Lecture 1&2

Course outlines

- **Chapter 1**

Overview of Optical fiber communication system.

- **Chapter 2**

Ray transmission theory and optical fiber as waveguide.

- **Chapter 3**

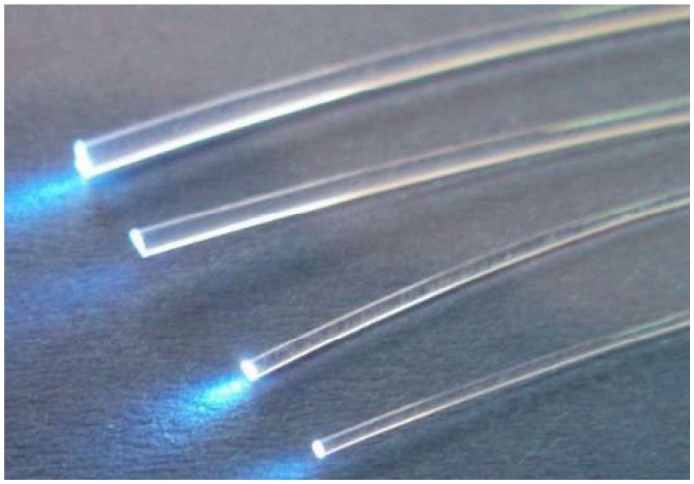
Propagation characteristics of optical fibers.

- **Chapter 4**

Wavelength division multiplexing

Introduction

- What is fiber optics?
- **Fiber** refers to a **thin, flexible, transparent material used** used as a transmission channel (waveguide).
- This fiber cable carries light wave that represents the transmitted information.

