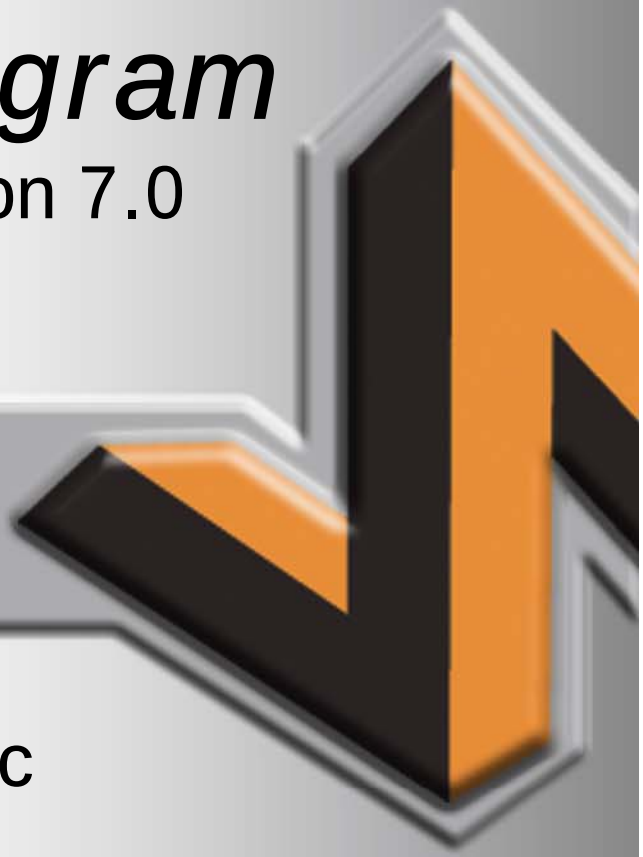
VPI University Program

Photonics Curriculum Version 7.0

Lecture Series



Introduction to Fiber-Optic Communications I

FOC1

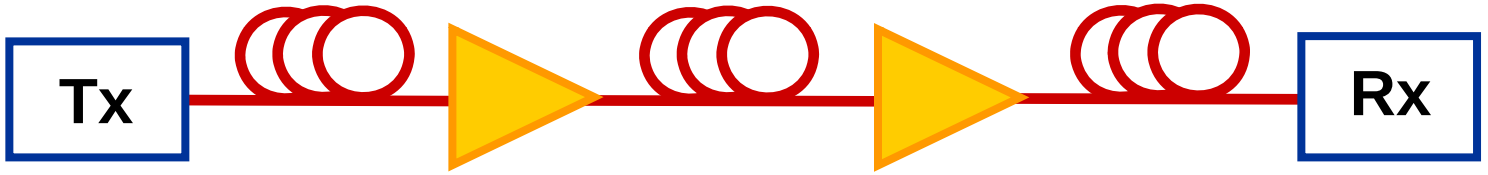
Course Prerequisites

- **Basic Theory of Communications**
- **Statistics and Stochastic Processes**
- **2nd Year Physics, Mathematics, Electric/Electronic/Communications Engineering**
- **Should have worked through the *User's Manual* of *VPItransmissionMaker*/*VPIcomponentMaker* before starting this unit (to understand how to handle the software).**

Course Objectives

By the end of this course, you should:

- **Understand how fiber-optic communication systems work**



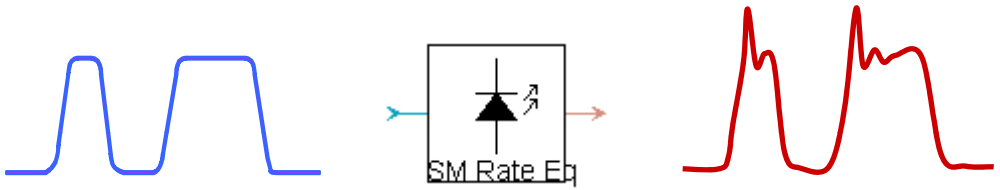
- **Understand how key devices in those systems work**

- **Be able to analyze the operation of those systems**

Course Objectives (continued)

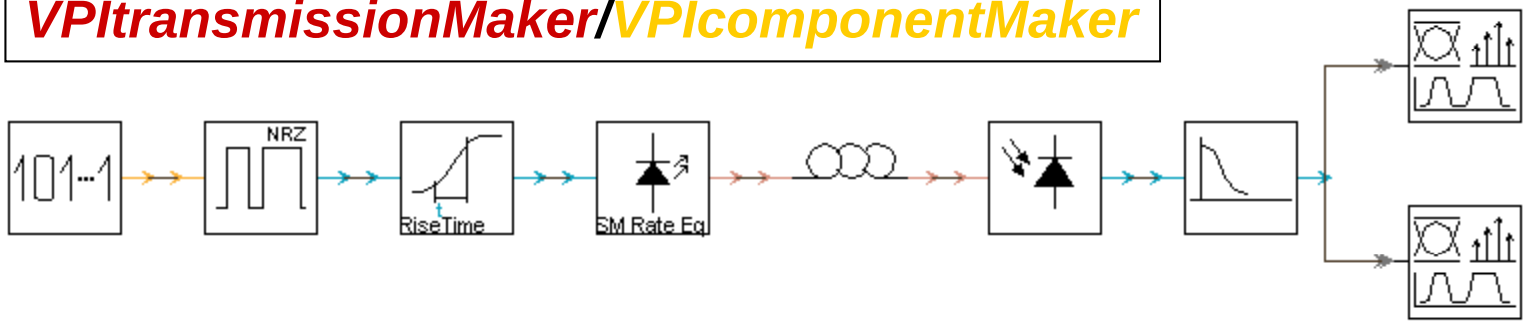
By the end of this course, you should:

