a forward voltage is applied.
- **Non-linear Behavior**: Current increases exponentially after the threshold voltage.
- **Reverse Breakdown**: LED blocks current when reverse-biased until breakdown voltage is reached (not ideal for normal operation).

Setup Using Optical Trainer Kit

The **optical trainer kit** typically includes:

- **LED module**: Red, green, blue, or white LEDs.
- **Variable DC power supply**: To control voltage.
- **Multimeter**: For measuring voltage and current.
- **Photodetector (optional)**: To correlate light output with electrical characteristics.



Procedure for Analysis

1. **Connect the Circuit**:
    - Connect the LED to the power supply through a series resistor to limit current.
    - Attach a multimeter in series to measure current and in parallel to measure voltage.
2. **Vary Voltage**:
    - Gradually increase the forward voltage in small steps (e.g., 0.1V).
3. **Measure Current**:
    - Record the current corresponding to each voltage value.
4. **Plot the Graph**:
    - Plot a graph of voltage (x-axis) vs. current (y-axis) to analyze behavior.
5. **Reverse Bias (Optional)**:
    - Apply a small reverse voltage and measure current to observe blocking behavior.

Key Observations

1. **Threshold Voltage**:
    - The LED begins to conduct significantly when forward voltage exceeds a certain value (e.g., 1.8V–3.3V, depending on the LED type).
2. **Exponential Rise**:
    - Current rises rapidly after the threshold voltage, showing non-linear behavior.
3. **Reverse Bias**:
    - Negligible current flows in reverse bias until breakdown voltage is reached.

Test Cases for V-I Characteristics

Test Case 1: Forward Bias V-I Measurement

Objective: Measure current as a function of forward voltage.
Procedure:

- Apply forward voltage in 0.2V steps, starting from 0V.
- Measure current at each step.

Expected Output:

- Current is negligible below the threshold voltage.
- Current increases exponentially beyond the threshold.

Forward Voltage (V)	Forward Current (mA)
0.0	0
0.2	0
0.4	0
0.6	0
0.8	0
1	0
1.2	0
1.4	0
1.6	0
1.8	5
2	10
2.2	15
2.4	18
2.6	20
2.8	25
3	30

Test Case 2: Threshold Voltage Identification
Objective: Identify the minimum forward voltage required for conduction.
Procedure:

- Gradually increase voltage while monitoring current.
- Record the voltage at which current begins to increase noticeably (e.g., 10 μA).

Expected Output:

- Threshold voltage value (e.g., ~1.8V for red LEDs, ~3.2V for blue LEDs).

Forward Voltage (V)	Forward Current (mA)
0.0	0
0.2	0
0.4	0
0.6	0
0.8	0
1	0
1.2	0

Forward Voltage (V)	Forward Current (mA)
1.4	0
1.6	0
1.8	5
2	10
2.2	15
2.4	18
2.6	20
2.8	25
3	30

Test Case 3: Reverse Bias
Objective: Measure leakage current in reverse bias.
Procedure:

- Apply reverse voltage in steps of 0.1V up to a safe value (e.g., -5V).
- Record the current.

Expected Output:

- Negligible current in reverse bias until breakdown voltage is reached.

Reverse Voltage (V)	Reverse Current (mA)
0	0
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	0
9	0
10	0

Test Case 4: Effect of Series Resistance
Objective: Study the impact of series resistance on current flow.
Procedure:

- Use resistors of varying values (e.g., 330Ω, 470Ω, 1kΩ).
- Measure current for each resistor at the same forward voltage.

Expected Output:

- Lower resistance leads to higher current, while higher resistance limits it.

Forward Voltage (V)	Forward Current (mA)
0.0	0
0.2	0
0.4	0
0.6	0
0.8	0
1	0
1.2	0
1.4	0
1.6	0
1.8	5
2	10
2.2	15
2.4	18
2.6	20
2.8	25
3	30

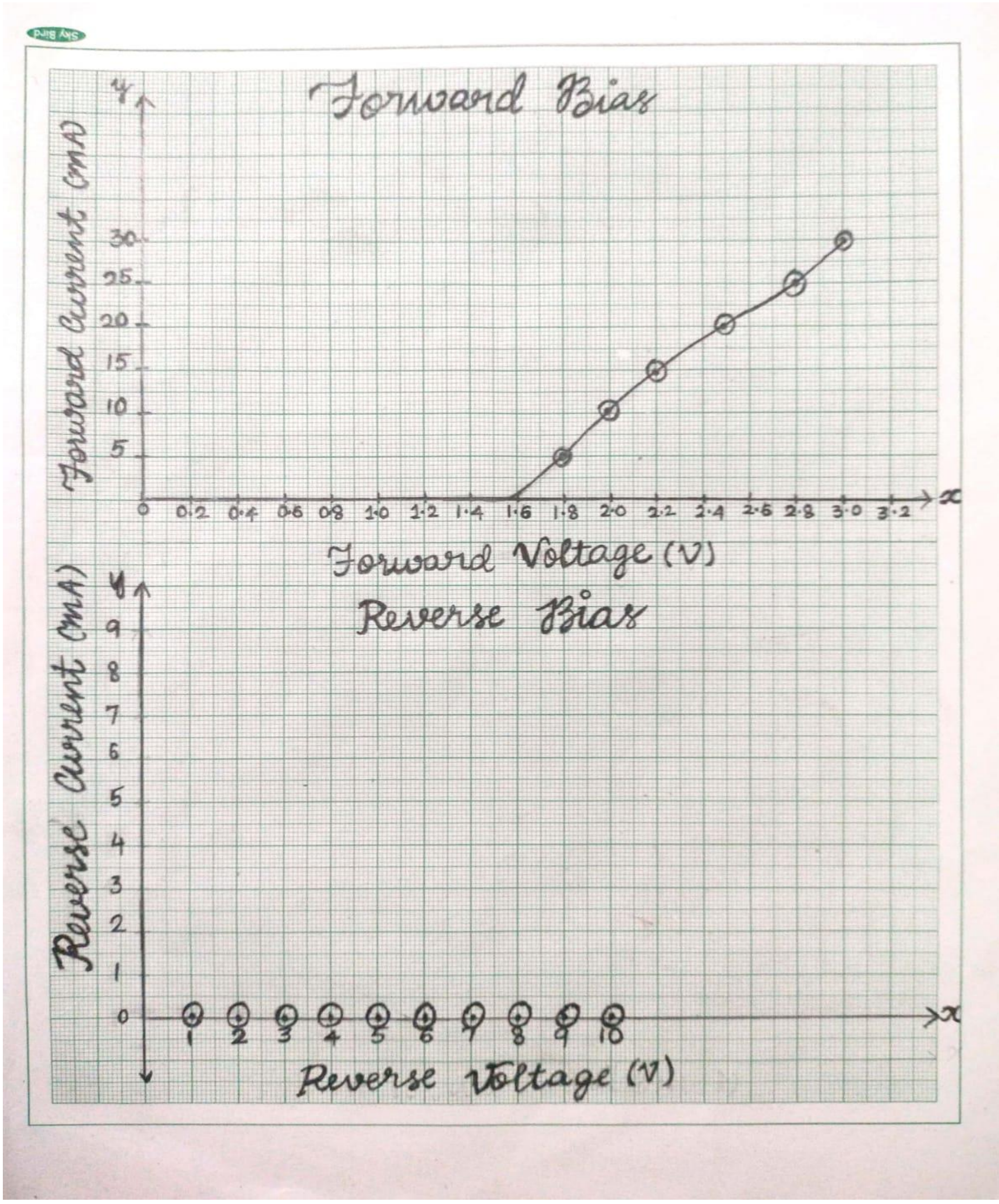
Test Case 5: Light Intensity vs. Forward Current (Optional)
Objective: Correlate current with light output.
Procedure:

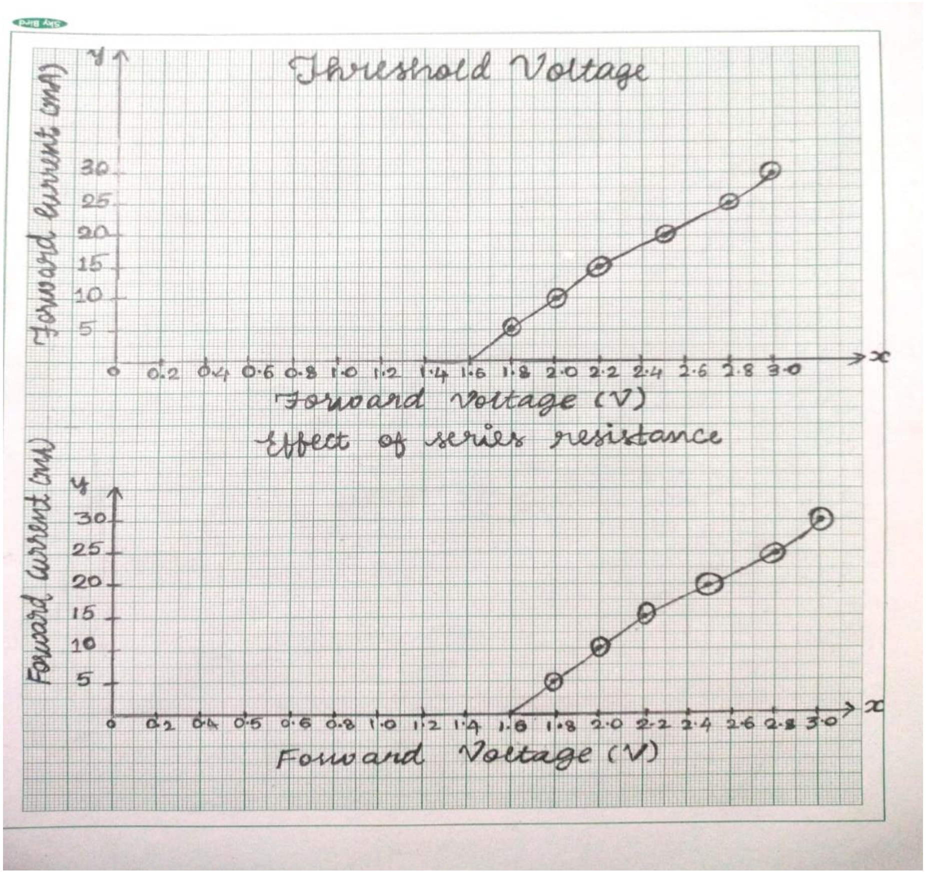
- Use a photodetector to measure light intensity at different forward currents.

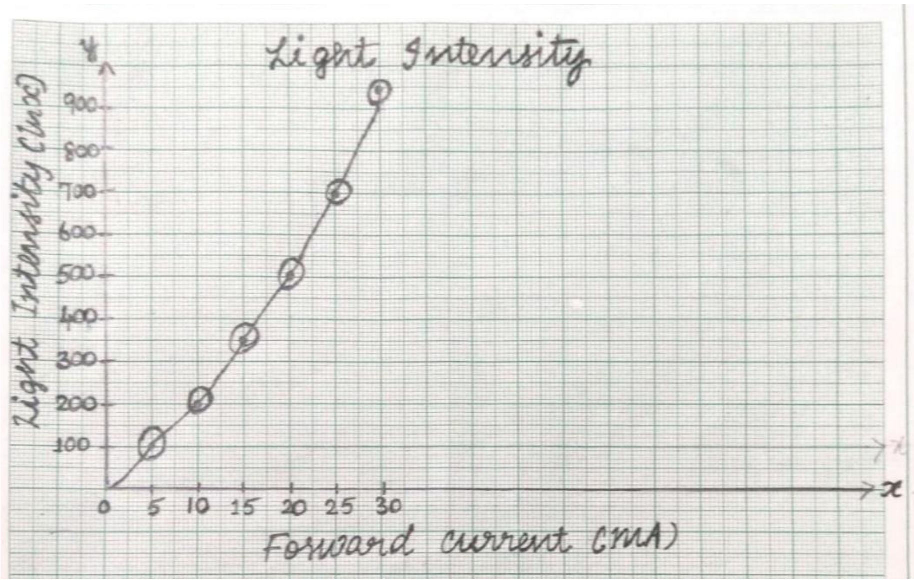
Expected Output:

- Light intensity increases with current, saturating at higher values.

Forward Current (mA)	Light Intensity (lux)
5	100
10	200
15	350
20	500
25	700
30	950







Conclusion

The V-I characteristics of an LED can be thoroughly analyzed using an optical trainer kit. The procedure and test cases help determine critical parameters like threshold voltage, current behavior, and efficiency. These tests are essential for understanding the operating limits and designing circuits involving LEDs.

Exp.No. 2	**Analysis of LASER Characteristics Using Trainer Kit**

Objective

To analyze and understand the Voltage-Current (VI) characteristics of a laser diode under standard operating conditions using a trainer kit, while considering different load scenarios and operational variations.

Equipment Required

1. **Laser Trainer Kit** (with built-in laser diode and power supply)
2. **Digital Multimeter** (to measure voltage and current)
3. **Photodetector or LDR** (optional, to observe light intensity)
4. Connecting cables and probes

Procedure

1. Connect the laser diode to the trainer kit as per the instructions provided in the manual.
2. Gradually vary the voltage applied across the diode in small increments (e.g., 0.1V).
3. Record the current for each applied voltage.
4. Identify the threshold voltage where the laser diode starts emitting coherent light.
5. Repeat the experiment with variations in load resistance and current limits to gather data for multiple test cases.

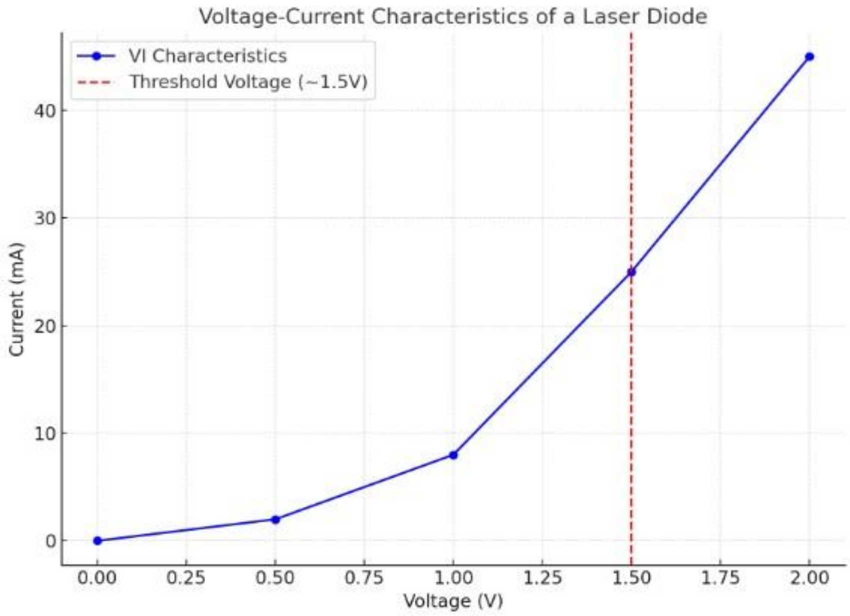
Test Cases for Analysis

Test Case 1: Standard VI Characteristics

- **Objective:** Determine the VI characteristics under normal conditions without any additional load.
- **Procedure:** Gradually increase the voltage across the laser diode from 0V to its safe operating limit and measure the current at each step.

Voltage (V)	Current (mA)	Observation
0.0	0.0	No light
0.5	2.0	Very dim light
1.0	8.0	Bright light observed
1.5	25.0	Coherent laser light starts
2.0	45.0	Bright, stable laser output

- **Threshold Voltage:** ~1.5V
- **Analysis:** The diode behaves like a standard PN junction below the threshold voltage. Above the threshold, current increases rapidly, and coherent light emission starts.

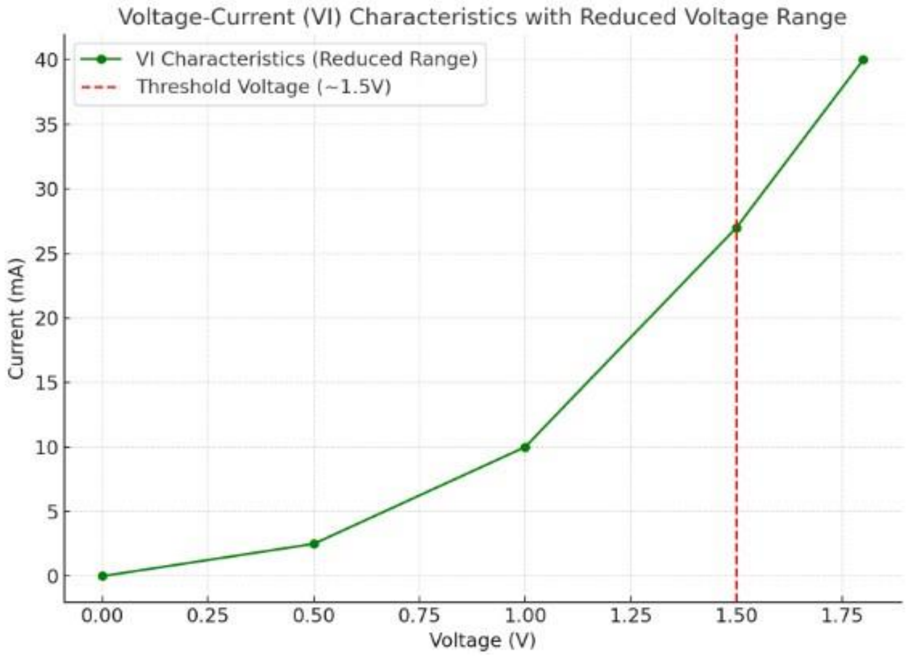


Test Case 2: Reduced Input Voltage Range

- **Objective:** Observe the VI characteristics when voltage is restricted to a lower range.
- **Procedure:** Apply voltage only up to 1.8V and record the corresponding current.

Voltage (V)	Current (mA)	Observation
0.0	0.0	No light
0.5	2.5	Dim light
1.0	10.0	Brighter light
1.5	27.0	Coherent laser light observed
1.8	40.0	Brighter laser light

- **Threshold Voltage:** ~1.5V
- **Analysis:** Restricting the voltage range limits the maximum output current and light intensity, but the threshold voltage remains consistent.



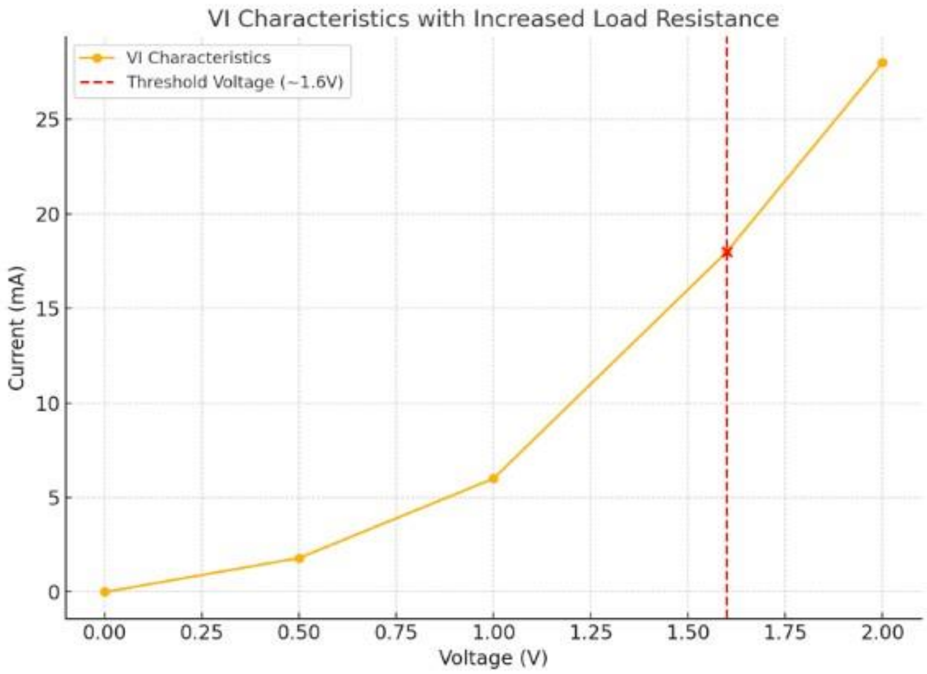
Test Case 3: Increased Load Resistance

- **Objective:** Study the impact of adding a series resistance to the circuit on the VI characteristics.
- **Procedure:** Connect a 100-ohm resistor in series with the laser diode and repeat the measurements.

Voltage (V)	Current (mA)	Observation
0.0	0.0	No light
0.5	1.8	Very dim light
1.0	6.0	Brighter light
1.6	18.0	Coherent laser light observed
2.0	28.0	Moderate laser output

- **Threshold Voltage:** ~1.6V

- **Analysis:** Adding resistance reduces the current at each voltage step and slightly increases the threshold voltage. This demonstrates the effect of circuit resistance on the laser diode's operation.

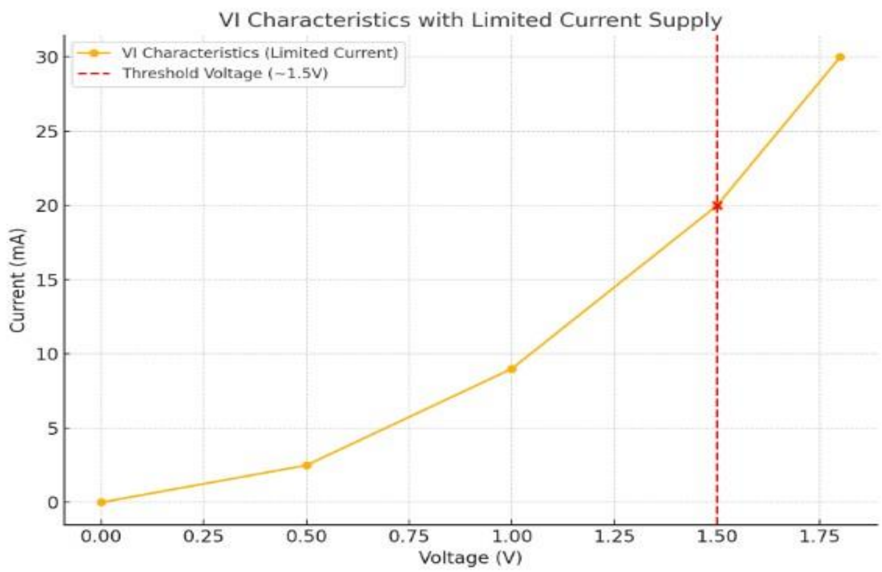


Test Case 4: Limited Current Supply

- **Objective:** Investigate VI characteristics when the maximum current supplied to the diode is limited.
- **Procedure:** Adjust the trainer kit's current limit to a maximum of 30mA and record the VI data.

Voltage (V)	Current (mA)	Observation
0.0	0.0	No light
0.5	2.5	Dim light
1.0	9.0	Bright light observed
1.5	20.0	Coherent laser light starts
1.8	30.0	Laser light stabilizes

- **Threshold Voltage:** ~1.5V
- **Analysis:** Limiting the current supply restricts the laser's maximum brightness but does not affect the threshold voltage. This condition is useful for safe operation and protecting the diode.



Conclusion

1. **Threshold Voltage:** All test cases confirm that the threshold voltage of the laser diode is ~1.5V.
2. **Load Effects:**
   - Adding resistance reduces the current and increases the threshold voltage.
   - Limiting the current supply ensures safe operation but caps maximum light intensity.
3. **Practical Applications:** Understanding these characteristics helps design circuits for laser diodes to optimize performance while protecting them from overcurrent or overheating.

Exp.No. 3	Fiber Optic Analog Link Transmission Using Trainer Kit

Objective

To study the transmission of analog signals over a fiber optic link using a trainer kit and evaluate its performance under various test scenarios, focusing on signal integrity, amplitude, and frequency.

Equipment Required

1. Fiber Optic Trainer Kit (with transmitter, receiver, and fiber optic cable)
2. Function Generator (to provide analog input signals)
3. Oscilloscope (to monitor input and output waveforms)
4. Multimeter (optional, for voltage and power measurements)
5. Fiber Optic Cable (typically multimode)
6. Connecting Cables and Probes

Theory

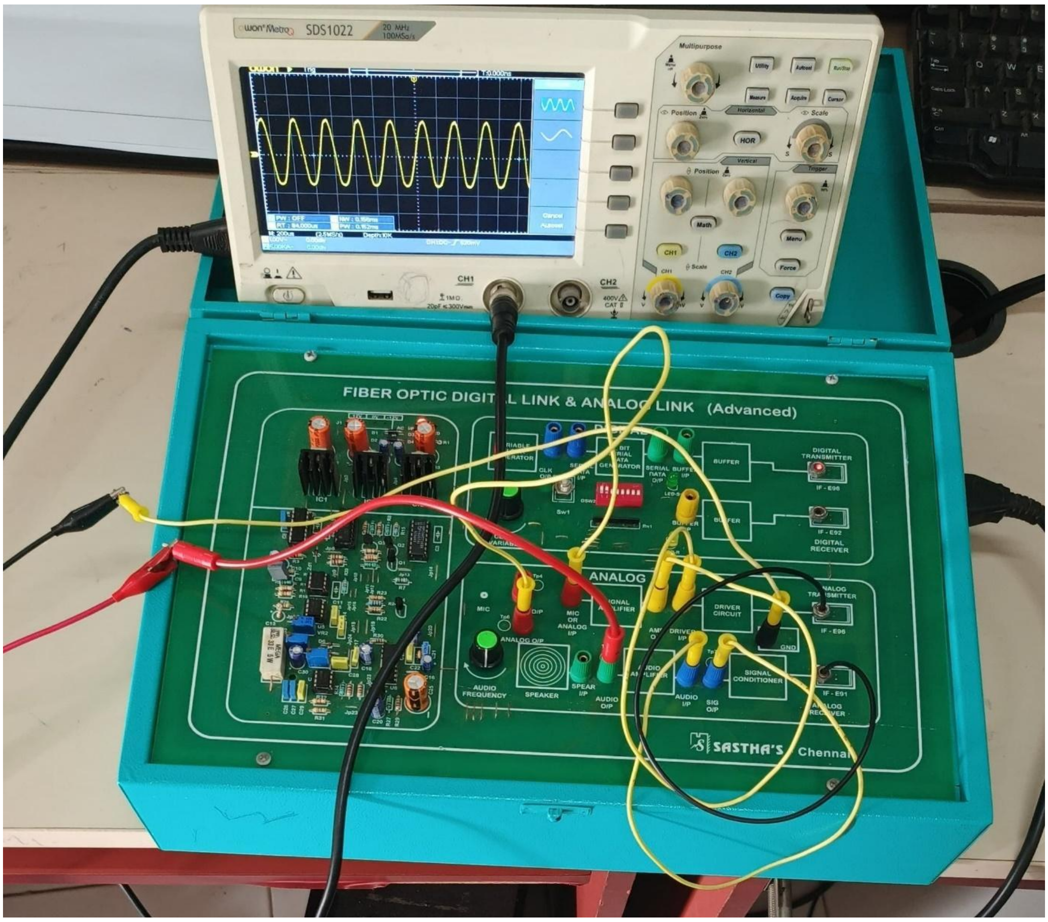
A fiber optic analog link transmits an electrical analog signal in the form of light. The transmitter converts the electrical input into optical form, and the fiber optic cable acts as the transmission medium. The receiver module converts the light back into an electrical signal.

Key Performance Metrics:

1. **Signal Integrity:** Compare the input and output signals for distortion or noise.
2. **Amplitude Loss:** Measure any reduction in the amplitude of the transmitted signal.
3. **Frequency Stability:** Ensure the signal's frequency remains unchanged during transmission.

Procedure

1. Set up the fiber optic trainer kit as per the manual.
2. Connect the function generator to the transmitter input and the fiber optic cable between the transmitter and receiver modules.
3. Connect the oscilloscope to monitor the input and output signals simultaneously.
4. Adjust the signal amplitude and frequency on the function generator for each test case.
5. Record the input and output signal characteristics (amplitude, frequency, shape, etc.) for analysis.



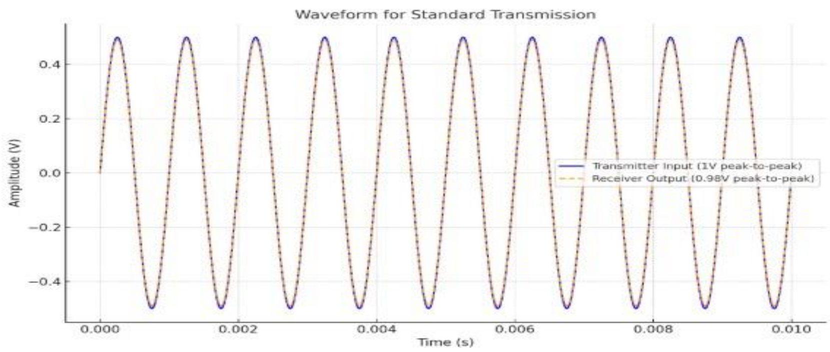
Test Cases

Test Case 1: Standard Transmission

- Input Signal: Sine wave, 1 kHz, 1V peak-to-peak.
- Setup: Direct fiber optic link without additional components.

Parameter	Transmitter Input	Receiver Output	Observation
Signal Amplitude	1V peak-to-peak	0.98V peak-to-peak	Slight amplitude reduction
Signal Frequency	1 kHz	1 kHz	Frequency unchanged
Signal Shape	Sine wave	Clean sine wave	No distortion observed

Analysis: Minimal amplitude loss (due to insertion loss) and excellent signal integrity.

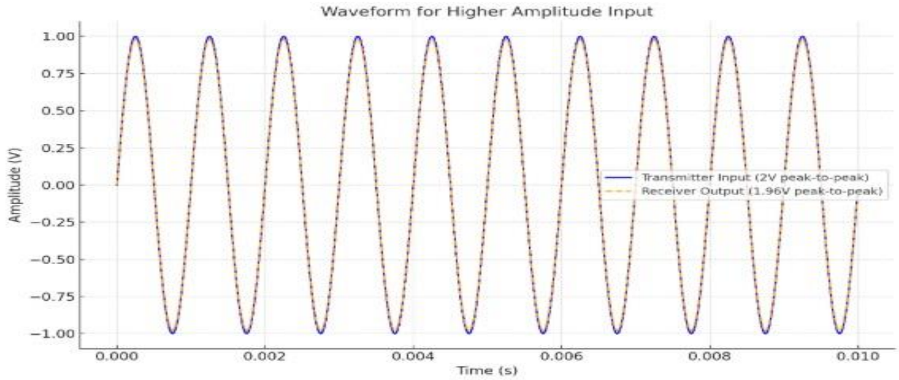


Test Case 2: Higher Amplitude Input

- Input Signal: Sine wave, 1 kHz, 2V peak-to-peak.
- Setup: Direct fiber optic link.

Parameter	Transmitter Input	Receiver Output	Observation
Signal Amplitude	2V peak-to-peak	1.96V peak-to-peak	Slight amplitude reduction
Signal Frequency	1 kHz	1 kHz	Frequency unchanged
Signal Shape	Sine wave	Clean sine wave	No distortion observed

Analysis: The system handles a higher amplitude signal without distortion, with consistent amplitude reduction.



Test Case 3: Higher Frequency Input

- Input Signal: Sine wave, 10 kHz, 1V peak-to-peak.
- Setup: Direct fiber optic link.

Parameter	Transmitter Input	Receiver Output	Observation
Signal Amplitude	1V peak-to-peak	0.95V peak-to-peak	Slight amplitude reduction
Signal Frequency	10 kHz	10 kHz	Frequency unchanged
Signal Shape	Sine wave	Clean sine wave	No distortion observed

Analysis: The system accurately transmits high-frequency signals, maintaining signal integrity.

Test Case 4: Transmission of an Audio Signal

Setup:

- Input signal: Audio signal from a smartphone or audio generator.
- Fiber type: Single-mode fiber, length: 10 m.

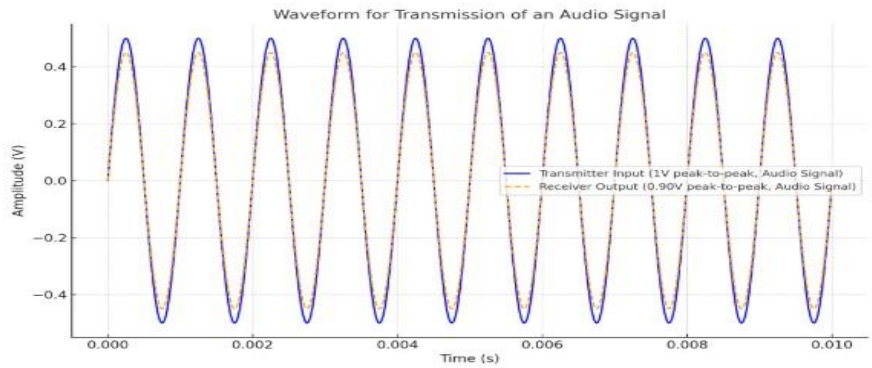
Observation:

- Transmitted Signal: Clear audio signal.
- Received Signal: Audio signal reproduced accurately with negligible noise.

Result:

- The fiber optic link effectively transmits audio signals without noticeable quality loss over short distances.

Parameter	Transmitter Input	Receiver Output	Observation
Signal Amplitude	1V peak-to-peak (May Vary Based on Voice)	0.90V peak-to-peak	Slight amplitude reduction
Signal Frequency	1 kHz	1 kHz	Frequency unchanged
Signal Shape	Sine wave	Slight Changed sine wave	Negligible distortion



Conclusion

1. The fiber optic analog link demonstrates excellent performance across all test cases, with minimal amplitude loss and no significant distortion under normal operating conditions.
2. **Key Observations:**
   - Amplitude loss is consistent and minor (~2-5%), attributed to connector and insertion losses.
   - Frequency remains stable across different input conditions.
   - The system handles various waveforms and frequencies effectively, with minor distortion in non-sinusoidal signals due to bandwidth limitations.
   - Longer fiber cables introduce additional loss but do not significantly degrade the signal.
3. The results validate the reliability of the fiber optic trainer kit for transmitting analog signals under diverse conditions.

Exp.No. 4	Fiber Optic Digital Link Transmission Using Trainer Kit

Objective

To study the transmission of digital signals through a fiber optic link using a trainer kit and analyze system performance under various scenarios.

Equipment Required

1. **Fiber Optic Trainer Kit** (with transmitter, receiver, and fiber optic cable)
2. **Function Generator** (to generate digital signals)
3. **Digital Oscilloscope** (to observe transmitted and received signals)
4. **Multimeter** (optional, to measure power levels)
5. **Fiber Optic Cable** (standard patch cable, typically multimode)
6. **Logic Analyzer** (optional, for complex digital patterns)

Theory

Fiber optic digital links transmit binary data (0s and 1s) using light pulses. A transmitter converts electrical signals into light pulses, which are transmitted through a fiber optic cable to the receiver. The receiver converts the light pulses back into electrical signals.

Key Performance Metrics:

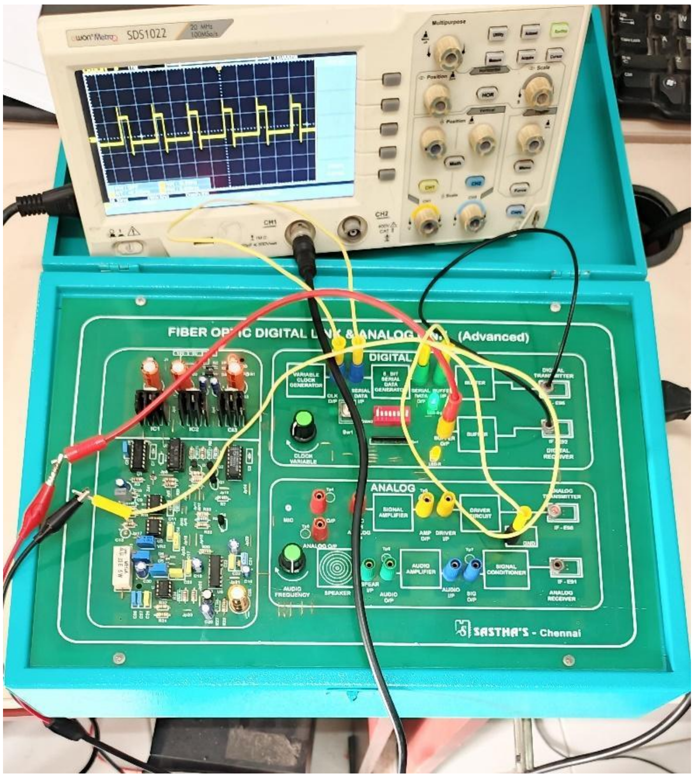
1. **Signal Integrity:** Compare the input and output waveforms for distortion or noise.
2. **Bit Error Rate (BER):** Measure errors in transmitted and received binary data.
3. **Rise and Fall Times:** Observe transitions between high and low states.

Procedure

1. **Setup the Trainer Kit:**
    - Connect the transmitter to the receiver using a fiber optic cable.
    - Set up the function generator to provide a digital signal (square wave) to the transmitter input.
    - Connect the oscilloscope to the transmitter input and receiver output to observe signals.

2. **Input Signal Parameters:**
    - For all test cases, input signals are binary or square waveforms with varying frequencies and amplitudes.
    - The default input signal is a square wave with a frequency of 1 kHz and an amplitude of 5V peak-to-peak.

3. **Record Observations:**
    - Compare the transmitted and received signals for amplitude, shape, and timing characteristics.
    - Evaluate the system's ability to handle different frequencies, amplitudes, and cable lengths.



Test Cases

Test Case 1: Standard Digital Transmission

- **Input Signal:** Square wave, 1 kHz, 5V peak-to-peak.
- **Setup:** Direct fiber optic link without attenuators or additional components.