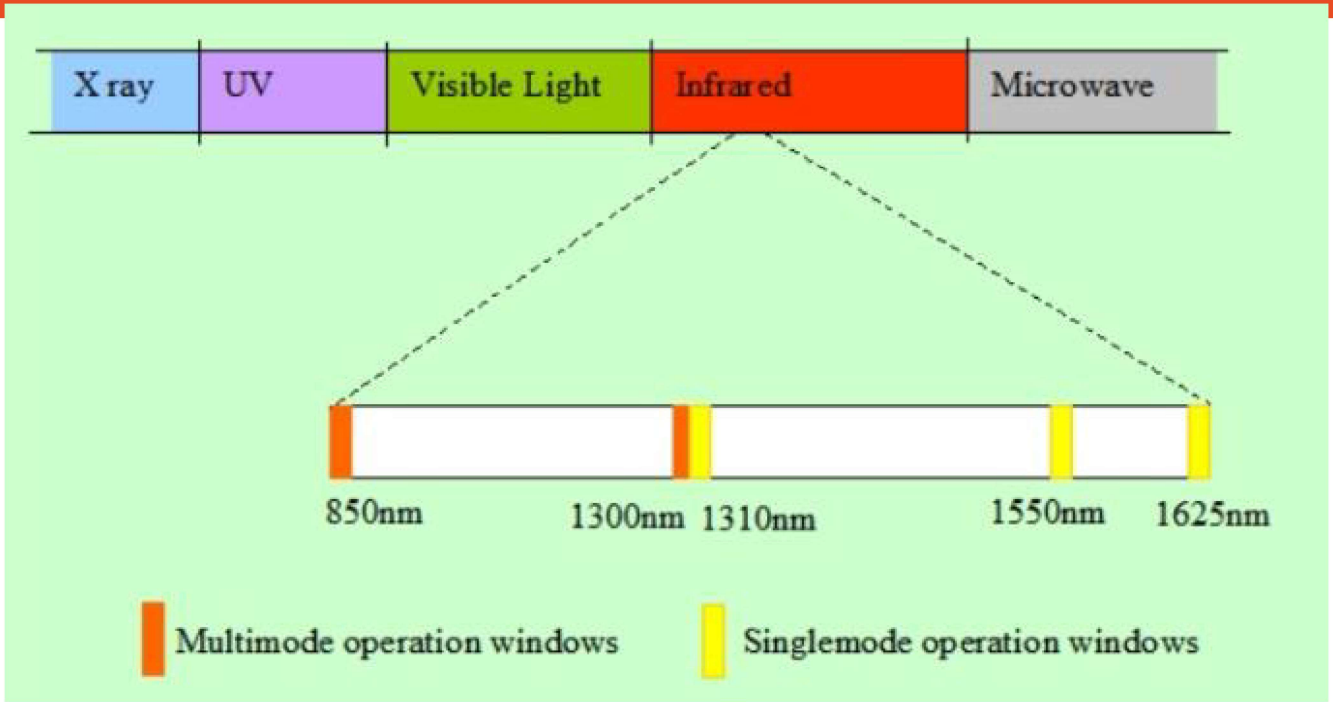


1.5 mm fiber cable [1m for 1.7 €]

Fiber optics wavelengths

- Fiber optics uses **visible and infrared light**.
- **Infrared light covers** a wide range of wavelengths and is generally used for all fiber optic communications.
- **Visible light** is normally used for very short-range transmission using a **plastic fiber**.
- In fiber optics, it is more convenient to use the wavelength of light instead of the frequency.

Fiber optics wavelengths



- **Visible Light** defines only the electro-magnetic radiation from the visual range of 380-780 nm.
- **Optical fiber transmission**, the electro-magnetic radiation from near infrared range (850 nm, 1310 nm, 1550 nm).

Fiber optics wavelengths

- **Optical fiber transmission** uses wavelengths that are in the **near-infrared portion** of the spectrum, just above the **visible, and thus undetectable to the unaided eye**.
- Typical optical transmission wavelengths are **850 nm, 1310 nm,** and **1550 nm**.
- Both **lasers** and **LEDs** are used to transmit light through optical fiber.
- **Lasers** are usually used for **1310- or 1550-nm** single-mode applications.
- **LEDs** are used for **850-** or **1300-nm** multimode applications.

Need of fiber optic communication

In long haul transmission system, there is a need of:

1. Low loss transmission medium.
2. Compact and least weight transmitters and receivers.
3. Increased bit rate-distance product.

A fiber optic communication system fulfills these requirements, hence it is most widely accepted.

Fiber cable Vs copper cable

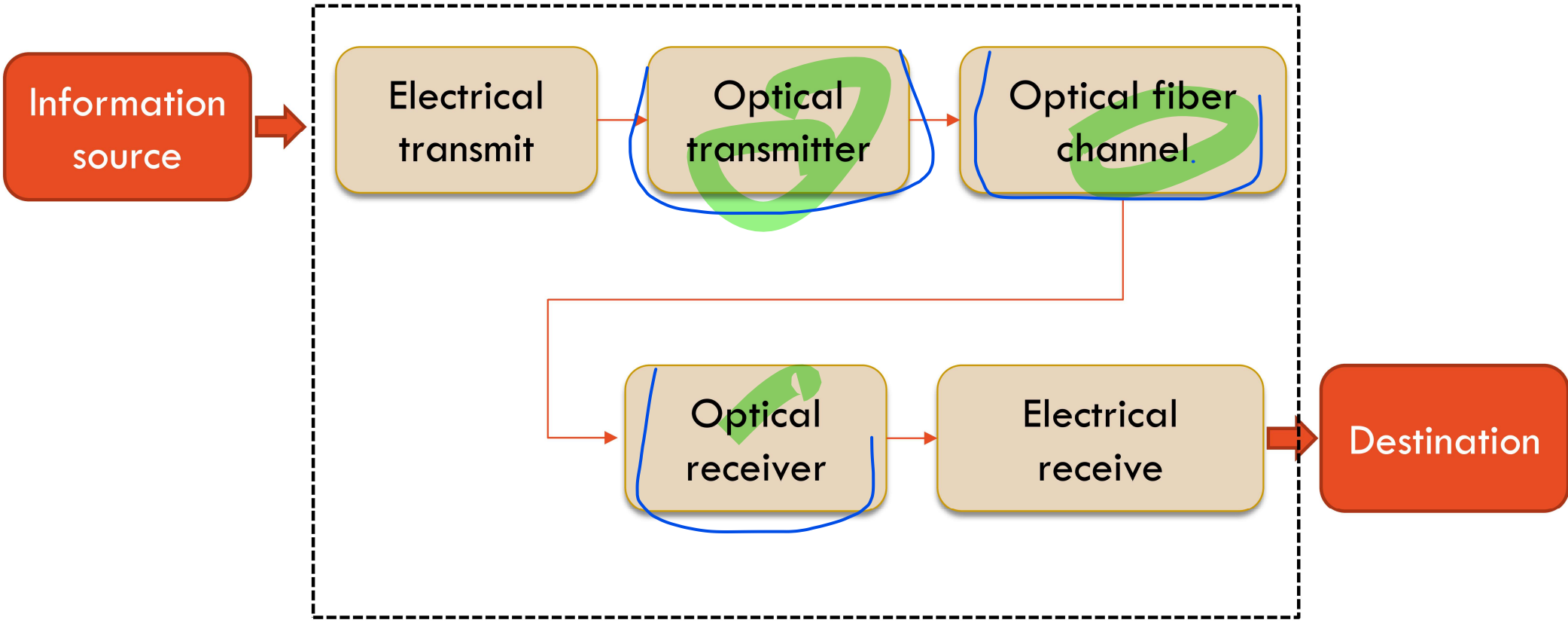
- Fibers are used instead of metal wires because signals travel along them with **high bit rate**, **less loss** and are also **immune to electromagnetic interference**.

