COURSE: *OPTICAL COMMUNICATION* (EC317)

UNIT-I

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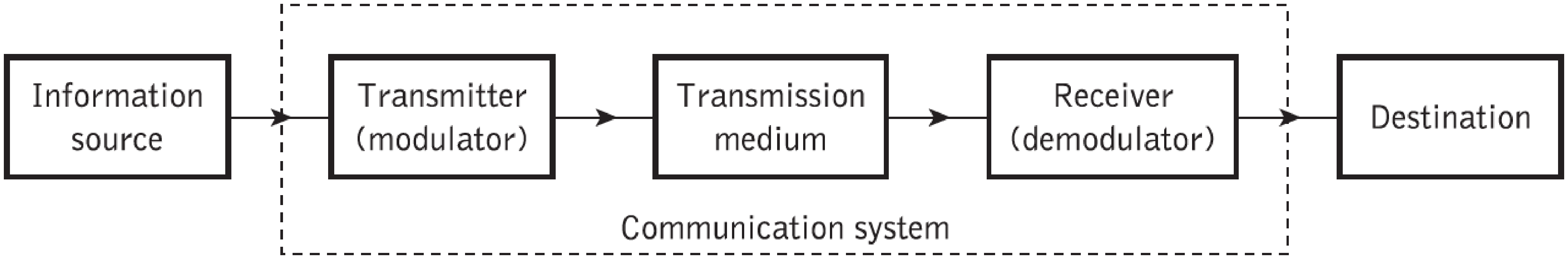
UNIT-I

- Motivation for optical communications,
- Advantages of optical fibers
- Key elements of optical fiber communication link
- Optical bands
- Optical windows, standards

INTRODUCION

- Communication system- transfer of the information from one point to another and consists of transmitter, transmission medium and receiver
- Transmitter comprising electrical and electronic components
  - which converts the information signal into a suitable form for propagation over the transmission medium.
  - achieved by modulating the information onto an electromagnetic wave which acts as a carrier for the information signal.
- This modulated carrier is then transmitted trough the transmission medium to the required destination where it is received and the original information signal is obtained by demodulation.
- The transmission medium can consist of a pair of wires, a coaxial cable or a radio link through free space down which the signal is transmitted to the receiver



MOTIVATION

- Pair of wires- low data rates, lossy at RF, used for telephone lines
- Coaxial cable- data rates in Mbps, moderate loss, used in LANs,
- Radio link- large bandwidth, long distance, more free space losses
- Satellite - large bandwidth (in GHz), large delay
- The first two media have a very limited bandwidth
- Microwave links and Satellite communication has comparable bandwidths as in principle their mode of operation is same but the spatial reach of satellite is far greater

MOTIVATION

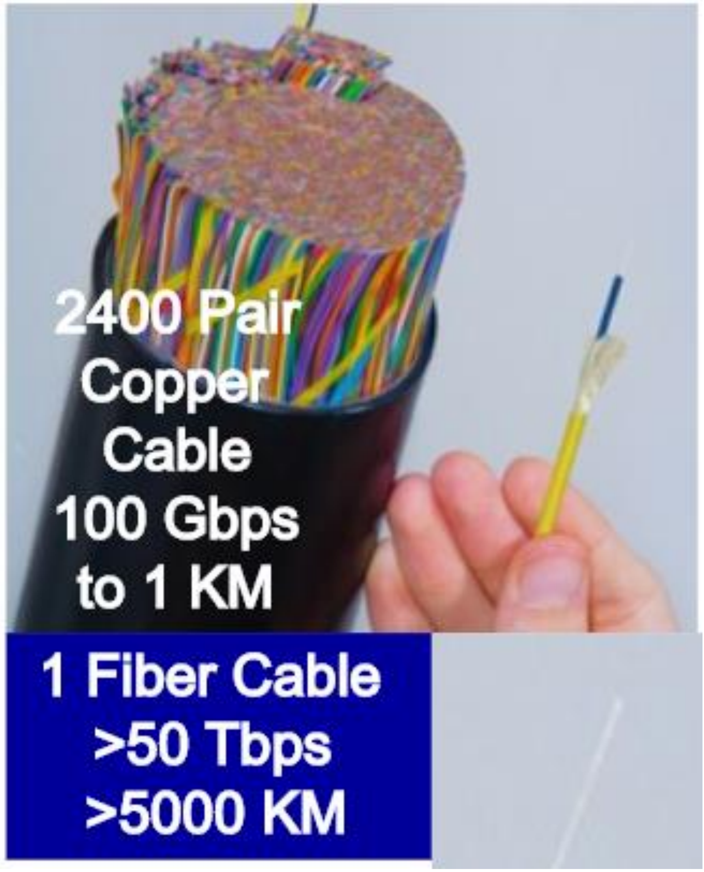
- The resources for good communication system
  - **Bandwidh (BW)-**
    - the amount of information that can be transmitted is directly related to the frequency range over which the carrier operates
    - increasing the carrier frequency theoretically increases the available transmission bandwidth and, consequently, provides a larger information capacity
  - **Signal Power- Good signal to noise ratio (SNR) i.e. low loss**
- Optical Communication is the most modern mode of wired communication because of it bandwidth (10 to 100 times more than the radio/microwave links)