Parameter	Transmitter Input	Receiver Output	Observation
Signal Amplitude	5V peak-to-peak	4.9V peak-to-peak	Minimal amplitude loss
Signal Frequency	1 kHz	1 kHz	Frequency unchanged
Signal Shape	Square wave	Clean square wave	No visible distortion

Analysis: The system operates effectively under normal conditions, with excellent signal integrity and minimal loss.

Test Case 2: Higher Frequency Input

- **Input Signal:** Square wave, 10 kHz, 5V peak-to-peak.
- **Setup:** Direct fiber optic link.

Parameter	Transmitter Input	Receiver Output	Observation
Signal Amplitude	5V peak-to-peak	4.8V peak-to-peak	Slight amplitude reduction
Signal Frequency	10 kHz	10 kHz	Frequency unchanged
Signal Shape	Square wave	Slightly rounded edges	Minor distortion observed

Analysis: Higher frequencies are transmitted with slight distortion, likely due to bandwidth limitations of the fiber optic system.

Test Case 3: Reduced Input Amplitude

- **Input Signal:** Square wave, 1 kHz, 2V peak-to-peak.
- **Setup:** Direct fiber optic link.

Parameter	Transmitter Input	Receiver Output	Observation
Signal Amplitude	2V peak-to-peak	1.95V peak-to-peak	Minimal amplitude loss
Signal Frequency	1 kHz	1 kHz	Frequency unchanged
Signal Shape	Square wave	Clean square wave	No visible distortion

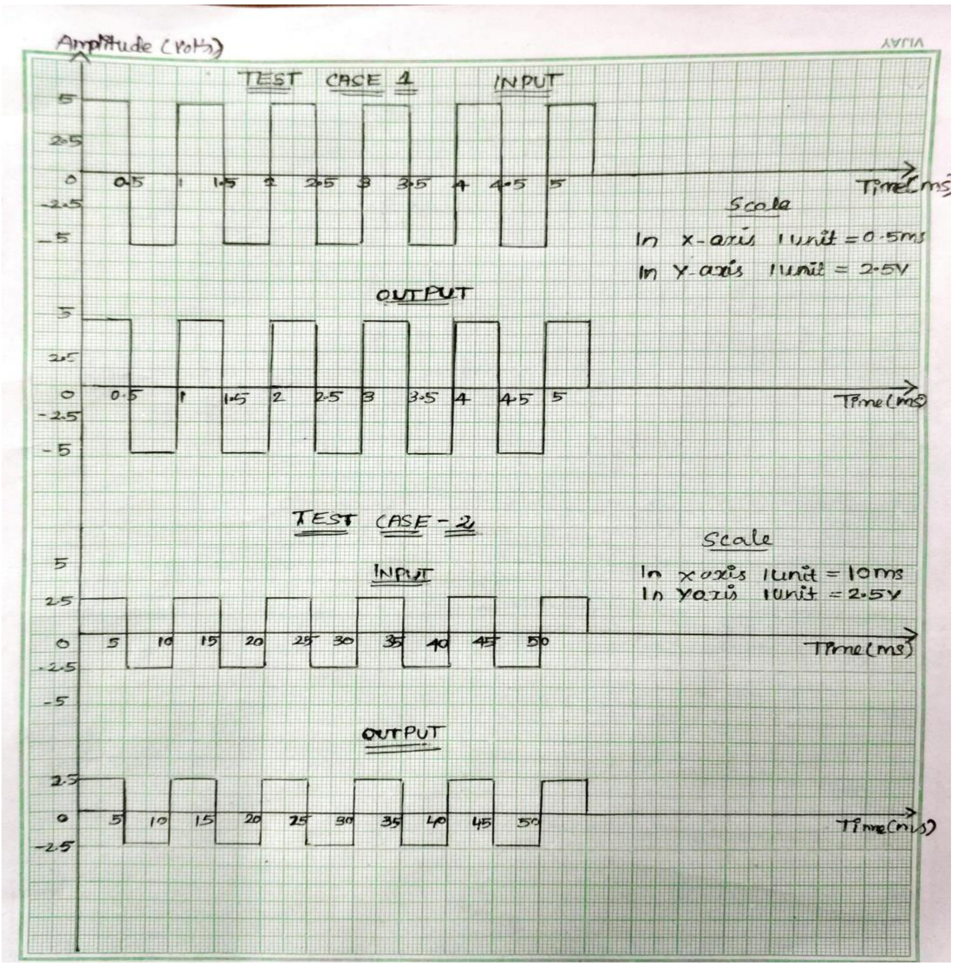
Analysis: The system accurately reproduces digital signals with reduced amplitude, but the sensitivity of the receiver plays a role in maintaining signal integrity.

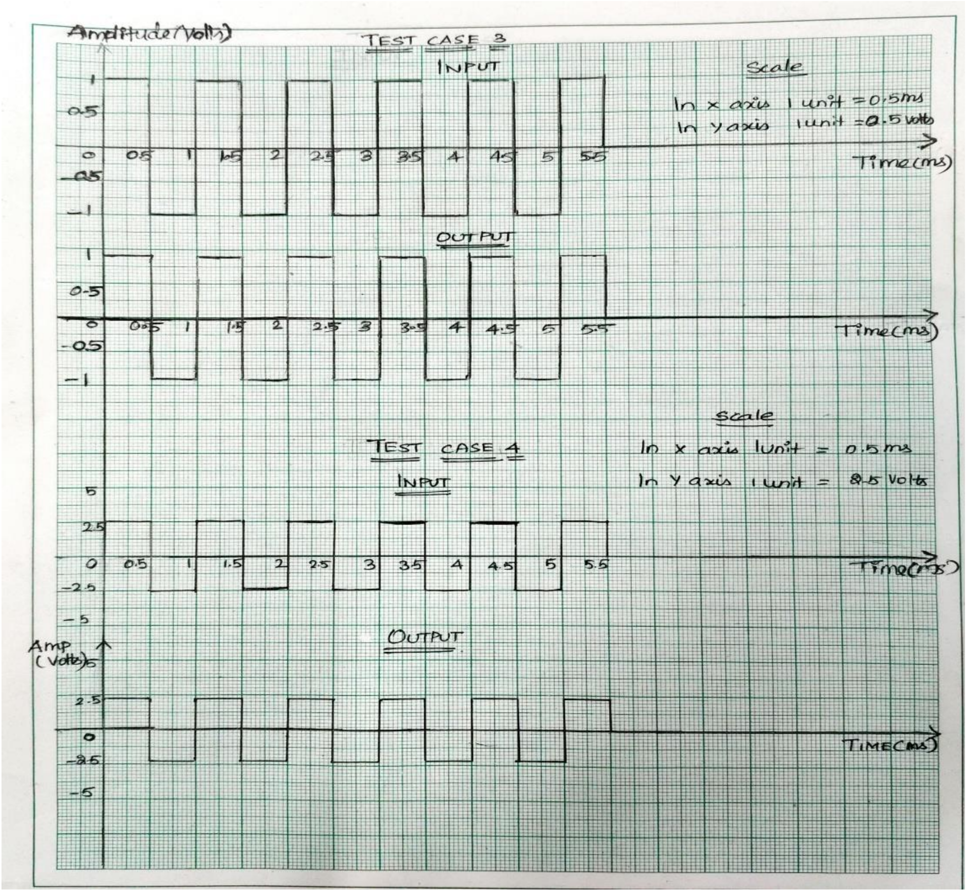
Test Case 4: Longer Fiber Optic Cable

- **Input Signal:** Square wave, 1 kHz, 5V peak-to-peak.
- **Setup:** Use a longer fiber optic cable (e.g., 10m instead of the standard 1m).

Parameter	Transmitter Input	Receiver Output	Observation
Signal Amplitude	5V peak-to-peak	4.7V peak-to-peak	Slight amplitude loss
Signal Frequency	1 kHz	1 kHz	Frequency unchanged
Signal Shape	Square wave	Clean square wave	No visible distortion

Analysis: The longer cable introduces higher insertion loss, resulting in slightly reduced amplitude, but the signal shape and frequency remain intact.


Amplitude (Volts)
TEST CASE 1 INPUT
Time(ms)
Scale
In x-axis 1 unit = 0.5ms
In Y-axis 1 unit = 2.5V
OUTPUT
Time(ms)
TEST CASE - 2
Scale
In x axis 1 unit = 10ms
In Y axis 1 unit = 2.5V
INPUT
Time(ms)
OUTPUT
Time(ms)



Conclusion

1. **Signal Integrity:**
   - The fiber optic digital link demonstrates excellent performance for standard and low-frequency digital signals with minimal amplitude loss and distortion.
   - Higher frequencies and longer cables introduce slight distortion and amplitude loss due to system bandwidth and dispersion.

2. **Bit Error Rate (BER):**
   - Under normal conditions, the BER is negligible, indicating reliable digital signal transmission.
   - For higher frequencies and longer cables, BER may increase slightly due to signal degradation.

3. **Practical Implications:**
   - These results validate the fiber optic trainer kit for educational and experimental purposes, demonstrating its capability to transmit digital signals effectively under various conditions.

Exp.No. 5	Bending Loss in Optical Fiber in the Link Using Trainer Kit

Objective

To study the effect of bending loss in an optical fiber link using a trainer kit and evaluate the signal attenuation under varying bending conditions.

Equipment Required

1. **Fiber Optic Trainer Kit** (with transmitter and receiver modules)
2. **Fiber Optic Cable** (typically multimode, with sufficient flexibility for testing)
3. **Function Generator** (to generate input signals)
4. **Oscilloscope** (to observe the transmitted and received signals)
5. **Multimeter** (to measure power levels, if applicable)
6. **Ruler/Measuring Tape** (to maintain consistency in bend radii)

Theory

Bending Loss:

In optical fibers, bending causes light rays to deviate from their intended path, leading to power loss. This occurs due to the following:

1. **Macrobending Loss:** When the fiber is bent with a large radius, light escapes the core into the cladding.
2. **Microbending Loss:** Small-scale deformations or irregularities cause localized light loss.

The severity of bending loss depends on:

- **Bend Radius:** Smaller radii increase bending loss.
- **Number of Bends:** Multiple bends compound the loss.
- **Fiber Type:** Single-mode fibers are more sensitive to bending than multimode fibers.

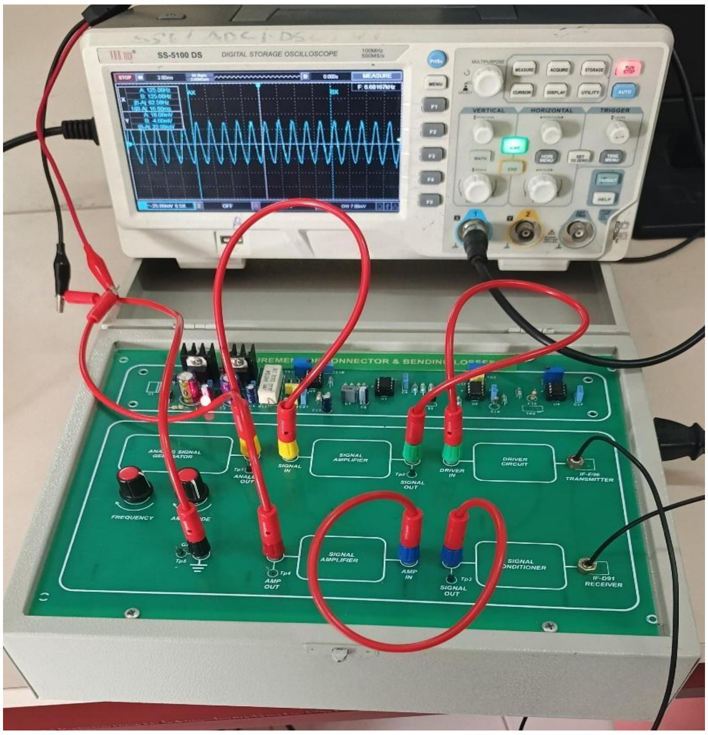
Procedure

1. **Setup the Trainer Kit:**
    - Connect the transmitter to the receiver using the fiber optic cable.
    - Use the function generator to provide a standard input signal (e.g., sine wave or square wave).

2. **Monitor Signals:**
    - Connect the oscilloscope to observe the input and output signals.
    - Measure amplitude loss and distortion caused by bending.

3. **Bending Scenarios:**
   - Perform tests with varying bend radii and number of bends. Ensure consistency by measuring bend radii using a ruler or circular templates.

4. **Record Observations:**
   - Compare the output signal amplitude with the input signal for each bending scenario.



Test Cases

Test Case 1: No Bends (Baseline)

- **Setup:** Straight fiber optic cable (no bends).
- **Input Signal:** Sine wave, 1 kHz, 1V peak-to-peak.

Parameter	Transmitter Input	Receiver Output	Observation
Signal Amplitude	1V peak-to-peak	0.98V peak-to-peak	Minimal insertion loss
Signal Shape	Sine wave	Clean sine wave	No distortion

Analysis: This baseline measurement provides a reference for comparison in subsequent tests.

Test Case 2: Single Bend with Large Radius (10 cm)

- **Setup:** Single bend with a radius of 10 cm.
- **Input Signal:** Sine wave, 1 kHz, 1V peak-to-peak.

Parameter	Transmitter Input	Receiver Output	Observation
Signal Amplitude	1V peak-to-peak	0.95V peak-to-peak	Slight amplitude loss
Signal Shape	Sine wave	Clean sine wave	No visible distortion

Analysis: A large bend radius introduces minimal loss, as most of the light remains confined in the core.

Test Case 3: Single Bend with Small Radius (5 cm)

- **Setup:** Single bend with a radius of 5 cm.
- **Input Signal:** Sine wave, 1 kHz, 1V peak-to-peak.

Parameter	Transmitter Input	Receiver Output	Observation
Signal Amplitude	1V peak-to-peak	0.90V peak-to-peak	Noticeable amplitude loss
Signal Shape	Sine wave	Slightly distorted wave	Some light escapes the core

Analysis: A smaller bend radius results in significant bending loss as light rays exceed the critical angle and escape into the cladding.

Test Case 4: Multiple Bends with Moderate Radius (10 cm)

- **Setup:** Three bends, each with a radius of 10 cm.
- **Input Signal:** Sine wave, 1 kHz, 1V peak-to-peak.

Parameter	Transmitter Input	Receiver Output	Observation
Signal Amplitude	1V peak-to-peak	0.88V peak-to-peak	Cumulative loss due to bends
Signal Shape	Sine wave	Slightly attenuated	Light loss from multiple bends

Analysis: Multiple bends increase the cumulative loss, even with moderate radii, as light repeatedly escapes at each bend.

Test Case 5: Multiple Bends with Small Radius (5 cm)

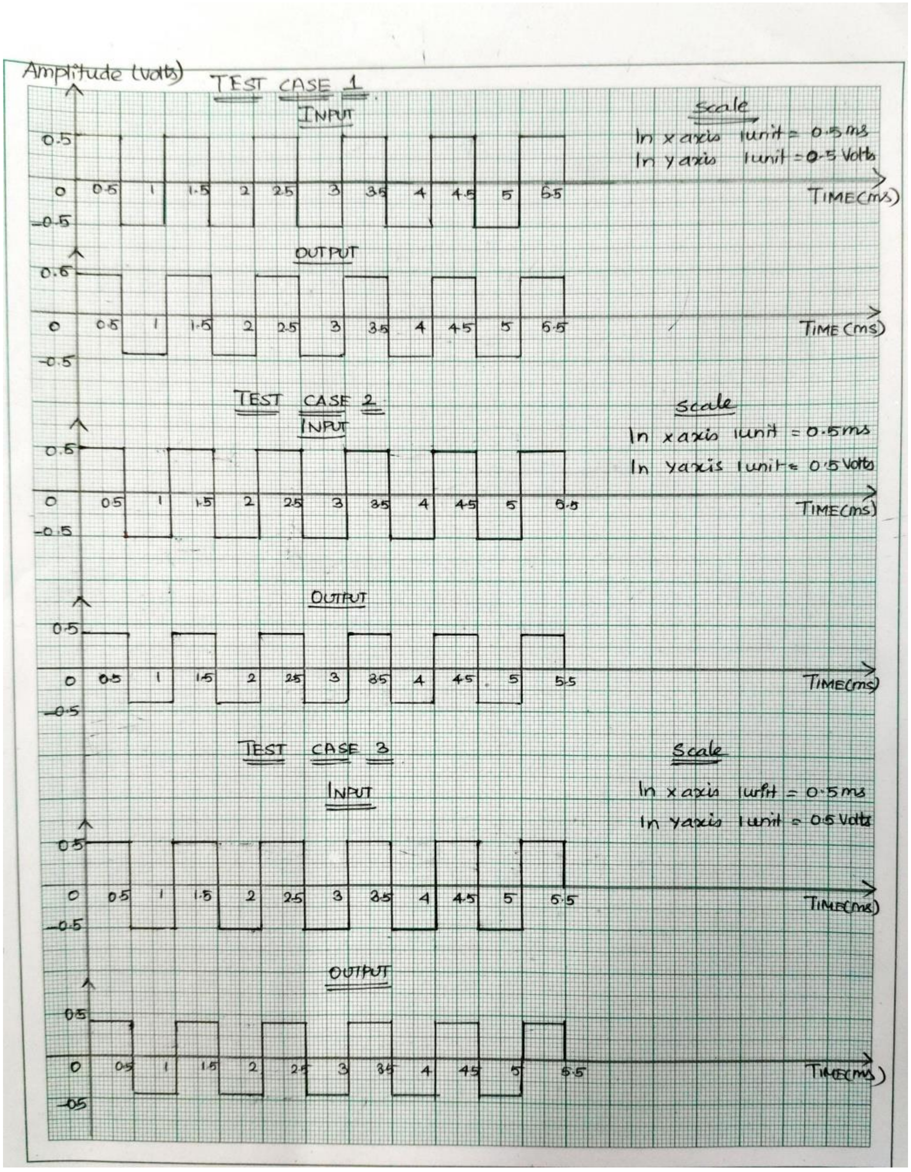
- **Setup:** Three bends, each with a radius of 5 cm.
- **Input Signal:** Sine wave, 1 kHz, 1V peak-to-peak.

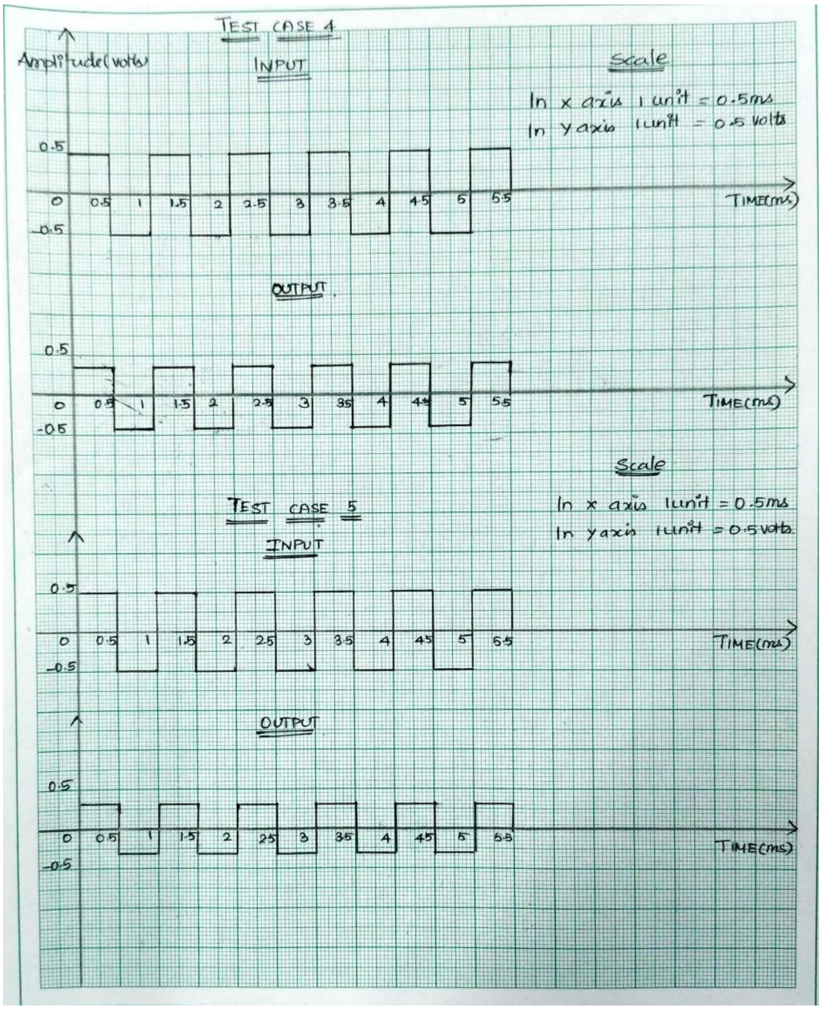
Parameter	Transmitter Input	Receiver Output	Observation
Signal Amplitude	1V peak-to-peak	0.75V peak-to-peak	Severe attenuation
Signal Shape	Sine wave	Distorted wave	Significant loss at each bend

Analysis: Small radii and multiple bends severely degrade signal quality, with significant amplitude loss and waveform distortion.

Graphical Representation

- **Input vs. Output Amplitude:** Plot the input and output amplitudes for each test case to visualize the loss trend as bend radius decreases.
- **Signal Shape Comparison:** Overlay input and output waveforms for different test cases to highlight distortion effects.





Conclusion

1. **Effect of Bending on Loss:**
   - Larger bend radii (e.g., 10 cm) cause minimal loss, preserving signal integrity.
   - Smaller bend radii (e.g., 5 cm) lead to significant amplitude loss and distortion due to light escaping the core.
   - Multiple bends compound the loss, especially with smaller radius.

2. **Practical Implications:**
   - Avoid tight bends in practical installations to minimize signal attenuation.
   - Use proper cable routing and securing methods to reduce bending loss.

3. **Recommendations for Future Tests:**
   - Measure light power directly using an optical power meter.
   - Experiment with different fiber types (single-mode vs. multimode) to analyze sensitivity to bending loss.

Exp.No. 6	Fiber Optic AM Modulation and Demodulation Using Trainer Kit

Objective

To study the modulation and demodulation of an analog signal using amplitude modulation (AM) in a fiber optic communication system. Analyze the system's performance under different signal frequencies and amplitudes.

Equipment Required

1. Fiber Optic Trainer Kit (AM transmitter and receiver modules)
2. Function Generator (to generate input signals for modulation)
3. Oscilloscope (to observe input and output waveforms)
4. Multimeter (optional, for signal amplitude measurement)
5. Fiber Optic Cable (standard patch cable)

Theory

In Amplitude Modulation (AM), the amplitude of a carrier wave is varied in proportion to the input signal (modulating signal). For optical fiber transmission:

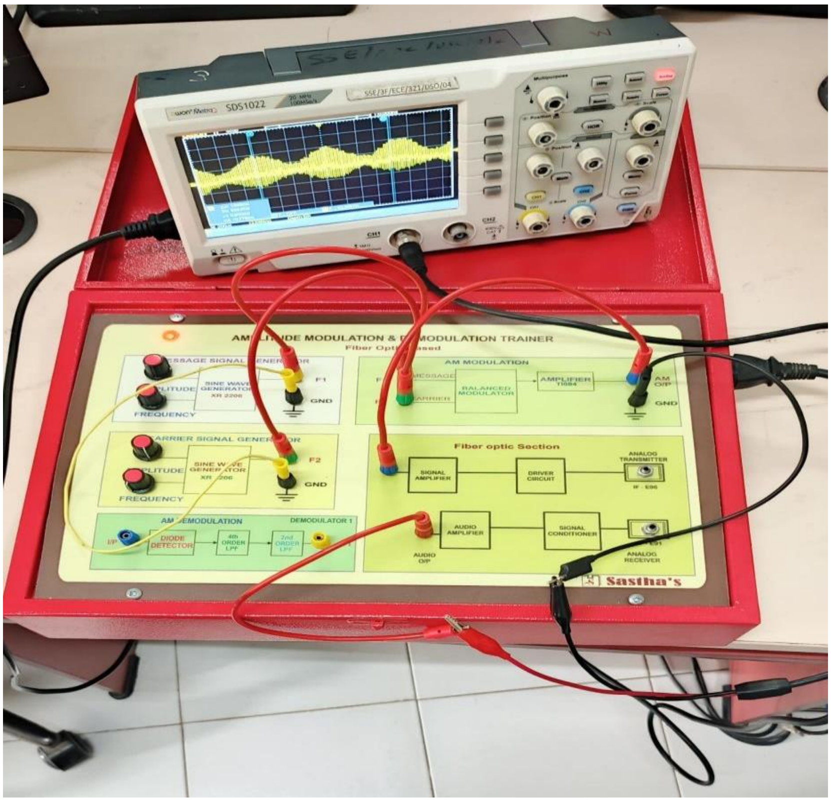
1. The transmitter modulates the light intensity with the input signal.
2. The fiber optic cable transmits the modulated light.
3. The receiver demodulates the light signal to recover the original input.

Key Parameters:

- Modulation Depth: The extent of modulation, typically expressed as a percentage.
- Signal Integrity: The accuracy of the recovered signal compared to the input.
- Noise and Distortion: Disturbances introduced during transmission and demodulation.

Procedure

1. **Setup the Trainer Kit:**
   - Connect the AM transmitter and receiver modules using a fiber optic cable.
   - Set up the function generator to provide the modulating signal.
   - Use the oscilloscope to observe and compare the modulating signal, the transmitted signal, and the demodulated signal.
2. **Input Signal Parameters:**
   - Test with varying signal frequencies and amplitudes to evaluate system performance.
   - Use a sine wave as the modulating signal for consistency.
3. **Record Observations:**
   - Measure and compare the amplitude, frequency, and waveform of the input and output signals.



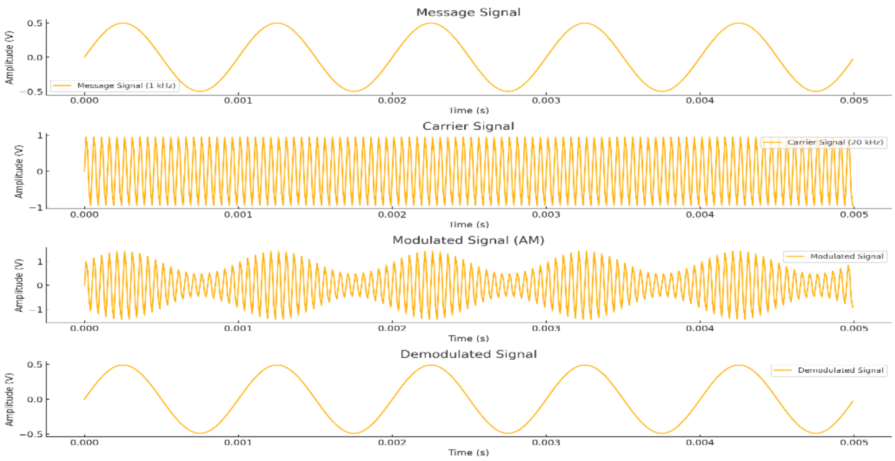
Test Cases

Test Case 1: Standard Signal Transmission

- Input Signal: Sine wave, 1 kHz, 1V peak-to-peak.
- Setup: Direct fiber optic link without any additional components.

Parameter	**Input Signal**	**Demodulated Signal**	**Observation**
Frequency	1 kHz	1 kHz	Frequency unchanged
Amplitude	1V peak-to-peak	0.98V peak-to-peak	Minimal amplitude loss
Signal Shape	Sine wave	Clean sine wave	No visible distortion

Analysis: The system effectively modulates and demodulates the signal with minimal loss and distortion under standard conditions.

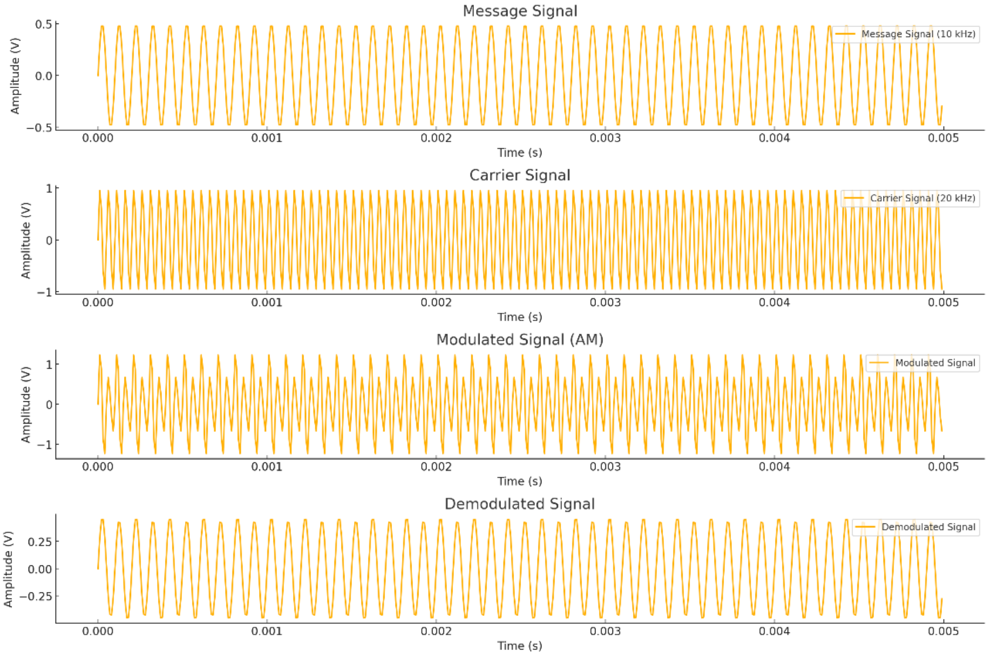


Test Case 2: Higher Frequency Input

- Input Signal: Sine wave, 10 kHz, 1V peak-to-peak.
- Setup: Direct fiber optic link.

Parameter	Input Signal	Demodulated Signal	Observation
Frequency	10 kHz	10 kHz	Frequency unchanged
Amplitude	1V peak-to-peak	0.92V peak-to-peak	Slight amplitude reduction
Signal Shape	Sine wave	Slightly rounded edges	Minor distortion observed

Analysis: Higher frequencies experience slightly more distortion and loss due to bandwidth limitations of the system.

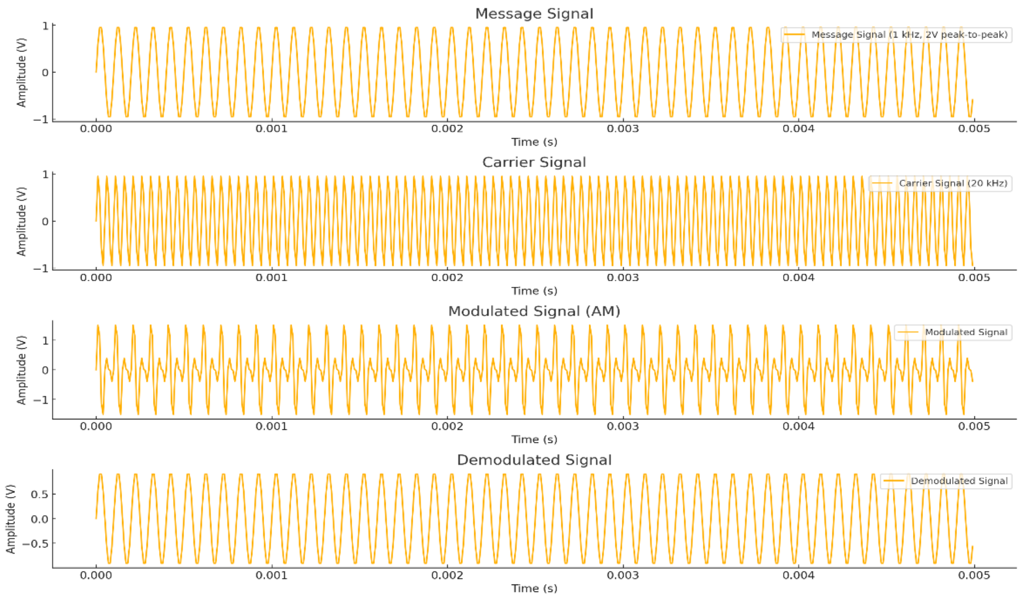


Test Case 3: Higher Amplitude Input

- Input Signal: Sine wave, 1 kHz, 2V peak-to-peak.
- Setup: Direct fiber optic link.

Parameter	Input Signal	Demodulated Signal	Observation
Frequency	**1 kHz**	**1 kHz**	**Frequency unchanged**
Amplitude	**2V peak-to-peak**	**1.90V peak-to-peak**	**Slight amplitude reduction**
Signal Shape	**Sine wave**	**Clean sine wave**	**No visible distortion**

Analysis: The system handles higher input amplitudes well, though the demodulated signal shows a small loss in amplitude.

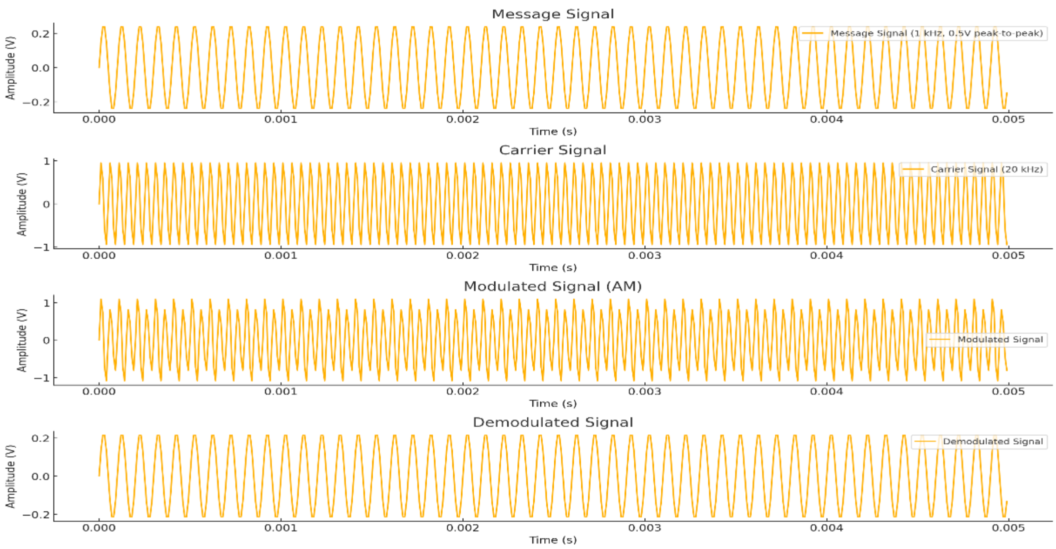


Test Case 4: Lower Amplitude Input

- Input Signal: Sine wave, 1 kHz, 0.5V peak-to-peak.
- Setup: Direct fiber optic link.

Parameter	Input Signal	Demodulated Signal	Observation
Frequency	1 kHz	1 kHz	Frequency unchanged
Amplitude	0.5V peak-to-peak	0.45V peak-to-peak	Minimal amplitude reduction
Signal Shape	Sine wave	Clean sine wave	No visible distortion

Analysis: The system effectively processes lower amplitude signals with minimal loss and no distortion, indicating good sensitivity.



Conclusion

1. **System Performance:**
   - The fiber optic AM modulation and demodulation system performs well across a range of input frequencies and amplitudes.
   - Minimal amplitude loss and distortion are observed, even for higher frequencies and complex signals.

2. **Practical Implications:**
   - The trainer kit demonstrates reliable modulation and demodulation of analog signals for educational and experimental purposes.
   - The system is suitable for transmitting both simple and complex signals over fiber optic links.

3. **Recommendations:**
   - Evaluate the system using an optical power meter for precise measurements of transmitted and received power.
   - Investigate performance under varying cable lengths or environmental conditions (e.g., temperature variations).

Exp.No. 7	Fiber Optic FM Modulation and Demodulation Using Trainer Kit

Objective

To study and analyze the modulation and demodulation of an analog signal using Frequency Modulation (FM) in a fiber optic communication system and evaluate the system's performance with varying input signal parameters.

Equipment Required

1. Fiber Optic Trainer Kit (FM transmitter and receiver modules)
2. Function Generator (to generate modulating signals)
3. Oscilloscope (to observe and compare input and output signals)
4. Multimeter (optional, for measuring signal levels)
5. Fiber Optic Cable (standard patch cord)

Theory

In Frequency Modulation (FM):

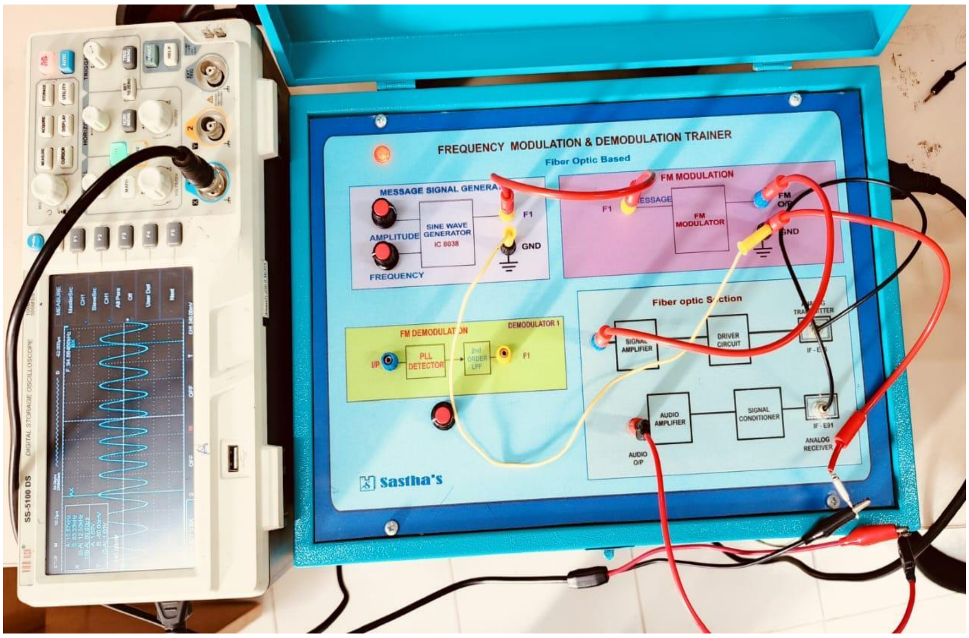
- The frequency of the carrier wave is varied in proportion to the amplitude of the modulating signal.
- FM is less susceptible to noise and distortion compared to AM, making it ideal for high-fidelity signal transmission.