	Fiber cable	Copper cable
Signal speed	higher	lower
Bandwidth	60 Tbps	10 Gbps
Repeaters	Every 50 Km	Every 5 Km
Electromagnetic Interference	Not affected	affected
Data security	More secured	Less secured
Weight	Less (4 lbs/1000 ft)	More (39 lbs/1000 ft)
Life-cycle	30-50 year	Nearly 10 years

Disadvantages of fiber cables compared to copper cables

- Installation and maintenance is not as easy as copper wires.
- Copper cables and connectors are much cheaper than fiber optic cables and connectors.
- Copper has excellent resale value.
- Propagation of signals in fiber optic cables is unidirectional. For **two-way communication** two cables are needed.

Fiber optical communication system



In Direct Modulation, the laser is turned on and off directly by varying the input current. This means it only emits light when transmitting data.

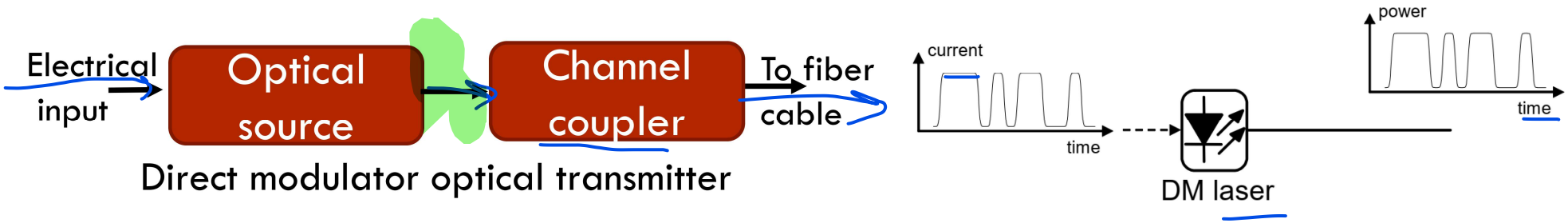
In External Modulation, the laser remains continuously on, emitting a constant light wave. However, an external modulator controls whether the light passes through or is blocked based on the transmitted data.