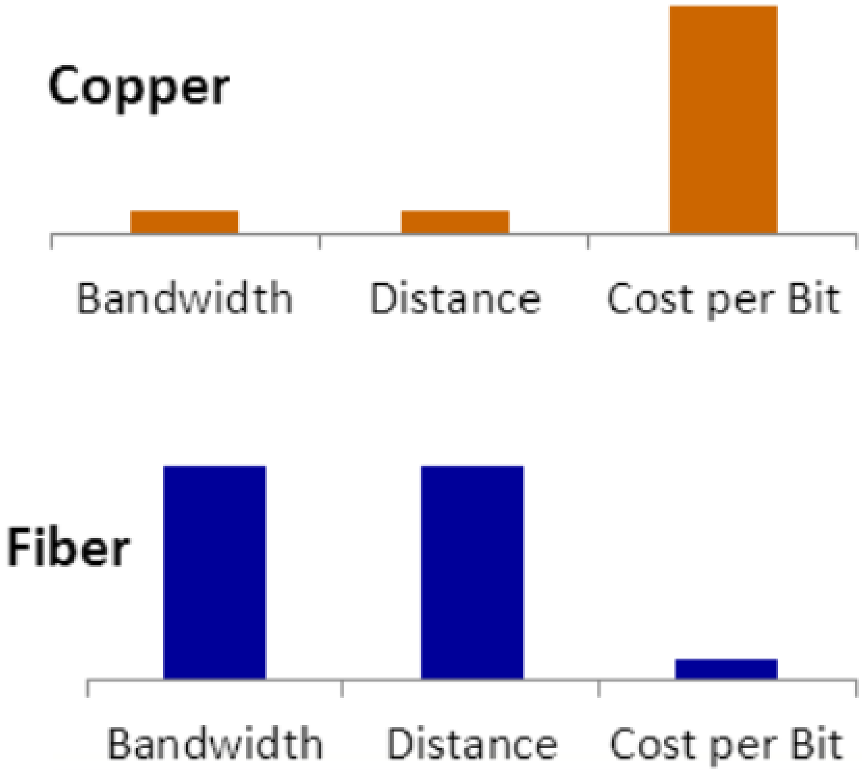
For example a system operating around the 1500 nm wavelength can use the following channel bandwidth:

Assume upper band = 1530 nm, or 196.078 THz

Assume lower band = 1550 nm, or 193.548 THz

and therefore a bandwidth of 196.078 − 193.548 = 2.530 THz.