- **Understand how fiber-optic systems and devices are modeled**



- **Be able to use a professional** *Photonic Design Automation* **tool to model and analyze fiber-optic systems**

VPItransmissionMaker/VPIcomponentMaker



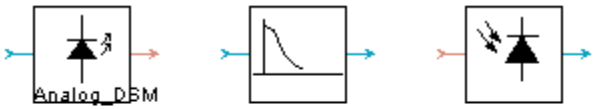
Module Objectives

Introduction to Fiber-Optic Communication Systems I

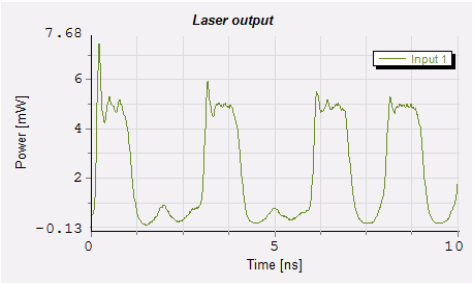
- Why fiber-optic communication systems?
- Advantages over other systems

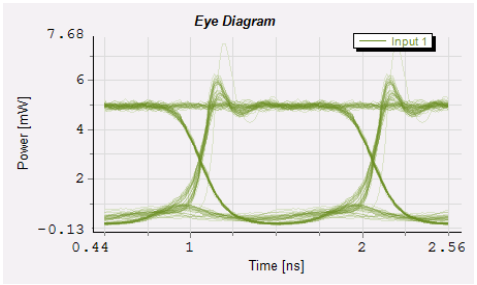
- Basic system concepts

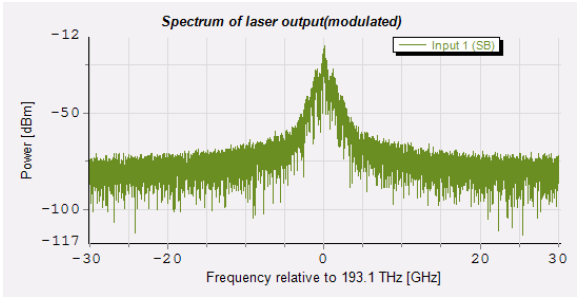
- Key elements of a basic system



- System performance and key issues







Transport information, over a long distance, with as few errors as possible.

Considerations:

- Cost
- Reliability
- Compatibility with existing methods
- Upgradability
- Security

Which Communication Media ?

- **Atmosphere**
  - Radio transmission
  - Microwave line-of-sight links(100 Mbit/s, 50 km)
  - Satellite (100 Mbit/s, around the world)