Optical transmitter

- The role of an *optical transmitter* is to convert the **electrical signal** into **optical form** and to launch the resulting optical signal into the optical fiber.
- **Optical source:**
  - Converts electrical signal into optical one.
  - There are two common optical sources:
    - Semiconductor laser.
    - Light-emitting diode (LED).
  - There are two common modulation techniques to convert the electrical signal into optical signal:
    - Direct modulation.
    - External modulation

Optical transmitter

A) **Direct Modulation:**

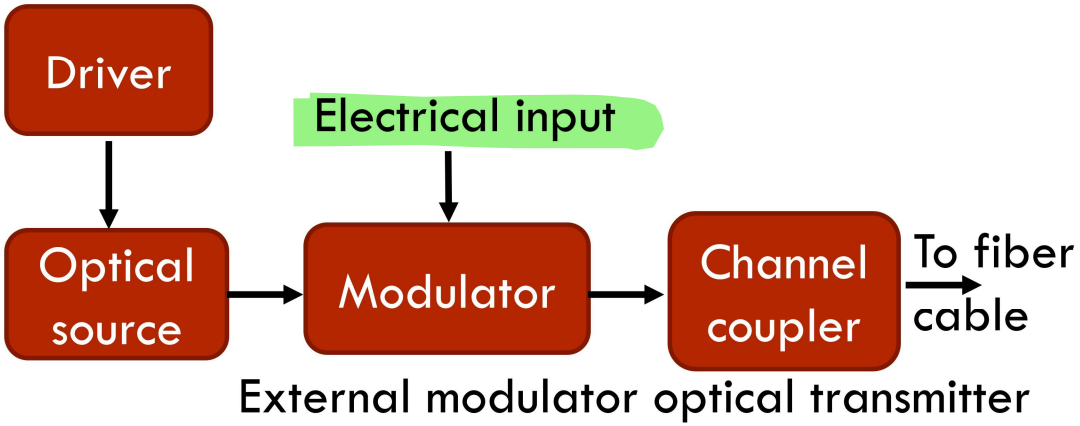


Direct modulator optical transmitter

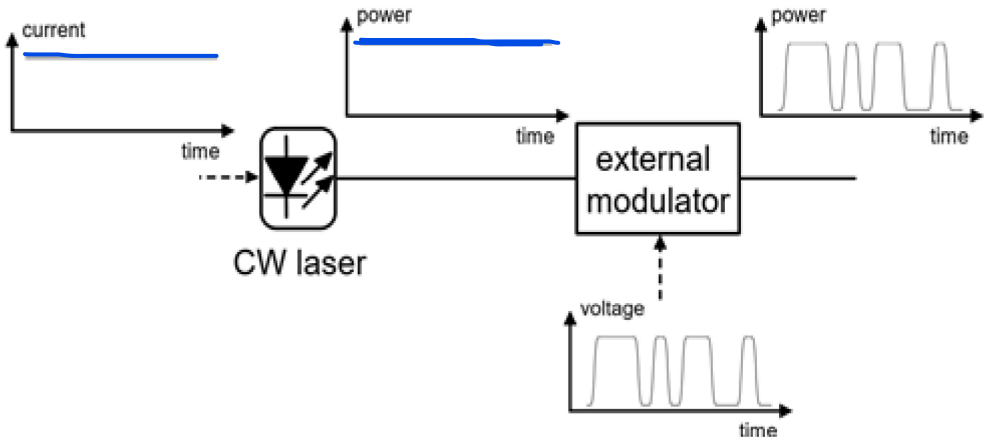
- **Optical source is modulated** directly by varying the **injection current by the information signal.**
- light is emitted from a semiconductor laser only when a "mark" is transmitted.
- Ideally, no light should be ~~emitted~~ when a "space" is transmitted
- Such a scheme simplifies the transmitter design and is generally **cost-effective.**

Optical transmitter

- **B) External modulator:**



External modulator optical transmitter



- In external modulator, a continuous wave laser is used to **emit light** whose power is constant with time.
- A second component, known as **modulator**, is then used **as a switch** to let the light pass whenever the data corresponds to a "mark" and to **block** it whenever the signal is a "space".
- **It is faster that direct modulation, but it is more expensive**

Optical transmitter

The coupler is typically **a micro lens** that focuses the optical signal onto the entrance plane of an optical fiber with the maximum possible efficiency.

Note:

- The optical carrier may be modulated using either **an analog** or **digital** information signal.
- **Analog modulation** involves the variation of the light emitted from the optical source in a continuous manner.
- **With digital modulation**, however, discrete changes in the light intensity are obtained (i.e. On–off pulses).