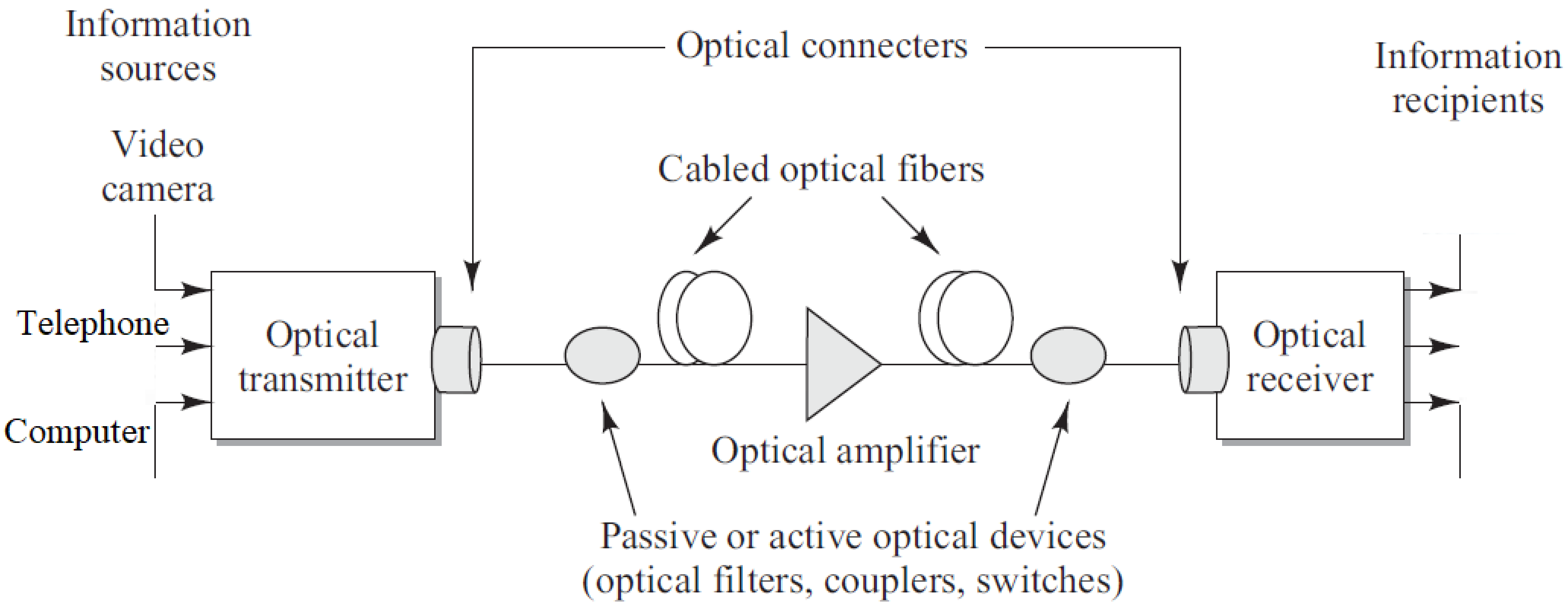




Advantages and disadvantages

- **Advantages :**
  - High bandwidth (in THz) - Large capacity of information transmission
  - Low transmission loss (0.2 dB/km) - long distance transmission without repeaters- less expensive
  - Small size and lighter weight than copper
  - No metallic conductors - immunity to electromagnetic interference (EMI)
  - Higher melting point than copper
- **Disadvantages:**
  - Connections and taps are more difficult to make than for copper
  - Fiber is not as flexible than as copper wire

OPTICAL FIBER COMMUNICATION SYSTEM

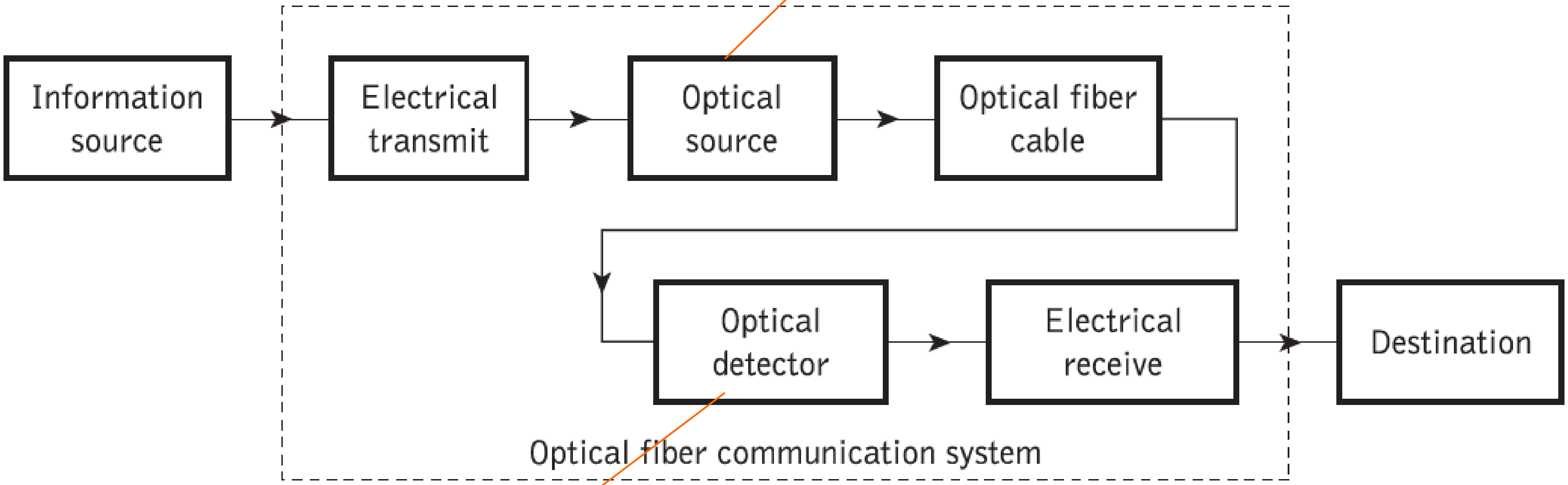


Key Elements of Optical Fiber Systems

- On transmitter side:
  - Electrical transmitter, light source and its associated drive circuitry,
  - a cable offering mechanical and environmental protection to the optical fibers contained inside
- On receiver side:
  - a photodetector plus amplification and electrical receiver
  - Additional components: optical amplifiers, connectors, splices, couplers, signal-restoring circuitry (regenerators) etc.