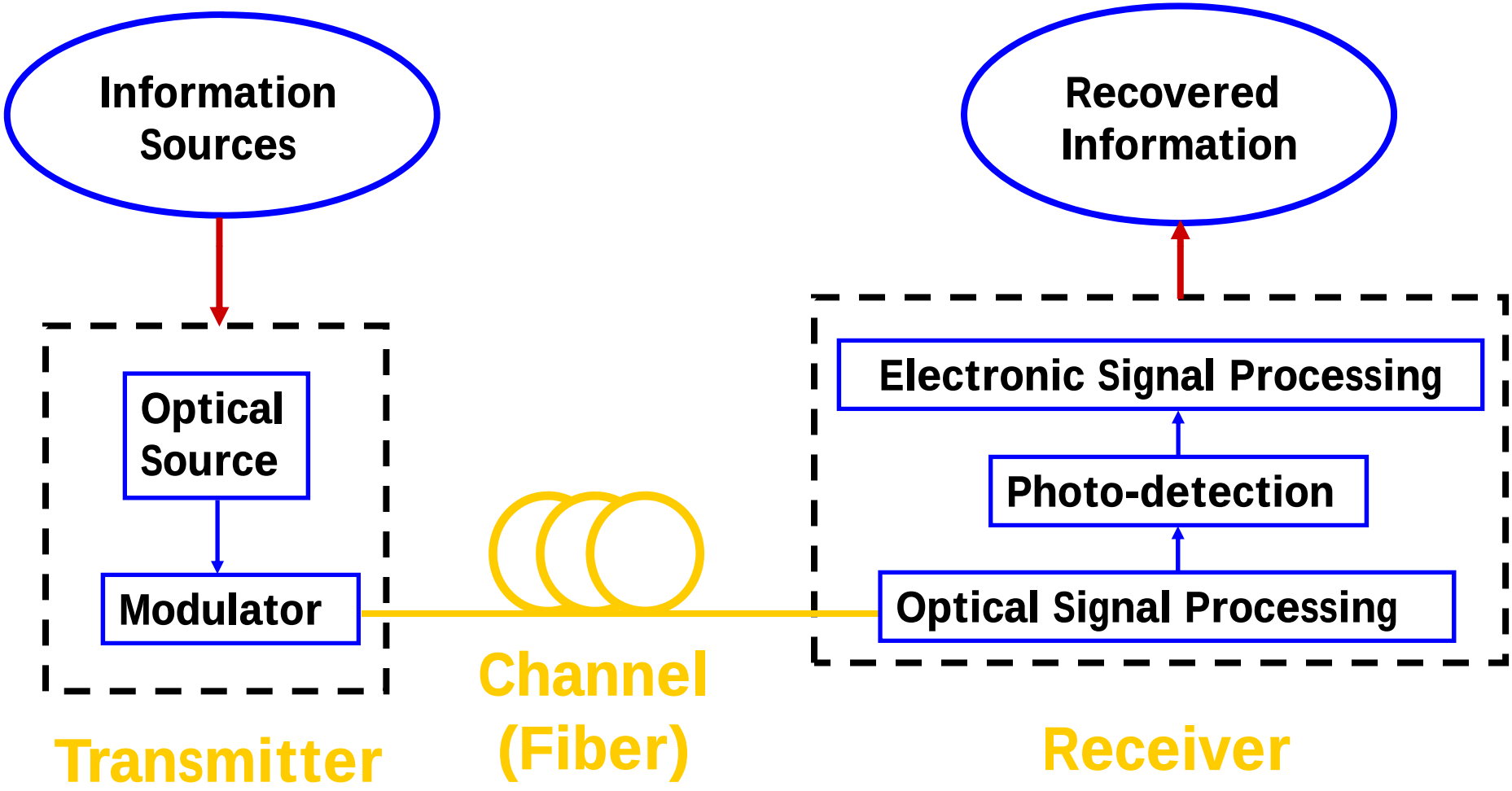
- **Cables**
  - Twisted-pair cable (1 Gbit/s, 100 m)
  - Local loop Twisted-pair (20 Mbit/s, 2 km)
  - Coaxial cable (>500 Mbit/s, few km)
  - Undersea cable (50 Mbit/s)

- **Optical Fiber**

Why Optical Fibers?

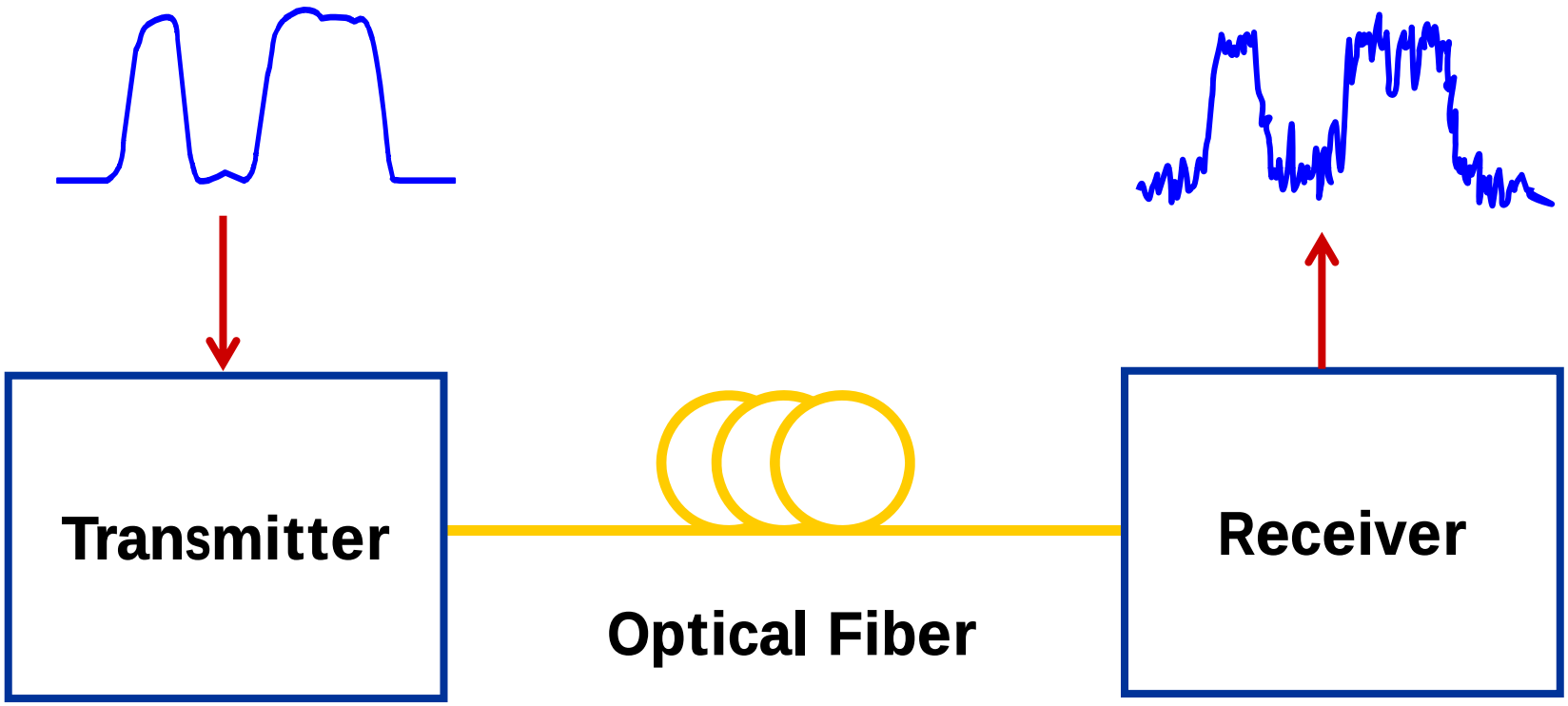
- **High transmission bandwidth and low loss**
  - **10 Gbit/s over 100 km (single fiber, single transmission wavelength without amplifier)**
  - **> 200 Gbit/s using multiple wavelength carriers**
  - **> 20,000 km at 10 Gbit/s using amplifiers**
- **Free of electromagnetic interference**
- **Small size and low weight**
- **Increased data security**