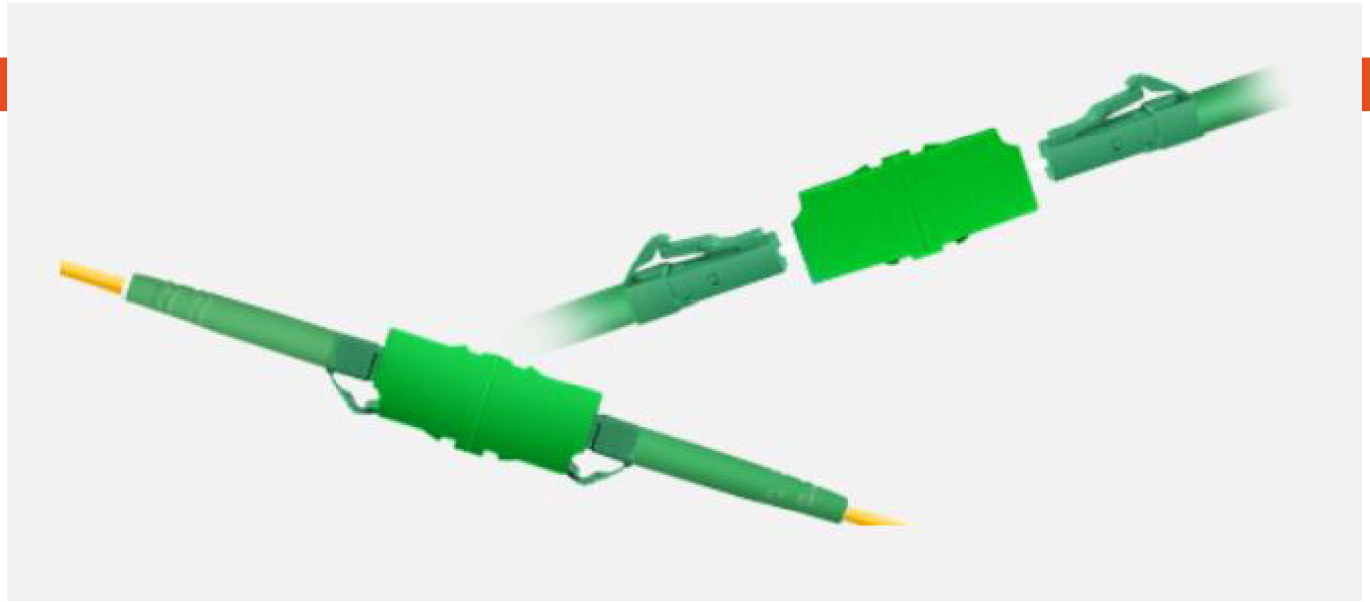
Optical transmitter

- **Analog modulation is not preferred in optical fiber communication system, why?**
  - less efficient, requiring a far higher signal-to-noise ratio at the receiver than digital modulation.
  - Also, the linearity needed for analog modulation is not always provided by semiconductor optical sources, especially at high modulation frequencies.
  - For these reasons, analog optical fiber communication links are generally **limited to shorter distances** and **lower bandwidth operation** than digital links.

Optical channel

- Optical fiber links have a requirement for **both jointing and termination** of the transmission medium.
- The number of intermediate fiber connections or joints is dependent upon **the link length** (between repeaters).
- To provide fiber–fiber connection, it is necessary to indicate the two major categories of fiber joint :
  - **Fiber connectors:** These are removable joints which allow easy, fast, manual coupling and uncoupling of fibers
  - **Fiber splices:** These are permanent joints which find major use in most optical fiber systems, it has 2 types: mechanical splicing and fusion splicing.