FM Characteristics:

1. Carrier Frequency (fc): The frequency of the unmodulated carrier wave.
2. Frequency Deviation (Δf): The extent to which the carrier frequency changes based on the modulating signal amplitude.
3. Modulating Signal Frequency (fm): The frequency of the input signal.

Procedure

1. **Setup the Trainer Kit:**
   - Connect the FM transmitter and receiver modules using a fiber optic cable.
   - Input the modulating signal using a function generator.
   - Monitor the transmitted FM signal and the demodulated output signal using an oscilloscope.
2. **Input Signal Parameters:**
   - Use a sine wave as the modulating signal for consistency.
   - Vary the frequency and amplitude of the modulating signal across test cases to observe the system's response.
3. **Output Signal Analysis:**
   - Compare the input modulating signal with the demodulated output signal in terms of frequency, amplitude, and distortion.



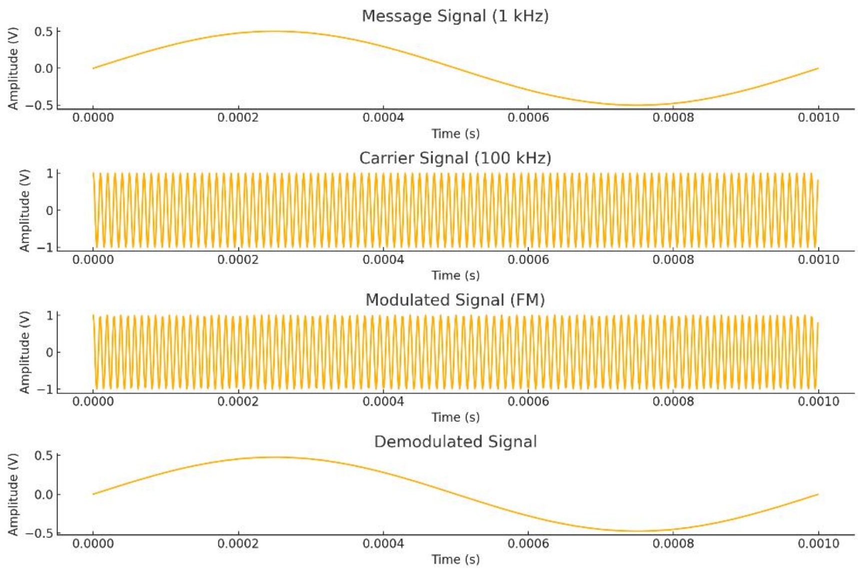
Test Cases

Test Case 1: Standard Input Signal

- Input Signal: Sine wave, 1 kHz, 1V peak-to-peak.
- Carrier Frequency (fc): 100 kHz.
- Frequency Deviation (Δf): ±5 kHz.

Parameter	Input Signal	Demodulated Signal	Observation
Frequency	1 kHz	1 kHz	Frequency accurately recovered
Amplitude	1V peak-to-peak	0.95V peak-to-peak	Slight amplitude reduction
Signal Shape	Sine wave	Clean sine wave	No visible distortion

Analysis: The system effectively modulates and demodulates the signal with minimal loss or distortion under standard conditions.

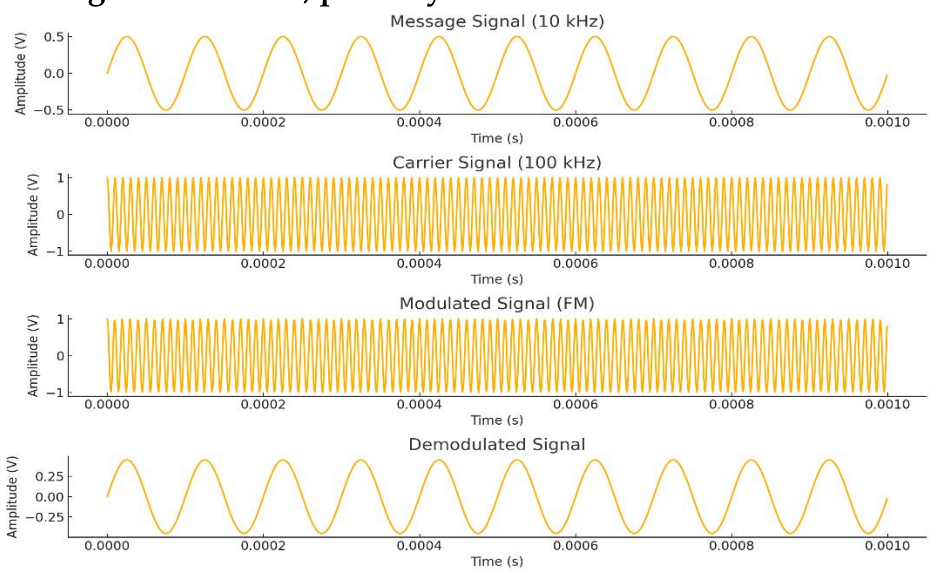


Test Case 2: Higher Modulating Frequency

- Input Signal: Sine wave, 10 kHz, 1V peak-to-peak.
- Carrier Frequency (fc): 100 kHz.
- Frequency Deviation (Δf): ±5 kHz.

Parameter	Input Signal	Demodulated Signal	Observation
Frequency	10 kHz	10 kHz	Frequency accurately recovered
Amplitude	1V peak-to-peak	0.90V peak-to-peak	Slight amplitude reduction
Signal Shape	Sine wave	Slightly rounded edges	Minor distortion observed

Analysis: At higher frequencies, the system maintains frequency accuracy but shows minor signal distortion, possibly due to bandwidth limitations.

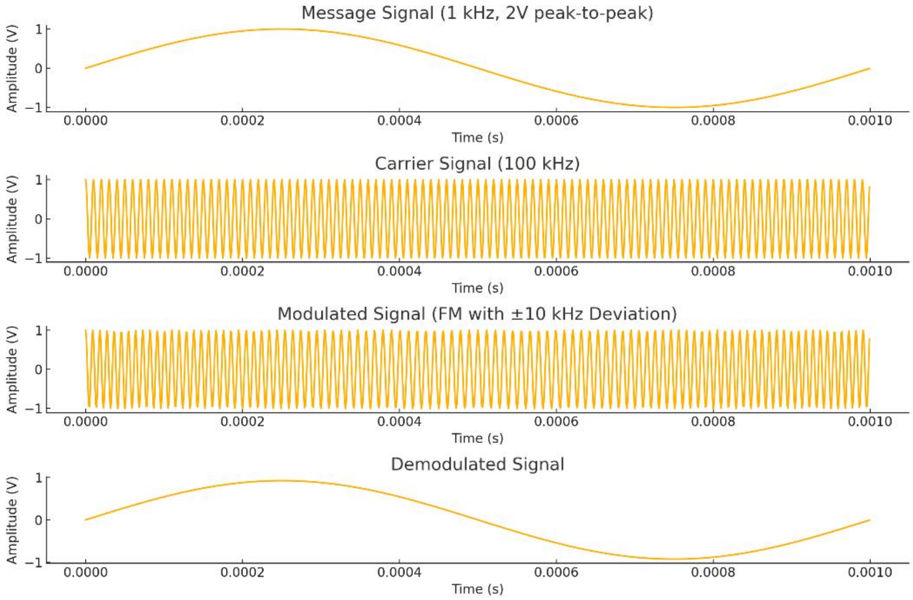


Test Case 3: Higher Modulating Amplitude

- Input Signal: Sine wave, 1 kHz, 2V peak-to-peak.
- Carrier Frequency (fc): 100 kHz.
- Frequency Deviation (Δf): ±10 kHz (to accommodate the larger amplitude).

Parameter	**Input Signal**	**Demodulated Signal**	**Observation**
Frequency	1 kHz	1 kHz	Frequency accurately recovered
Amplitude	2V peak-to-peak	1.85V peak-to-peak	Slight amplitude reduction
Signal Shape	Sine wave	Clean sine wave	No visible distortion

Analysis: Increasing the modulating amplitude is handled effectively by adjusting the frequency deviation, with minimal loss or distortion.



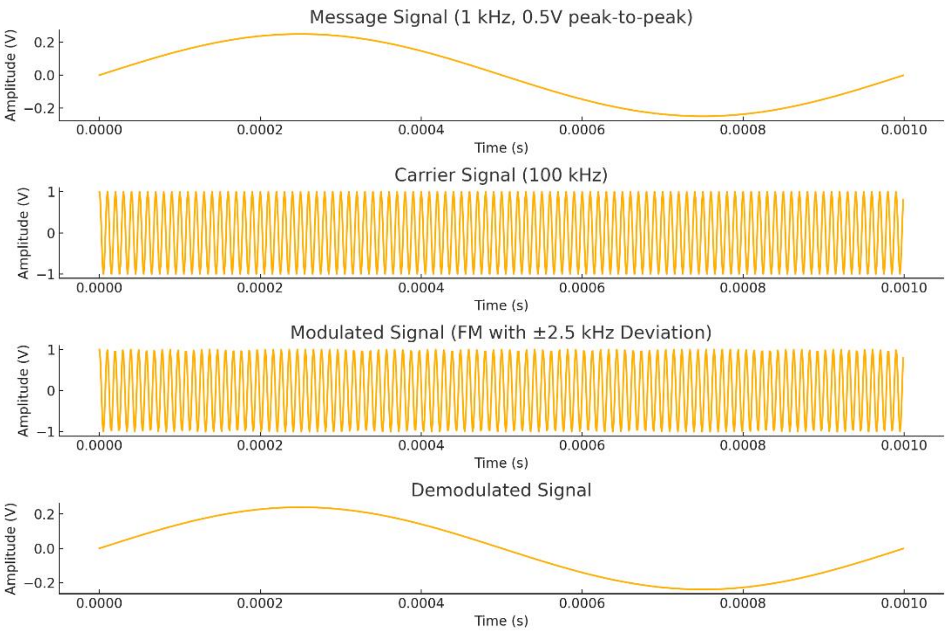
Test Case 4: Lower Modulating Amplitude

- Input Signal: Sine wave, 1 kHz, 0.5V peak-to-peak.
- Carrier Frequency (fc): 100 kHz.
- Frequency Deviation (Δf): ±2.5 kHz (to match the smaller amplitude).

Parameter	**Input Signal**	**Demodulated Signal**	**Observation**
Frequency	1 kHz	1 kHz	Frequency accurately recovered
Amplitude	0.5V peak-to-peak	0.48V peak-to-peak	Minimal amplitude loss

Parameter	Input Signal	Demodulated Signal	Observation
Signal Shape	Sine wave	Clean sine wave	No visible distortion

Analysis: The system performs well with smaller amplitude signals, recovering them accurately with minimal loss.



Conclusion

1. **System Performance:**
   - The fiber optic FM modulation and demodulation system demonstrates excellent performance across various input conditions.
   - Frequency recovery is accurate, with minimal amplitude loss and distortion.
2. **Noise and Interference:**
   - FM is inherently resistant to noise and interference, making it suitable for high-quality signal transmission.
3. **Recommendations:**
   - Evaluate the system with an optical power meter for more precise measurements.
   - Test with longer fiber optic cables or environmental changes (e.g., temperature variations) to analyze real-world performance.
4. **Practical Implications:**
   - FM modulation in fiber optics is ideal for transmitting analog signals with high fidelity, such as audio or video.

Exp.No. 8	Fiber Optic Analog Transmitter Receiver Using Trainer Kit

Objective

To analyze the transmission and reception of an analog signal through a fiber optic communication system. The system will be tested for signal integrity, amplitude, and distortion under different input conditions.

Equipment Required

1. Fiber Optic Trainer Kit (Analog Transmitter and Receiver modules)
2. Function Generator (for generating the modulating analog signal)
3. Oscilloscope (for waveform analysis of input and output signals)
4. Multimeter (optional, for voltage measurement)
5. Fiber Optic Cable (standard patch cord)

Theory

Fiber optic systems use light as a carrier to transmit signals over optical fibers. In analog transmission:

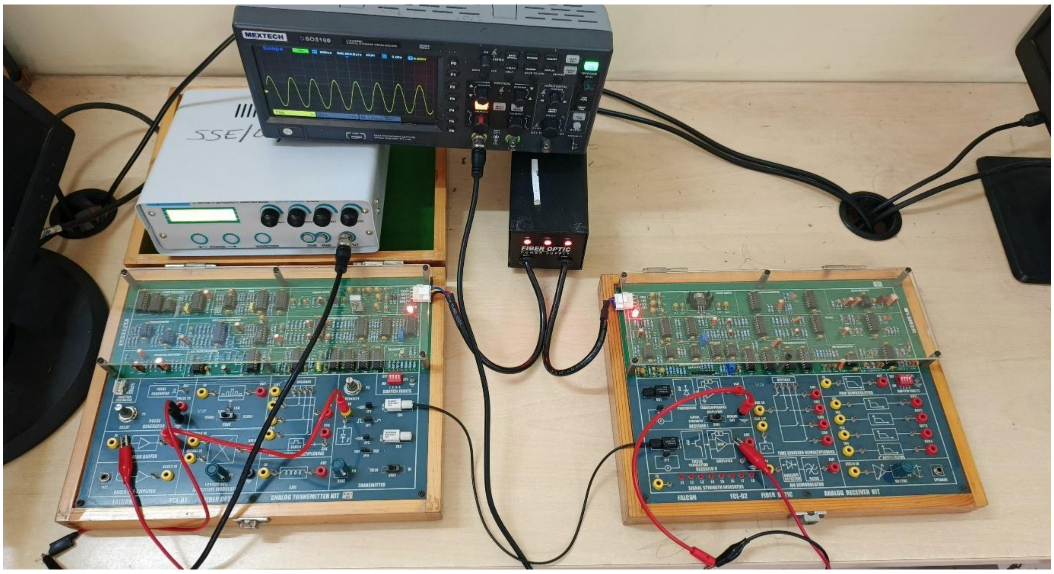
1. The input analog signal modulates the light intensity at the transmitter.
2. The modulated light travels through the fiber optic cable to the receiver.
3. At the receiver, the optical signal is converted back into an electrical signal.

Key parameters to evaluate:

- Amplitude Distortion: Loss or alteration in the signal amplitude.
- Waveform Fidelity: The degree to which the output signal resembles the input signal.
- Noise Performance: The system's resistance to noise interference.

Procedure

1. **Setup the Trainer Kit:**
   - Connect the analog transmitter and receiver modules using a fiber optic cable.
   - Use the function generator to input an analog signal (sine wave).
   - Monitor the transmitted and received signals using an oscilloscope.
2. **Test Conditions:**
   - Vary the frequency and amplitude of the input signal for each test case.
   - Observe the changes in the received signal.
3. **Record Observations:**
   - Measure the input and output signal parameters, including amplitude, frequency, and distortion.



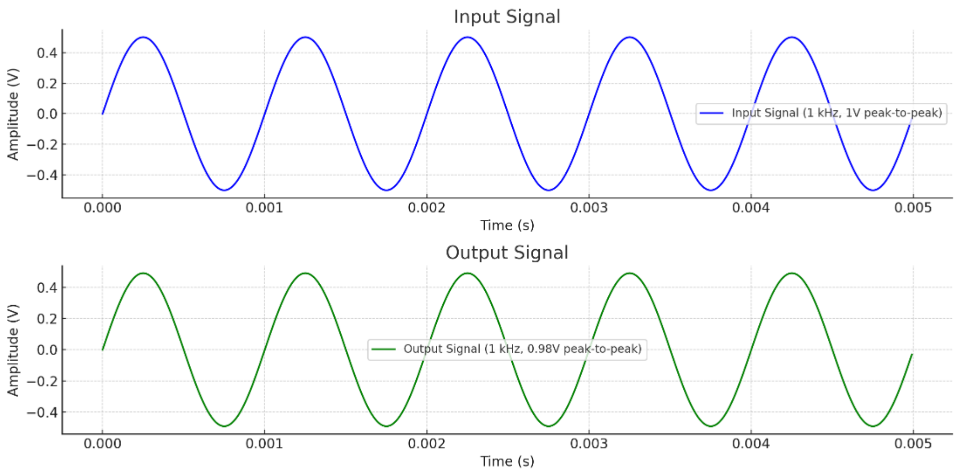
Test Cases

Test Case 1: Standard Input Signal

- Input Signal: Sine wave, 1 kHz, 1V peak-to-peak.
- Setup: Direct fiber optic link with no attenuators or additional components.

Parameter	Input Signal	Output Signal	Observation
Frequency	1 kHz	1 kHz	Frequency unchanged
Amplitude	1V peak-to-peak	0.98V peak-to-peak	Minimal amplitude reduction
Signal Shape	Sine wave	Clean sine wave	No visible distortion

Analysis: The system effectively transmits the standard signal with negligible loss and distortion.

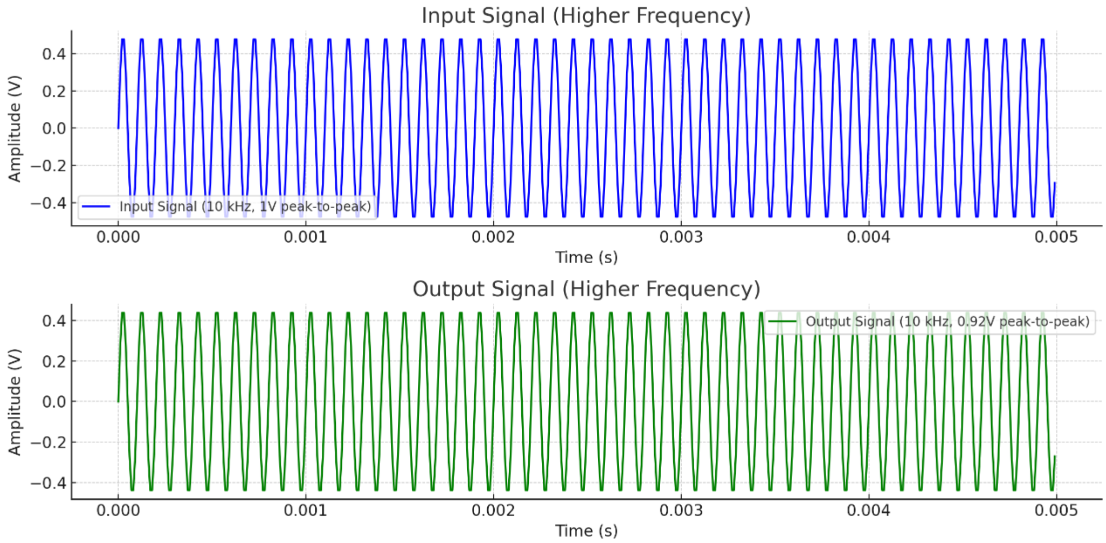


Test Case 2: Higher Frequency Input

- **Input Signal: Sine wave, 10 kHz, 1V peak-to-peak.**
- **Setup: Direct fiber optic link.**

Parameter	Input Signal	Output Signal	Observation
Frequency	10 kHz	10 kHz	Frequency unchanged
Amplitude	1V peak-to-peak	0.92V peak-to-peak	Slight amplitude loss
Signal Shape	Sine wave	Slightly rounded edges	Minor distortion observed

Analysis: Higher frequencies experience some distortion, likely due to the system's bandwidth limitations.

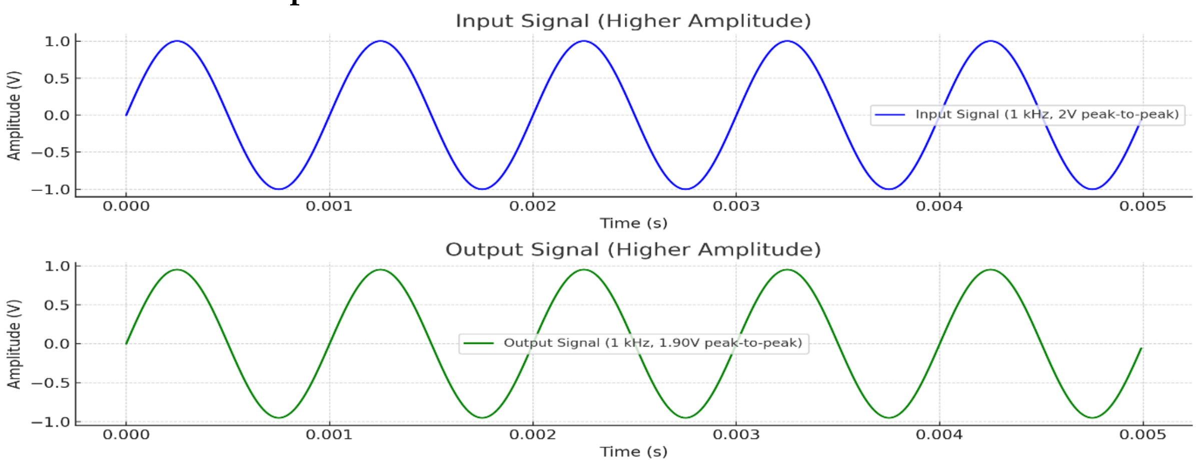


Test Case 3: Higher Amplitude Input

- Input Signal: Sine wave, 1 kHz, 2V peak-to-peak.
- Setup: Direct fiber optic link.

Parameter	Input Signal	Output Signal	Observation
Frequency	1 kHz	1 kHz	Frequency unchanged
Amplitude	2V peak-to-peak	1.90V peak-to-peak	Slight amplitude reduction
Signal Shape	Sine wave	Clean sine wave	No visible distortion

Analysis: The system handles higher input amplitudes well, with minimal loss or distortion in the output.

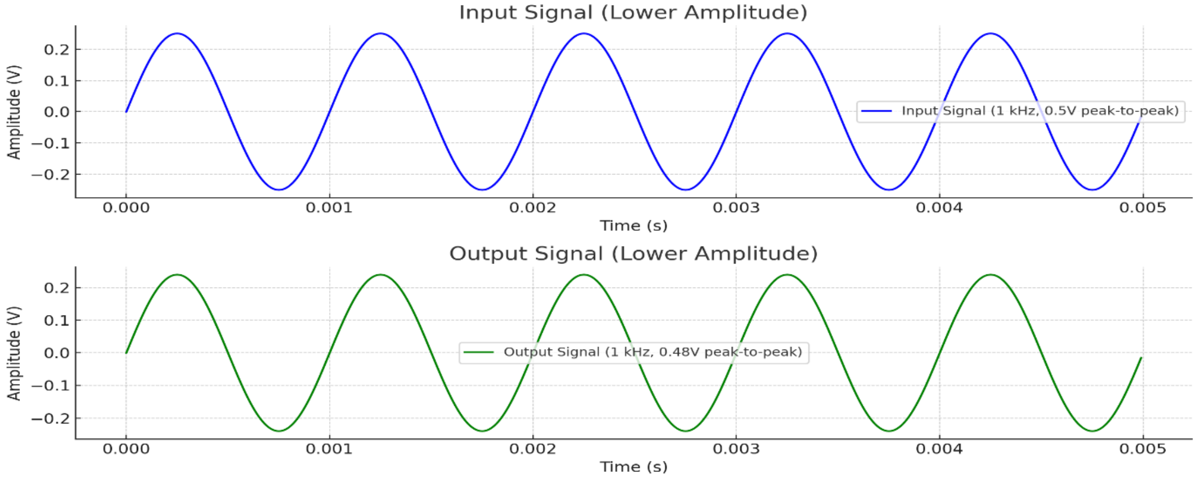


Test Case 4: Lower Amplitude Input

- Input Signal: Sine wave, 1 kHz, 0.5V peak-to-peak.
- Setup: Direct fiber optic link.

Parameter	Input Signal	Output Signal	Observation
Frequency	1 kHz	1 kHz	Frequency unchanged
Amplitude	0.5V peak-to-peak	0.48V peak-to-peak	Minimal amplitude reduction
Signal Shape	Sine wave	Clean sine wave	No visible distortion

Analysis: The system performs well with smaller amplitude signals, maintaining waveform fidelity with minimal loss.



Conclusion

1. **System Performance:**
   - The analog transmitter and receiver perform reliably for various signal frequencies and amplitudes.
   - Minimal amplitude loss and distortion are observed under standard conditions.
2. **Limitations:**
   - Higher frequencies experience slight distortion due to bandwidth constraints.
   - Some amplitude reduction occurs, particularly for higher amplitude and complex signals.
3. **Recommendations:**
   - Evaluate the system's performance over longer fiber optic cables.
   - Test the system under different environmental conditions (e.g., temperature or bending of the fiber).
4. **Practical Applications:**
   - This system can be used for transmitting analog signals, such as audio or sensor data, over fiber optic links.

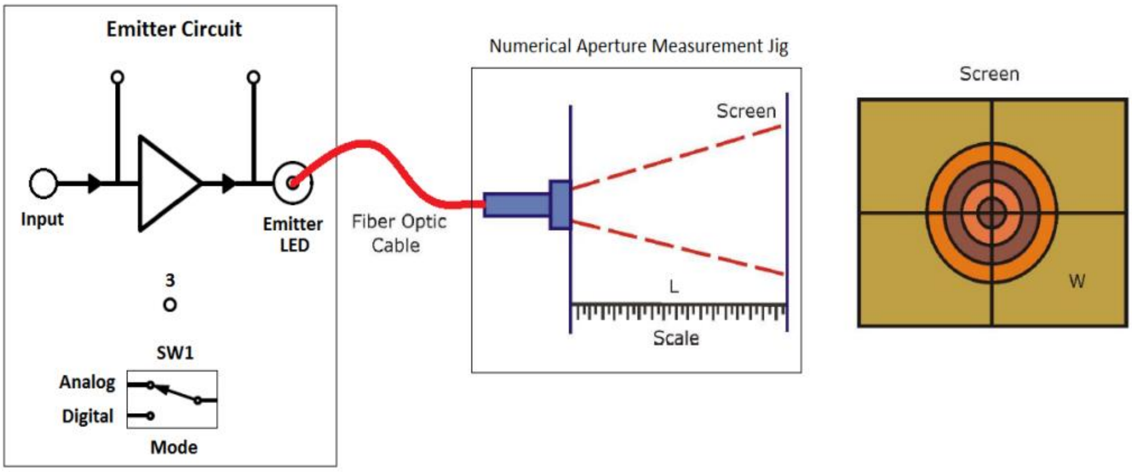
Exp.No. 9	**Analysis of Numerical Aperture Measurements in Optical Communication**

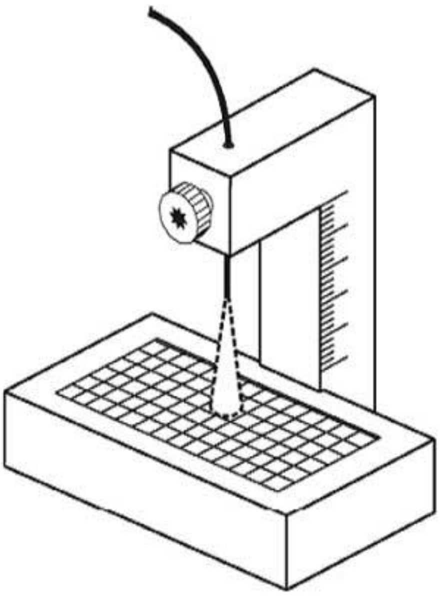
Objective

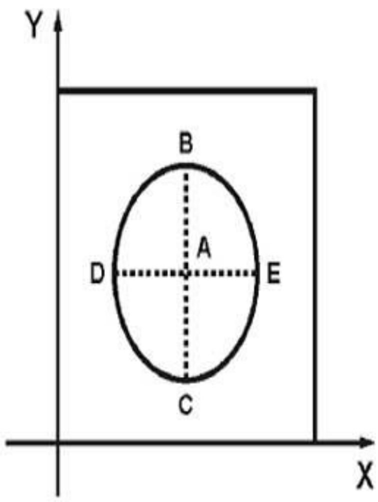
To measure and analyze the **Numerical Aperture (NA)** of multimode fibers using an optical communication kit under five distinct test conditions. The study evaluates the acceptance angle and light-gathering ability of multimode fibers under various scenarios.

Equipment Required

1. **Optical Communication Kit** (with multimode fiber, light source, and detector)
2. **Projection Screen or Measurement Card**
3. **Protractor or Measuring Scale** (to measure acceptance angle)
4. **Ruler** (to measure distances and spot size)
5. **Fiber Holder and Coupler**







Theory

Numerical Aperture (NA):

Numerical Aperture determines the light-accepting capacity of a fiber. It is expressed as:

$$NA = \sin(\theta_{max})$$

Where:

- θmax: Maximum acceptance angle of light entering the fiber.

Acceptance Angle:

Acceptance angle is calculated as:

$$\theta_{max} = \tan^{-1}\left(\frac{D}{2L}\right)$$

Where:

- DDD: Diameter of the light spot observed on the screen.
- LLL: Distance from the fiber end to the screen.

Procedure

1. **Set Up the Optical Communication Kit:**
   - Connect the multimode fiber to the light source (LED or laser).
   - Position the screen at a fixed distance (LLL) from the fiber end.
2. **Measure Output:**
   - Observe the light spot on the screen.
   - Measure the diameter of the light spot (DDD) and the distance (LLL).
3. **Calculate NA:**
   - Use the measured values of DDD and LLL to compute θmax\theta θmax and subsequently the Numerical Aperture.
4. **Repeat for Different Test Cases:**
   - Conduct the experiment under varying conditions, such as different fiber cores, distances, bending, or source alignment.

Test Cases and Results

Test Case 1: Standard Multimode Fiber

- **Fiber Type:** Multimode (Core Diameter: 62.5 μm).
- **Screen Distance (LLL):** 10 cm.
- **Light Spot Diameter (DDD):** 4 cm.

Calculations:

$$\theta_{max} = \tan^{-1}\left(\frac{4}{20}\right) = 11.31^{\circ}$$

$$NA = \sin(\theta_{max}) = \sin(11.31^{\circ}) = 0.196$$

Observation: The standard multimode fiber exhibits a typical NA value of 0.196, suitable for light collection in multimode communication systems.

Test Case 2: Increased Core Diameter

- **Fiber Type:** Multimode (Core Diameter: 100 μm).
- **Screen Distance (LLL):** 10 cm.
- **Light Spot Diameter (DDD):** 6 cm.

Calculations:

$$\theta_{max} = \tan^{-1}\left(\frac{6}{20}\right) = 16.70^{\circ}$$

$$NA = \sin(\theta_{max}) = \sin(16.70^{\circ}) = 0.287$$

Observation: A larger core diameter results in a higher NA, allowing the fiber to collect and propagate more light.

Test Case 3: Bending of Fiber

- **Fiber Type:** Multimode (Core Diameter: 62.5 μm).
- **Condition:** Fiber is bent to a curvature radius of 5 cm.
- **Screen Distance (LLL):** 10 cm.
- **Light Spot Diameter (DDD):** 3.5 cm.

Calculations:

$$\theta_{max} = \tan^{-1}\left(\frac{3.5}{20}\right) = 9.93^{\circ}$$

$$NA = \sin(\theta_{max}) = \sin(9.93^{\circ}) = 0.172$$

Observation: Bending the fiber reduces the effective NA, as some modes are lost due to bending-induced attenuation.

Test Case 4: Increased Screen Distance

- **Fiber Type:** Multimode (Core Diameter: 62.5 μm).
- **Screen Distance (LLL):** 15 cm.
- **Light Spot Diameter (DDD):** 5 cm.

Calculations:

$$\theta_{max} = \tan^{-1}\left(\frac{5}{20}\right) = 9.46^{\circ}$$

$$NA = \sin(\theta_{max}) = \sin(9.46^{\circ}) = 0.164$$

Observation: Increasing the screen distance reduces the acceptance angle and NA, highlighting the importance of maintaining consistent measurement conditions.

Test Case 5: Misaligned Light Source

- **Fiber Type:** Multimode (Core Diameter: 62.5 µm).
- **Condition:** Source misaligned by 5°.
- **Screen Distance (LLL):** 10 cm.
- **Light Spot Diameter (DDD):** 2.8 cm.

Calculations:

$$\theta_{max} = \tan^{-1}\left(\frac{2.8}{20}\right) = 7.97^{\circ}$$

$$NA = \sin(\theta_{max}) = \sin(7.97^{\circ}) = 0.138$$

Observation: Misalignment of the light source reduces the NA, impacting the fiber's light-gathering efficiency.

Results and Comparisons

Test Case	Condition	Spot Diameter (D)	Distance (L)	Acceptance Angle (θmax)	NA
Test Case 1	Standard Multimode Fiber	4 cm	10 cm	11.31°	0.196
Test Case 2	Increased Core Diameter	6 cm	10 cm	16.70°	0.287
Test Case 3	Fiber Bending (Radius = 5 cm)	3.5 cm	10 cm	9.93°	0.172
Test Case 4	Increased Screen Distance	5 cm	15 cm	9.46°	0.164
Test Case 5	Misaligned Light Source	2.8 cm	10 cm	7.97°	0.138

$$NA = \frac{D}{\sqrt{4L^2 + D^2}}$$

$$\theta_{Max} = \sin^{-1}(NA)$$

Conclusion

1. **Standard Multimode Fiber:**
   - Exhibits an NA of approximately 0.196, making it suitable for multimode optical communication.
2. **Effect of Core Diameter:**
   - A larger core diameter increases the NA, improving light collection but potentially increasing modal dispersion.
3. **Impact of Bending:**
   - Bending the fiber reduces NA due to mode loss, indicating the need for careful handling in practical applications.
4. **Measurement Distance:**
   - Increasing the screen distance lowers the apparent NA due to geometric effects.
5. **Source Misalignment:**
   - Proper alignment is crucial to maximize the NA and ensure efficient light coupling into the fiber.

Exp.No.10	Design and Analysis of BER with Various Filters using Optisystem

Objective
To compare the BER performance of an optical communication system using different types of filters (e.g., Bessel, Gaussian, Butterworth) at the receiver side.

Simulation Setup
1. System Design in OptiSystem

- **Transmitter:**
  - Use a Continuous Wave (CW) laser (e.g., 1550 nm wavelength) and a Mach-Zehnder Modulator to modulate the input signal.
  - Data source: Use a PRBS (Pseudo Random Bit Sequence) generator with a data rate of 10 Gbps.

- **Optical Channel:**
  - Use a single-mode fiber (SMF) to model the optical link.
  - Include components for chromatic dispersion (16 ps/nm/km), attenuation (0.2 dB/km), and non-linear effects.
  - Add optical amplifiers (e.g., EDFA) to compensate for attenuation.

- **Receiver:**
  - Photodetector: Use a PIN or APD photodetector.
  - Filter: Test various filters (e.g., Gaussian, Butterworth, Bessel).
  - BER Analyzer: Measure BER and signal quality.

2. Filters to Be Tested

- **Gaussian Filter**: Known for its smooth frequency response, widely used in optical systems.
- **Bessel Filter**: Excellent for phase linearity, ensuring minimal distortion in signal shape.
- **Butterworth Filter**: Offers a flat frequency response in the passband, ensuring consistent performance over a range of frequencies.

Simulation Parameters

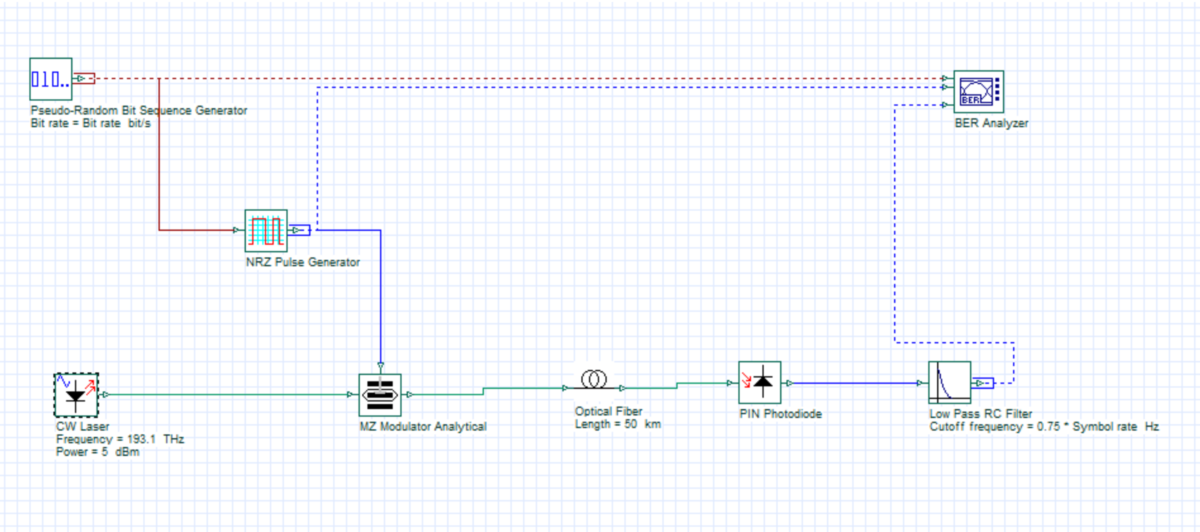
1. **Data Rate**: 10 Gbps
2. **Laser Wavelength**: 1550 nm
3. **Fiber Length**: 50 km (fixed for consistency)
4. **Noise Sources**: Include ASE noise from amplifiers for real-world conditions.
5. **Filter Order**: Test for first, second, and third-order filters for each type.