General block diagram of optical communication system

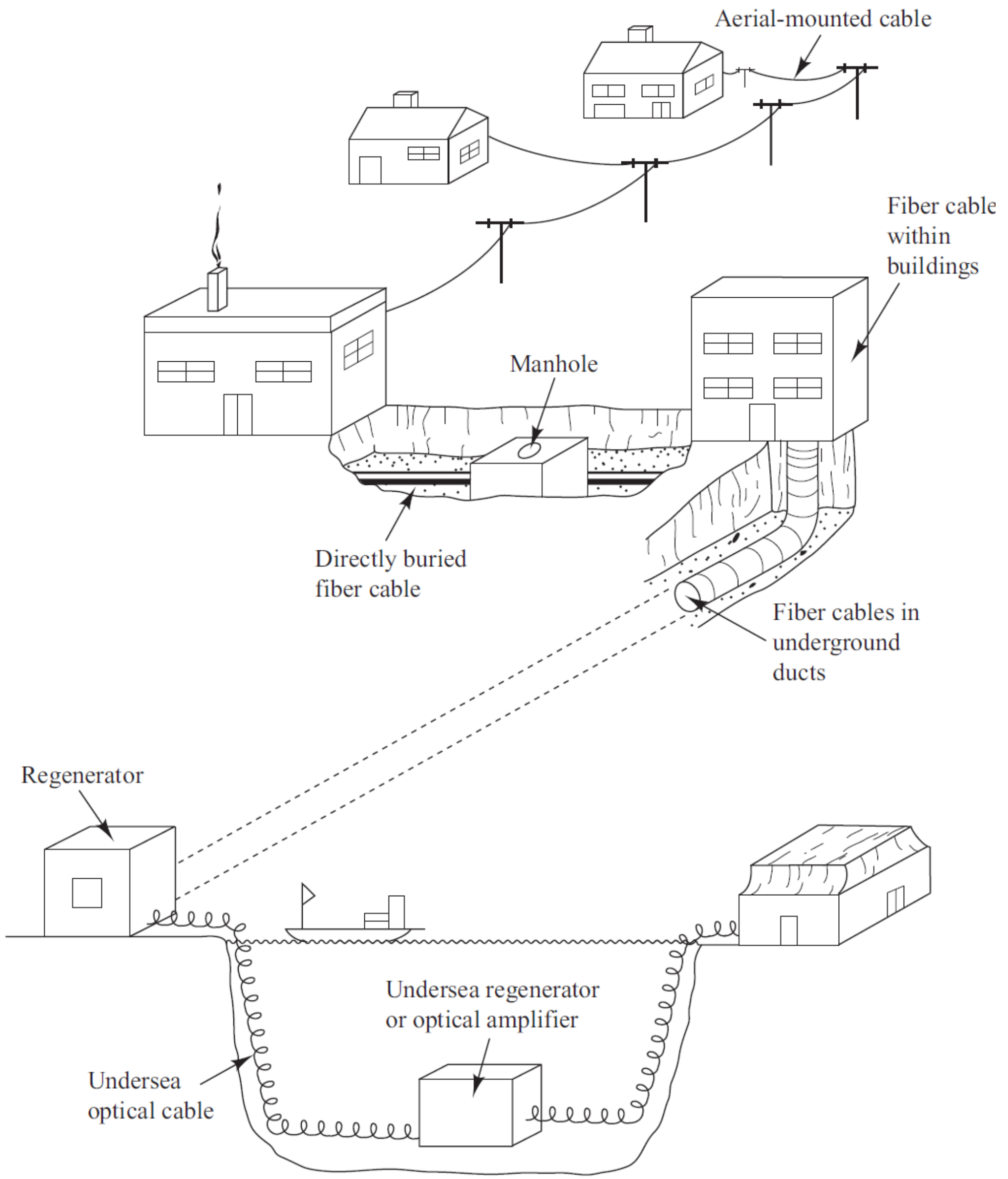
provides the electrical–optical conversion may be either a semiconductor laser or light-emitting diode (LED)



Provides optical–electrical conversion. Photodiodes (*p–n*, *p–i–n* or avalanche), phototransistors and photoconductors are utilized for the detection of the optical signal

Applications:

- Extensively used for data transmission including video data stream, perfect choice for HDTV
- Intelligent transport systems: smart highways with intelligent traffic lights, tool booths etc.
- Bio-medical industry: telemedicine devices for transmission of digital diagnostic images
- Space, Defense Automotive, and Industrial sector