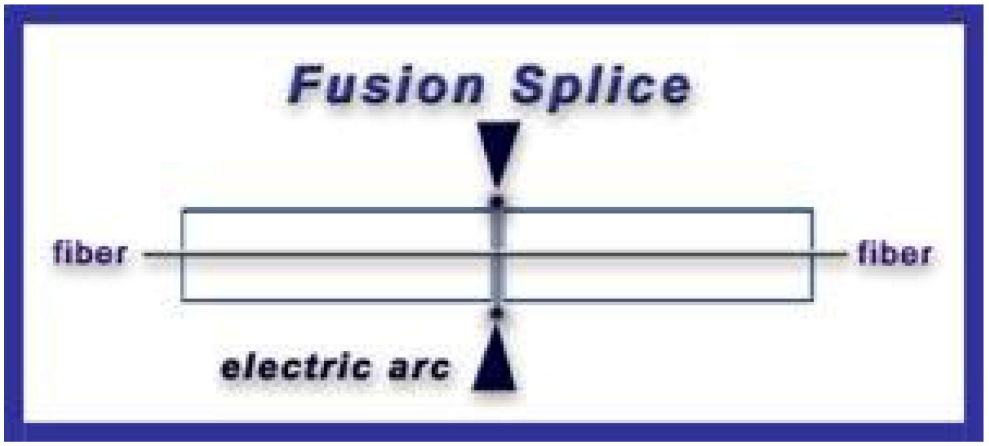
Fiber connector



Fiber splicing

- **Fusion Splicing:**

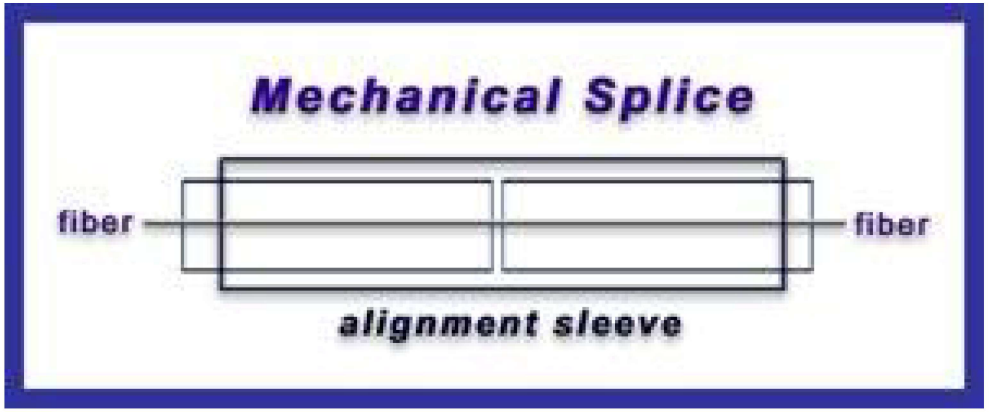
In fusion splicing, a machine is used to precisely align the two fiber ends then the glass ends are fused together using some type of heat or electric arc. This produces a continuous connection between the fibers enabling very low loss light transmission. (Typical loss: 0.1 dB)



Fiber splicing

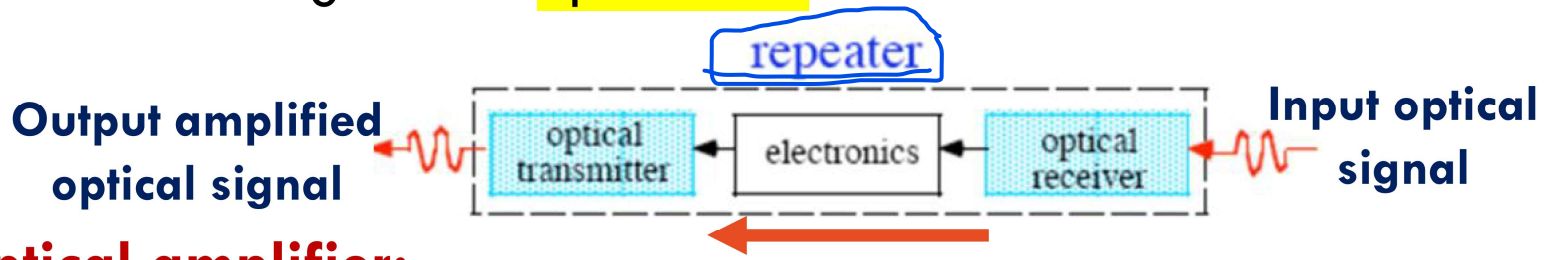
- **Mechanical Splicing:**

It simply alignment devices, designed to hold the two fiber ends in a precisely aligned position thus enabling light to pass from one fiber into the other. (Typical loss: 0.3 dB).