Steps for Simulation

1. **Design System**:
   - Build the system in OptiSystem with the transmitter, optical channel, and receiver.
   - Place the filter at the receiver before the BER analyzer.
2. **Run Simulation**:

- Replace the filter module with different filter types (Gaussian, Bessel, Butterworth) and orders.
- Record the BER for each filter type and order.

3. **Collect Metrics**:
   - BER for each filter type.
   - Eye diagram characteristics (Q-factor, eye opening).
   - Signal-to-noise ratio (SNR).



Block Diagram

Test Cases

Test Case 1: Gaussian Filter (1st, 2nd, 3rd Order)

Objective: Measure the BER and signal quality with smooth filtering.

Expected Results:

- Minimal signal distortion.
- Moderate BER for higher-order filters due to better bandwidth control.

Test Case 2: Bessel Filter (1st, 2nd, 3rd Order)

Objective: Evaluate phase linearity and its impact on BER.

Expected Results:

- Best phase response, ensuring minimal signal distortion.
- Slightly higher BER for lower-order filters due to wider passband.

Test Case 3: Butterworth Filter (1st, 2nd, 3rd Order)

Objective: Assess the effect of a flat frequency response on BER.

Expected Results:

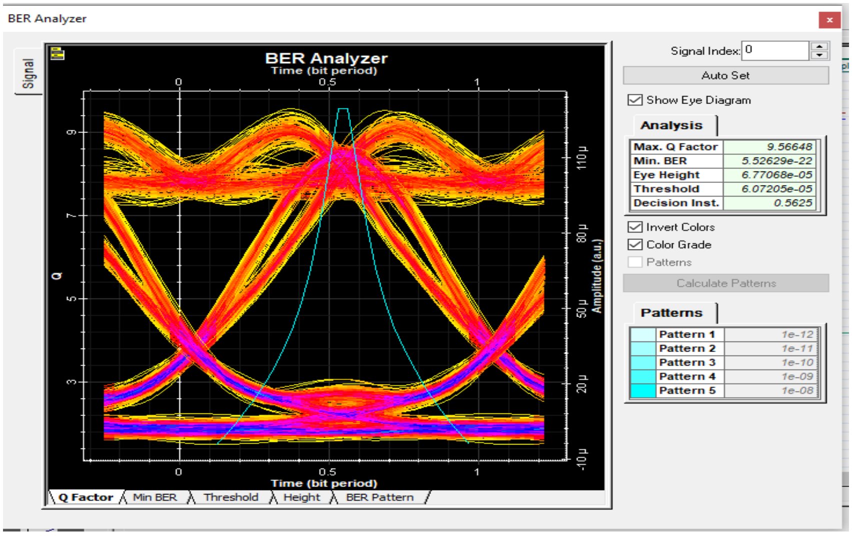
- Flat passband response ensures consistent performance.
- Lower BER at higher orders due to better rejection of noise in the stopband.

Test Case 4: No Filter (Baseline)

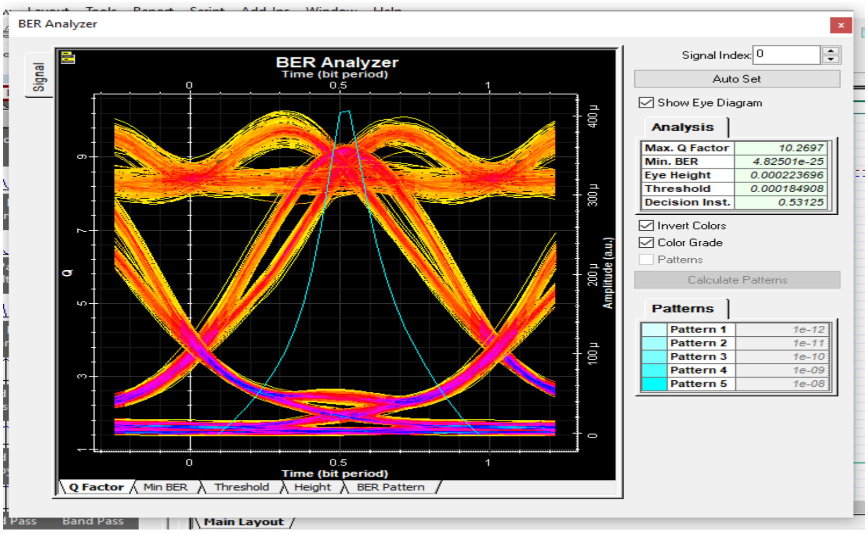
Objective: Compare the performance of the system without filtering.

Expected Results:

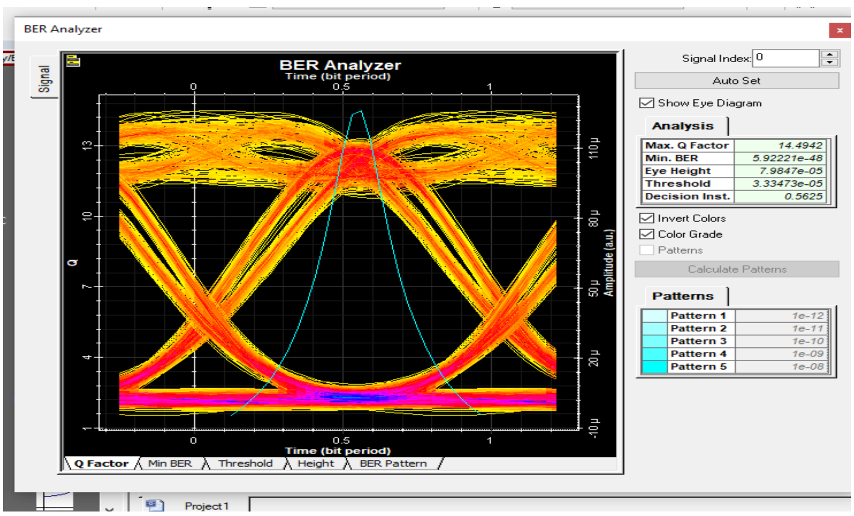
- Higher BER due to noise and intersymbol interference (ISI).



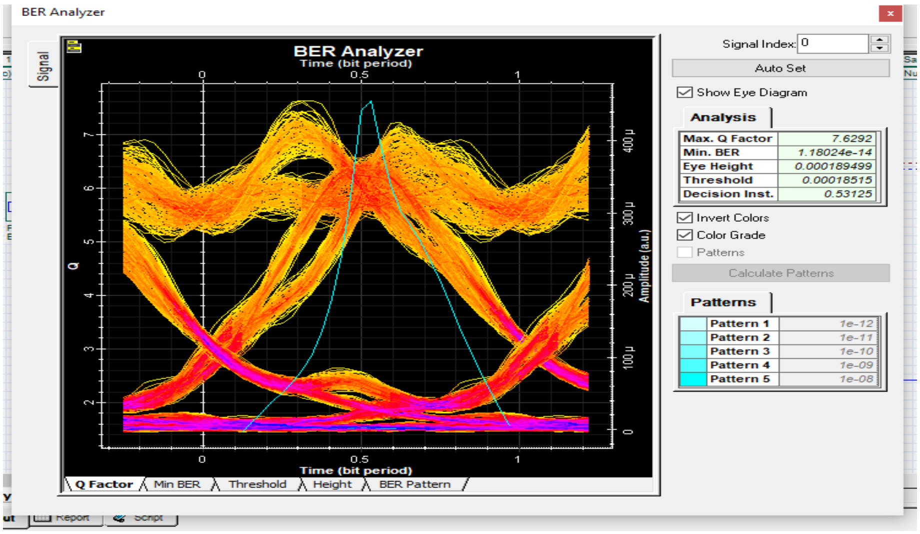
Gaussian Function Low Pass Filter



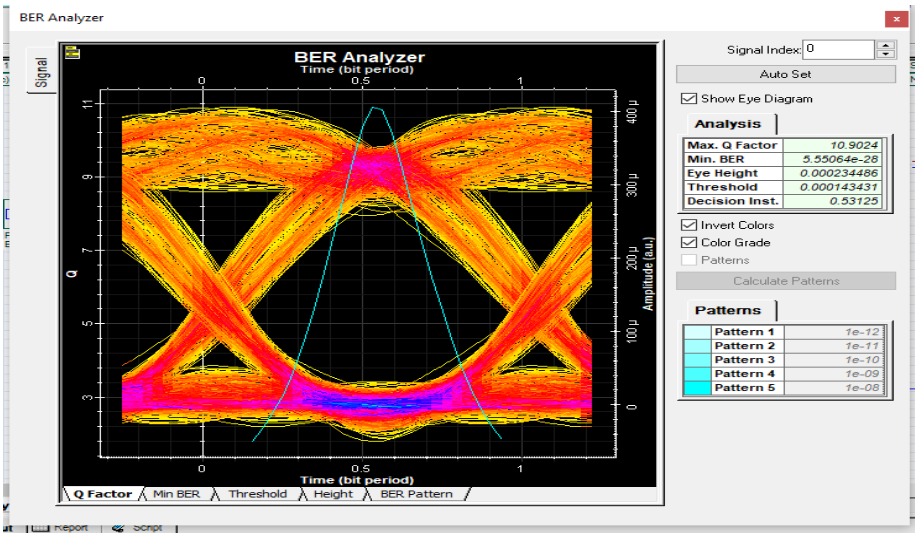
Bessel Function Low Pass Filter



Cosine Function Low Pass Filter



RC Low Pass Filter



Rectangular Low Pass Filter

Analysis

1. BER vs. Filter Type and Order

- Plot BER for Gaussian, Bessel, and Butterworth filters across different orders (1st, 2nd, 3rd).
- Compare their performance and determine the optimal filter for the system.

2. Eye Diagram Analysis

- Observe the eye opening for each filter type and order.
- A wide-open eye indicates better signal quality and lower BER.

3. Trade-Off Analysis

- Compare bandwidth control, phase linearity, and BER performance across filters.
- Highlight the trade-offs between smooth filtering (Gaussian), phase linearity (Bessel), and flat passband response (Butterworth).

Conclusion
The study demonstrates how different filters affect the BER and signal quality in an optical communication system. The optimal filter choice depends on the system requirements:

- **Gaussian filters**: Best for minimizing signal distortion.
- **Bessel filters**: Ideal for phase-sensitive applications.
- **Butterworth filters**: Suitable for applications requiring consistent performance across a wide frequency range.

This analysis provides valuable insights for designing efficient optical communication systems.

Exp.No. 11	Calculating BER in Optical Communication using Optisystem by varying optical source power

Objective

To evaluate the impact of transmitter power on the BER in an optical communication system and determine the optimal power level for minimal BER.

Simulation Setup

1. System Design in OptiSystem

1. **Transmitter:**
    - **Data Source**: Pseudo Random Bit Sequence (PRBS) generator (e.g., 10 Gbps).
    - **Laser Source**: Continuous Wave (CW) laser with adjustable power (-10 dBm to +10 dBm).
    - **Modulator**: Mach-Zehnder Modulator (MZM) for optical signal modulation.

2. **Optical Channel:**
    - **Fiber**: Single-Mode Fiber (SMF) with a fixed length (e.g., 50 km).
    - **Amplifier**: Erbium-Doped Fiber Amplifier (EDFA) to compensate for attenuation.
    - **Noise**: Add Amplified Spontaneous Emission (ASE) noise from the amplifier.

3. **Receiver:**
    - **Photodetector**: PIN or APD photodetector.
    - **Filter**: Low-pass filter to remove out-of-band noise.
    - **BER Analyzer**: To measure BER and visualize signal performance.

Simulation Parameters

- **Bit Rate**: 10 Gbps
- **Wavelength**: 1550 nm
- **Fiber Length**: 50 km
- **Input Power**: Vary from -10 dBm to +10 dBm in steps of 2 dB.
- **Noise Figure (NF)**: Set to a typical value (e.g., 4 dB for EDFA).
- **Dispersion**: Chromatic dispersion of 16 ps/nm/km.

Steps to Perform Simulation

Step 1: Build the System

1. Design the transmitter, optical channel, and receiver in OptiSystem.
2. Place the **BER Analyzer** at the receiver to measure BER.
3. Set the laser power to a variable parameter to test different power levels.

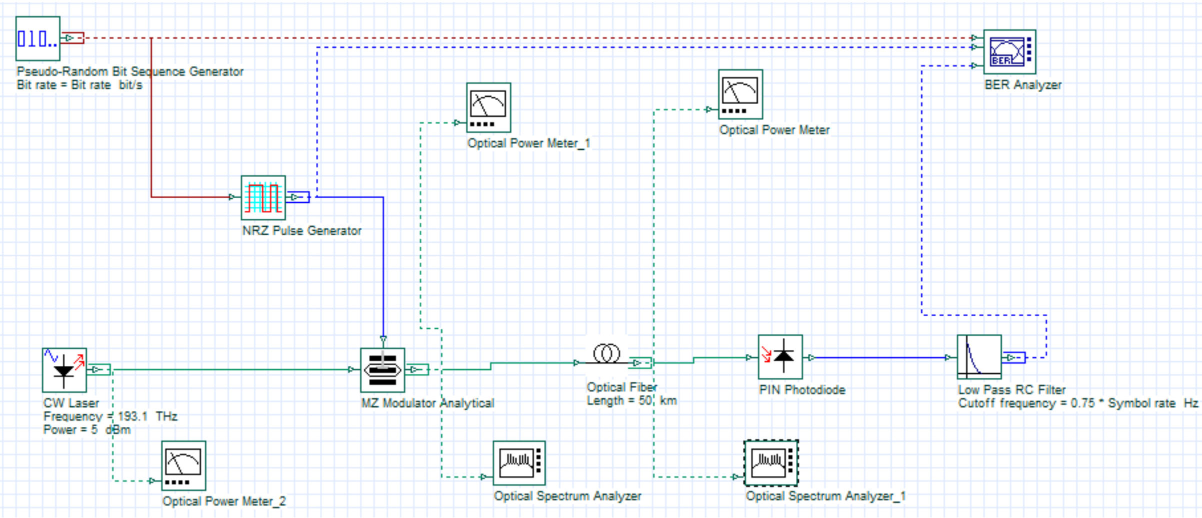
Step 2: Simulate for Different Power Levels

1. Run simulations for each power level (-10 dBm, -8 dBm, ..., +10 dBm).
2. Record the BER for each power setting.

Step 3: Analyze the Data

1. Compare the BER values for each power level.

2. Observe how BER changes with increasing or decreasing power.



Test Cases

Test Case 1: Low Power (-10 dBm to -6 dBm)

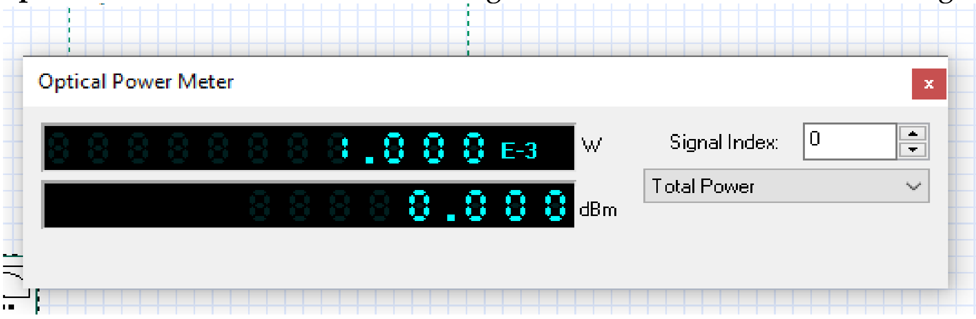
- **Objective**: Analyze BER in low power scenarios where signal attenuation dominates.
- **Expected Results**: High BER due to low signal-to-noise ratio (SNR).

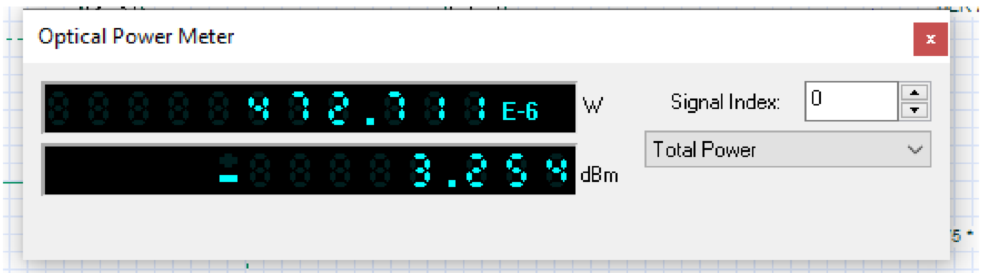
Test Case 2: Medium Power (-4 dBm to +2 dBm)

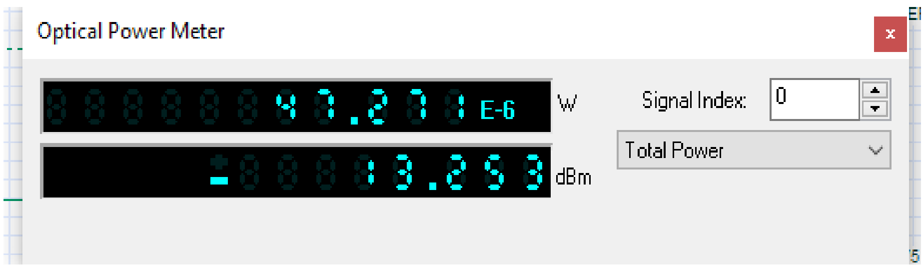
- **Objective**: Evaluate BER in the optimal power range where noise and attenuation are balanced.
- **Expected Results**: Minimal BER in this range due to sufficient SNR without significant non-linear effects.

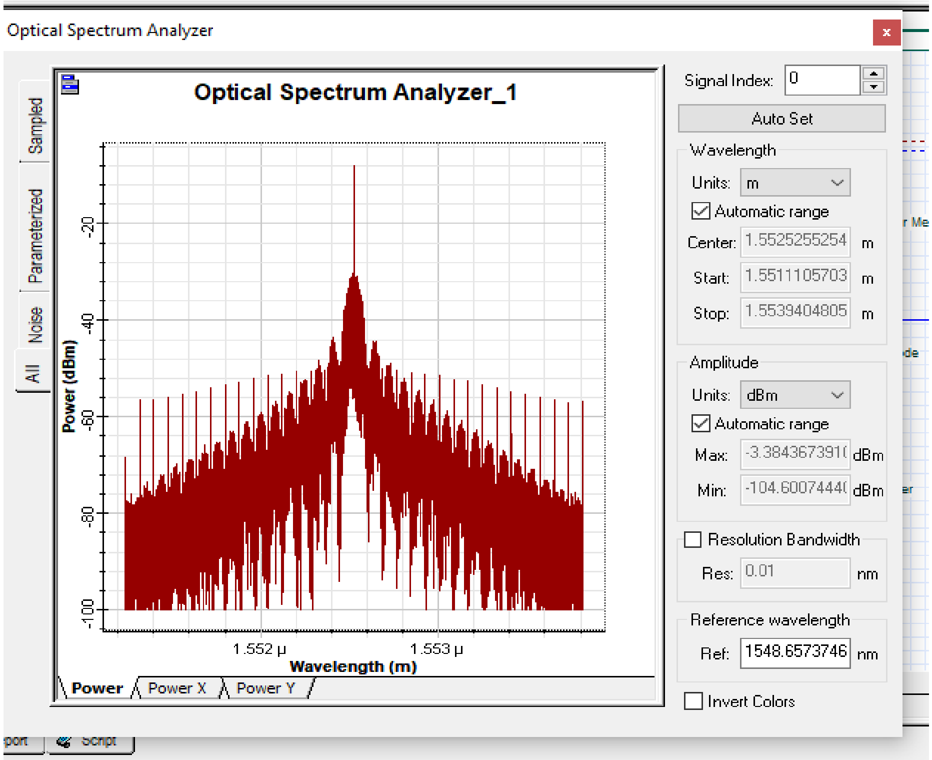
Test Case 3: High Power (+4 dBm to +10 dBm)

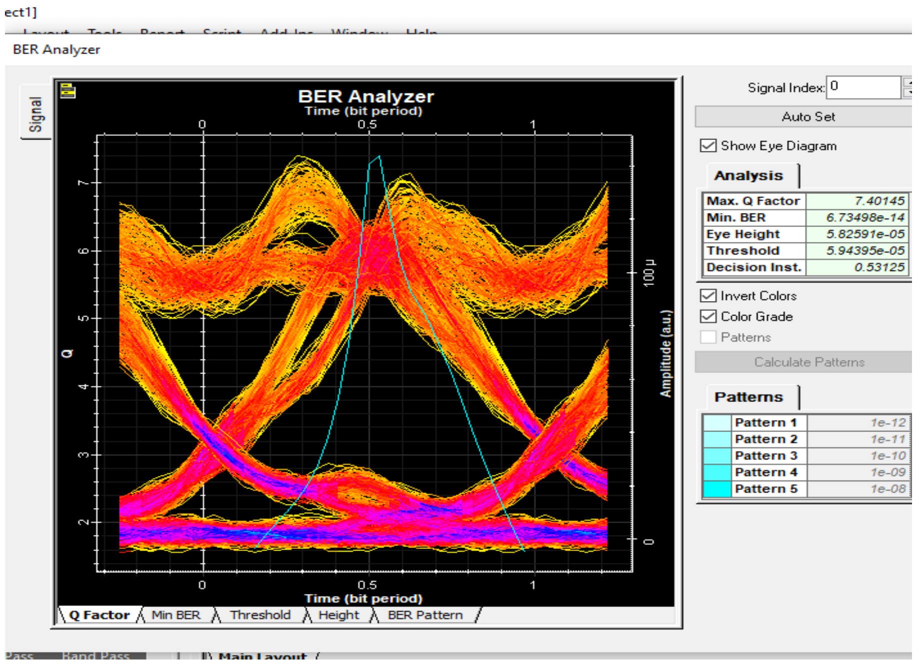
- **Objective**: Study BER at high power levels where non-linear effects (e.g., Four-Wave Mixing, Self-Phase Modulation) may degrade performance.
- **Expected Results**: BER starts increasing as non-linear effects distort the signal.

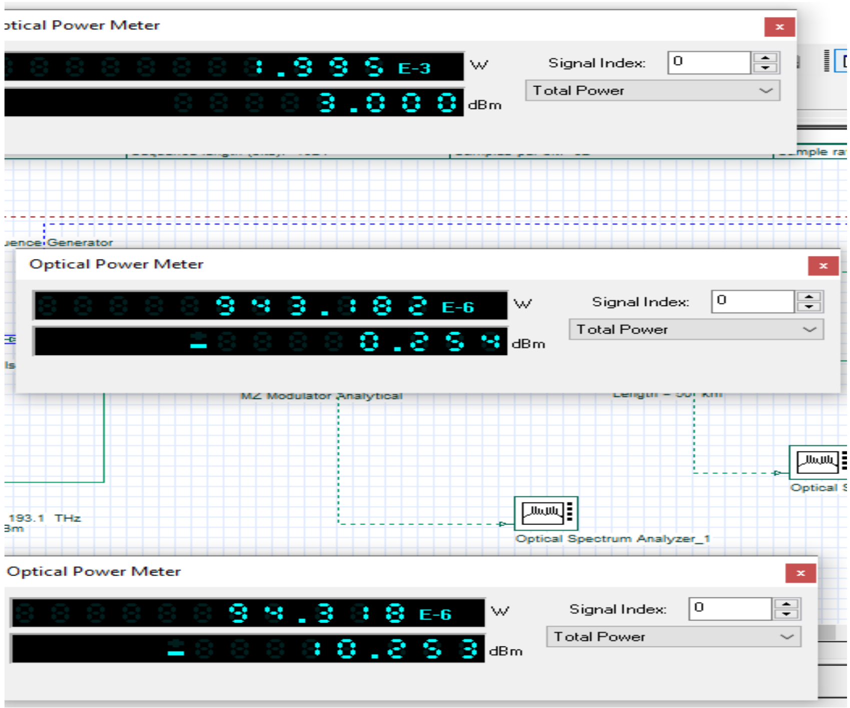


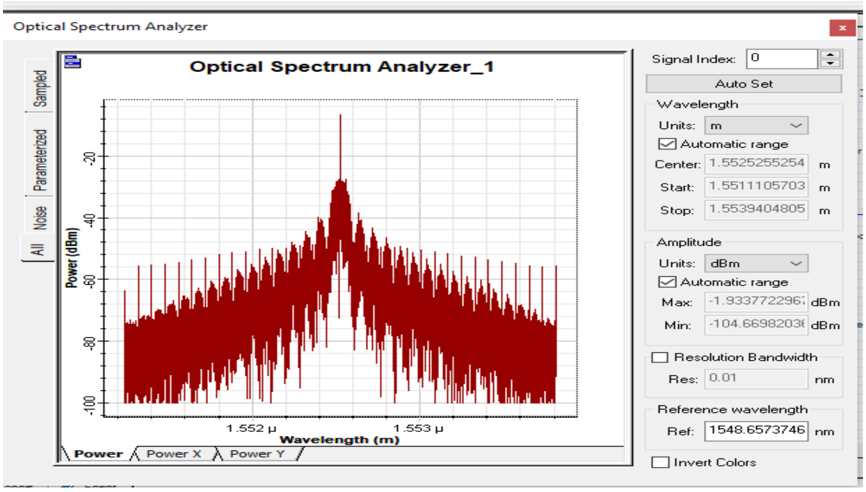


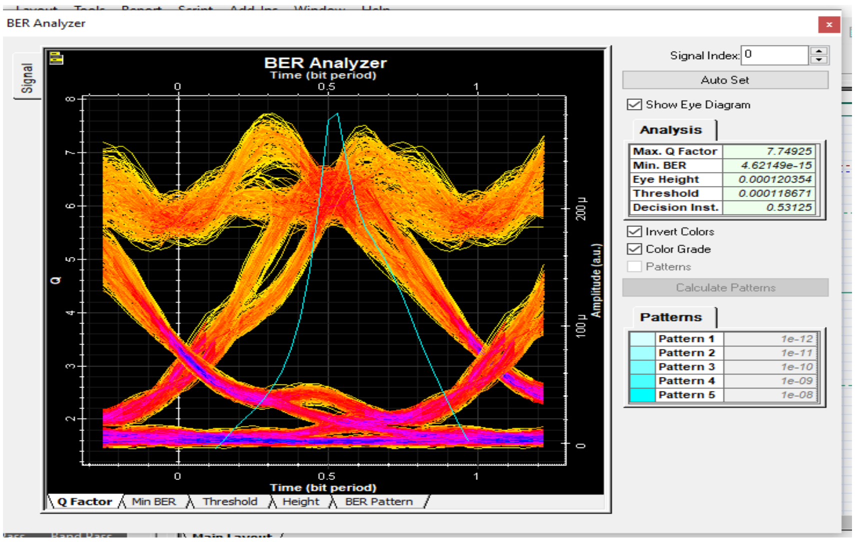

Optical Power Meter
47.271 E-6
W
-13.253
dBm
Signal Index:
0
Total Power

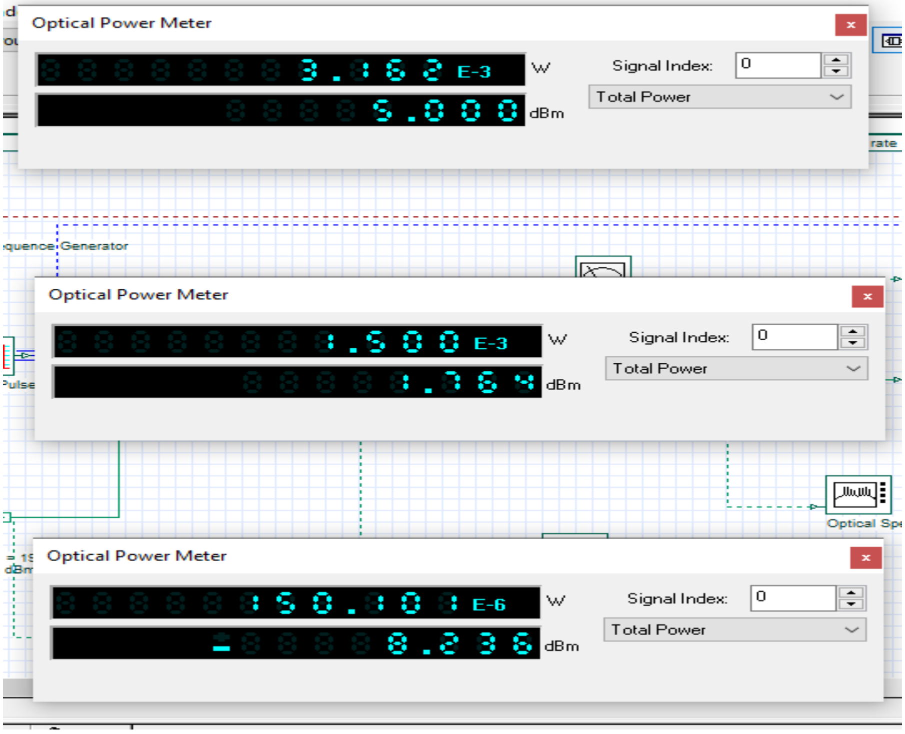

Optical Spectrum Analyzer
Optical Spectrum Analyzer_1
Sampled
Parameterized
Noise
All
Power (dBm)
-20
-40
-60
-80
-100
1.552 μ
1.553 μ
Wavelength (m)
Power
Power X
Power Y
Signal Index:
0
Auto Set
Wavelength
Units:
m
Automatic range
Center:
1.5525255254
Start:
1.5511105703
Stop:
1.5539404805
Amplitude
Units:
dBm
Automatic range
Max:
-3.3843673910(
Min:
-104.6007444(
Resolution Bandwidth
Res:
0.01
nm
Reference wavelength
Ref:
1548.6573746
Invert Colors

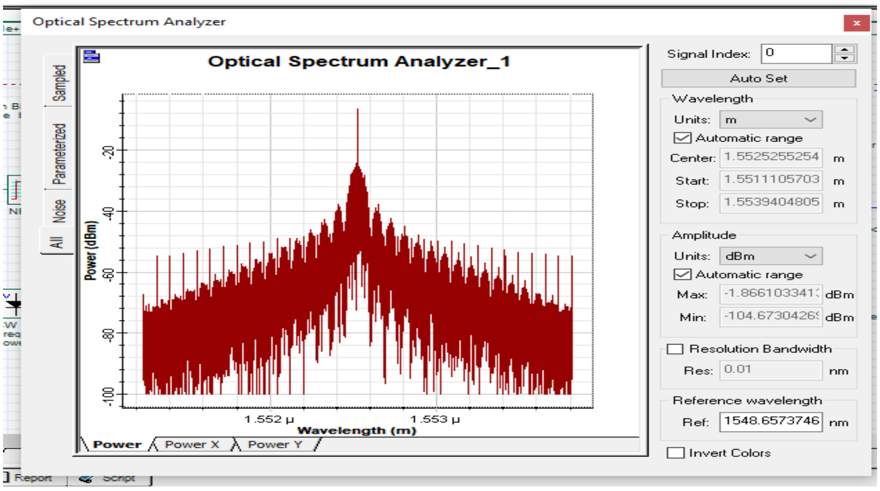

BER Analyzer
BER Analyzer
Time (bit period)
0
0.5
1
Q
7
6
5
4
3
2
100 μ
0
Amplitude (a.u.)
Q Factor
Min BER
Threshold
Height
BER Pattern
Signal
Signal Index:
0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 7.40145
Min. BER 6.73498e-14
Eye Height 5.82591e-05
Threshold 5.94395e-05
Decision Inst. 0.53125
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08

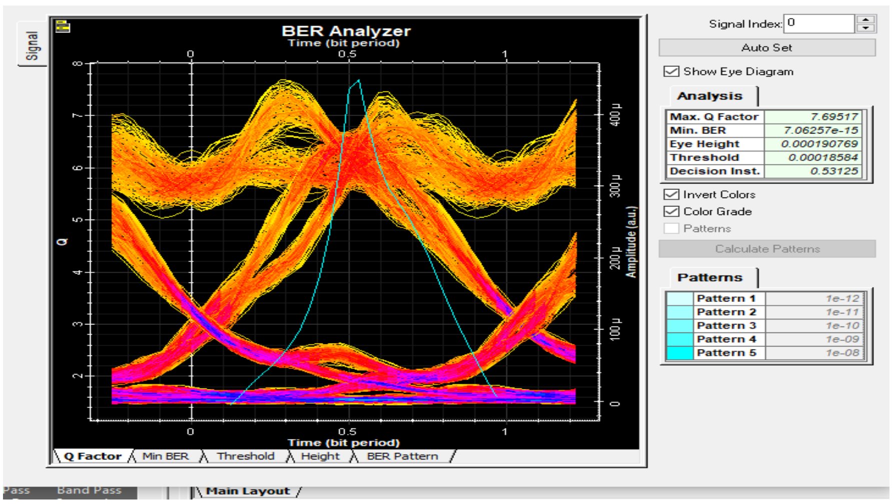

Optical Power Meter
1.995 E-3
W
3.000
dBm
Signal Index: 0
Total Power
Optical Power Meter
943.182 E-6
W
-0.254
dBm
Signal Index: 0
Total Power
MZ Modulator Analytical
193.1 THz
Optical Spectrum Analyzer_1
Optical Power Meter
94.318 E-6
W
-10.253
dBm
Signal Index: 0
Total Power

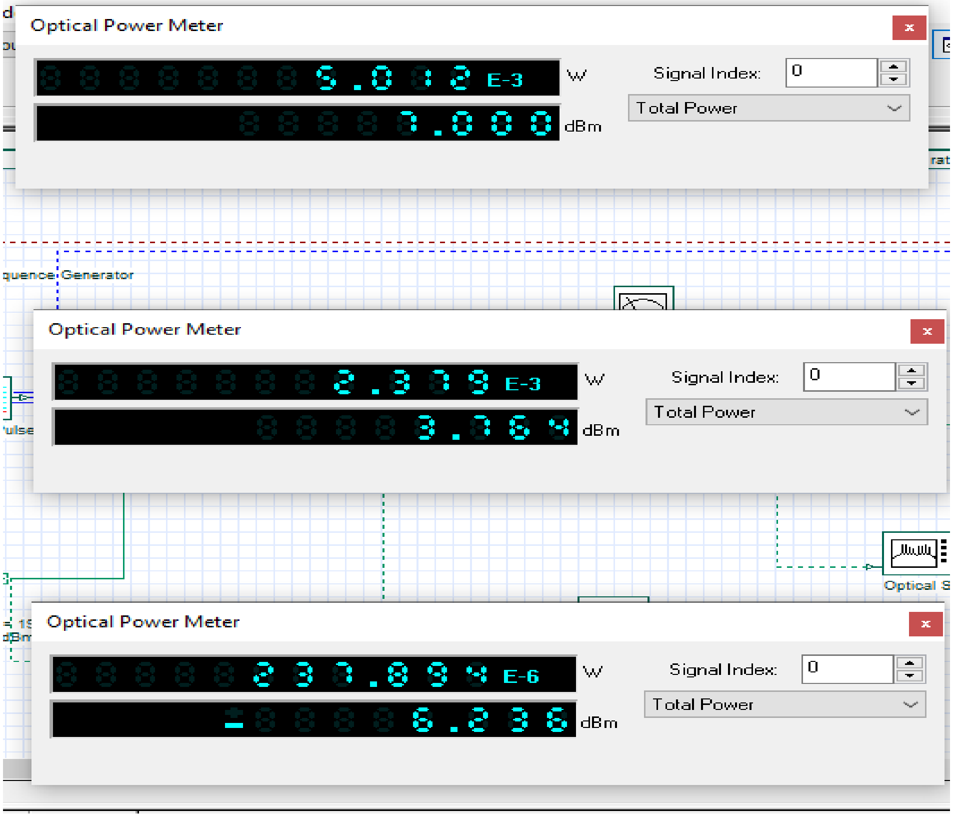

Optical Spectrum Analyzer
Optical Spectrum Analyzer_1
Power (dBm)
Wavelength (m)
1.552 µ
1.553 µ
Power
Power X
Power Y
Sampled
Parameterized
Noise
All
Signal Index: 0
Auto Set
Wavelength
Units: m
Automatic range
Center: 1.5525255254 m
Start: 1.5511105703 m
Stop: 1.5539404805 m
Amplitude
Units: dBm
Automatic range
Max: -1.933772296 dBm
Min: -104.6698203 dBm
Resolution Bandwidth
Res: 0.01 nm
Reference wavelength
Ref: 1548.6573746 nm
Invert Colors


BER Analyzer
BER Analyzer
Time (bit period)
Q
Amplitude (a.u.)
Q Factor
Min BER
Threshold
Height
BER Pattern
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 7.74925
Min. BER 4.62149e-15
Eye Height 0.000120354
Threshold 0.000118671
Decision Inst. 0.53125
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08

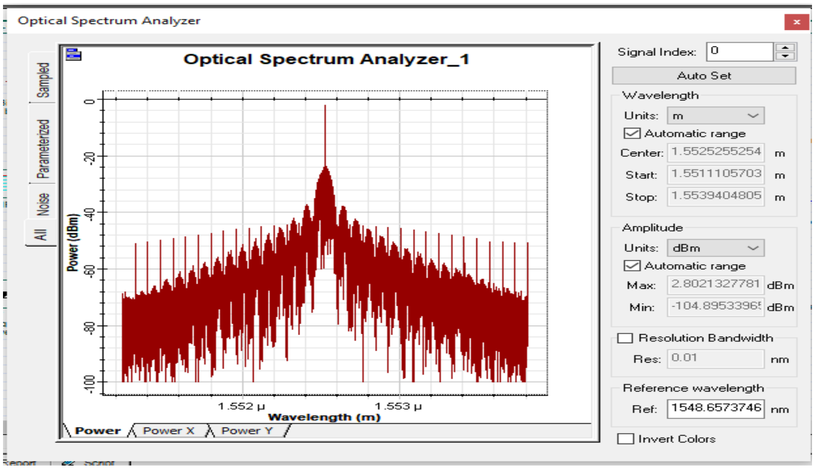

Optical Power Meter
3.162 E-3 W
5.000 dBm
Signal Index: 0
Total Power
Optical Power Meter
1.500 E-3 W
1.764 dBm
Signal Index: 0
Total Power
Optical Power Meter
150.101 E-6 W
-8.236 dBm
Signal Index: 0
Total Power