An Optical Communication System



Types of Optical Communication Systems

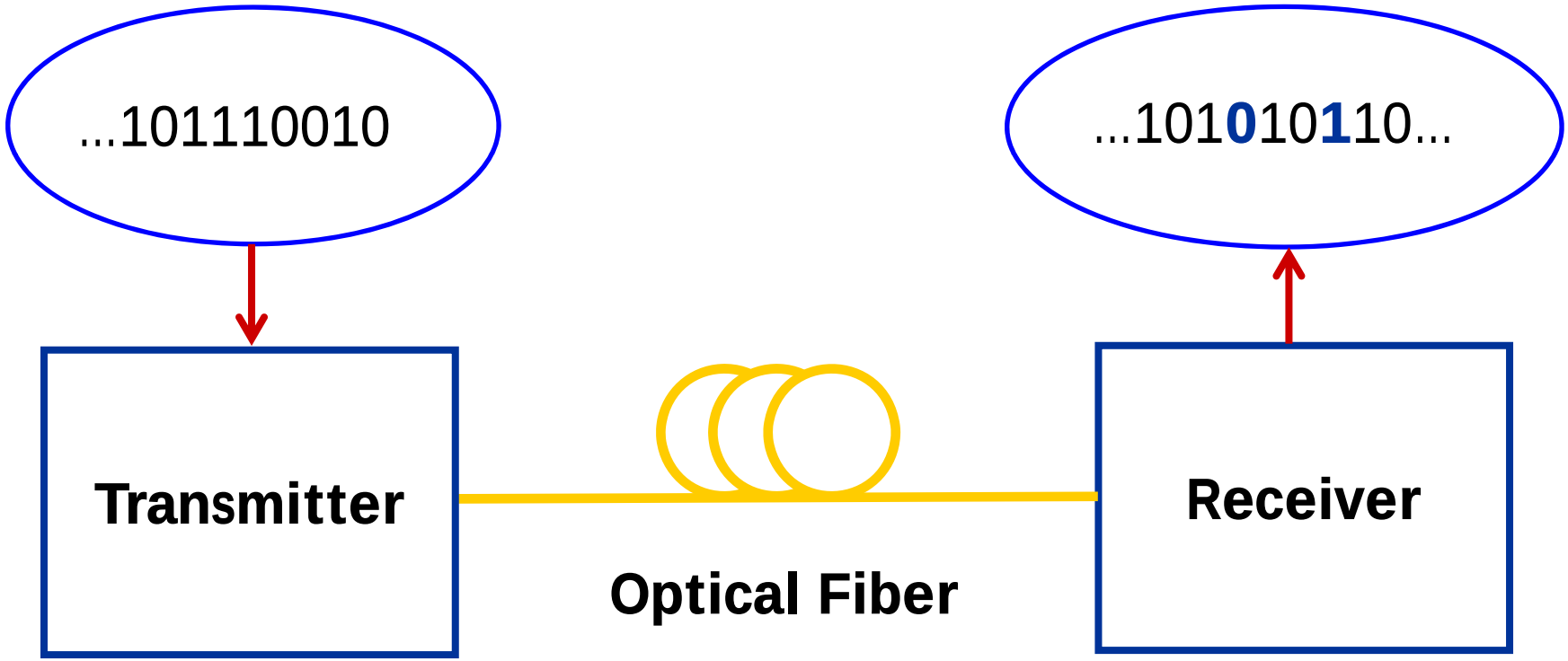
Analog Optical Communications



- information represented by analog waveforms

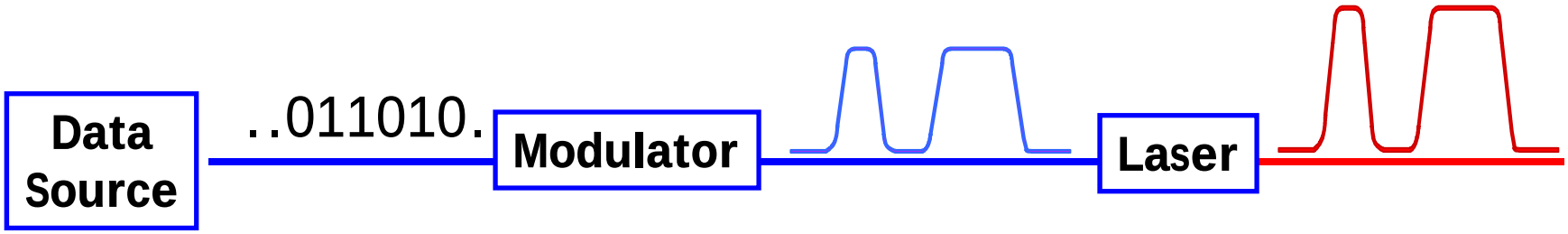
Types of Optical Communication Systems

Digital Optical Communications



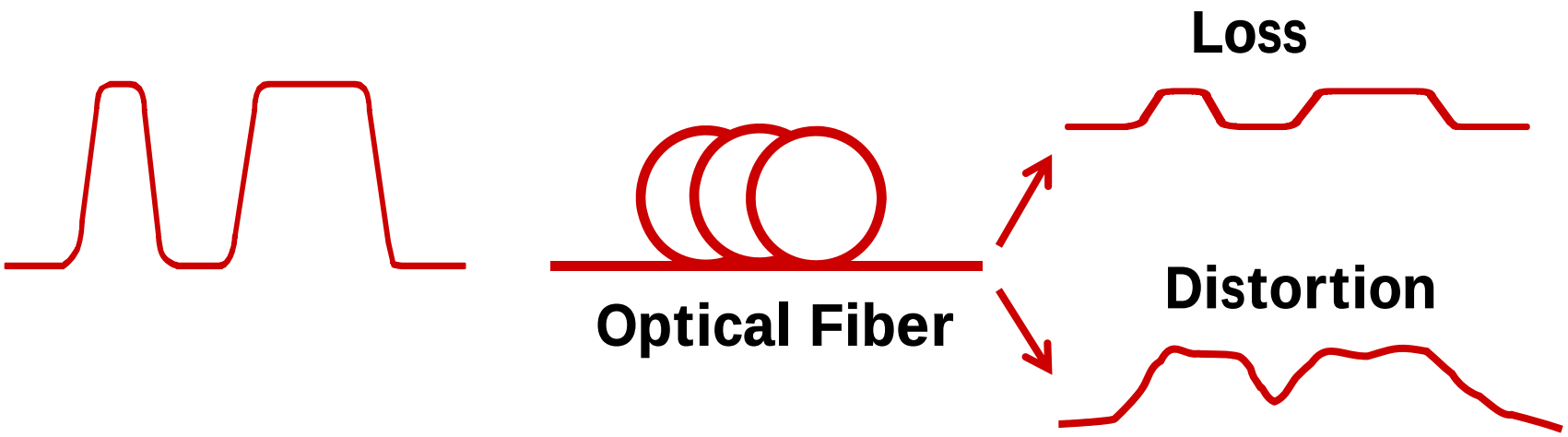
- information represented by digital (binary) bits