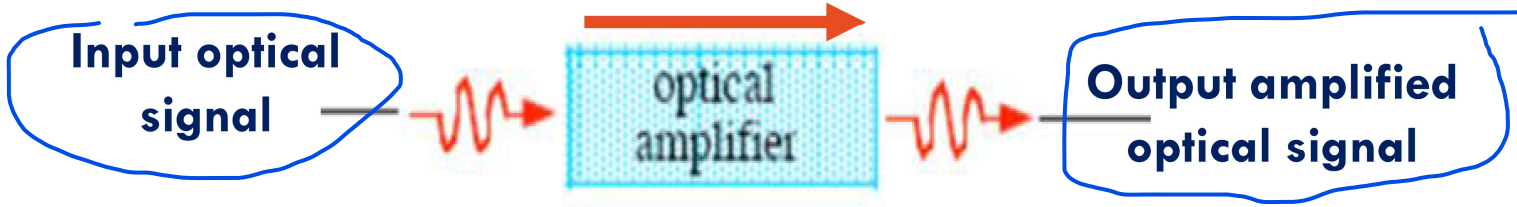


Optical channel

- The optical channel may contain optical amplifier or regenerative one.
- **Optical regenerative repeater:**
  - It converts the signal into electrical form then amplify it, finally it is converted again into optical one.



- **Optical amplifier:**
  - operate solely in the optical domain with no interconversion of photons to electrons.
  - It provides linear amplification of the transmitted optical signal.



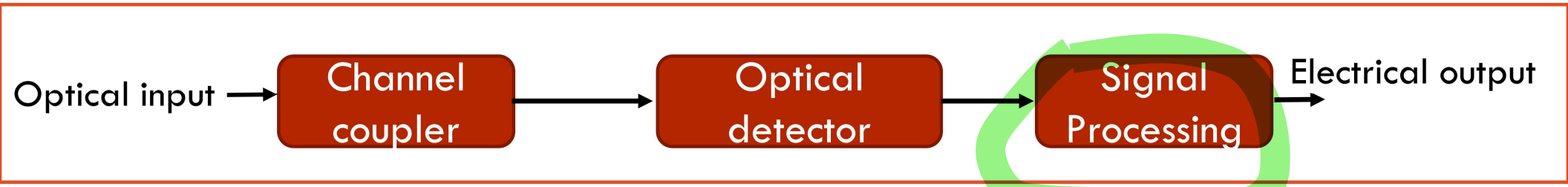
Optical Amplifier

- It amplifies the received distorted optical signal.
- This amplified distorted signal gets further distorted when it travels over the path till it reaches destination.
- It is fine to employ optical amplifier when path distance is smaller between transmitter and receiver.
- Optical Amplifiers are placed at shorter distances over the path.