Optical Spectrum Analyzer
Optical Spectrum Analyzer_1
Power (dBm)
Wavelength (m)
1.552 µ
1.553 µ
Power
Power X
Power Y
Signal Index: 0
Auto Set
Wavelength
Units: m
Automatic range
Center: 1.5525255254 m
Start: 1.5511105703 m
Stop: 1.5539404805 m
Amplitude
Units: dBm
Automatic range
Max: -1.866103341 dBm
Min: -104.6730426 dBm
Resolution Bandwidth
Res: 0.01 nm
Reference wavelength
Ref: 1548.6573746 nm
Invert Colors

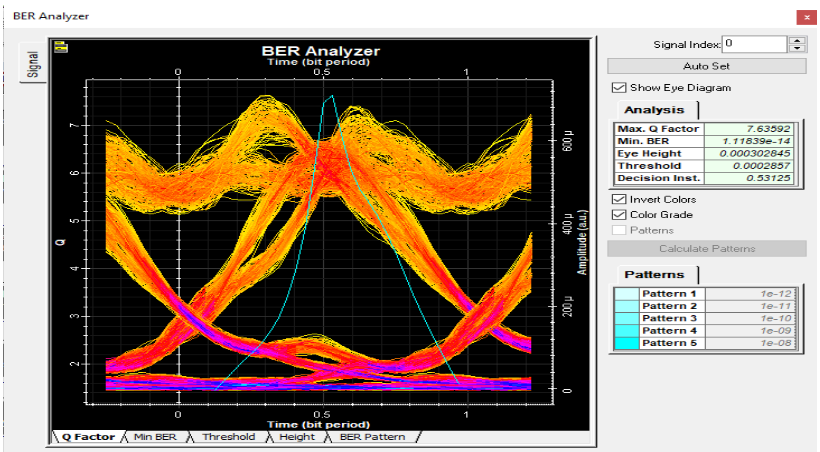

BER Analyzer
Time (bit period)
Q
Amplitude (a.u.)
Q Factor
Min BER
Threshold
Height
BER Pattern
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 7.69517
Min. BER 7.06257e-15
Eye Height 0.000190769
Threshold 0.00018584
Decision Inst. 0.53125
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08



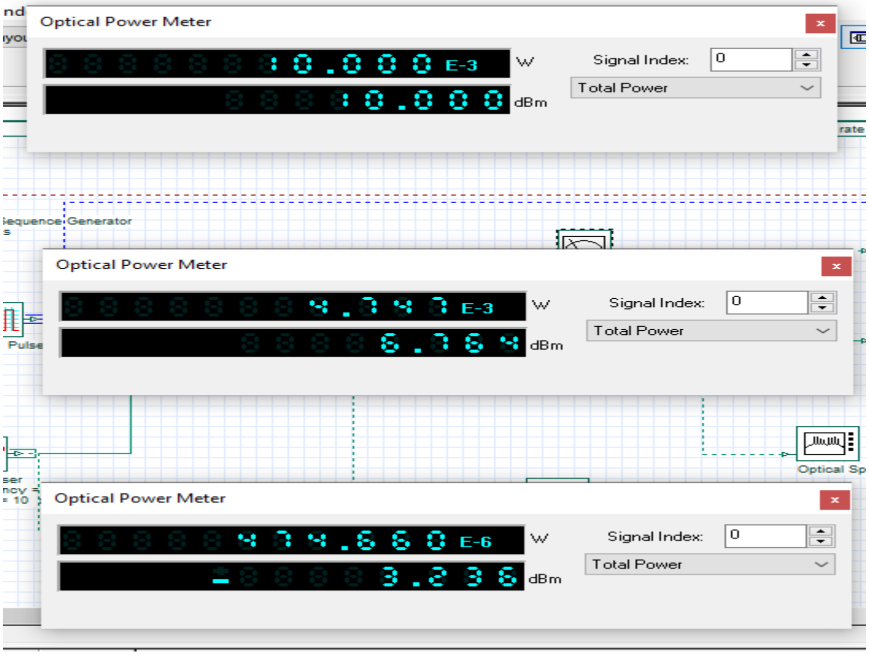
Optical Power Meter
5.012 E-3 W
7.000 dBm
Signal Index: 0
Total Power
Optical Power Meter
2.379 E-3 W
3.764 dBm
Signal Index: 0
Total Power
Optical Power Meter
237.894 E-6 W
-6.236 dBm
Signal Index: 0
Total Power

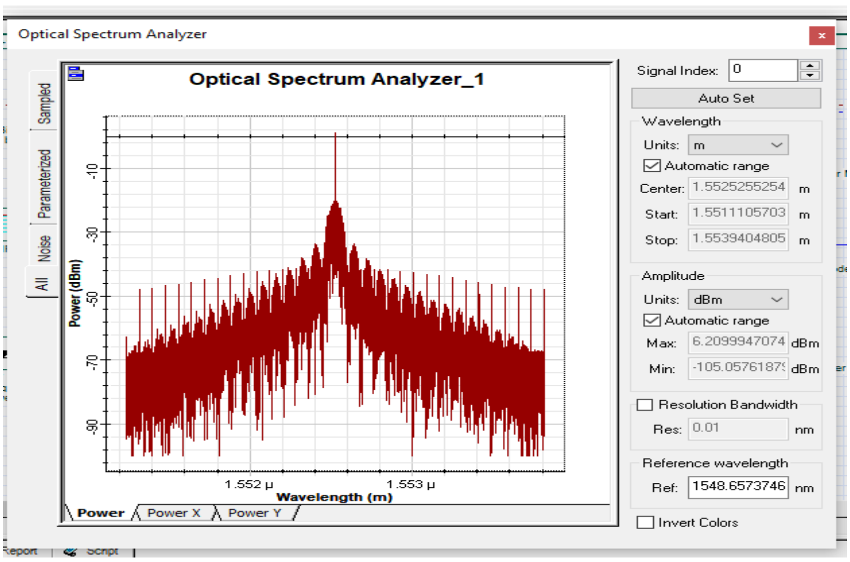


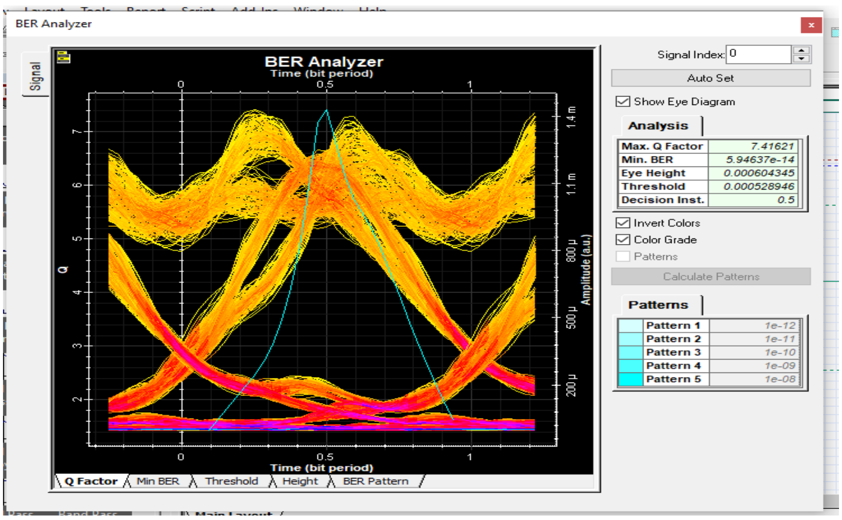
Optical Spectrum Analyzer
Optical Spectrum Analyzer_1
Power (dBm)
Wavelength (m)
1.552 µ
1.553 µ
Power
Power X
Power Y
Signal Index: 0
Auto Set
Wavelength
Units: m
Automatic range
Center: 1.5525255254 m
Start: 1.5511105703 m
Stop: 1.5539404805 m
Amplitude
Units: dBm
Automatic range
Max: 2.8021327781 dBm
Min: -104.89533965 dBm
Resolution Bandwidth
Res: 0.01 nm
Reference wavelength
Ref: 1548.6573746 nm
Invert Colors



BER Analyzer
Time (bit period)
Q
Amplitude (a.u.)
Q Factor
Min BER
Threshold
Height
BER Pattern
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 7.63592
Min. BER 1.11839e-14
Eye Height 0.000302845
Threshold 0.0002857
Decision Inst. 0.53125
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08


Optical Power Meter
10.000 E-3 W
10.000 dBm
Signal Index: 0
Total Power
Optical Power Meter
4.747 E-3 W
6.764 dBm
Signal Index: 0
Total Power
Optical Power Meter
474.660 E-6 W
-3.236 dBm
Signal Index: 0
Total Power


Optical Spectrum Analyzer
Optical Spectrum Analyzer_1
Power (dBm)
Wavelength (m)
1.552 µ
1.553 µ
Power
Power X
Power Y
Sampled
Parameterized
Noise
All
Signal Index: 0
Auto Set
Wavelength
Units: m
Automatic range
Center: 1.5525255254 m
Start: 1.5511105703 m
Stop: 1.5539404805 m
Amplitude
Units: dBm
Automatic range
Max: 6.2099947074 dBm
Min: -105.0576187 dBm
Resolution Bandwidth
Res: 0.01 nm
Reference wavelength
Ref: 1548.6573746 nm
Invert Colors


BER Analyzer
BER Analyzer
Time (bit period)
Amplitude (a.u.)
Q Factor
Min BER
Threshold
Height
BER Pattern
Signal
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 7.41621
Min. BER 5.94637e-14
Eye Height 0.000604345
Threshold 0.000528946
Decision Inst. 0.5
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08

Analysis

1. BER vs. Power Curve

Expected Trend:

- BER decreases as power increases in the low-to-medium range.
- BER increases at higher powers due to non-linear effects.

Optimal Power Range: Identify the power range with minimal BER.

2. Eye Diagram Analysis

- Observe the eye opening at each power level using the **Eye Diagram Analyzer**.
- A wide-open eye indicates lower BER, while a closed eye indicates signal degradation.

3. Signal-to-Noise Ratio (SNR)

- Calculate SNR for each power level and correlate it with BER performance.

Conclusion

This analysis provides insights into the relationship between input power and BER in optical communication systems. Key findings include:

1. **Low Power**: High BER due to insufficient signal strength.
2. **Medium Power**: Minimal BER in the optimal power range.
3. **High Power**: Increased BER due to non-linear effects, emphasizing the need to avoid excessive power levels.

By identifying the optimal power range, this study helps in designing efficient and reliable optical communication systems.

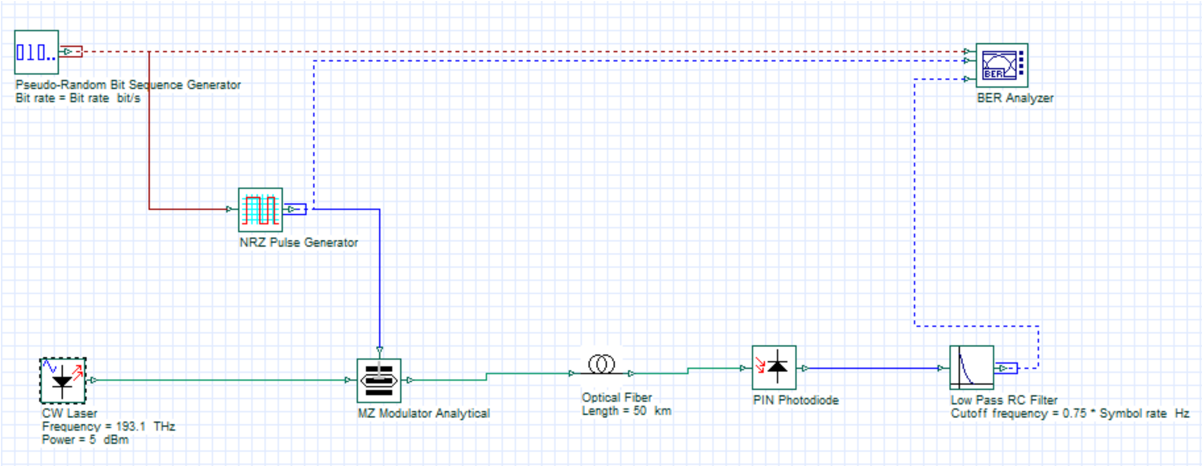
Exp.No. 12	Analysis of BER for Different Length in Optical Communication System Using Optisystem

Objective
To analyze the BER performance of an optical communication system by simulating different fiber lengths using OptiSystem software.

Steps for Simulation
1. Define the System Components
- **Transmitter**: Use a laser source (Continuous Wave Laser) and a modulator (e.g., Mach-Zehnder Modulator) to generate the optical signal.
- **Channel**: Implement a single-mode optical fiber (SMF) with different lengths to study its impact. Add attenuation, chromatic dispersion, and non-linear effects as per the simulation requirements.
- **Receiver**: Use a photodetector (PIN or APD) and a low-pass filter. Analyze the signal using a BER analyzer or an eye diagram analyzer.
- **Additional Components**: Include optical amplifiers (EDFA), dispersion compensating modules (if needed), and noise sources for a realistic system.

2. Set Simulation Parameters
- **Data Rate**: Define a fixed data rate (e.g., 10 Gbps).
- **Wavelength**: Set the laser wavelength (e.g., 1550 nm).
- **Fiber Lengths**: Simulate for varying lengths, e.g., 10 km, 50 km, 100 km, 200 km, etc.
- **Channel Properties**:
    - Attenuation: 0.2 dB/km
    - Dispersion: 16 ps/nm/km
    - Non-linear effects: Enabled/Disabled as per requirement.
- **Noise Level**: Adjust the ASE noise from EDFAs to simulate real-world scenarios.

3. Perform the Simulation
- **Run the Simulation**: Simulate for each fiber length by replacing the fiber module with the desired length.
- **Collect Data**:
    - BER values for each length.
    - Eye diagram quality metrics (Q-factor, opening width).
    - Signal-to-noise ratio (SNR).



Test Case Details

Test Case 1: Short Fiber (10 km)

- **Expected Results**: Minimal attenuation and dispersion effects. BER should be low, with a wide-open eye diagram.

Test Case 2: Medium Fiber (50 km)

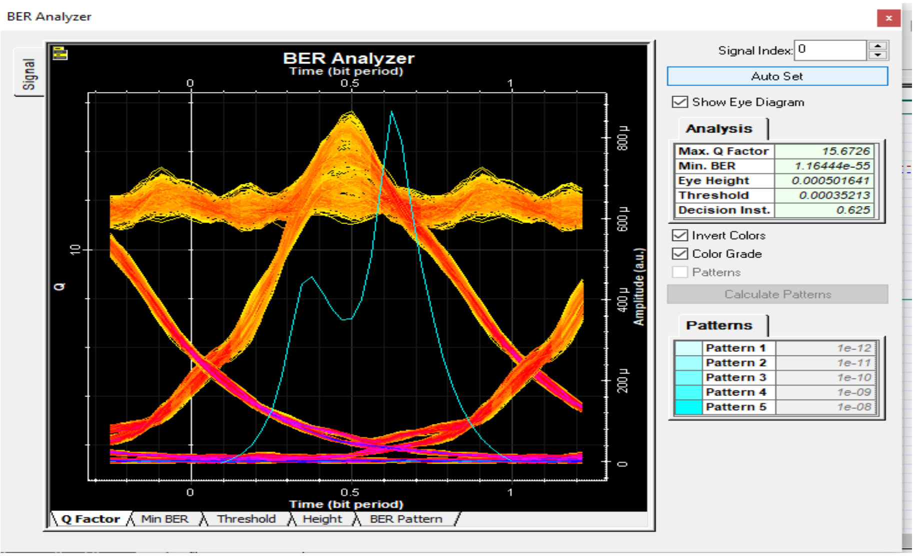
- **Expected Results**: Increased attenuation and dispersion, potentially affecting BER. Eye diagram may show slight closure.

Test Case 3: Long Fiber (100 km)

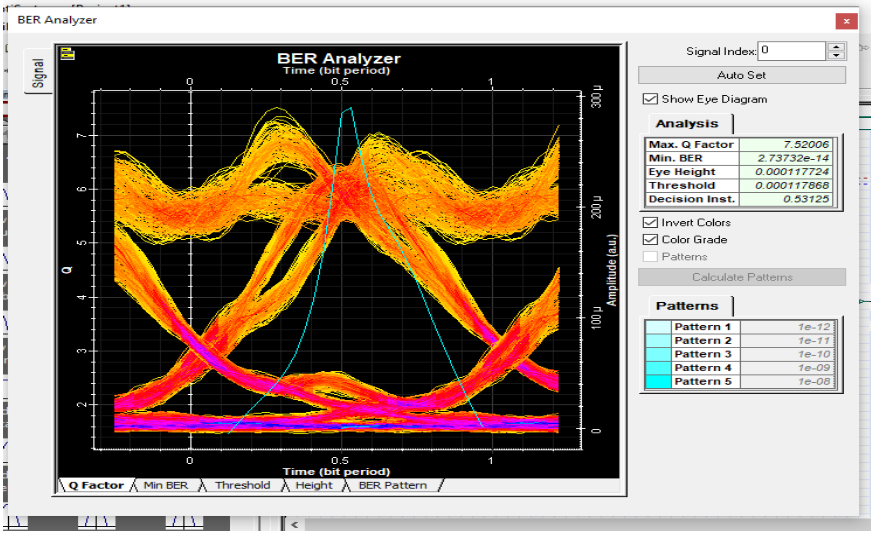
- **Expected Results**: Significant dispersion and attenuation. BER will increase unless compensated using EDFAs or dispersion compensation modules.

Test Case 4: Very Long Fiber (200 km)

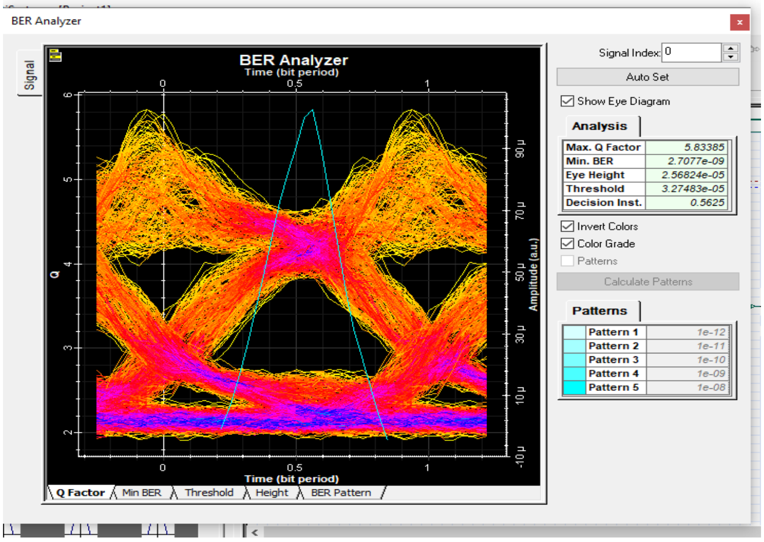
- **Expected Results**: Severe signal degradation. BER will be high without proper amplification and dispersion compensation. Eye diagram may collapse.



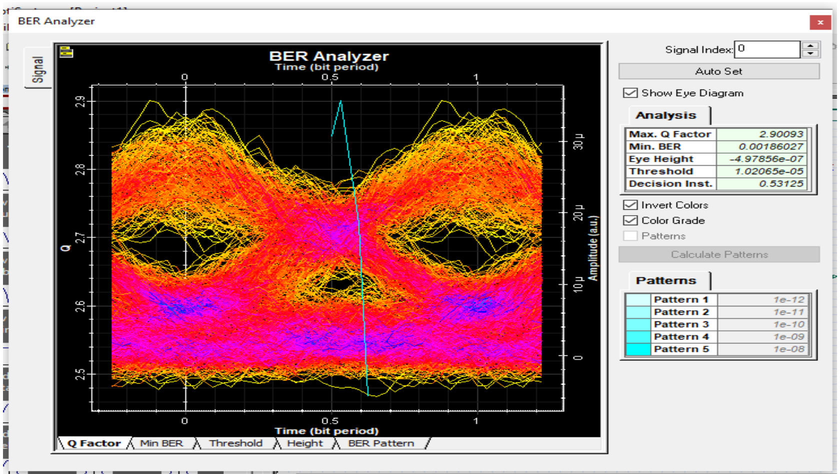
25 KM



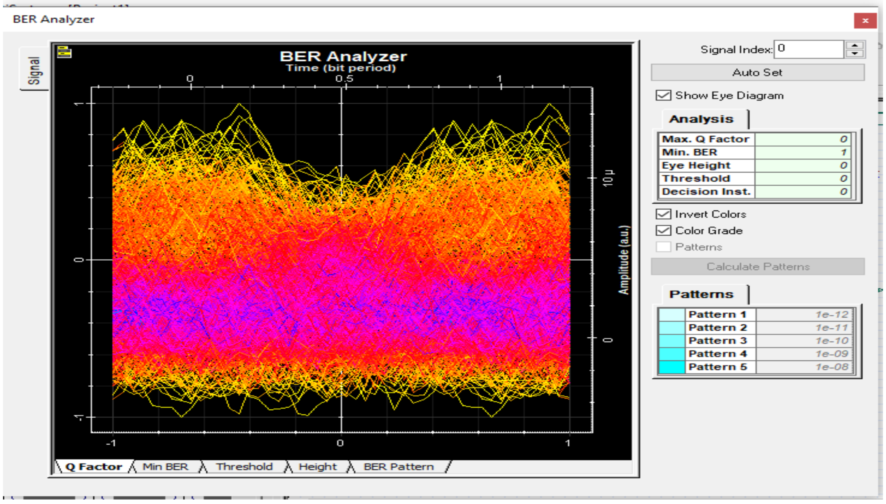
50KM



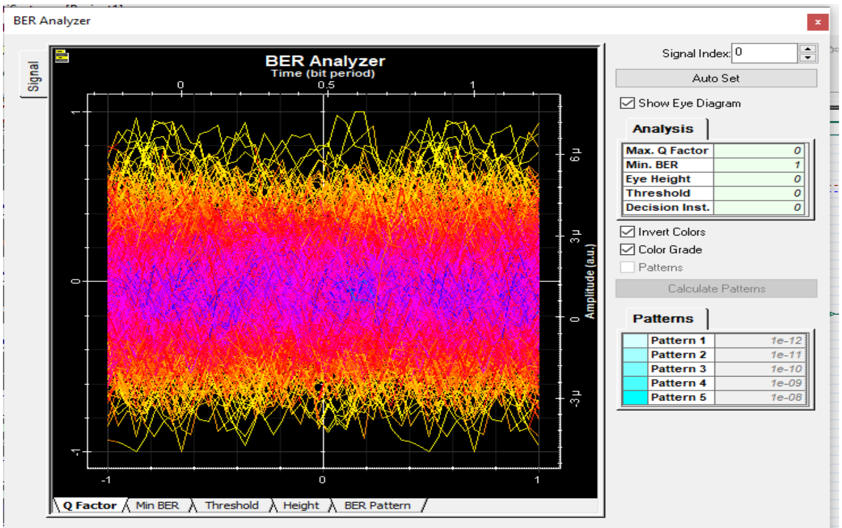
75KM



100 KM



125 KM



150 KM

Analysis

- **Plot BER vs. Fiber Length**: Visualize how BER deteriorates as fiber length increases.
- **Q-factor Analysis**: Compare the Q-factor across different fiber lengths to assess system robustness.
- **Impact of Amplification/Compensation**: Add amplifiers or dispersion compensation modules and observe performance improvements.

Conclusion

The BER analysis for different fiber lengths using OptiSystem demonstrates the trade-offs between transmission distance, signal quality, and system design requirements (e.g., amplification and dispersion compensation). The simulation provides insights into the maximum achievable transmission distance without exceeding acceptable BER thresholds.

Exp.No. 13	**Analysis of Dense Wavelength Division Multiplexing in Fiber Optic Communication Systems using Optisystem**

Objective

To analyze the performance of DWDM systems under different test conditions by varying key parameters such as wavelength spacing, modulation formats, fiber length (loop count), and optical amplifier placements using OptiSystem simulations.

Simulation Design in OptiSystem

DWDM System Components:

1. **Transmitter**:
   - Multiple laser sources emitting at ITU grid wavelengths (e.g., 193.1 THz, 193.2 THz, etc.).
   - Modulation schemes: NRZ, RZ, or advanced schemes like QPSK or 16-QAM.
   - Power level for each source: 0–10 dBm.

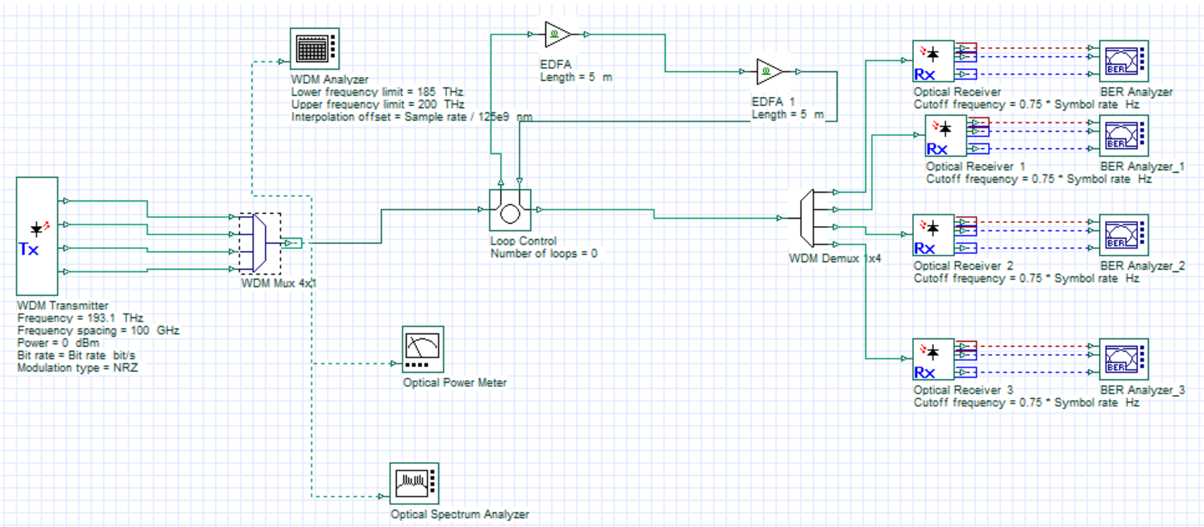
2. **Multiplexer (MUX)**:
   - Combines multiple wavelengths into a single fiber for transmission.
   - Wavelength spacings: 100 GHz, 50 GHz, 25 GHz.

3. **Optical Fiber**:
   - Single-mode fiber (SMF) with:
     - Attenuation: 0.2 dB/km.
     - Dispersion: 16 ps/nm/km.
     - Nonlinear effects: Self-Phase Modulation (SPM), Cross-Phase Modulation (XPM).
   - Add **loops** to simulate long distances (e.g., 50 km per loop).

4. **Amplifiers**:
   - EDFAs (Erbium-Doped Fiber Amplifiers) or Raman amplifiers for loss compensation.
   - Noise figure: 5 dB.

5. **Demultiplexer (DEMUX)**:
   - Separates multiplexed wavelengths for individual detection.

6. **Receiver**:
   - PIN photodiodes or avalanche photodiodes.
   - Evaluates BER, Q-factor, and optical signal-to-noise ratio (OSNR).



Test Cases for Simulation

Test Case 1: Wavelength Spacing Variation

- **Setup**:
  - Fixed fiber length (e.g., 100 km).
  - Use three wavelength spacings: 100 GHz, 50 GHz, and 25 GHz.
- **Objective**:
  - Evaluate the effect of spacing on spectral efficiency, BER, Q-factor, and crosstalk.
- **Expected Outcome**:
  - Smaller spacing increases spectral efficiency but worsens crosstalk and signal degradation.

Test Case 2: Transmission Distance (Loop Count) Variation

- **Setup**:
  - Fixed wavelength spacing (e.g., 50 GHz).
  - Vary the number of fiber loops: 1 (50 km), 5 (250 km), 10 (500 km).
- **Objective**:
  - Analyze signal degradation with increasing distance.
- **Expected Outcome**:
  - Longer distances introduce higher dispersion, nonlinearities, and ASE noise, reducing Q-factor and increasing BER.

Test Case 3: Modulation Format

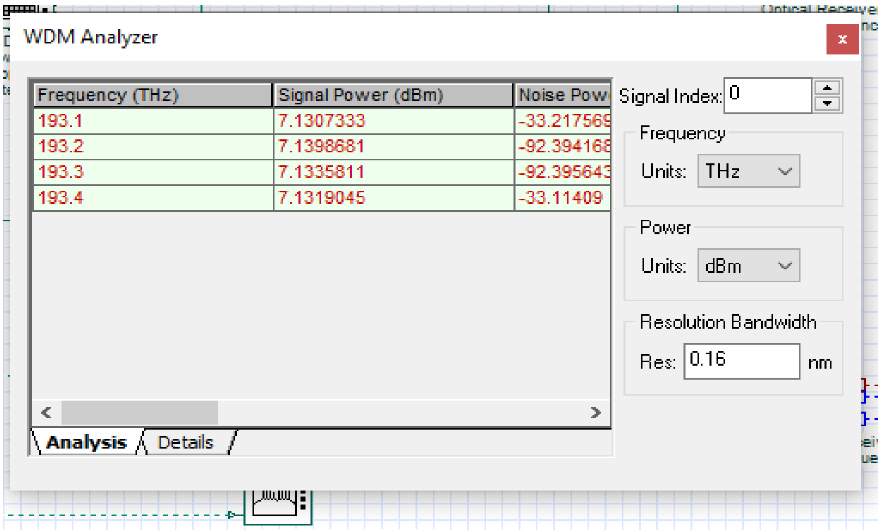
- **Setup**:
  - Fixed distance (e.g., 200 km) and wavelength spacing (e.g., 50 GHz).
  - Compare NRZ, RZ, and QPSK modulation formats.
- **Objective**:
  - Study the impact of modulation format on system performance.
- **Expected Outcome**:
  - Advanced formats like QPSK offer better spectral efficiency but may require higher OSNR.

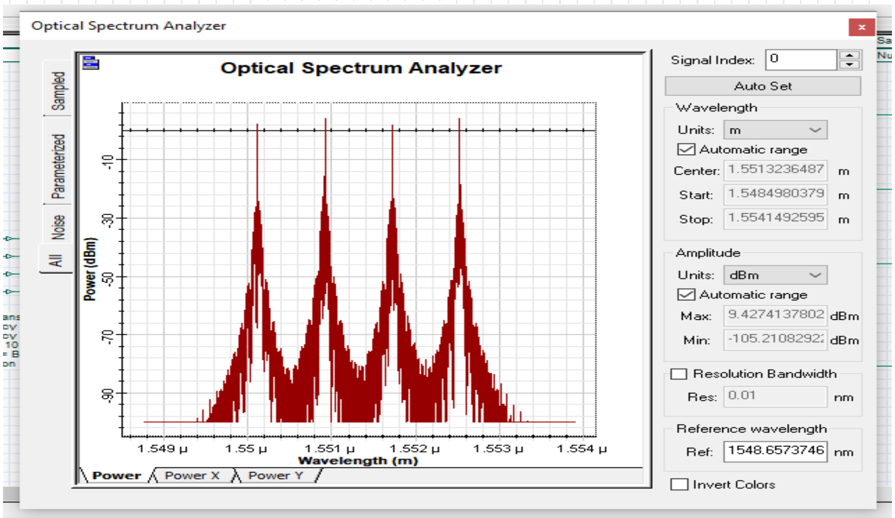
Test Case 4: Amplifier Placement

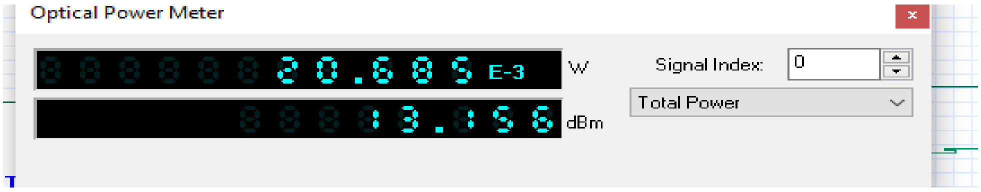
- **Setup**:
  - Fixed distance (e.g., 500 km) and wavelength spacing (e.g., 50 GHz).
  - Place EDFAs at different intervals: 50 km, 100 km, and 150 km.
- **Objective**:
  - Determine the optimal placement of amplifiers to minimize power penalties and noise.
- **Expected Outcome**:
  - Closer amplifier spacing reduces attenuation but may increase noise accumulation.

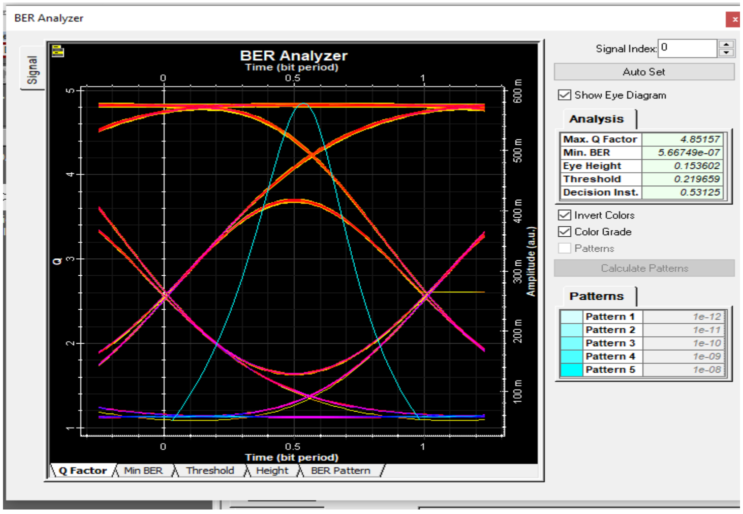
Test Case 5: Channel Power Variation

- **Setup**:
  - Fixed distance (e.g., 300 km) and wavelength spacing (e.g., 100 GHz).
  - Vary the channel power between 0 dBm and 10 dBm.
- **Objective**:
  - Examine the impact of power levels on nonlinear effects like SPM and XPM.
- **Expected Outcome**:
  - Higher power increases nonlinear impairments, degrading performance.






Optical Power Meter
20.685 E-3
W
13.156
dBm
Signal Index:
0
Total Power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BER Analyzer
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Decision Inst. 0.53125
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-12
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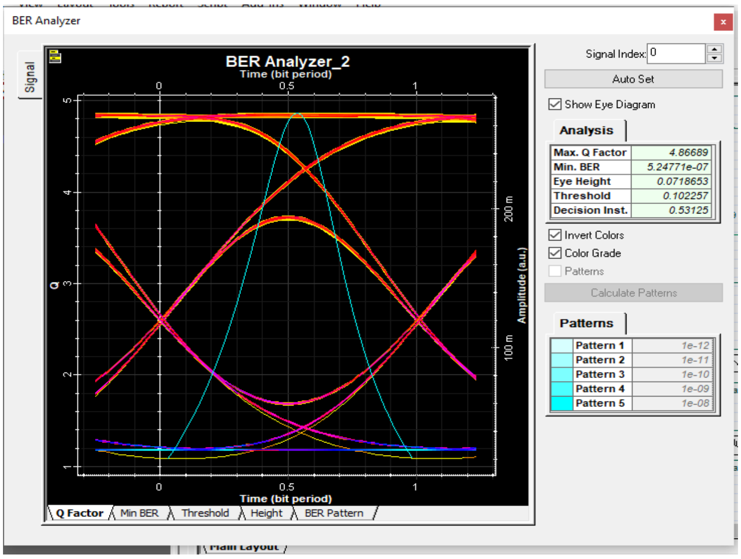
Pattern 4 1e-09
Pattern 5 1e-08
Amplitude (a.u.)
Q Factor
Min BER
Threshold
Height
BER Pattern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Min. BER 5.24771e-07
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Decision Inst. 0.53125
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-12
Pattern 2 1e-11
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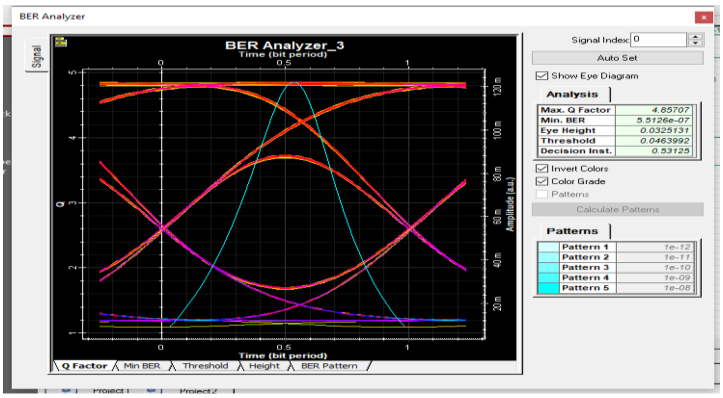
Pattern 4 1e-09
Pattern 5 1e-08
Amplitude (a.u.)
Q Factor
Min BER
Threshold
Height
BER Pattern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BER Analyzer_3
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Color Grade
Patterns
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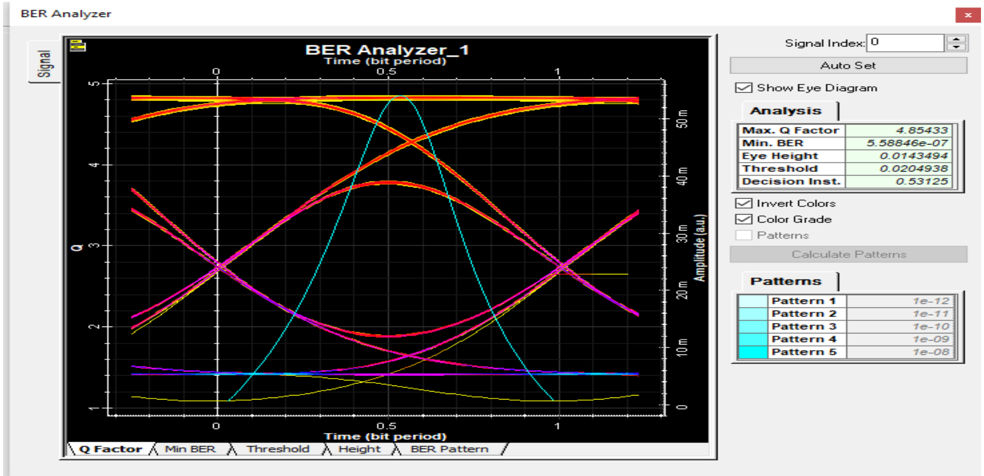
Pattern 5 1e-08
Q Factor
Min BER
Threshold
Height
BER Pattern



Metrics to Evaluate

For each test case, evaluate the following:

1. **Bit Error Rate (BER)**:
   - Measure the system's error performance.
2. **Q-factor**:
   - Quantifies signal quality at the receiver.
3. **OSNR**:
   - Evaluate the impact of noise and crosstalk.
4. **Crosstalk**:
   - Analyze interference between channels at smaller spacings.
5. **Power Penalty**:
   - Quantify the loss of signal power due to impairments.