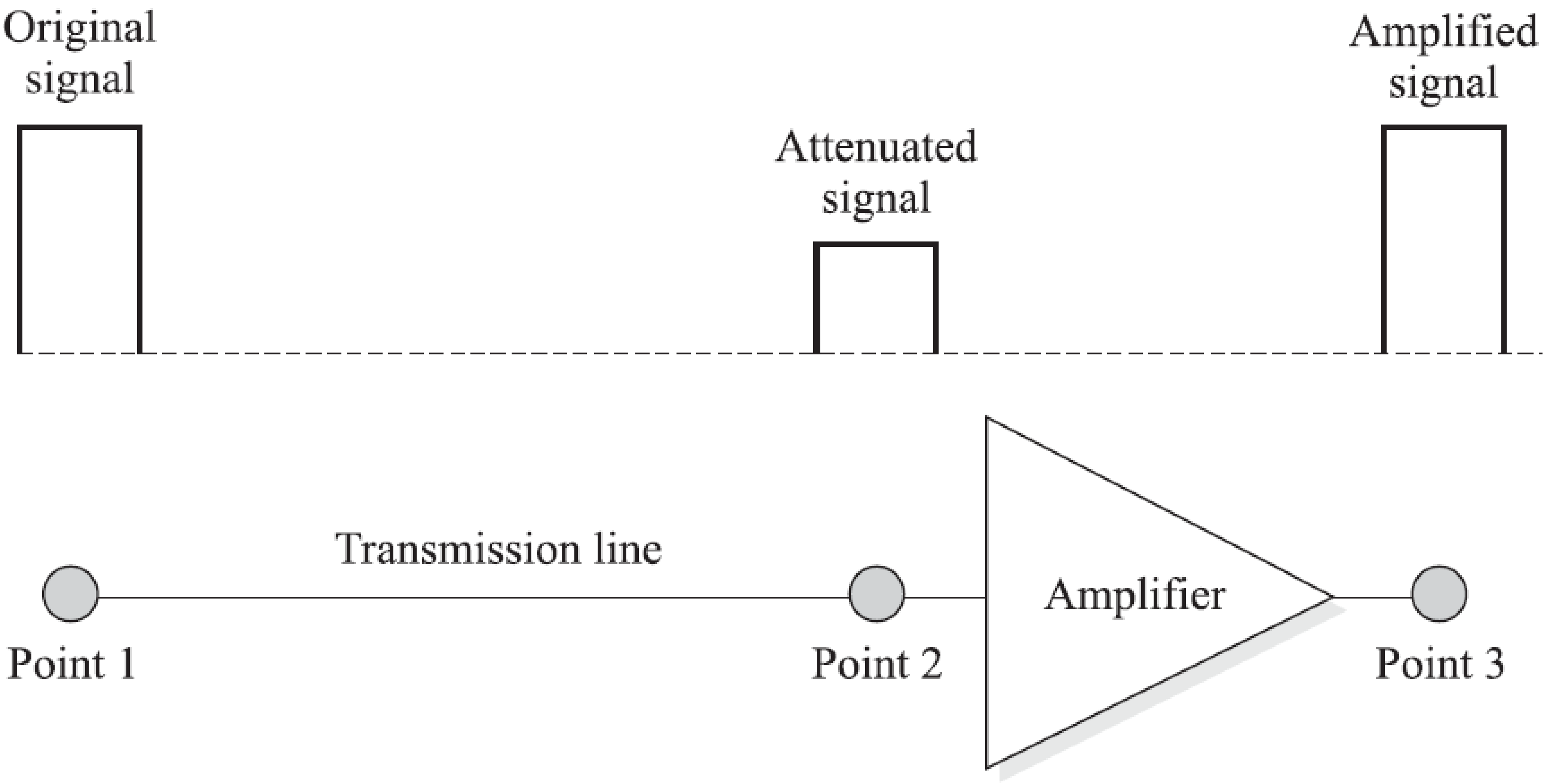


MEASURING ATTENUATION IN DECIBELS

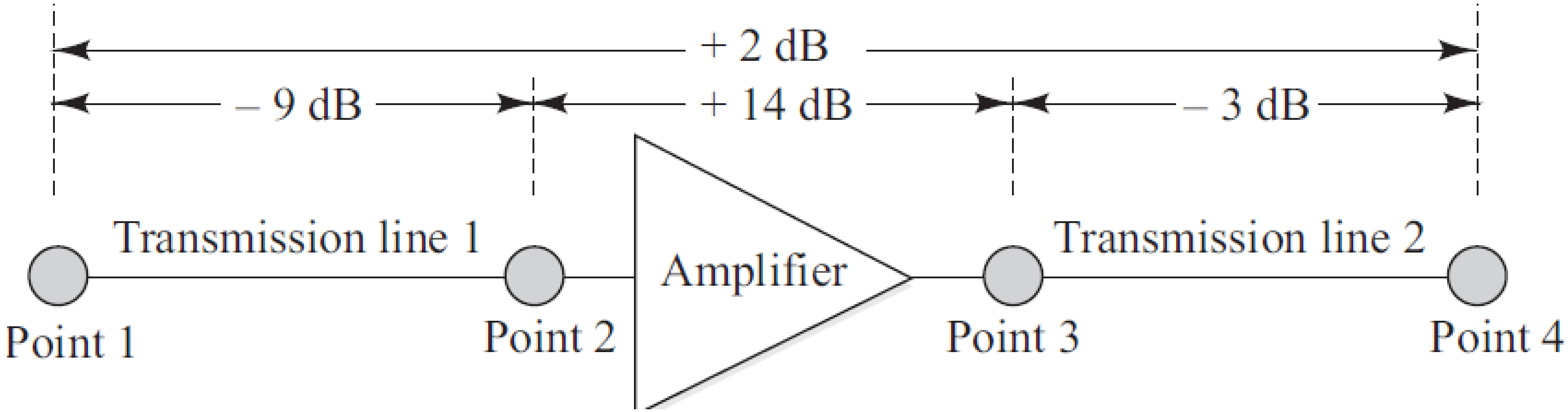
- Reduction or attenuation of signal strength arises from various loss mechanisms in a transmission medium.
- when designing and implementing an optical fiber link
  - Required to measure, and/or interrelate the optical signal levels at each of the elements of a transmission link.
  - Necessary to know parameter values such as the optical output power from a light source, the power level needed at the receiver to properly detect a signal, and the amount of optical power lost at the constituent elements of the transmission link
- A standard and convenient method for measuring attenuation through a link or a device is to reference the output signal level to the input level.
- For convenience it can designate in terms of a logarithmic power ratio measured in decibels (dB). The dB unit is defined by

$$Power\ ration\ in\ dBs = 10\log_{10}\left(\frac{P_2}{P_1}\right)$$

- To compensate for these energy losses, amplifiers are used periodically along a channel path to boost the signal level


Original
signal
Attenuated
signal
Amplified
signal
Transmission line
Amplifier
Point 1
Point 2
Point 3