A Typical Transmitter



- **Intensity modulation (laser directly modulated)**

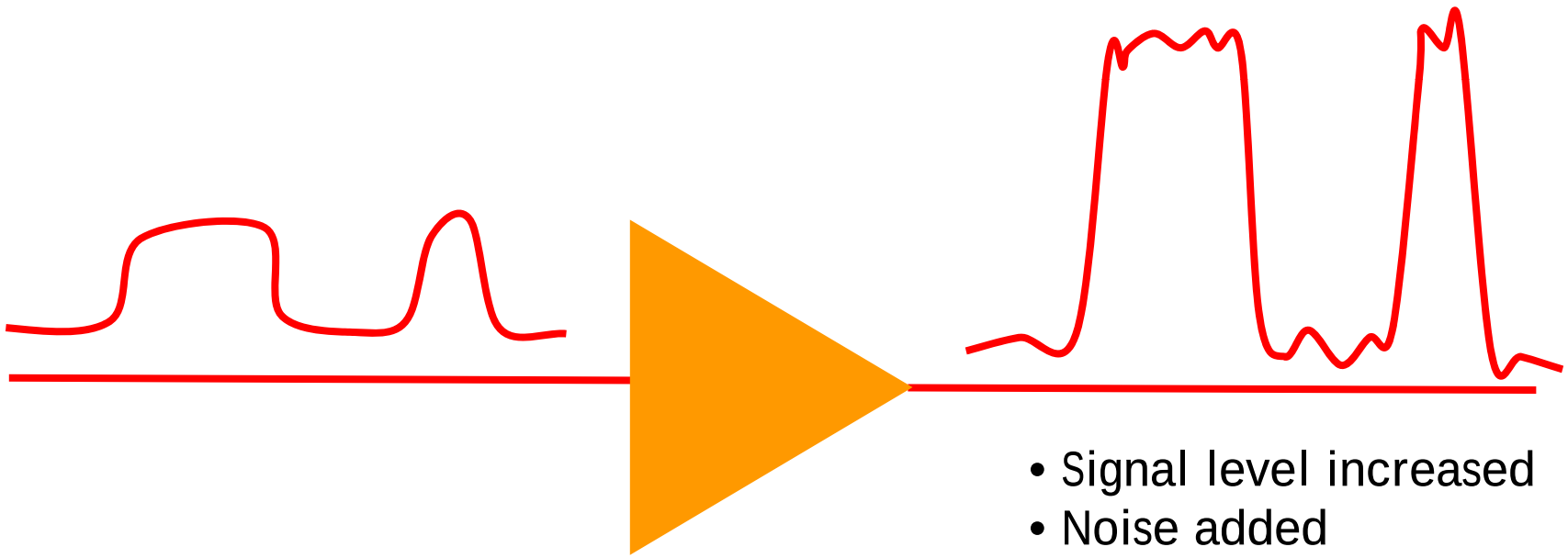
Channel Effects



- Loss and distortion act simultaneously

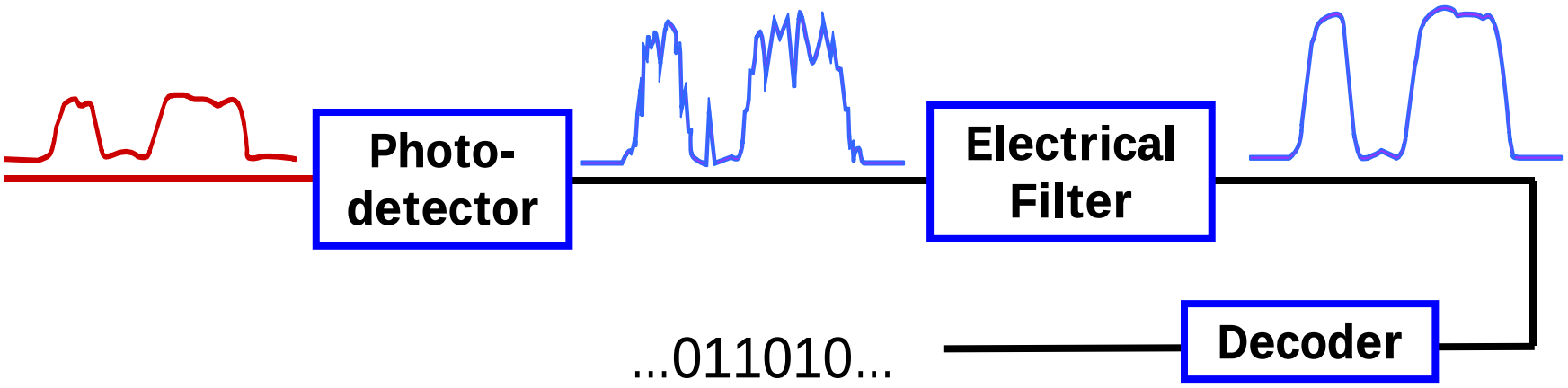
Optical Amplifier

- **A Typical Optical Amplifier**



- Signal level increased
- Noise added

A Typical Receiver



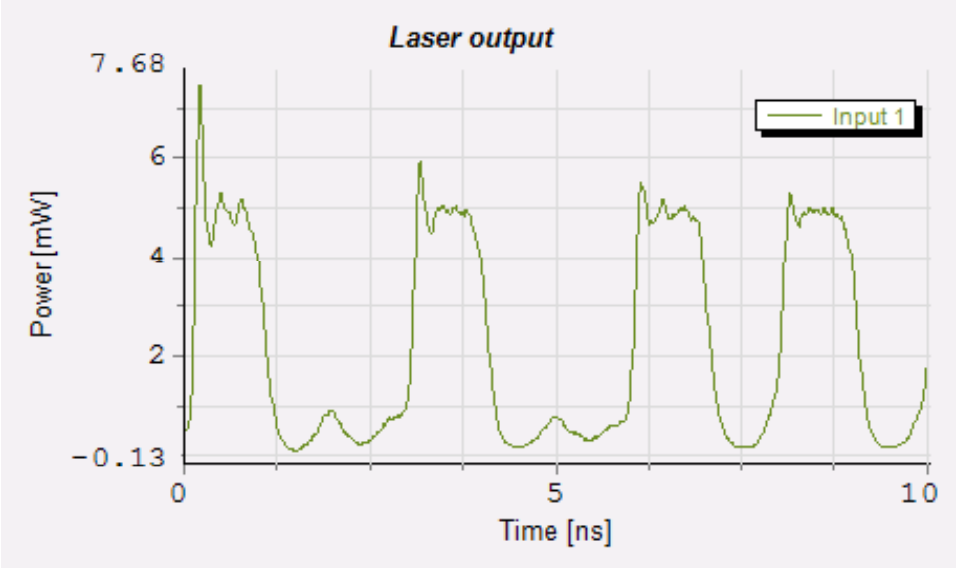
- optical signal is directly detected by photodetector
- noise is added, requires filter to reduce it