Expected Observations

1. **Wavelength Spacing**:
   - Larger spacing improves signal quality but reduces spectral efficiency.
   - Smaller spacing leads to higher crosstalk and BER.
2. **Distance**:
   - Increasing the loop count degrades signal quality due to dispersion and noise accumulation.
   - Proper dispersion management is crucial for long-haul transmission.
3. **Modulation Format**:
   - Advanced modulation schemes (e.g., QPSK) offer better spectral efficiency but require high OSNR.
4. **Amplifier Placement**:
   - Proper amplifier spacing minimizes attenuation and noise buildup, maintaining Q-factor.
5. **Power Levels**:
   - Optimal power levels mitigate nonlinear effects and ensure efficient transmission.

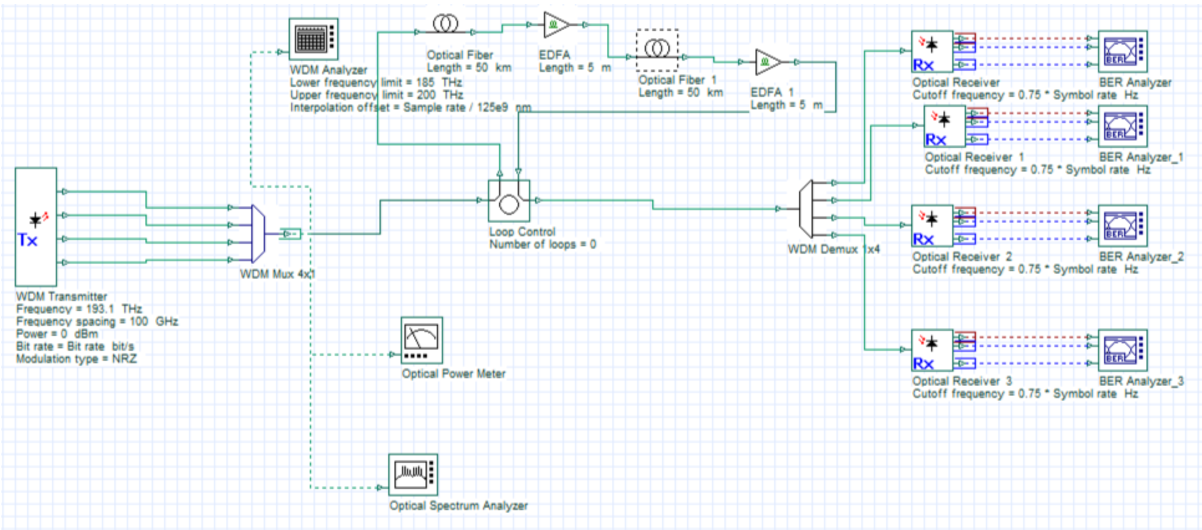
Conclusion

Using OptiSystem to simulate DWDM systems enables detailed performance evaluation under various conditions. The insights from these test cases help optimize DWDM designs for high-capacity, long-haul communication networks.

Exp.No. 14	**Analysis of Dense Wavelength Division Multiplexing with Amplifier on Differential length of optical fiber using Optisystem**

Objective
To analyze the performance of DWDM systems when amplifiers are introduced at different lengths of optical fibers and to evaluate the effects of fiber length, channel spacing, and amplifier placement on overall system performance.

Simulation Design in OptiSystem
System Architecture
1. **Transmitter**:
   - Multiple lasers operating at different wavelengths (ITU grid) with channel spacings such as 100 GHz, 50 GHz, or 25 GHz.
   - Modulation schemes: NRZ, RZ, or advanced formats like QPSK.
2. **Multiplexer (MUX)**:
   - Combines multiple wavelengths into a single optical fiber.
3. **Optical Fiber**:
   - Single-Mode Fiber (SMF):
     - Attenuation: 0.2 dB/km.
     - Dispersion: 16 ps/nm/km.
     - Nonlinear effects: Self-Phase Modulation (SPM), Cross-Phase Modulation (XPM), and Four-Wave Mixing (FWM).
4. **Amplifiers**:
   - EDFAs (Erbium-Doped Fiber Amplifiers) or Raman amplifiers.
   - Fixed Noise Figure: 5 dB.
   - Placed at varying intervals depending on fiber length (e.g., 50 km, 100 km, etc.).
5. **Demultiplexer (DEMUX)**:
   - Separates individual channels for detection.
6. **Receiver**:
   - Photodetectors and filters for signal recovery.
   - BER analyzer and Q-factor measurement.



Test Cases for Analysis

Test Case 1: Differential Fiber Lengths

- **Setup**:
  - Fixed amplifier placement (e.g., every 50 km).
  - Vary fiber lengths: 50 km, 100 km, 150 km, 200 km.
- **Objective**:
  - Analyze the impact of longer fiber spans on signal degradation due to dispersion and attenuation.
- **Expected Outcome**:
  - Longer spans increase dispersion and nonlinear effects, reducing Q-factor and increasing BER.

Test Case 2: Amplifier Placement

- **Setup**:
  - Fixed fiber length (e.g., 200 km).
  - Vary amplifier placement intervals: 50 km, 100 km, 150 km.
- **Objective**:
  - Evaluate the effect of amplifier placement on maintaining signal power and reducing ASE noise.
- **Expected Outcome**:
  - Closer amplifier spacing reduces attenuation but may lead to noise accumulation over long distances.

Test Case 3: Wavelength Spacing

- **Setup**:
  - Fixed fiber length (e.g., 100 km) and amplifier placement (e.g., every 50 km).
  - Vary channel spacings: 100 GHz, 50 GHz, 25 GHz.
- **Objective**:
  - Study the effect of smaller channel spacing on spectral efficiency, crosstalk, and BER.
- **Expected Outcome**:
  - Smaller spacings increase spectral efficiency but lead to higher crosstalk and OSNR degradation.

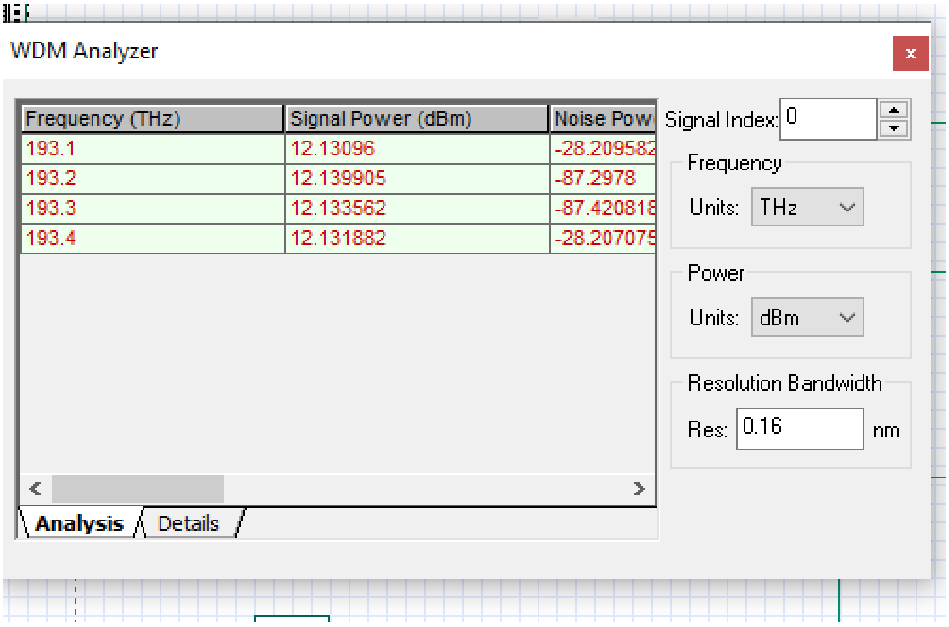
Test Case 4: Modulation Formats

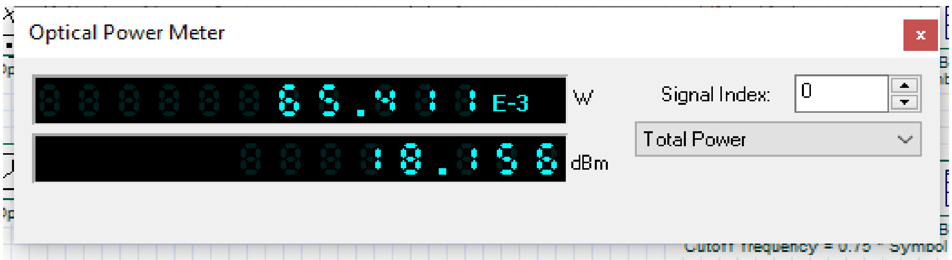
- **Setup**:
  - Fixed fiber length (e.g., 150 km) and amplifier placement (e.g., every 75 km).
  - Compare different modulation formats: NRZ, RZ, and QPSK.
- **Objective**:
  - Understand the impact of modulation format on performance metrics.
- **Expected Outcome**:
  - Advanced formats like QPSK provide better spectral efficiency but require higher OSNR.

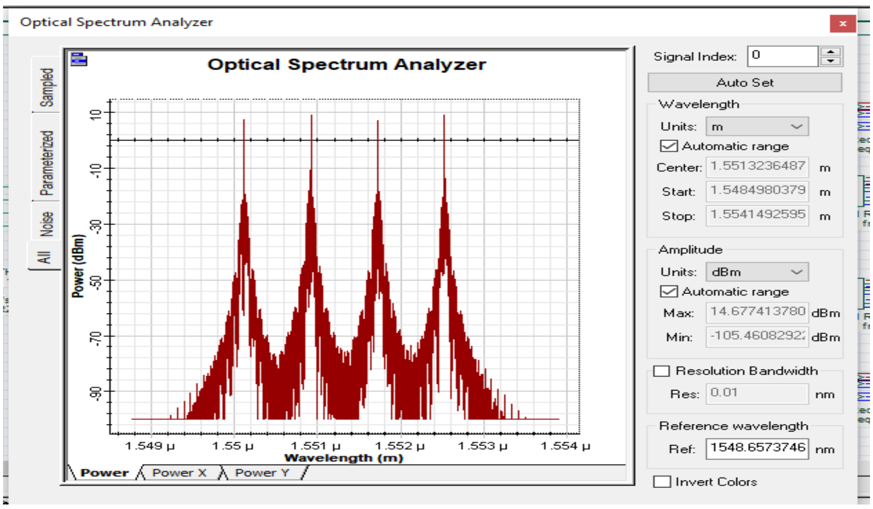
Test Case 5: Nonlinear Effects

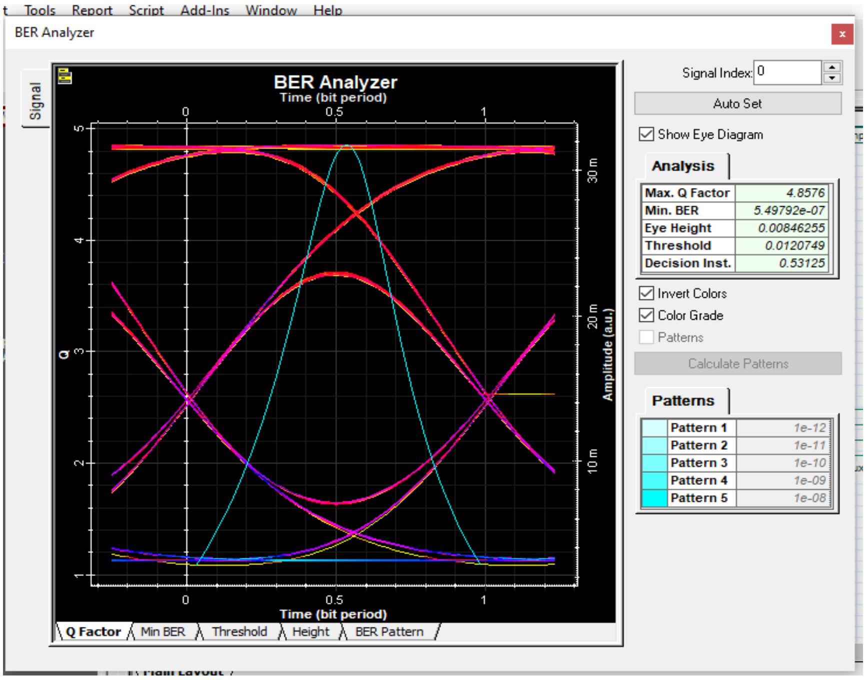
- **Setup**:
  - Fixed fiber length (e.g., 200 km) and amplifier placement (e.g., every 100 km).
  - Vary channel power: 0 dBm, 5 dBm, 10 dBm.

- **Objective**:
  - Examine how channel power influences nonlinear effects such as SPM, XPM, and FWM.
- **Expected Outcome**:
  - Higher power levels increase nonlinear effects, degrading system performance by reducing Q-factor and increasing BER. However, lower power may result in insufficient OSNR.





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Q Factor
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Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 4.8576
Min. BER 5.49792e-07
Eye Height 0.00846255
Threshold 0.0120749
Decision Inst. 0.53125
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Pattern 2 1e-11
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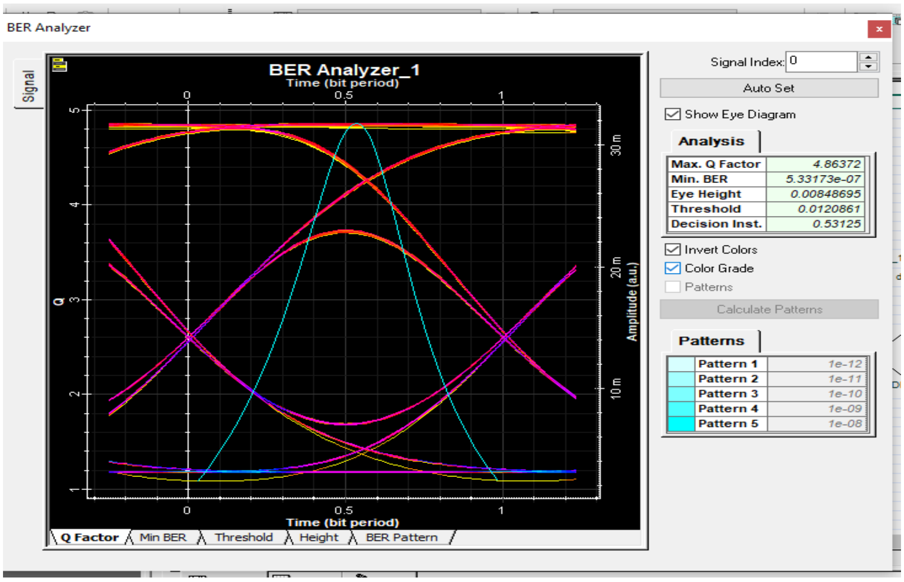
Pattern 5 1e-08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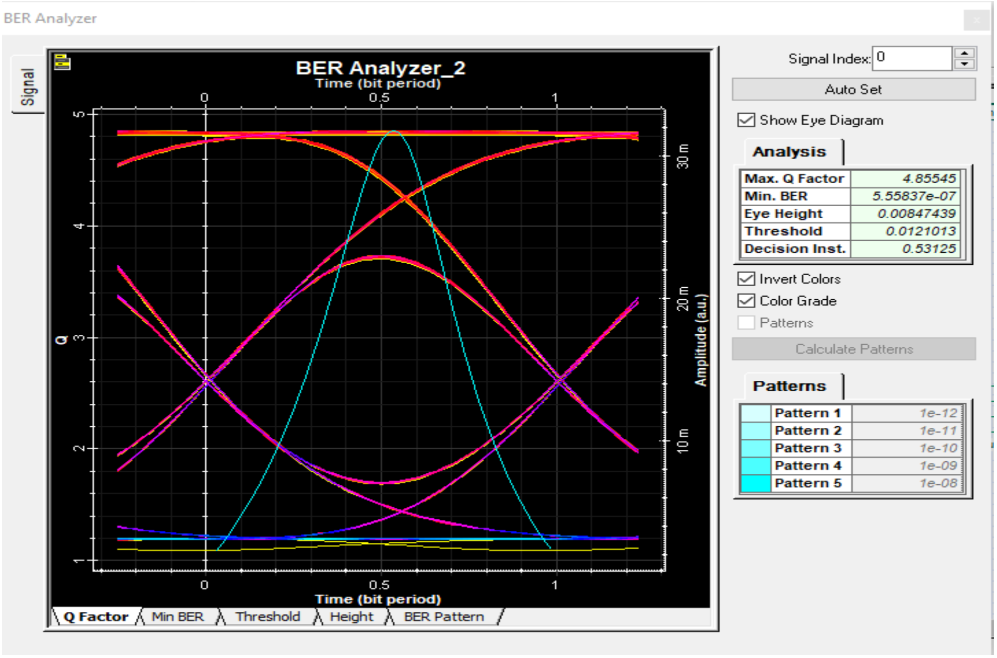
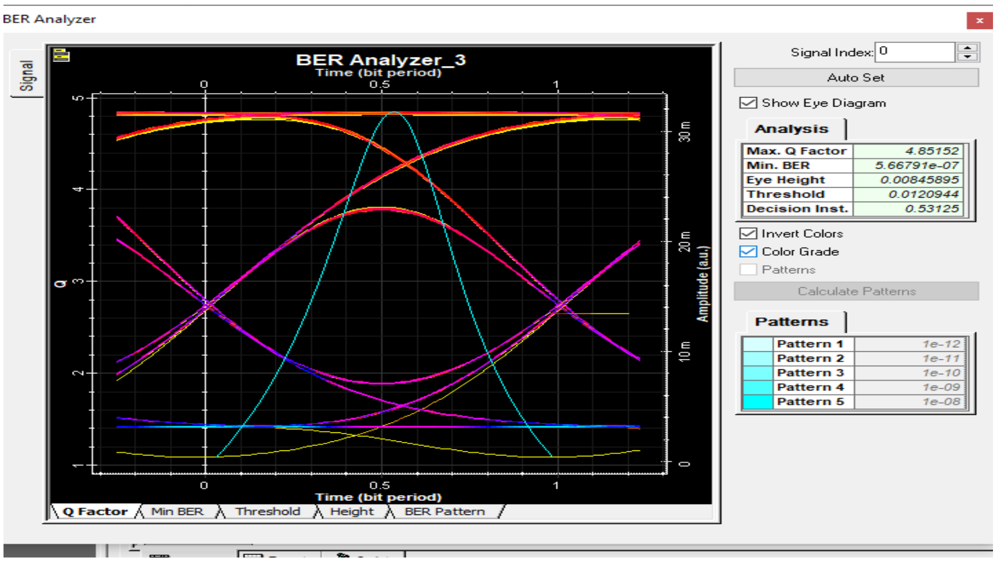




Key Metrics for Evaluation

For all test cases, the following metrics should be evaluated to understand system behavior:

1. **Bit Error Rate (BER):**
    - Measures the rate of errors in the transmitted data.
2. **Q-Factor:**
    - Assesses the quality of the received signal, with higher values indicating better performance.
3. **Optical Signal-to-Noise Ratio (OSNR):**
    - Determines the signal quality in the presence of noise and is critical for long-distance transmission.
4. **Crosstalk:**
    - Measures interference between adjacent channels, especially for narrower wavelength spacings.

5. **Power Penalty:**
    - Quantifies the reduction in signal power due to attenuation, dispersion, and nonlinear effects.

Simulation Procedure

1. **Design the DWDM System:**
    - Set up the transmitter, MUX, optical fiber, amplifiers, DEMUX, and receiver in OptiSystem.
2. **Parameter Adjustment:**
    - For each test case, modify the appropriate parameters (fiber length, amplifier spacing, channel spacing, etc.).
3. **Run Simulations:**
    - Use the OptiSystem simulator to measure BER, Q-factor, OSNR, and power at the receiver for each scenario.
4. **Data Collection:**
    - Record the results for all test cases and analyze trends.

Observations and Analysis

1. **Differential Fiber Lengths:**
    - Increased fiber length worsens dispersion and attenuation, reducing signal quality.
    - Amplifier placement is critical to counter these effects.
2. **Amplifier Placement:**
    - Proper amplifier placement reduces attenuation and ASE noise.
    - Excessive amplification can cause noise buildup, reducing OSNR.
3. **Wavelength Spacing:**
    - Smaller spacings improve spectral efficiency but lead to higher crosstalk, requiring advanced filtering techniques.
4. **Modulation Formats:**
    - Advanced modulation formats like QPSK are more resilient to noise but need higher OSNR.
5. **Nonlinear Effects:**
    - Higher channel power exacerbates SPM, XPM, and FWM, requiring optimization of input power and fiber parameters.

Conclusion

This analysis provides insights into optimizing DWDM systems for varying fiber lengths and amplifier placements. The results can guide network design choices for high-capacity, long-distance optical communication systems.

Exp.No. 15	Design and Analysis of Free Space Optics (FSO) System by Varying Range and Attenuation Using OptiSystem

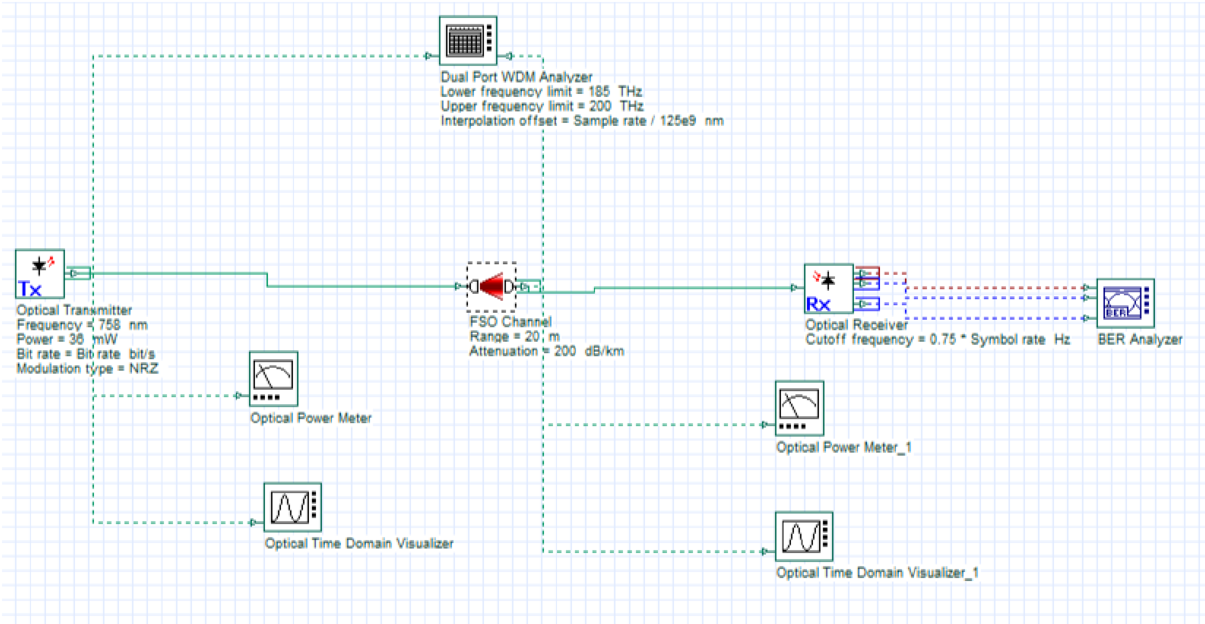
Objective
To design an FSO communication system and evaluate the effects of:
- Range (1–10 km or more) on received power and system performance.
- Atmospheric attenuation due to varying weather conditions (e.g., clear skies, fog, rain).

FSO System Design in OptiSystem
System Components
1. **Optical Transmitter**:
    - Laser source (1550 nm or 850 nm) for communication.
    - Transmit power: Adjustable (e.g., 0 dBm to 20 dBm).
    - Modulation: NRZ or advanced modulation formats like QPSK.
2. **Free Space Optical Channel**:
    - Includes:
        - Atmospheric attenuation (clear, fog, rain conditions).
        - Geometric losses due to range.
        - Turbulence effects (optional for advanced modeling).
3. **Optical Receiver**:
    - PIN or Avalanche photodiode (APD) with known responsivity.
    - Filters to reduce noise from ambient light.
    - Performance analyzers: BER, Q-factor, power meter.
4. **Performance Measurement Tools**:
    - Power Meter: To calculate received optical power.
    - BER Analyzer: To evaluate error performance.
    - Q-Factor Analyzer: To assess signal quality.

Parameters to Vary
Range (Link Distance)
- Vary distances between 1 km and 10 km.
- Understand free-space path loss and its impact on received power.

Atmospheric Attenuation
- Introduce attenuation values for different weather conditions:
    - **Clear weather:** 0.2 dB/km.
    - **Light fog:** 10 dB/km.
    - **Moderate fog:** 30 dB/km.
    - **Heavy fog:** 100 dB/km.
    - **Rain:** 5–25 dB/km (depending on rain intensity).

Transmit Power
- Use power levels: 0 dBm, 10 dBm, 20 dBm.
- Study the impact of higher transmit power on mitigating attenuation.



Test Cases

Test Case 1: Effect of Range on Received Power

- **Setup**:
  - Fixed transmit power (e.g., 10 dBm).
  - Fixed attenuation (clear weather, 0.2 dB/km).
  - Vary link distances: 1 km, 5 km, 10 km.
- **Objective**:
  - Analyze how range impacts received power due to geometric spreading and atmospheric attenuation.
- **Expected Outcome**:
  - Longer distances result in reduced received power due to exponential path loss.

Test Case 2: Effect of Atmospheric Attenuation

- **Setup**:
  - Fixed link distance (e.g., 5 km).
  - Fixed transmit power (e.g., 10 dBm).
  - Apply attenuation coefficients for clear, light fog, moderate fog, and heavy fog.
- **Objective**:
  - Study the impact of weather conditions on the received power.
- **Expected Outcome**:
  - Clear weather results in maximum received power, while heavy fog severely attenuates the signal.

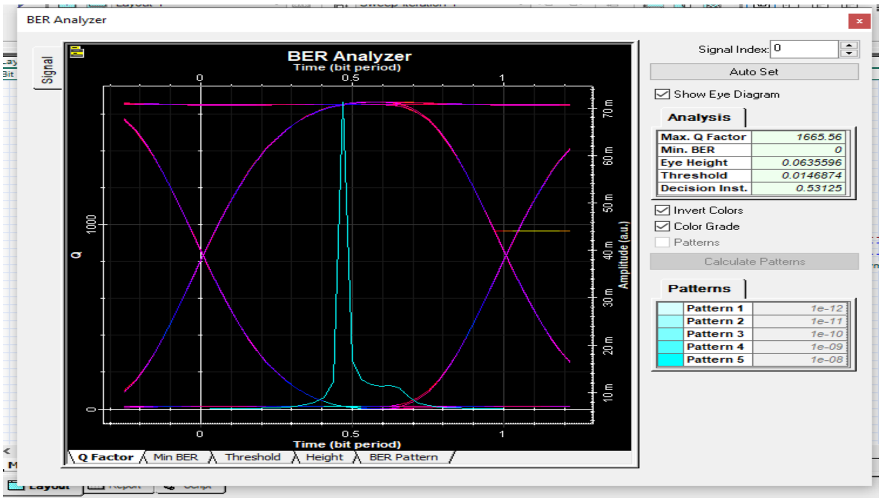
Test Case 3: Combined Effect of Range and Attenuation

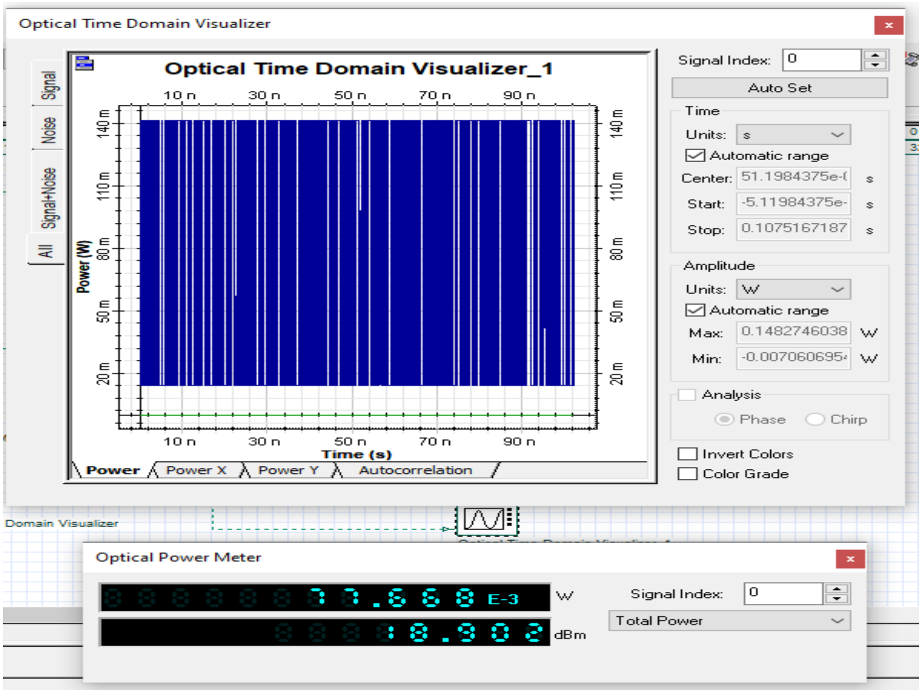
- **Setup**:
  - Vary link distance: 1 km, 5 km, 10 km.
  - Apply weather conditions (e.g., light fog: 10 dB/km).
  - Fixed transmit power (e.g., 10 dBm).

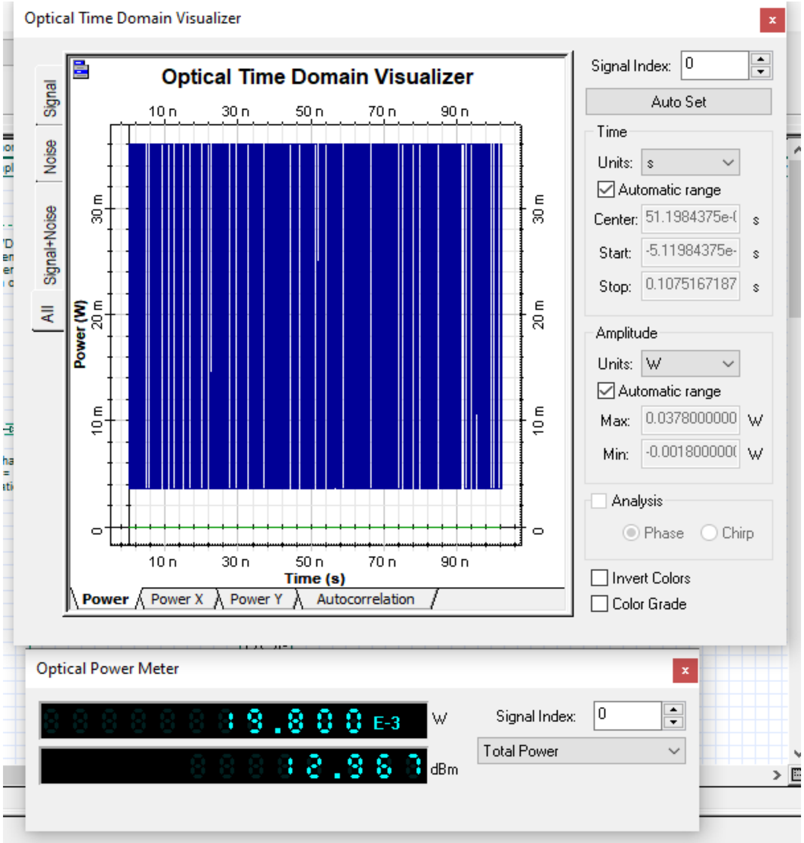
- **Objective**:
    - Evaluate the combined impact of increasing range and attenuation on the received power and BER.
- **Expected Outcome**:
    - The combined effect exacerbates signal degradation, especially for longer ranges and higher attenuation values.

Test Case 4: Impact of Transmit Power

- **Setup**:
    - Fixed distance (e.g., 5 km).
    - Fixed attenuation (e.g., light fog: 10 dB/km).
    - Vary transmit power: 0 dBm, 10 dBm, 20 dBm.
- **Objective**:
    - Assess the ability of increased transmit power to compensate for attenuation.
- **Expected Outcome**:
    - Higher transmit power improves received power but is limited by laser safety and hardware constraints.