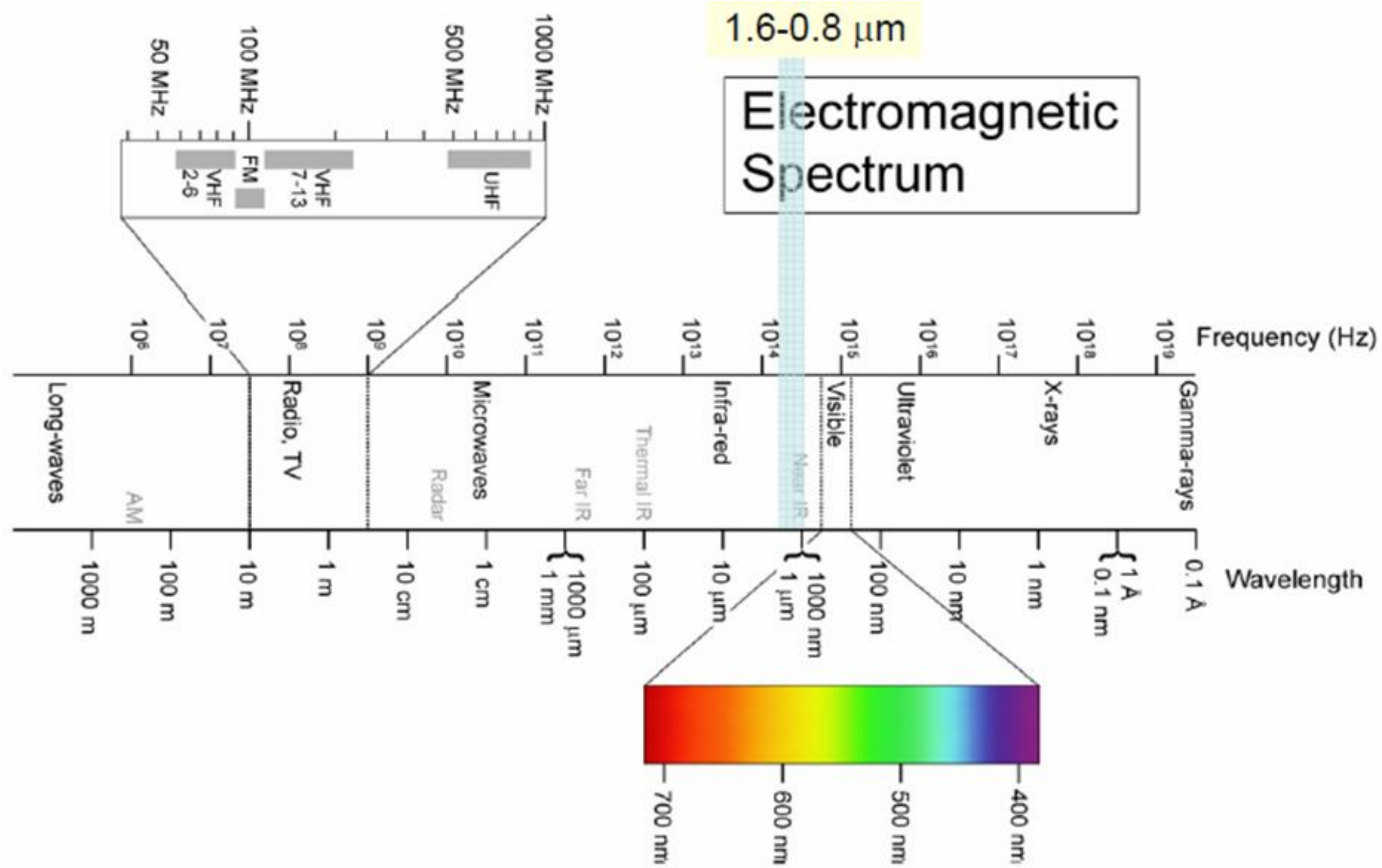
Example

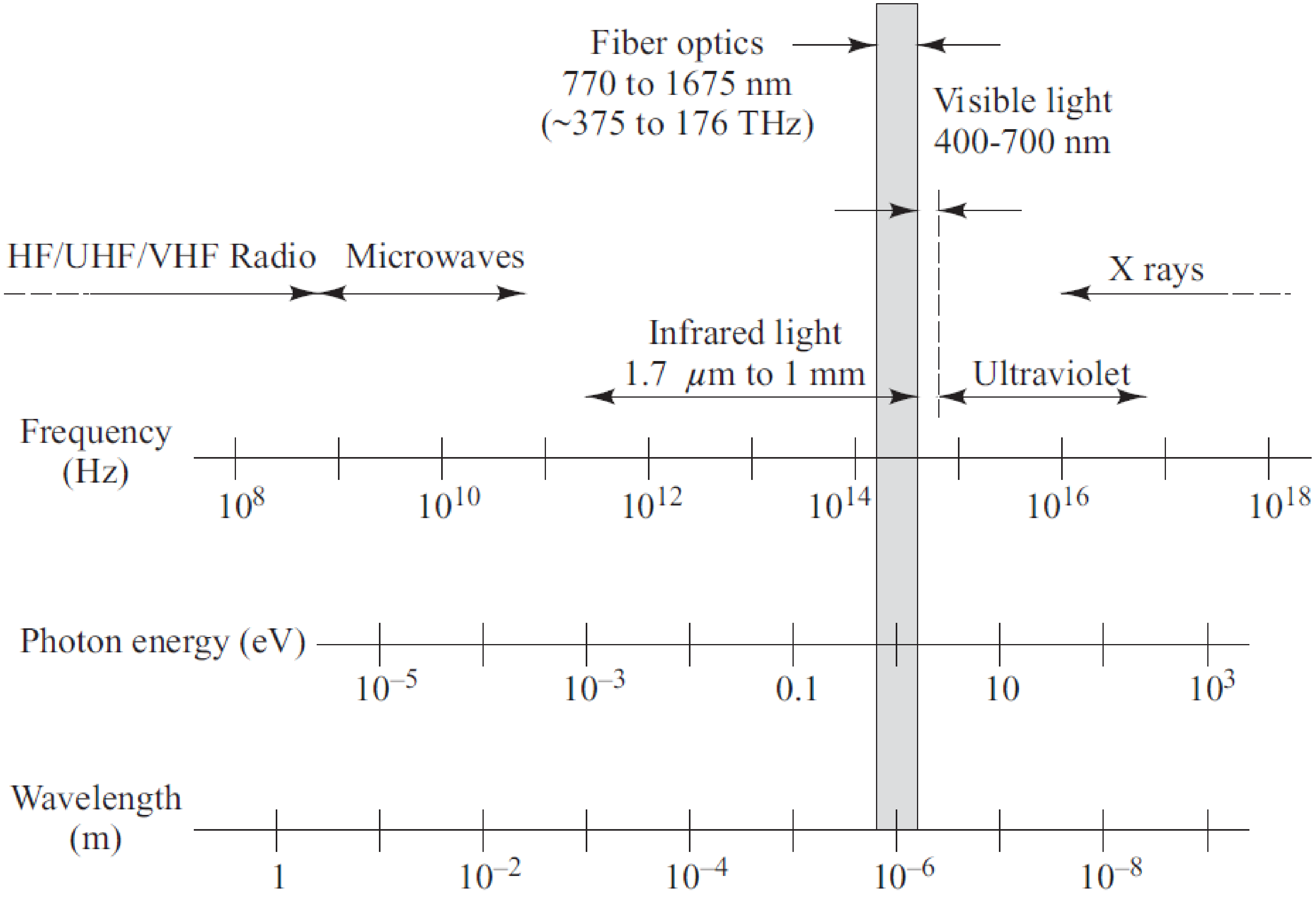


+ 2 dB
– 9 dB
+ 14 dB
– 3 dB
Transmission line 1
Amplifier
Transmission line 2
Point 1
Point 2
Point 3
Point 4