System Performance

- **Signal waveform in time domain**

Equipment	Resolution
Oscilloscope:	~ 100 ps
Sampling Scope	~ 20 ps
Streak Camera	~ 2 ps
Auto-correlator	~ 10 - 100 fs

Typical Result of SignalAnalyzer (Scope view)

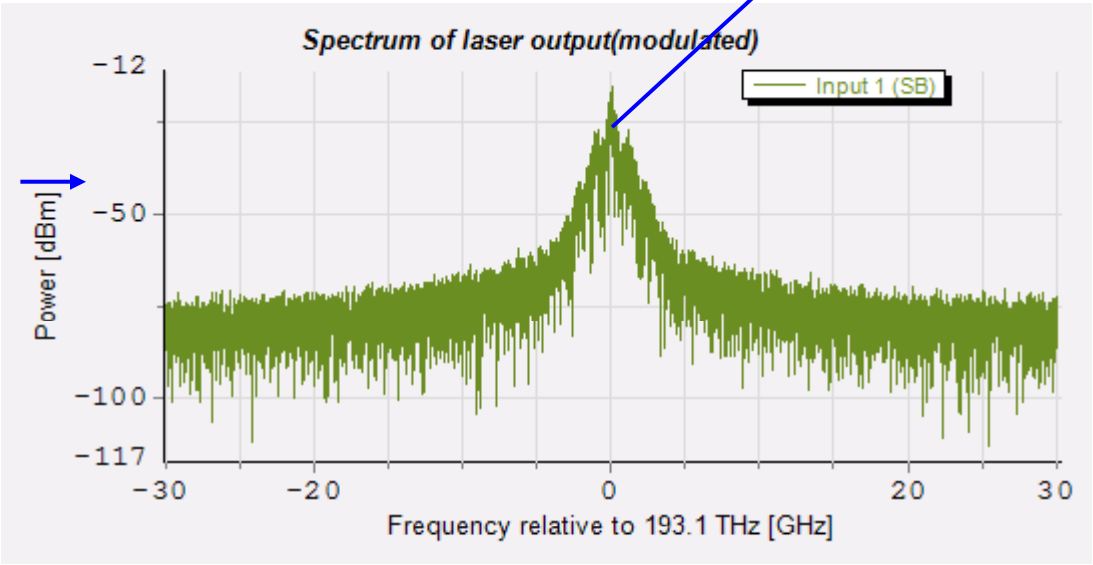


Evaluating System Performance

- **Optical spectrum**

Lasing wavelength
Linewidth
Noise
:

Typical Result of SignalAnalyzer (OSA view)

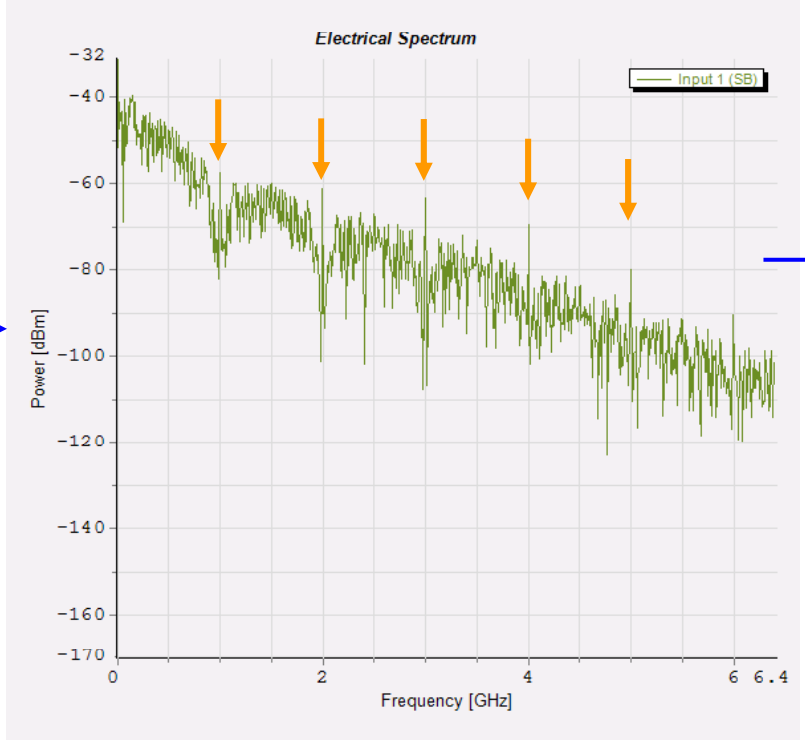


Evaluating System Performance

- **RF Spectrum**

RF components at f_o, $2f_o$, $3f_o$...