Optical Time Domain Visualizer
Optical Time Domain Visualizer
Signal
Noise
Signal+Noise
All
Power (W)
Time (s)
Power
Power X
Power Y
Autocorrelation
Signal Index: 0
Auto Set
Time
Units: s
Automatic range
Center: 51.1984375e-
Start: -5.11984375e-
Stop: 0.1075167187
Amplitude
Units: W
Automatic range
Max: 0.0378000000 W
Min: -0.001800000 W
Analysis
Phase
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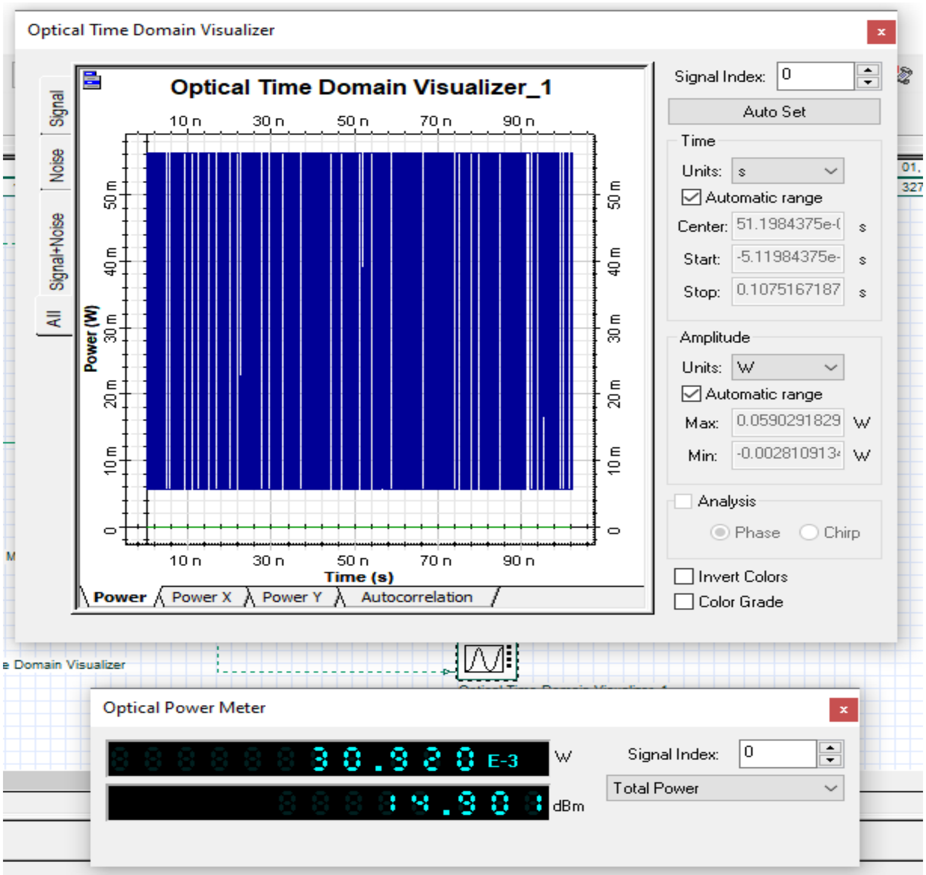
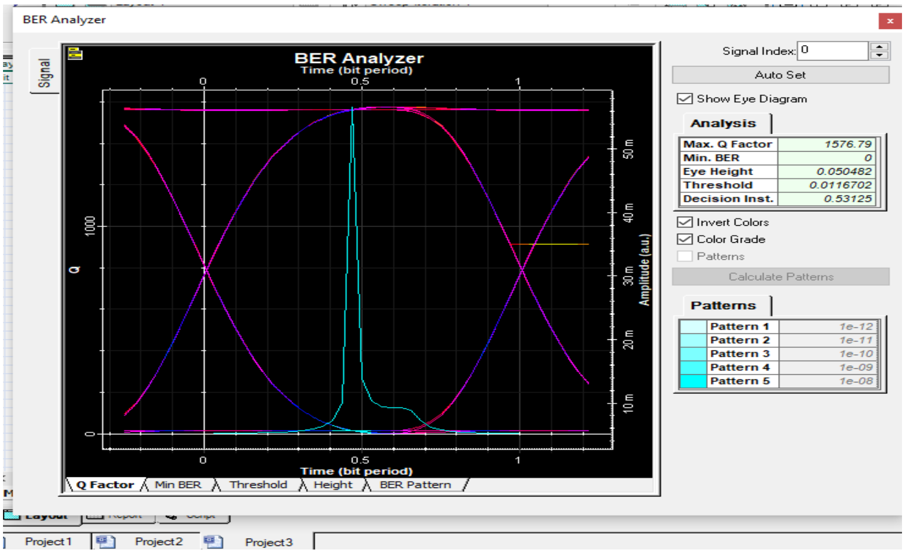
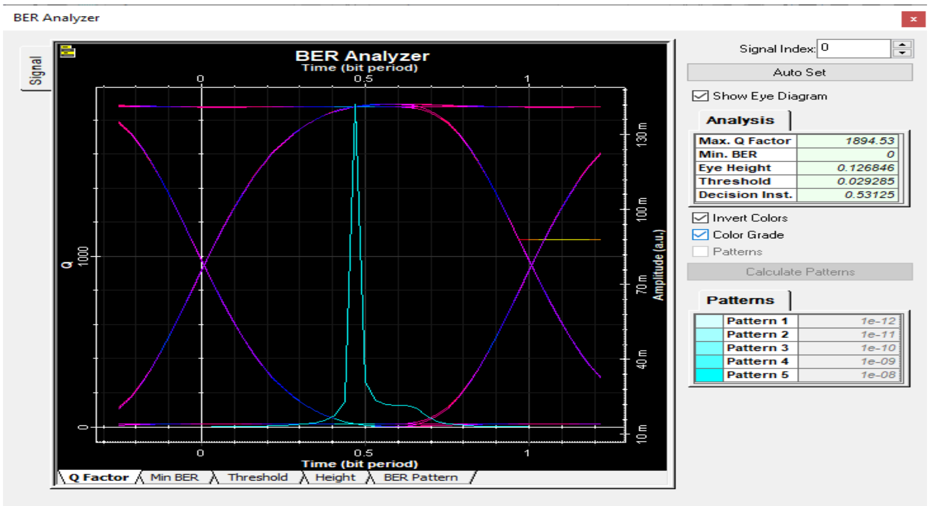
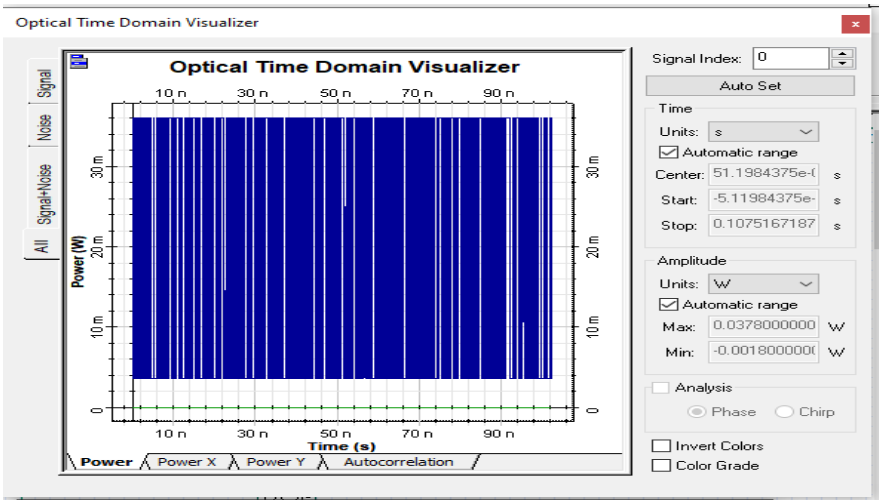
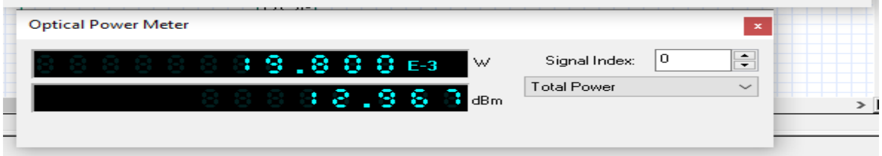
Color Grade
Optical Power Meter
19.800 E-3 W
12.967 dBm
Signal Index: 0
Total Power

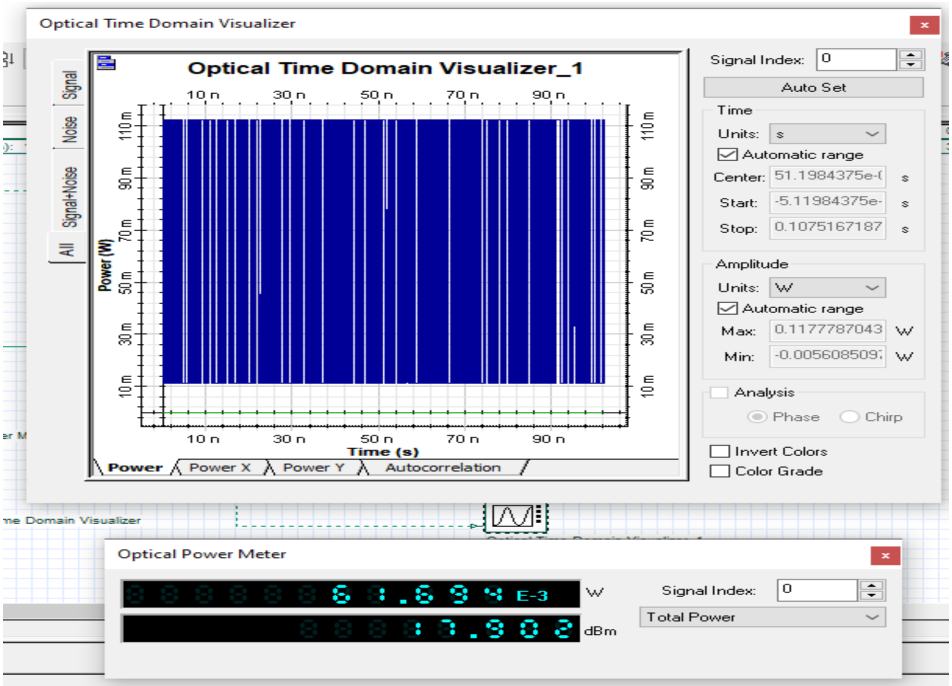

Optical Time Domain Visualizer
Optical Time Domain Visualizer_1
Signal
Noise
Signal+Noise
All
Power (W)
Time (s)
Power
Power X
Power Y
Autocorrelation
Signal Index: 0
Auto Set
Time
Units: s
Automatic range
Center: 51.1984375e-
Start: -5.11984375e-
Stop: 0.1075167187
Amplitude
Units: W
Automatic range
Max: 0.0590291829 W
Min: -0.002810913 W
Analysis
Phase
Chirp
Invert Colors
Color Grade
Optical Power Meter
30.920 E-3 W
14.901 dBm
Signal Index: 0
Total Power

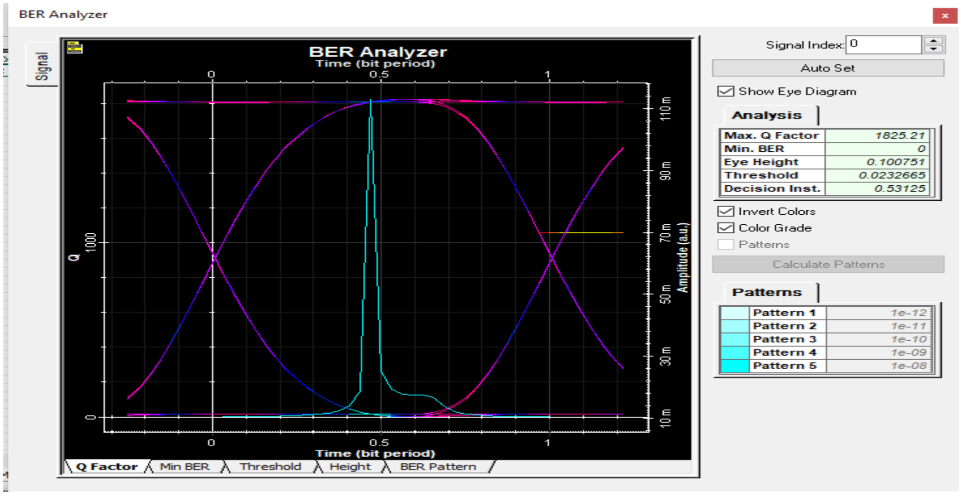

BER Analyzer
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 1576.79
Min. BER 0
Eye Height 0.050482
Threshold 0.0116702
Decision Inst. 0.53125
Invert Colors
Color Grade
Patterns
Calculate Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08
Time (bit period)
Amplitude (a.u.)
Q Factor
Min BER
Threshold
Height
BER Pattern
Project1
Project2
Project3

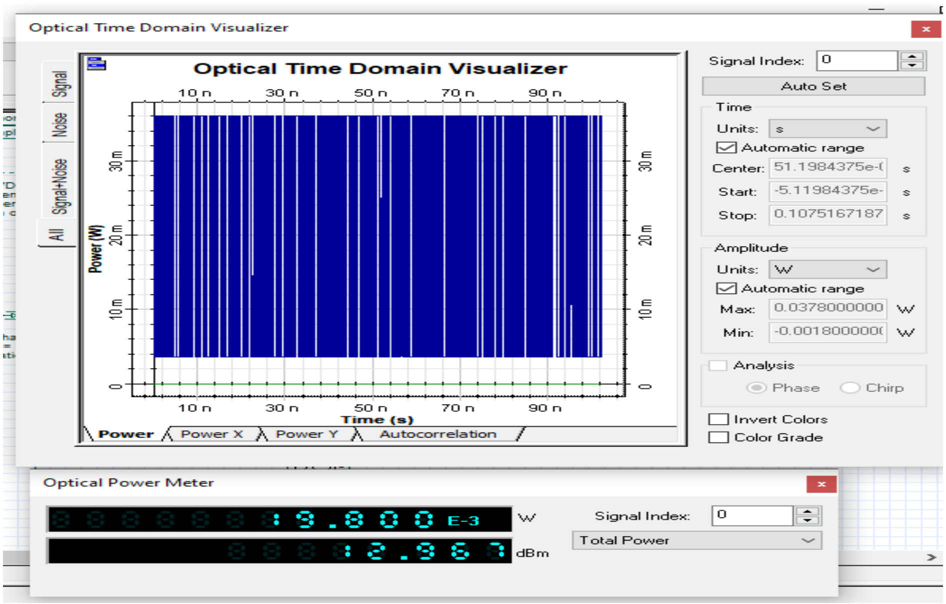

BER Analyzer
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 1894.53
Min. BER 0
Eye Height 0.126846
Threshold 0.029285
Decision Inst. 0.53125
Invert Colors
Color Grade
Patterns
Calculate Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08
Time (bit period)
Amplitude (a.u.)
Q Factor
Min BER
Threshold
Height
BER Pattern

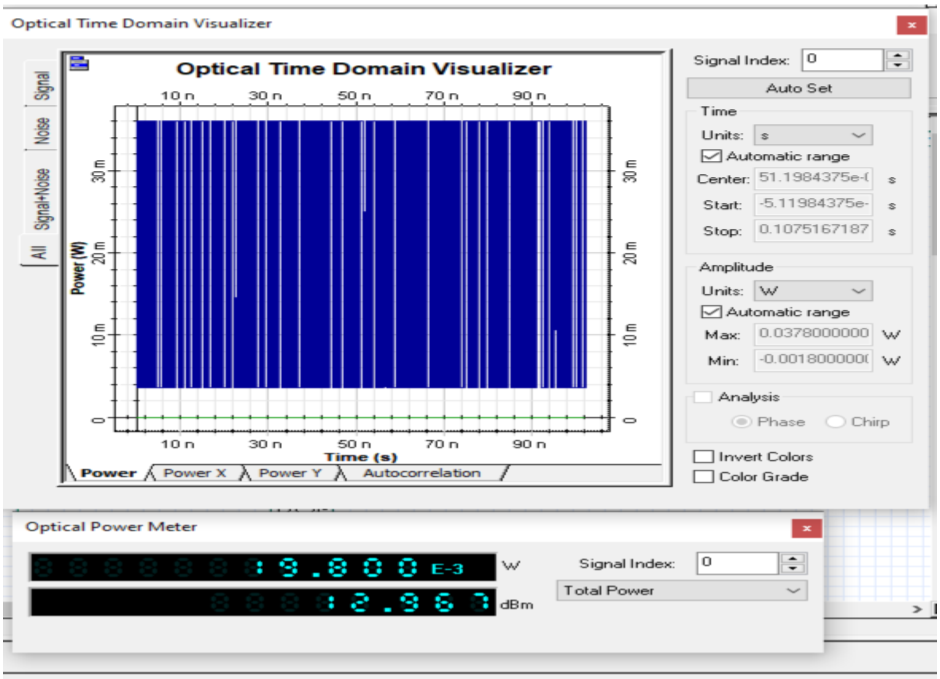

Optical Time Domain Visualizer
Signal Index: 0
Auto Set
Time
Units: s
Automatic range
Center: 51.1984375e-
Start: -5.11984375e-
Stop: 0.1075167187
Amplitude
Units: W
Automatic range
Max: 0.0378000000
Min: -0.001800000
Analysis
Phase
Chirp
Invert Colors
Color Grade
Time (s)
Power (W)
Power
Power X
Power Y
Autocorrelation

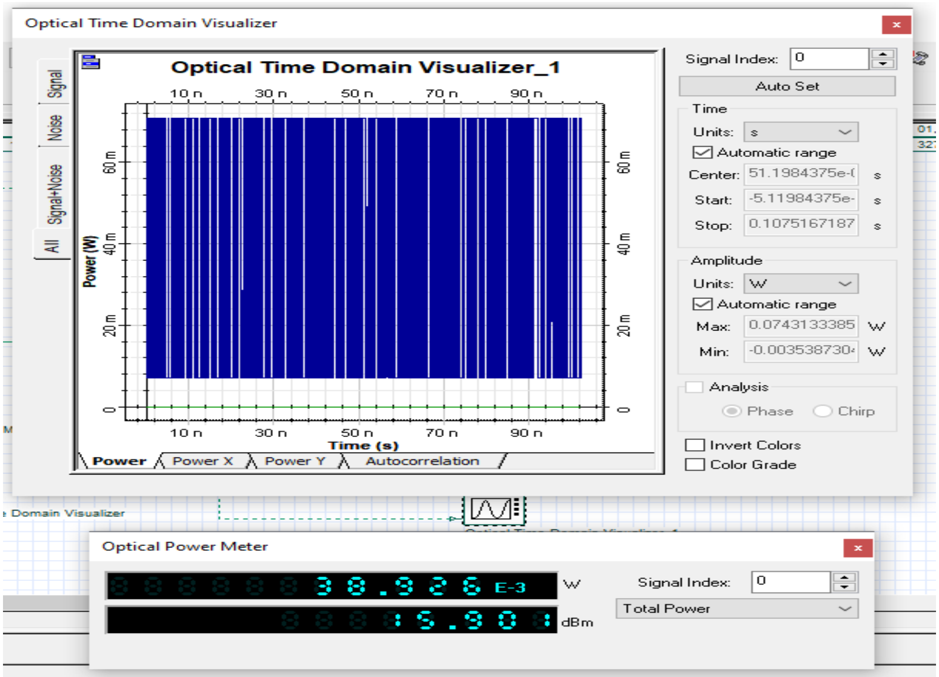

Optical Power Meter
9.800 E-3 W
12.967 dBm
Signal Index: 0
Total Power


Optical Time Domain Visualizer
Optical Time Domain Visualizer_1
Time (s)
Power (W)
Signal Index: 0
Auto Set
Time
Units: s
Automatic range
Center: 51.1984375e-(
Start: -5.11984375e-
Stop: 0.1075167187
Amplitude
Units: W
Max: 0.1177787043
Min: -0.005608509:
Analysis
Phase
Chirp
Invert Colors
Color Grade
Power
Power X
Power Y
Autocorrelation
Optical Power Meter
61.694 E-3 W
17.902 dBm
Total Power


BER Analyzer
Time (bit period)
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 1825.21
Min. BER 0
Eye Height 0.100751
Threshold 0.0232665
Decision Inst. 0.53125
Invert Colors
Color Grade
Patterns
Calculate Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08
Q Factor
Min BER
Threshold
Height
BER Pattern


Optical Time Domain Visualizer
Optical Time Domain Visualizer
Time (s)
Power (W)
Signal Index: 0
Auto Set
Time
Units: s
Automatic range
Center: 51.1984375e-(
Start: -5.11984375e-
Stop: 0.1075167187
Amplitude
Units: W
Max: 0.0378000000
Min: -0.0018000000
Analysis
Phase
Chirp
Invert Colors
Color Grade
Power
Power X
Power Y
Autocorrelation
Optical Power Meter
19.800 E-3 W
12.967 dBm
Total Power





Performance Metrics

Received Power (dBm)

- The primary metric to evaluate how much optical power is received after accounting for losses due to range and attenuation.

Bit Error Rate (BER)

- Indicates the reliability of the communication link.

Q-Factor

- Measures the quality of the received signal.

Power Penalty

- Quantifies the additional power needed to maintain acceptable BER in adverse conditions.

Calculation of Received Power

The received power (P_{recv}) can be calculated as:

$$P_{\text{recv}} = P_{\text{trans}} - \text{Free-space path loss} - \text{Atmospheric attenuation}$$

- **Free-space path loss** (L_{fspl}):

$$L_{\text{fspl}} = 20 \cdot \log_{10}(d) + 20 \cdot \log_{10}(f) + 20 \cdot \log_{10}(4\pi/c)$$

- d: Distance in meters.
- f: Frequency in Hz.
- c: Speed of light.
- **Atmospheric attenuation**:
  - Calculated as $\text{Attenuation coefficient (dB/km)} \times \text{Distance (km)}$.

Expected Results

1. **Range Variation**:
   - Received power decreases with increasing range due to free-space path loss.
2. **Atmospheric Attenuation**:
   - Higher attenuation values (e.g., in foggy conditions) lead to significant power loss and degradation in BER and Q-factor.
3. **Combined Range and Attenuation**:
   - The worst-case scenario arises with long-range links and adverse weather conditions.
4. **Transmit Power**:
   - Increasing transmit power can compensate for attenuation to some extent but is not a solution for very high attenuation values.

Conclusion

The simulation in OptiSystem provides a clear understanding of how FSO systems perform under varying ranges and atmospheric conditions. This analysis helps design robust FSO systems for different applications, ensuring reliable performance in various environments.

Exp.No. 16	Design and Analysis of Optical Spectrum using Optisystem by Varying Source Power and Optic Fiber Length

Objective

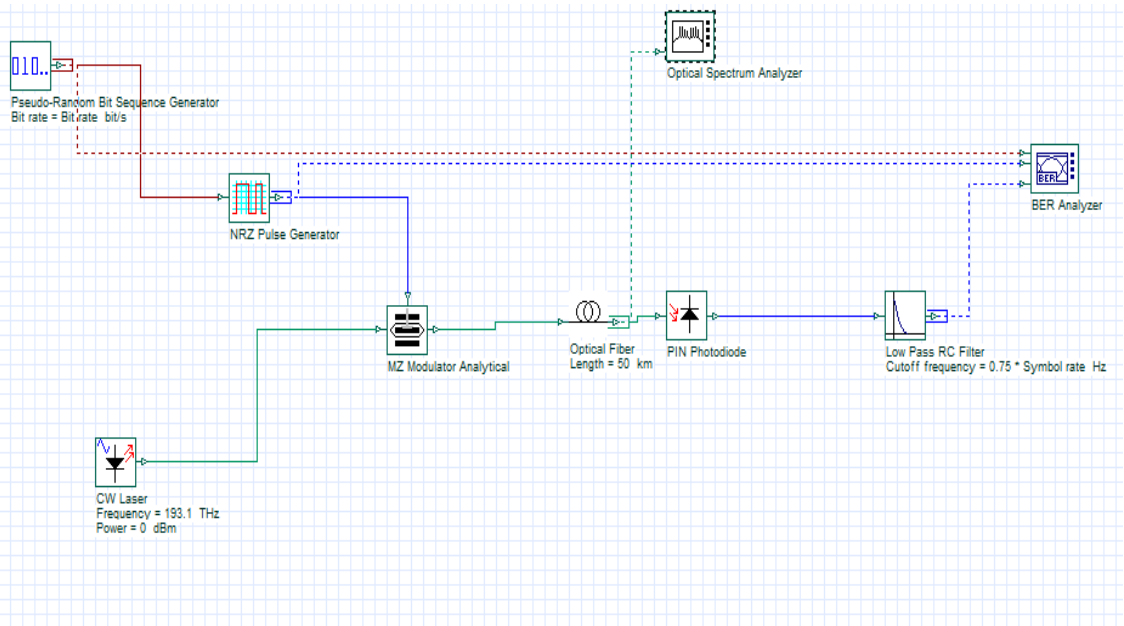
To design an optical communication system and analyze the effect of:

- Varying source power on the spectral shape and intensity.
- Increasing optical fiber length on signal attenuation, dispersion, and non-linear effects.

System Design in OptiSystem

Key Components

1. **Optical Transmitter**:
   - **Laser Source**: Tunable wavelength (e.g., 1550 nm) with variable output power.
   - **Modulator**: NRZ or advanced modulation schemes.
2. **Optical Fiber**:
   - Single-mode fiber with configurable length.
   - Includes attenuation, dispersion, and nonlinear effects such as Self-Phase Modulation (SPM) and Four-Wave Mixing (FWM).
3. **Amplifiers (optional)**:
   - Erbium-Doped Fiber Amplifier (EDFA) to counteract attenuation in long fibers.
4. **Receiver**:
   - PIN or Avalanche photodiode with noise modeling.
   - Spectrum analyzer for optical spectrum visualization.
5. **Performance Measurement Tools**:
   - Optical Spectrum Analyzer (OSA) to observe changes in spectral width and power.
   - BER Analyzer and Q-Factor Analyzer for performance evaluation.



Parameters to Vary

Source Power:

- Adjust the laser output power between low, medium, and high levels (e.g., 0 dBm, 10 dBm, 20 dBm).
- Observe how increasing source power influences signal strength, spectral broadening, and nonlinear effects.

Optical Fiber Length:

- Vary fiber length from short (e.g., 10 km) to long distances (e.g., 100 km or more).
- Study the impact on attenuation, dispersion-induced broadening, and nonlinear effects.

Test Cases

Test Case 1: Impact of Source Power on Optical Spectrum

- **Setup**:
  - Fixed fiber length (e.g., 10 km).
  - Vary source power: 0 dBm, 10 dBm, 20 dBm.
- **Objective**:
  - Evaluate how higher power levels affect spectral intensity and nonlinear effects.
- **Expected Outcome**:
  - Higher source power results in increased spectral intensity and nonlinear spectral broadening.

Test Case 2: Impact of Fiber Length on Optical Spectrum

- **Setup**:
  - Fixed source power (e.g., 10 dBm).
  - Vary fiber length: 10 km, 50 km, 100 km.
- **Objective**:
  - Observe the impact of attenuation, dispersion, and nonlinear effects on the optical spectrum.
- **Expected Outcome**:
  - Longer fibers cause spectral attenuation, broadening due to dispersion, and distortion from nonlinear effects.

Test Case 3: Combined Effect of Source Power and Fiber Length

- **Setup**:
  - Vary both source power (e.g., 0 dBm, 10 dBm, 20 dBm) and fiber length (10 km, 50 km, 100 km).
- **Objective**:
  - Analyze the combined impact of these parameters on the optical spectrum and system performance.
- **Expected Outcome**:
  - Higher power and longer fibers amplify nonlinear effects, causing spectrum distortion and increased signal degradation.

Performance Metrics

1. **Optical Spectrum**:
   - Analyze the spectral shape, power distribution, and bandwidth using an optical spectrum analyzer.

2. **Spectral Broadening**:
    - Measure the increase in spectral width caused by dispersion and nonlinear effects.
3. **Received Power (dBm)**:
    - Evaluate the signal strength at the receiver.
4. **Signal-to-Noise Ratio (SNR)**:
    - Quantify the quality of the transmitted signal.
5. **Nonlinear Effects**:
    - Identify distortions like Self-Phase Modulation (SPM) and Four-Wave Mixing (FWM) in the spectrum.

Simulation Procedure in OptiSystem

1. **System Design**:
    - Create an optical communication system using a laser source, optical fiber, and receiver.
    - Include an optical spectrum analyzer to visualize the spectrum.
2. **Parameter Variation**:
    - Adjust source power and fiber length for different test cases.
3. **Simulation**:
    - Run the simulations to generate spectral data for each configuration.
4. **Data Analysis**:
    - Use the optical spectrum analyzer to observe spectral changes.
    - Record BER, Q-factor, and received power for performance analysis.

Results and Analysis

Source Power Effects:

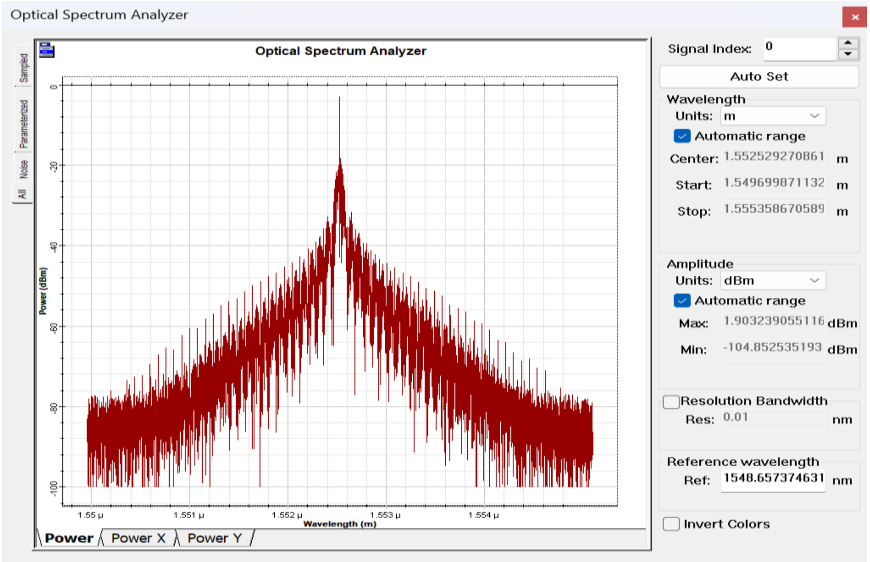
- Higher source power leads to:
    - Increased spectral intensity.
    - Broader spectrum due to nonlinear effects like SPM.
    - Enhanced signal strength at the cost of spectral distortion.

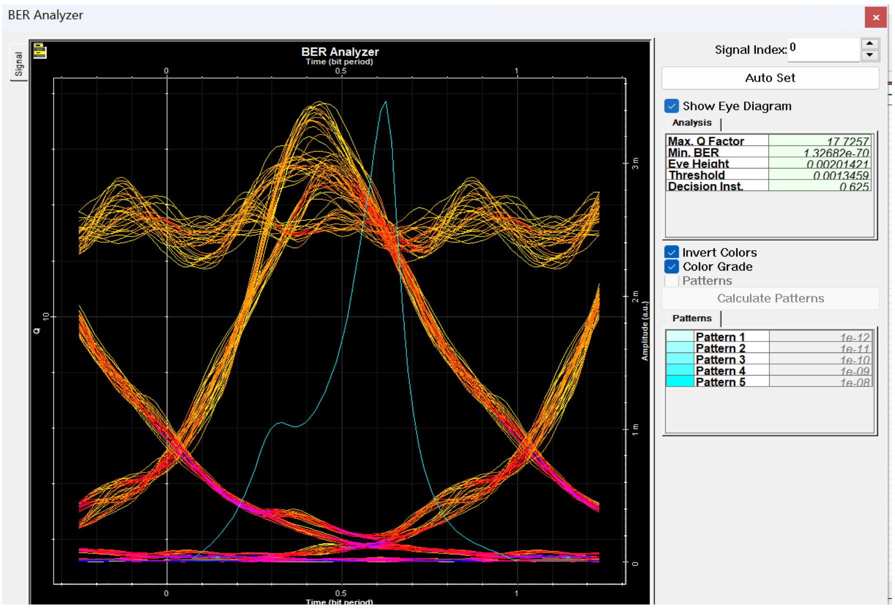
Fiber Length Effects:

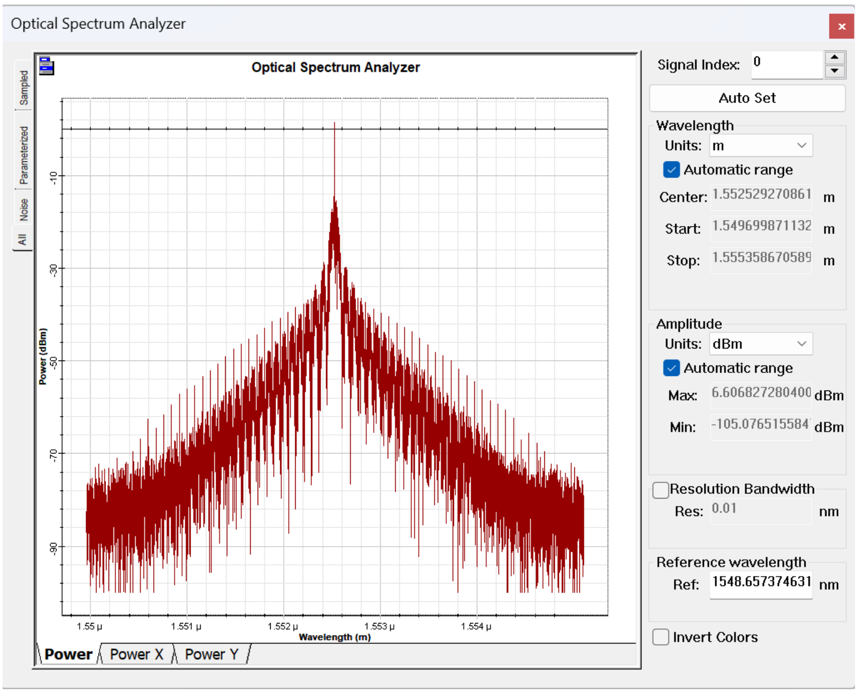
- Longer fibers cause:
    - Increased attenuation, reducing spectral intensity.
    - Broader spectrum due to chromatic dispersion.
    - Higher nonlinear effects, distorting the spectrum further.

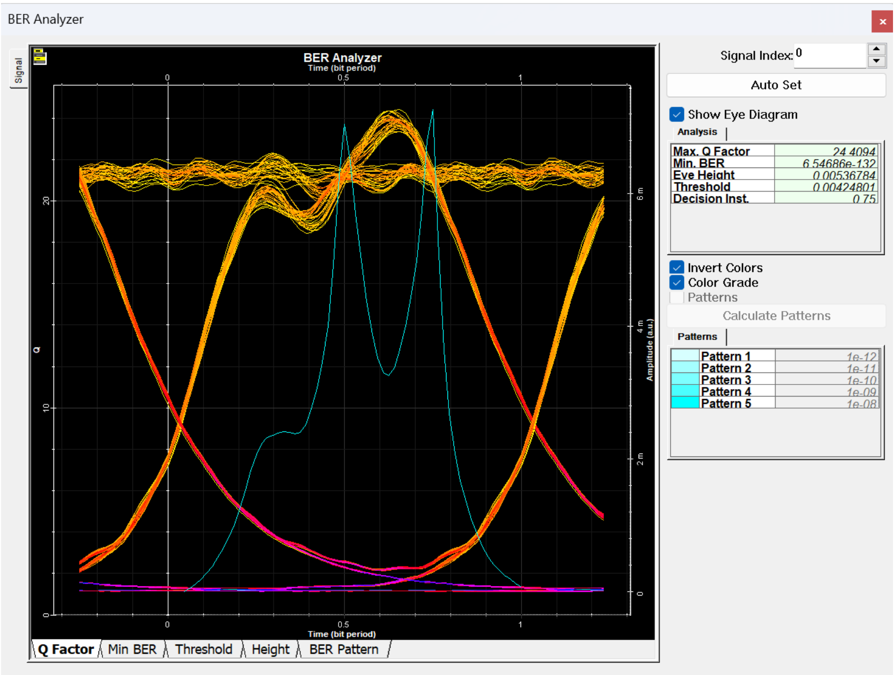
Combined Effects:

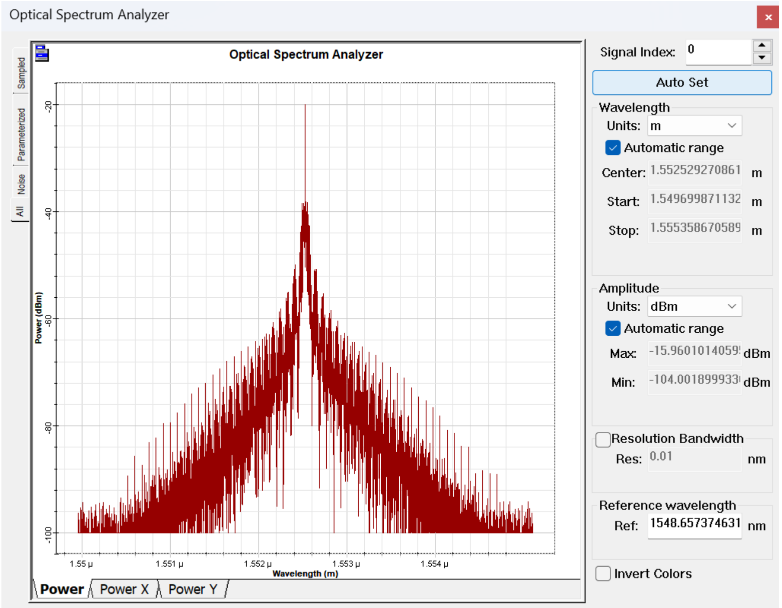
- The combination of high power and long fiber amplifies:
    - Nonlinear distortions, significantly altering the spectrum.
    - Signal degradation, affecting system performance.