Optical Spectral Bands

- All telecommunication systems use some form of electromagnetic energy to transmit signals.





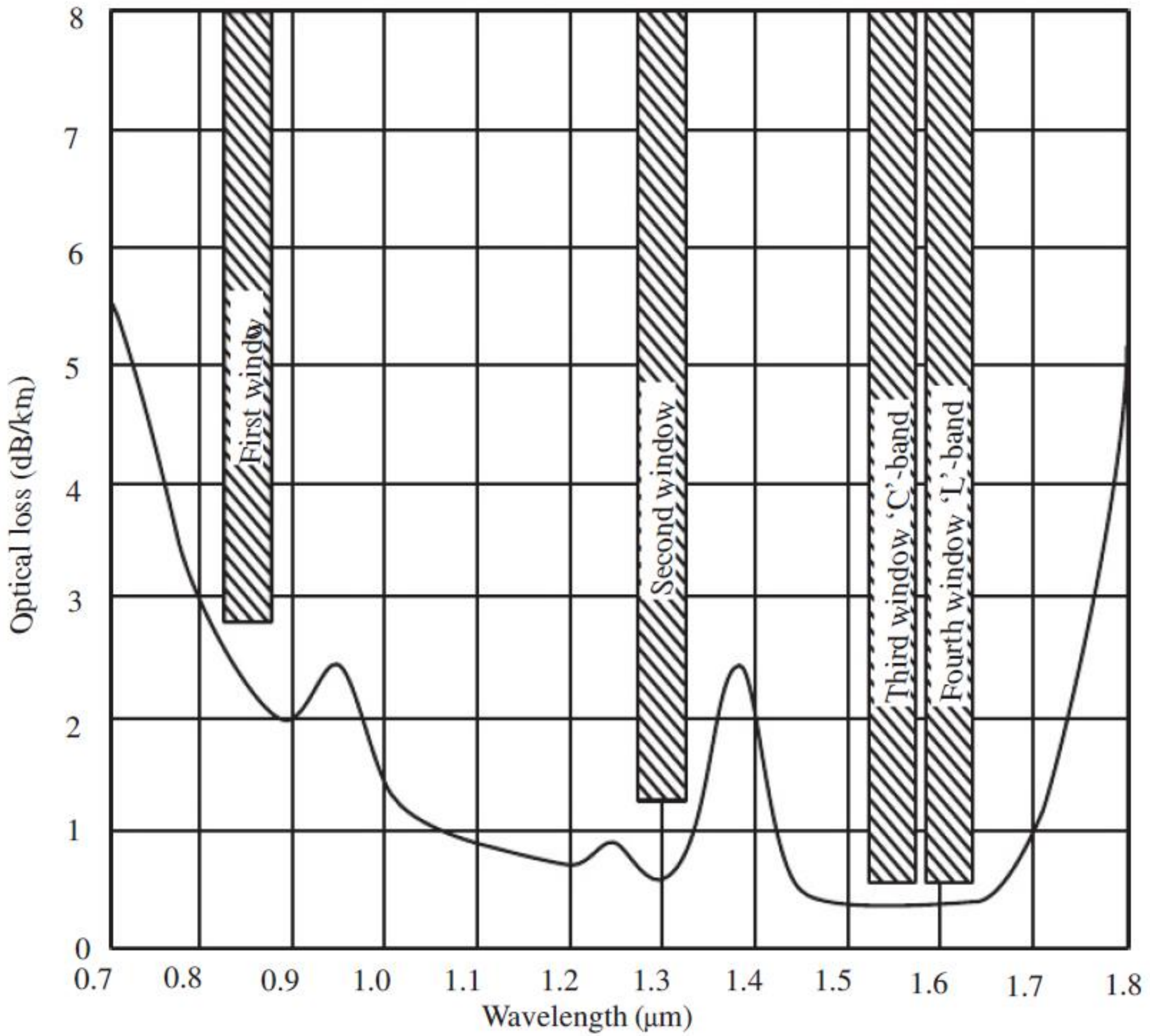
The spectrum of electromagnetic radiation