Optical Repeater

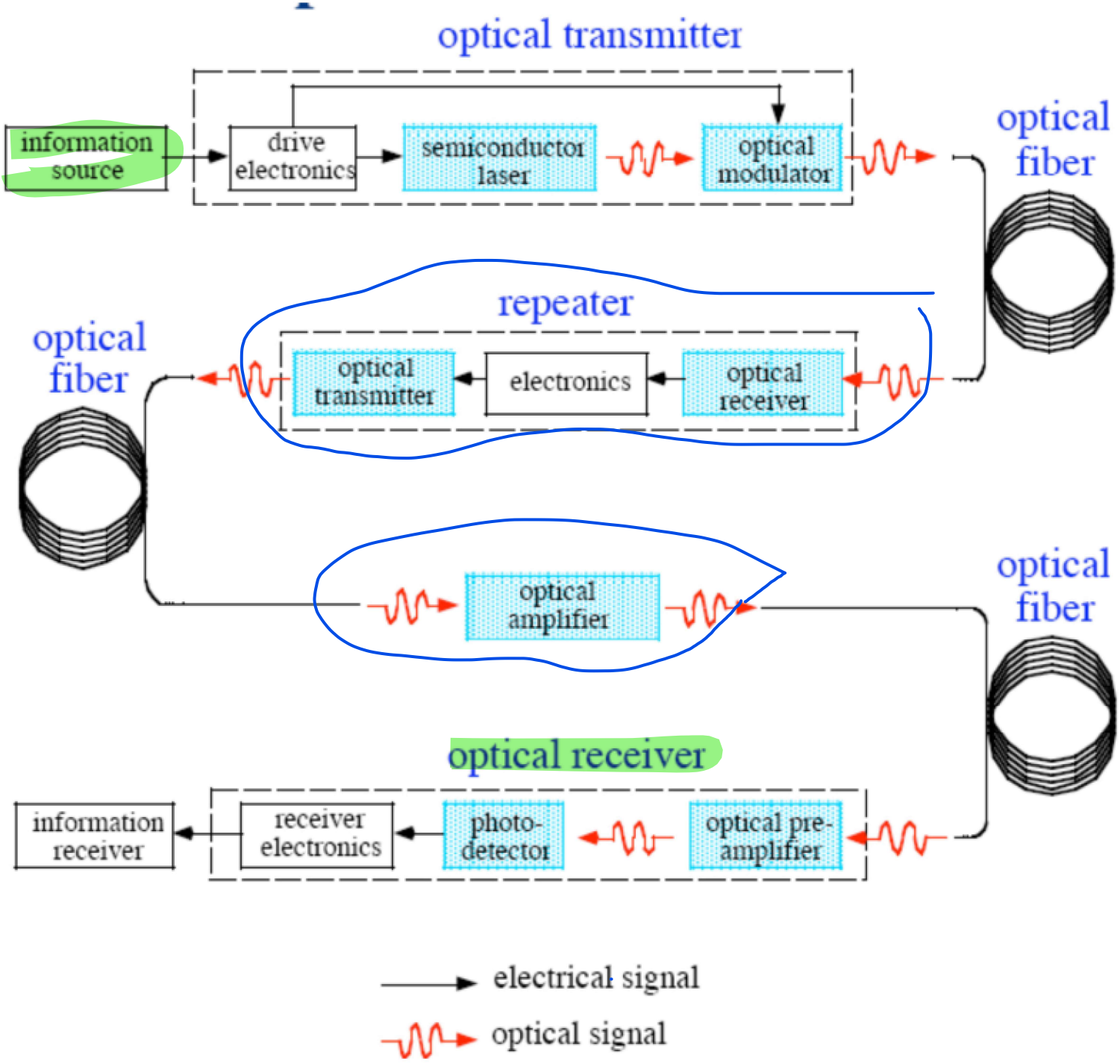
- It converts the optical signal to electrical form.
- It preforms reshaping and amplification operations on the signal before re-transmission.
- less signal distortion due to noise and other distortion components.
- Optical Repeaters are placed at longer distances over the path compared to optical amplifiers.

Optical receiver



- An ***optical receiver*** converts the optical signal received at the output end of the optical fiber back into the original electrical signal.
- The **coupler** focuses the received optical signal onto the optical detector (photodetector).
- **Optical detector:**
  - Converts the received optical signal into electrical one / or demodulate of the optical carrier.
  - Optical detector may be:
    - Photodiodes (*p–n*, *p–i–n* or avalanche)
    - Phototransistors.
    - Photoconductors.
- Signal processing includes amplification and filtering and decision circuit in case of digital signal.

Basic architecture of an optical fibre link



Advantages of Optical Fiber Communications

- Wide bandwidth
- Low losses
- Immune to cross talk &electromagnetic radiation
- Light weight
- Small size
- Security
- Safe and easy installation
- Less cost

Disadvantages of Optical Fiber Communications

- High initial cost
- Maintenance and repairing cost
- Jointing and test procedures
- Tensile stress
- Short links
- Fiber losses