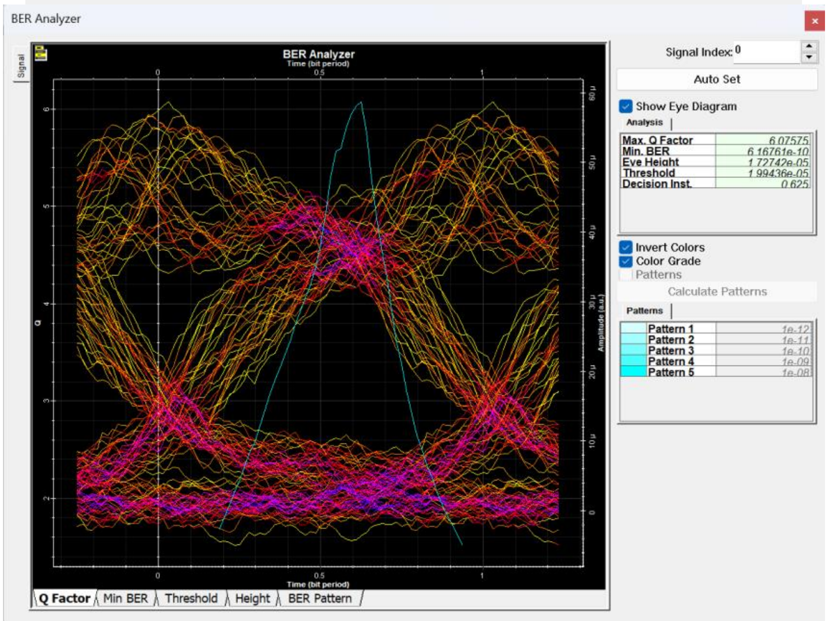

Optical Spectrum Analyzer
Optical Spectrum Analyzer
Power (dBm)
Wavelength (m)
1.55 μ
1.551 μ
1.552 μ
1.553 μ
1.554 μ
Power
Power X
Power Y
Signal Index: 0
Auto Set
Wavelength
Units: m
Automatic range
Center: 1.552529270861 m
Start: 1.549699871132 m
Stop: 1.555358670589 m
Amplitude
Units: dBm
Automatic range
Max: 1.903239055116 dBm
Min: -104.852535193 dBm
Resolution Bandwidth
Res: 0.01 nm
Reference wavelength
Ref: 1548.657374631 nm
Invert Colors

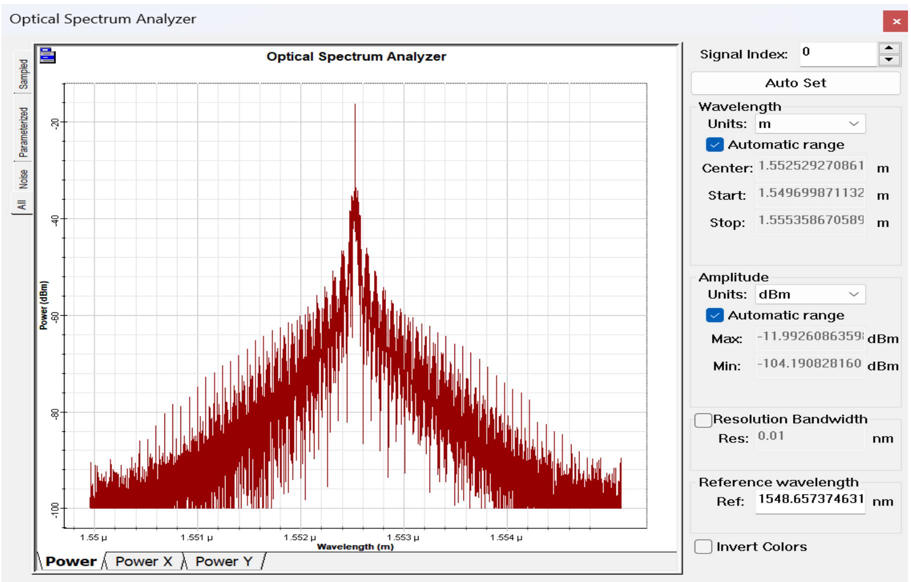

BER Analyzer
BER Analyzer
Time (bit period)
Amplitude (a.u.)
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 17.7257
Min. BER 1.32682e-70
Eye Height 0.00201421
Threshold 0.0013459
Decision Inst. 0.625
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08


Optical Spectrum Analyzer
Optical Spectrum Analyzer
Signal Index: 0
Auto Set
Wavelength
Units: m
Automatic range
Center: 1.552529270861 m
Start: 1.549699871132 m
Stop: 1.555358670589 m
Amplitude
Units: dBm
Automatic range
Max: 6.606827280400 dBm
Min: -105.076515584 dBm
Resolution Bandwidth
Res: 0.01 nm
Reference wavelength
Ref: 1548.657374631 nm
Invert Colors
Power (dBm)
Wavelength (m)
Power
Power X
Power Y


BER Analyzer
BER Analyzer
Time (bit period)
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 24.4094
Min. BER 6.54686e-132
Eye Height 0.00536784
Threshold 0.00424801
Decision Inst. 0.75
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08
Amplitude (a.u.)
Q Factor
Min BER
Threshold
Height
BER Pattern


Optical Spectrum Analyzer
Optical Spectrum Analyzer
Power (dBm)
Wavelength (m)
1.55 μ
1.551 μ
1.552 μ
1.553 μ
1.554 μ
Power
Power X
Power Y
Signal Index: 0
Auto Set
Wavelength
Units: m
Automatic range
Center: 1.552529270861 m
Start: 1.549699871132 m
Stop: 1.555358670589 m
Amplitude
Units: dBm
Automatic range
Max: -15.9601014059 dBm
Min: -104.001899933 dBm
Resolution Bandwidth
Res: 0.01 nm
Reference wavelength
Ref: 1548.657374631 nm
Invert Colors


BER Analyzer
BER Analyzer
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 6.07575
Min. BER 6.16761e-10
Eye Height 1.72742e-05
Threshold 1.99436e-05
Decision Inst. 0.625
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08


Optical Spectrum Analyzer
Optical Spectrum Analyzer
Power (dBm)
Wavelength (m)
1.55 μ
1.551 μ
1.552 μ
1.553 μ
1.554 μ
Power
Power X
Power Y
Signal Index: 0
Auto Set
Wavelength
Units: m
Automatic range
Center: 1.552529270861 m
Start: 1.549699871132 m
Stop: 1.555358670589 m
Amplitude
Units: dBm
Automatic range
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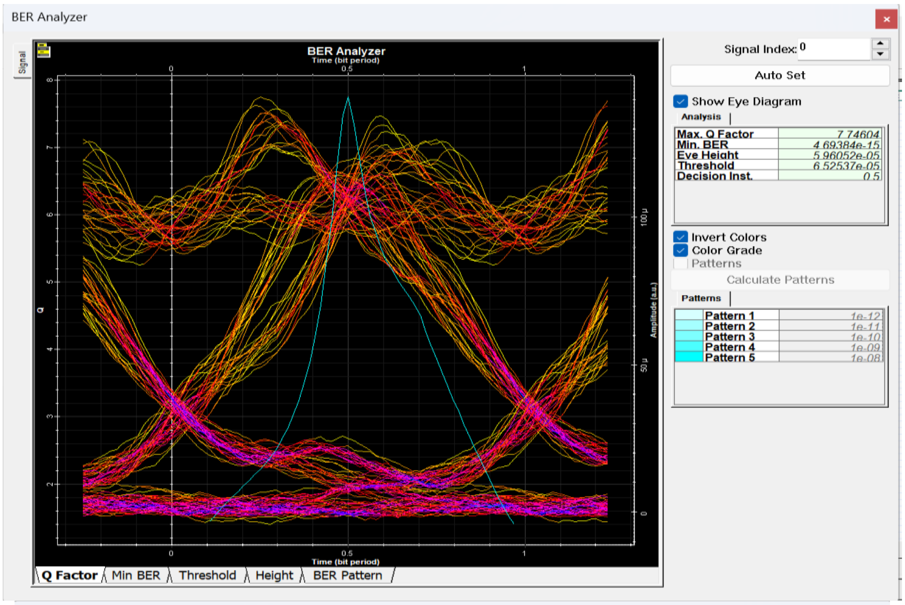
Min: -104.190828160 dBm
Resolution Bandwidth
Res: 0.01 nm
Reference wavelength
Ref: 1548.657374631 nm
Invert Colors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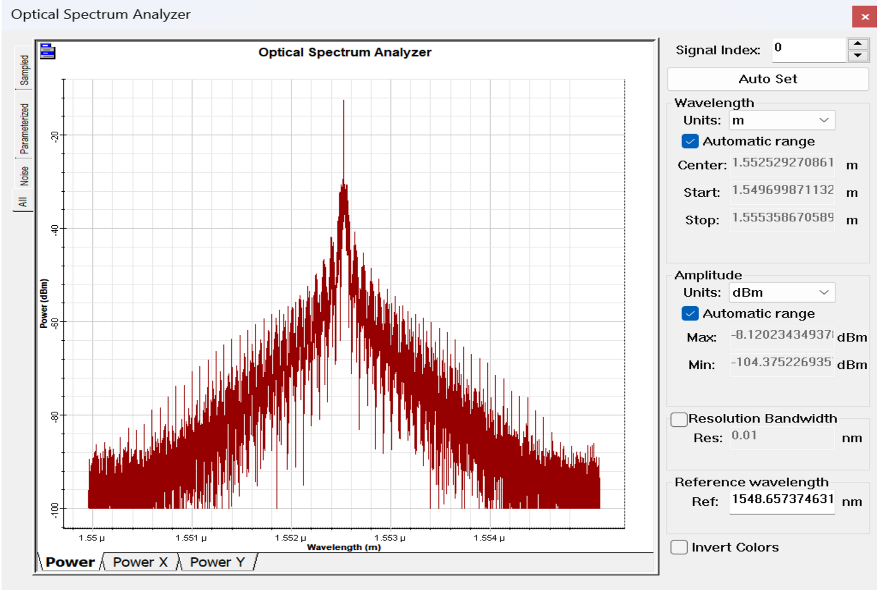
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 7.74604
Min. BER 4.69384e-15
Eye Height 5.96052e-05
Threshold 6.52537e-05
Decision Inst. 0.5
Invert Colors
Color Grade
Patterns
Calculate Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern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Signal Index: 0
Auto Set
Wavelength
Units: m
Automatic range
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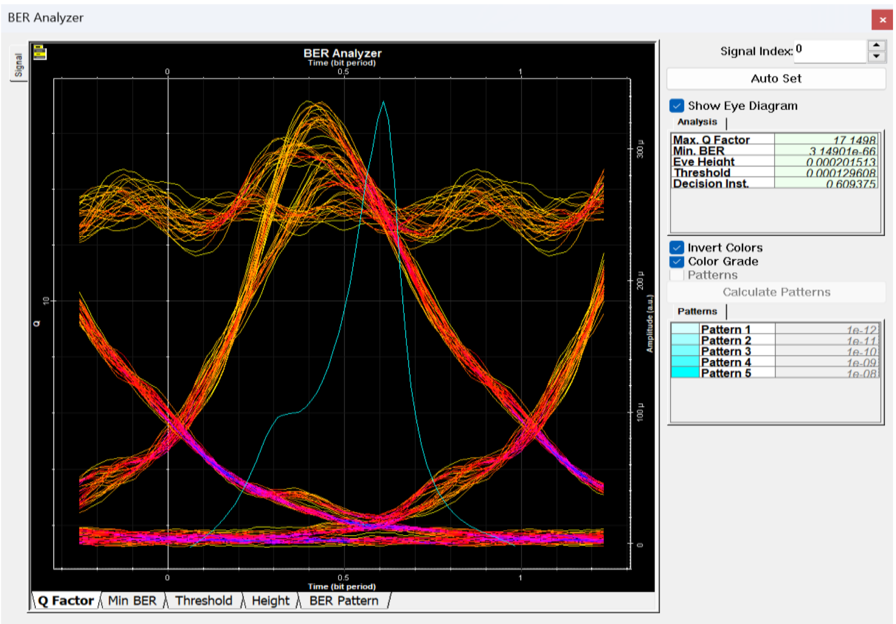
Start: 1.549699871132 m
Stop: 1.555358670589 m
Amplitude
Units: dBm
Automatic range
Max: -8.12023434937 dBm
Min: -104.375226935 dBm
Resolution Bandwidth
Res: 0.01 nm
Reference wavelength
Ref: 1548.657374631 nm
Invert Colors
Power (dBm)
Wavelength (m)
Power
Power X
Power Y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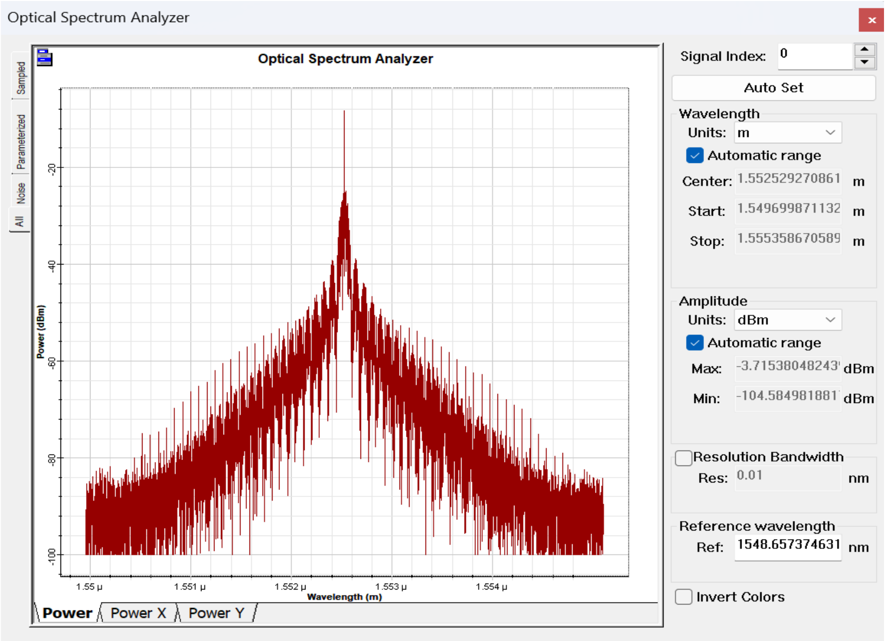
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 17.1498
Min. BER 3.14901e-66
Eye Height 0.000201513
Threshold 0.000129608
Decision Inst. 0.609375
Invert Colors
Color Grade
Patterns
Calculate Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern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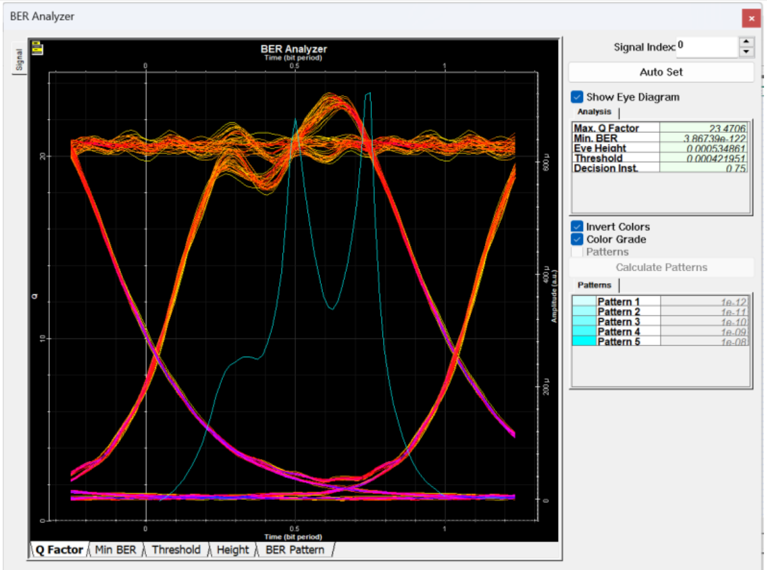
Signal Index: 0
Auto Set
Wavelength
Units: m
Automatic range
Center: 1.552529270861 m
Start: 1.549699871132 m
Stop: 1.555358670589 m
Amplitude
Units: dBm
Automatic range
Max: -3.71538048243 dBm
Min: -104.584981881 dBm
Resolution Bandwidth
Res: 0.01 nm
Reference wavelength
Ref: 1548.657374631 nm
Invert Colors
Power (dBm)
Wavelength (m)
Power
Power X
Power Y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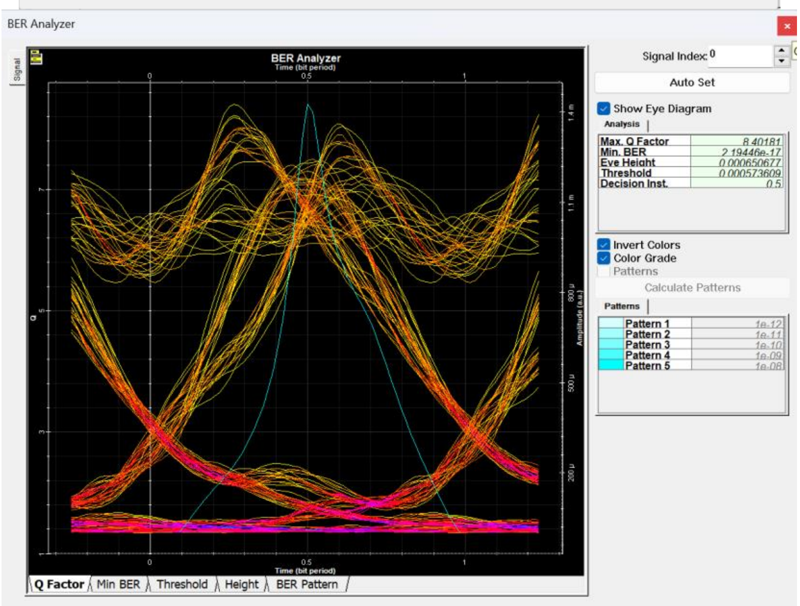
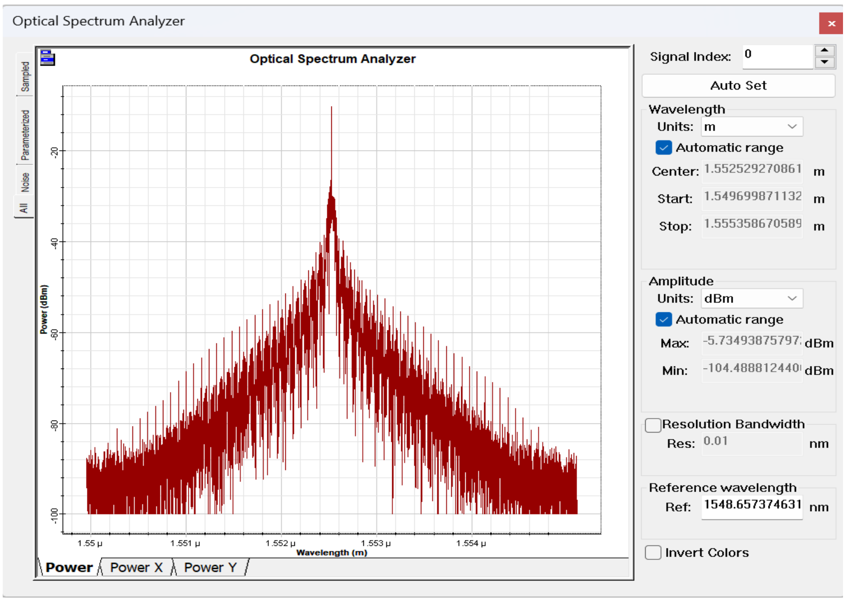
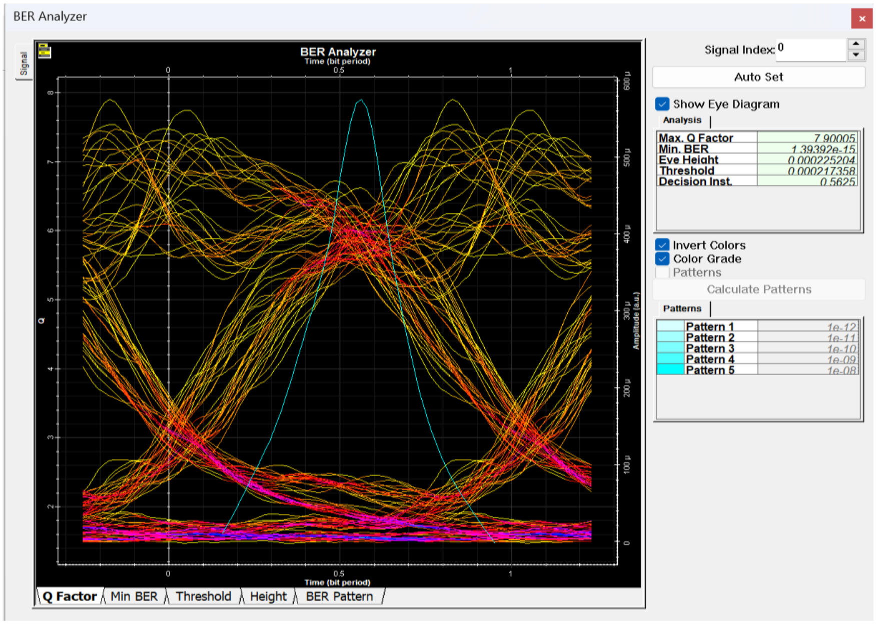
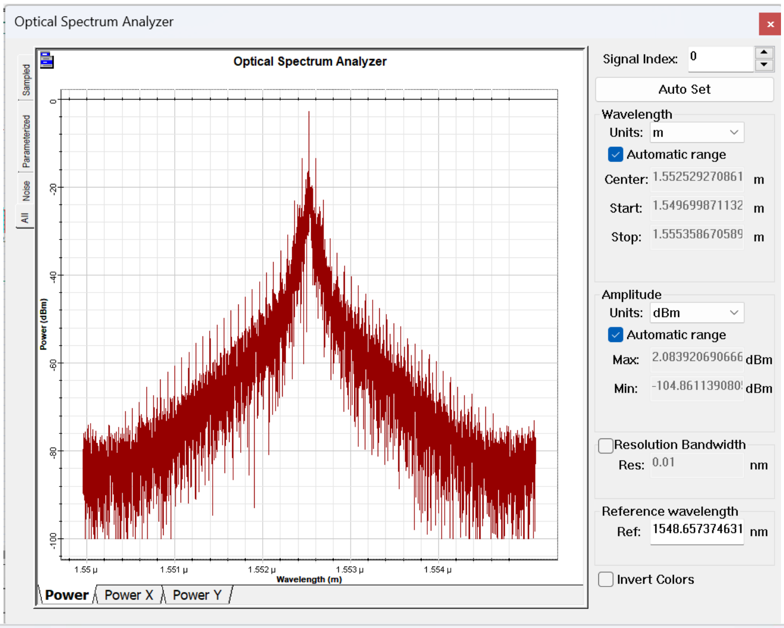
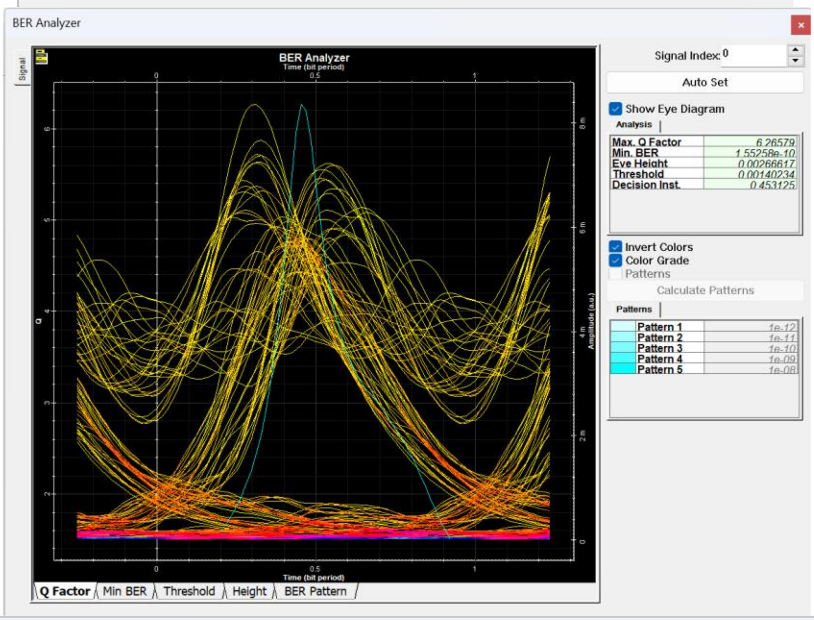
Signal Index: 0
Auto Set
Show Eye Diagram
Max. Q Factor 23.4706
Min. BER 3.86739e-122
Eye Height 0.000534861
Threshold 0.000421951
Decision Inst. 0.75
Invert Colors
Color Grade
Calculate Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern

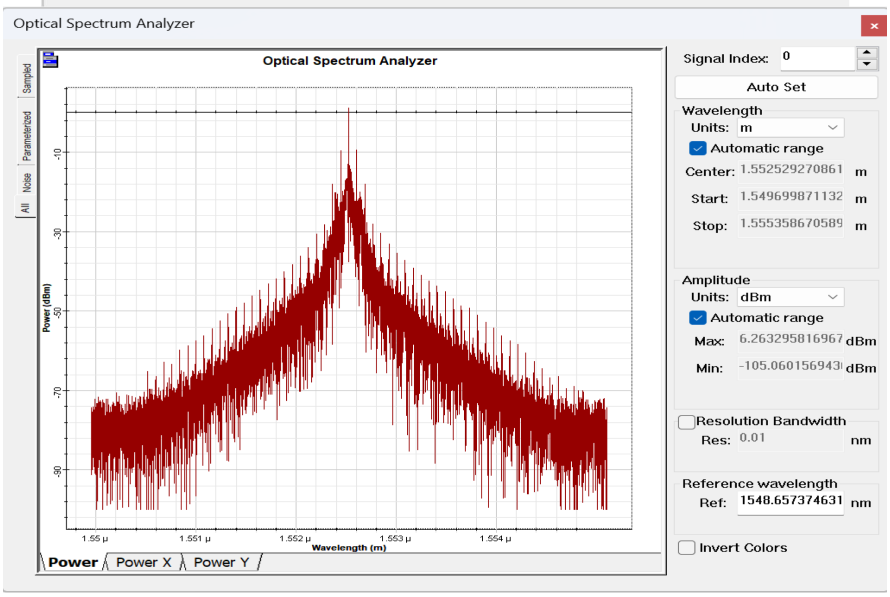

BER Analyzer
Signal Index: 0
Auto Set
Show Eye Diagram
Max. Q Factor 8.40181
Min. BER 2.19446e-17
Eye Height 0.000650677
Threshold 0.000573609
Decision Inst. 0.5
Invert Colors
Color Grade
Calculate Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern

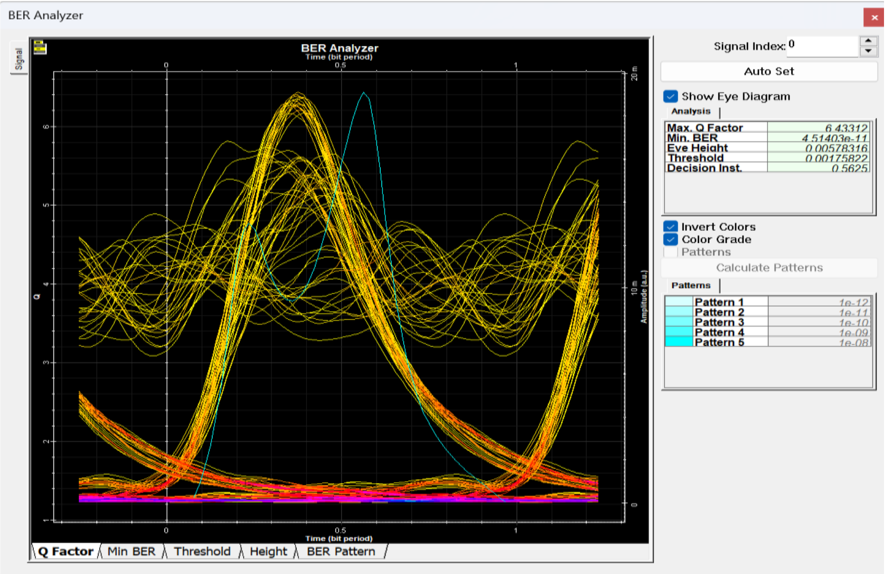

Optical Spectrum Analyzer
Optical Spectrum Analyzer
Power (dBm)
Wavelength (m)
Power
Power X
Power Y
Signal Index: 0
Auto Set
Wavelength
Units: m
Automatic range
Center: 1.552529270861 m
Start: 1.549699871132 m
Stop: 1.555358670589 m
Amplitude
Units: dBm
Automatic range
Max: -5.73493875797 dBm
Min: -104.488812440 dBm
Resolution Bandwidth
Res: 0.01 nm
Reference wavelength
Ref: 1548.657374631 nm
Invert Colors

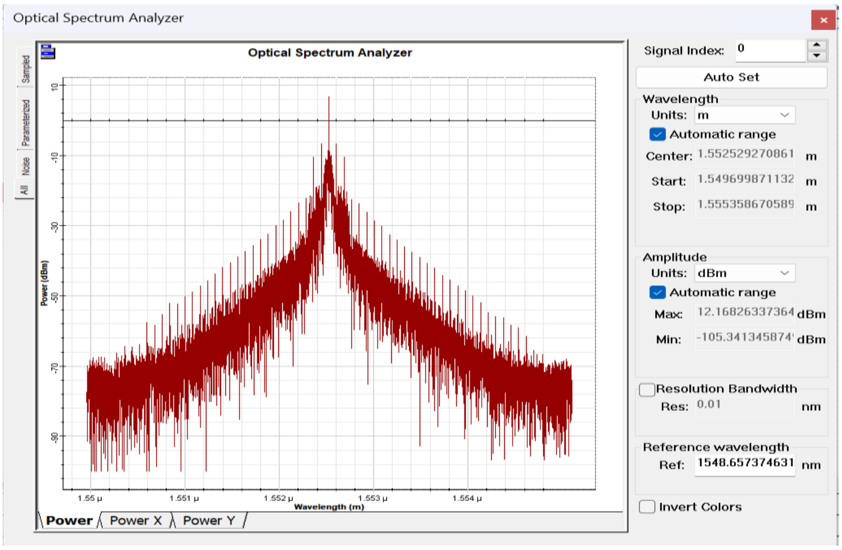

BER Analyzer
BER Analyzer
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 7.90005
Min. BER 1.39392e-15
Eye Height 0.000225204
Threshold 0.000217358
Decision Inst. 0.5625
Invert Colors
Color Grade
Patterns
Calculate Patterns
Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08

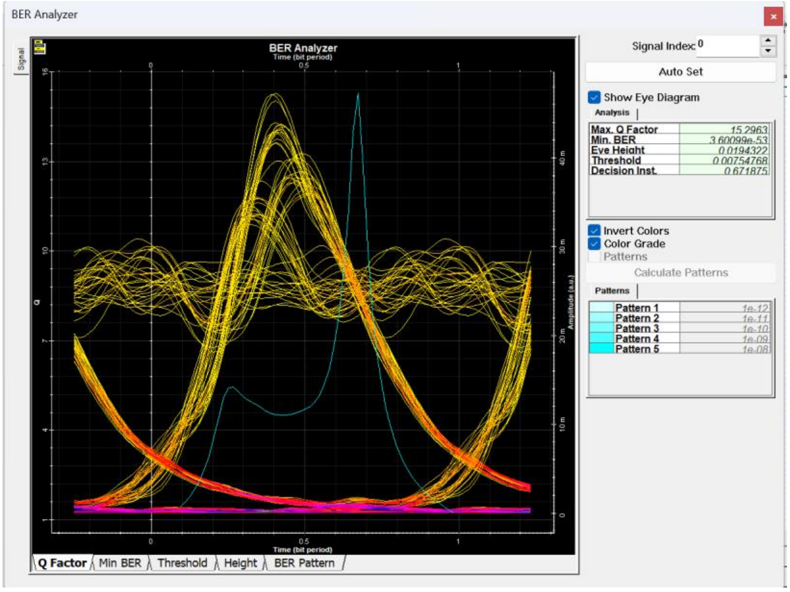

Optical Spectrum Analyzer
Signal Index: 0
Auto Set
Wavelength
Units: m
Automatic range
Center: 1.552529270861 m
Start: 1.549699871132 m
Stop: 1.555358670589 m
Amplitude
Units: dBm
Automatic range
Max: 2.083920690666 dBm
Min: -104.861139080 dBm
Resolution Bandwidth
Res: 0.01 nm
Reference wavelength
Ref: 1548.657374631 nm
Invert Colors
Power (dBm)
Wavelength (m)
Power
Power X
Power Y

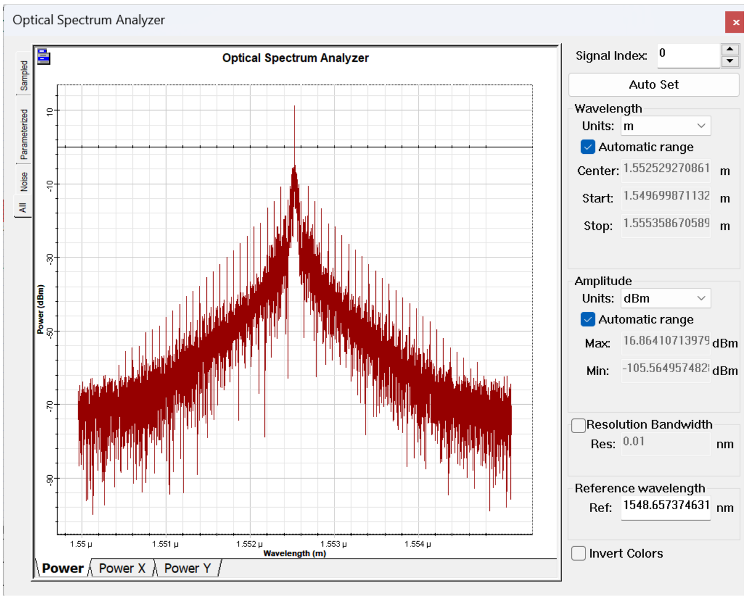

BER Analyzer
Signal Index: 0
Auto Set
Show Eye Diagram
Analysis
Max. Q Factor 6.26579
Min. BER 1.55258e-10
Eye Height 0.00266617
Threshold 0.00140234
Decision Inst. 0.453125
Invert Colors
Color Grade
Patterns
Calculate Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08
Time (bit period)
Q Factor
Min BER
Threshold
Height
BER Pattern

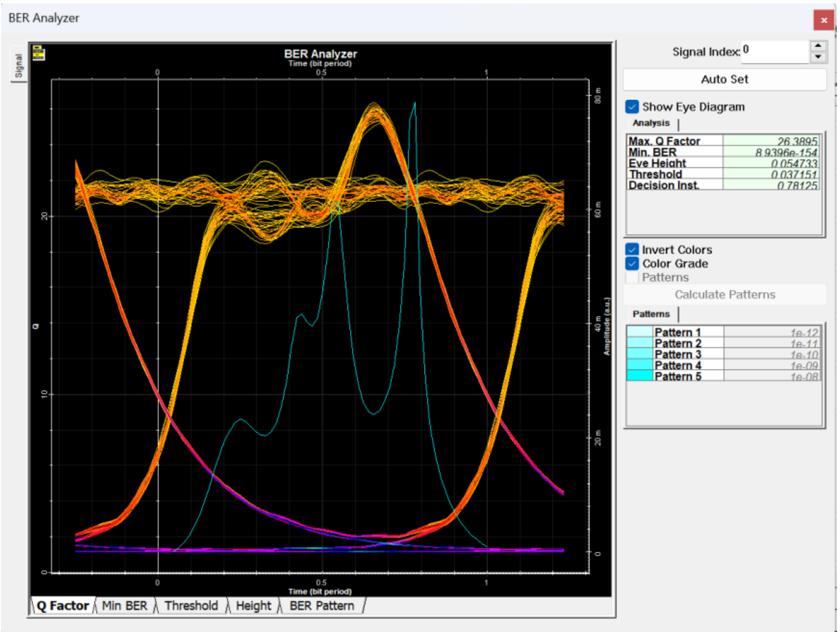

Optical Spectrum Analyzer
Signal Index: 0
Auto Set
Wavelength
Units: m
Automatic range
Center: 1.552529270861 m
Start: 1.549699871132 m
Stop: 1.555358670589 m
Amplitude
Units: dBm
Automatic range
Max: 6.263295816967 dBm
Min: -105.060156943 dBm
Resolution Bandwidth
Res: 0.01 nm
Reference wavelength
Ref: 1548.657374631 nm
Invert Colors
Power (dBm)
Wavelength (m)
Power
Power X
Power Y

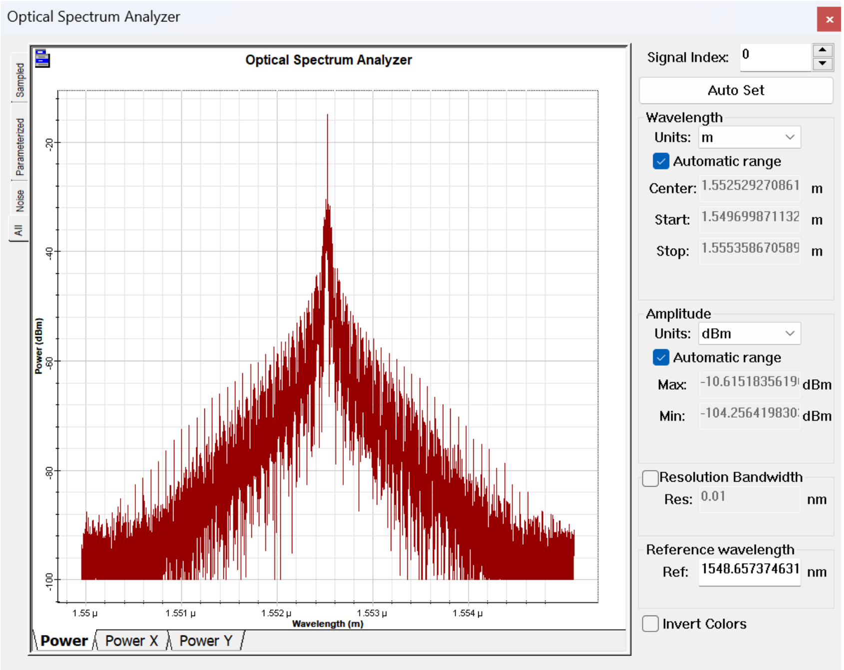

BER Analyzer
Signal Index: 0
Auto Set
Show Eye Diagram
Max. Q Factor 6.43312
Min. BER 4.51403e-11
Eye Height 0.00578316
Threshold 0.00175822
Decision Inst. 0.5625
Invert Colors
Color Grade
Patterns
Calculate Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08
Q Factor
Min BER
Threshold
Height
BER Pattern


Optical Spectrum Analyzer
Signal Index: 0
Auto Set
Wavelength
Units: m
Automatic range
Center: 1.552529270861 m
Start: 1.549699871132 m
Stop: 1.555358670589 m
Amplitude
Units: dBm
Automatic range
Max: 12.16826337364 dBm
Min: -105.341345874 dBm
Resolution Bandwidth
Res: 0.01 nm
Reference wavelength
Ref: 1548.657374631 nm
Invert Colors
Wavelength (m)
Power (dBm)
Power
Power X
Power Y


BER Analyzer
Signal Index 0
Auto Set
Show Eye Diagram
Max. Q Factor 15.2963
Min. BER 3.60099e-53
Eye Height 0.0194322
Threshold 0.00754768
Decision Inst. 0.671875
Invert Colors
Color Grade
Patterns
Calculate Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08
Q Factor
Min BER
Threshold
Height
BER Pattern


Optical Spectrum Analyzer
Signal Index: 0
Auto Set
Wavelength
Units: m
Automatic range
Center: 1.552529270861 m
Start: 1.549699871132 m
Stop: 1.555358670589 m
Amplitude
Units: dBm
Automatic range
Max: 16.86410713979 dBm
Min: -105.5649574821 dBm
Resolution Bandwidth
Res: 0.01 nm
Reference wavelength
Ref: 1548.657374631 nm
Invert Colors
Power (dBm)
Wavelength (m)
Power
Power X
Power Y


BER Analyzer
Signal Index 0
Auto Set
Show Eye Diagram
Max. Q Factor 26.3895
Min. BER 8.9396e-154
Eye Height 0.054733
Threshold 0.037151
Decision Inst. 0.78125
Invert Colors
Color Grade
Patterns
Calculate Patterns
Pattern 1 1e-12
Pattern 2 1e-11
Pattern 3 1e-10
Pattern 4 1e-09
Pattern 5 1e-08
Q Factor
Min BER
Threshold
Height
BER Pattern



Conclusion

This study demonstrates how source power and fiber length impact the optical spectrum and overall system performance. While higher power improves received signal strength, it introduces nonlinear distortions. Similarly, longer fibers degrade performance due to attenuation, dispersion, and nonlinearities.