SPECTRAL BAND DESIGNATIONS USED IN OPTICAL FIBER COMMUNICATIONS

Name	*Designation*	*Spectrum (nm)*
Original band	O-band	1260 to 1360
Extended band	E-band	1360 to 1460
Short band	S-band	1460 to 1530
Conventional band	C-band	1530 to 1565
Long band	L-band	1565 to 1625
Ultra-long band	U-band	1625 to 1675

Optical Windows

- In early 1970s due to technology limitation, the optical fiber had a low loss window around 850nm. Also the semiconductor optical sources were made of GaAs which emitted light at 850nm. Due to compatibility of the medium properties and the sources, the optical communication started in **850nm band** so called the **‘First window’**. This window exhibited a relatively high loss of the order of 3 dB/km.
- As the glass purification technology improved, the true silica loss profile emerged in 1980s. The loss profile shows two low loss windows, one around 1300nm and other around 1550nm. In 1980s the optical communication shifted to **1300nm band** , so called the ‘ **Second Window'** . This window is attractive as it can support the highest data rate with theoretically **zero dispersion** for silica fibers and attenuation around **0.5 dB/km**.
- In 1990s the communication was shifted to **1550nm** window, so called **‘Third Window’** due to invention of the Erbium Doped Fiber Amplifier (EDFA). The EDFA can amplify light only in a narrow band around 1550nm. Also this window has intrinsically lowest loss of about **0.2 dB/Km** . This band has higher dispersion, meaning lower bandwidth. However, this problem has been solved by use of so called ‘dispersion shifted fibers'.



8
7
6
5
4
3
2
1
0
Optical loss (dB/km)
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
Wavelength (μm)
First window
Second window
Third window 'C'-band
Fourth window 'L'-band

Standards for Optical Fiber Communications

- Three basic standard classes for fiber optics: primary standards, component testing standards, and system standards
- **Primary standards**
  - refer to measuring and characterizing fundamental physical parameters such as attenuation, bandwidth, operational characteristics of fibers, and optical power levels and spectral widths
  - National Institute of Standards and Technology (NIST)
- **Component testing standards**
  - define tests for fiber-optic component performance and establish equipment-calibration procedures
  - Telecommunications Industry Association (TIA) in association with the Electronics Industries Alliance (EIA), Telecommunication Sector of the International Telecommunication Union (ITU-T), International Electrotechnical Commission (IEC)
- **System standards**
  - refer to measurement methods for links and networks.
  - The major organizations are the American National Standards Institute (ANSI), the Institute for Electrical and Electronic Engineers (IEEE), and the ITU-T.

EVOLUTION OF OPTICAL COMMUNICATION SYSTEMS/NETWORKS

First generation:

- Operating at 850 nm; GaAs semiconductor lasers, fiber losses were high
- Bit rate: 45 Mb/s;
- repeater spacing upto 10 km;

Second generation:

- Operating wavelength: 1.3 μm, minimum dispersion; fiber losses <0.5 dB/km
- bit rate: 100 Mb/s (Multimode fibers); Single-mode fibers (1987), 1.7 Gb/s
- Repeater spacing: 50 km

Third generation:

- Operating at 1.55 μm, fiber losses <0.2 dB/km, dispersion-shifted fibers
- bit rate : 2.5 Gb/s - 10 Gb/s
- Repeaters every 60 Km, E - O conversion

Evolution of optical communication systems/networks

Fourth generation:

- Operating wavelength: 1.45 to 1.62 μm, WDM,
- Optical amplifiers (EDFAs)
- bit rate: 10 Tb/s
- Repeater spacing: > 10,000 km

Fifth generation:

- uses Roman amplification technique and optical solitiors.
- Bit rate: 40 - 160 Gb/s
- Repeater spacing: 24000 km - 35000 km
- Operating wavelength: 1.53 to 1.57 μm

TEXT BOOKS

- Gerd Keiser, Optical Fiber Communications, TMH India, Fourth Edition, 2010.
- Senior John M., Optical Fiber Communications, Pearson Education India, Third Edition, 2009.
- R.P. Khare, *Fiber optics and optoelectronics, Oxford University Press 2004*