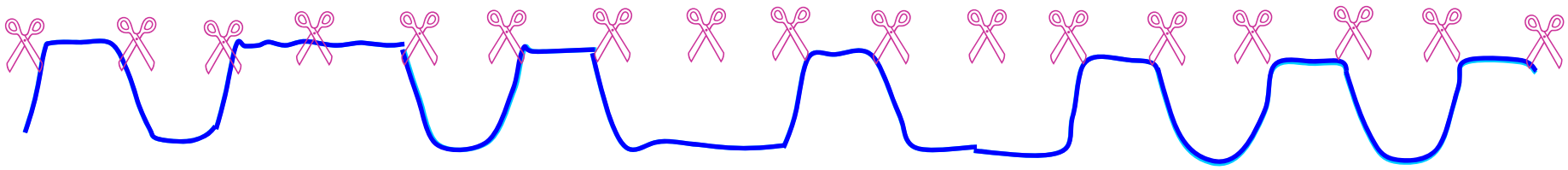
Typical Result of SignalAnalyzer (RFSA view)



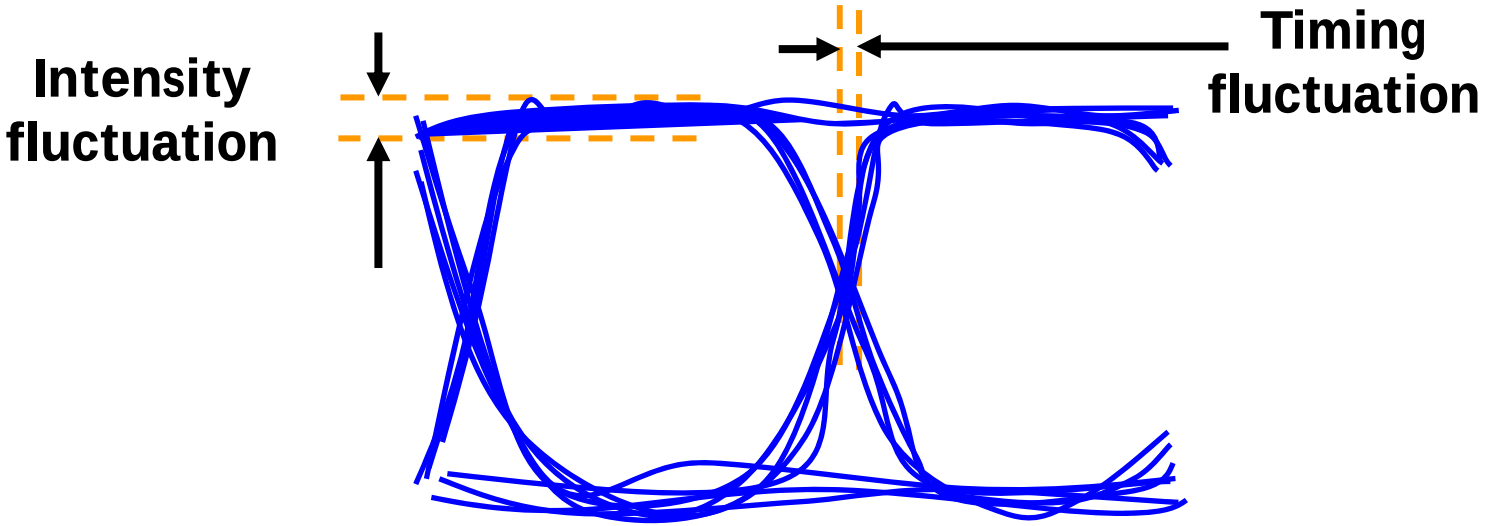
Repetition rate
Phase noise
RIN
⋮

Evaluating System Performance

- **Eye diagram**



Detected bit stream waveform



Bits overlaid to form Eye diagram

Evaluating System Performance

- **Bit Error Ratio (BER)**

$$BER = \frac{Number\ of\ bits\ detected\ incorrectly}{Total\ number\ of\ bits\ transmitted}$$

How is the BER of a system obtained?

- **Directly detect the bits and compare against original**

Transmitted: ...00100110010111010011000101010010011...

Detected: ...00100**0**1001011**0**0100110**1**0101011010011...

- **Estimate from Eye diagrams (statistical)**
- **Other methods** **(to be discussed in another module)**

Summary

So far, the following have been introduced:

- **Basic fiber-optic communication system concepts**
- **A basic system overview**
- **Key devices/components in a basic system**
- **How the performance of a system is evaluated**

Proceed with the *Interactive Learning Module*