Unit 1: Overview

Overview – Chapter 1

- Overview of Optical Fiber Communications
- Motivations for Lightwave Communications
- Optical Spectral Bands
- Decibel Units
- Network Information Rates
- WDM Concepts
- Key Elements of Optical Fiber Systems
- Standards for Optical Fiber Communications
- Modeling and Simulation Tools

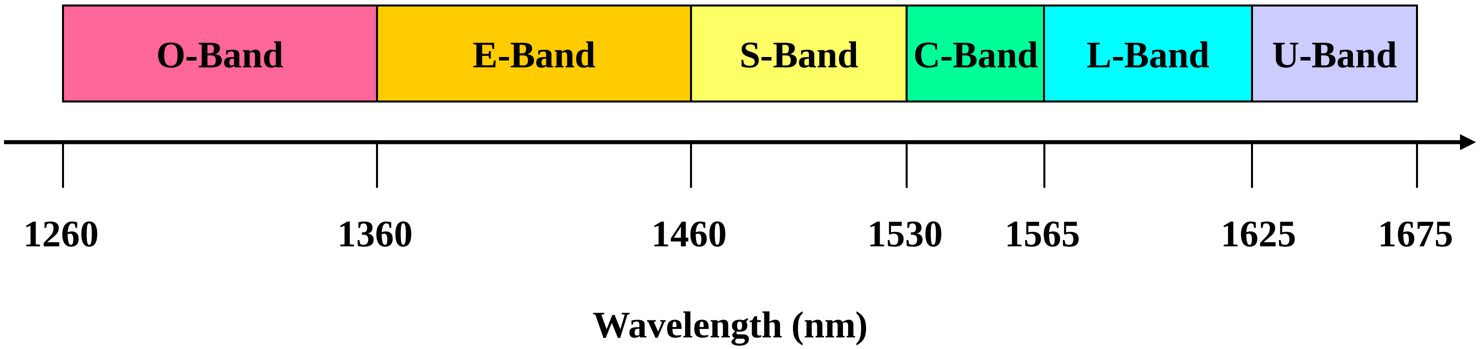
Motivations

- Lifestyle changes from Internet growth and use
  - Average phone call lasts 3 minutes
  - Average Internet session is 20 minutes
- More and more bandwidth-hungry services are appearing
  - Web searching, home shopping, high-definition interactive video, remote education, telemedicine and e-health, high-resolution editing of home videos, blogging, and large-scale high-capacity e-science and Grid computing
- Increase in PC storage capacity and processing power
  - 20G hard drives were fine around 2000; now standard is 160G
  - Laptops ran at 300 MHz; now the speed is over 3 GHz
- There is an extremely large choice of remotely accessible programs and information databases

Advantages of optical fibers

- ***Long Distance Transmission*: The lower transmission losses in fibers compared to copper wires allow data to be sent over longer distances.**
- ***Large Information Capacity*: Fibers have wider bandwidths than copper wires, so that more information can be sent over a single physical line.**
- ***Small Size and Low Weight*: The low weight and the small dimensions of fibers offer a distinct advantage over heavy, bulky wire cables in crowded underground city ducts or in ceiling-mounted cable trays.**
- ***Immunity to Electrical Interference*: The dielectric nature of optical fibers makes them immune to the electromagnetic interference effects.**
- ***Enhanced Safety*: Optical fibers do not have the problems of ground loops, sparks, and potentially high voltages inherent in copper lines.**
- ***Increased Signal Security*: An optical signal is well-confined within the fiber and an opaque coating around the fiber absorbs any signal emissions.**

Optical Spectral Bands



- **Original band (O-band): 1260 to 1360 nm**
  - **Region originally used for first single-mode fibers**
- **Extended band (E-band): 1360 to 1460 nm**
  - **Operation extends into the high-loss water-peak region**
- **Short band (S-band): 1460 to 1530 nm (shorter than C-band)**
- **Conventional band (C-band): 1530 to 1565 nm (EDFA region)**
- **Long band (L-band): 1565 to 1625 nm (longer than C-band)**
- **Ultra-long band (U-band): 1625 to 1675 nm**

Optical Spectral Bands

Optical communication uses *wavelength* to designate the spectral operating region and *photon energy* or *optical power* when discussing topics such as signal strength or electro-optical component performance.

1.In a vacuum the speed of light c is equal to the wavelength λ times the frequency ν, so that

$$c = \lambda \nu$$

2.The relationship between the *energy of a photon* and its *frequency (or wavelength)* is determined by *Planck's Law*

$$E = h \nu$$

where h = 6.63 × 10^{-34} J-s = 4.14 × 10^{-15} eV-s is *Planck's constant*.

3.In terms of wavelength (measured in units of µm), the *energy* in electron volts is given by

$$E(\text{eV}) = 1.2406/\lambda(\mu\text{m})$$

Decibel Units

- The **decibel** (dB) unit is defined by

$$\text{Power ratio in dB} = 10 \log \frac{P_2}{P_1}$$

Table 1.2 *Representative values of decibel power loss and the remaining percentages*

Power loss (in dB)	*Percent of power left*
0.1	98
0.5	89
1	79
2	63
3	50
6	25
10	10
20	1

Decibel Units

- **Since the decibel is used to refer to ratios or relative units, it gives no indication of the absolute power level.**
- **A derived unit called the dBm can be used for this purpose.**
- ***This unit expresses the power level P as a logarithmic* ratio of *P referred to 1 mW.***
- ***The power in dBm* is an absolute value defined by**

$$\text{Power level (in dBm)} = 10 \log \frac{P\,(\text{in mW})}{1\ \text{mW}}$$

Decibel Units

- **A rule-of-thumb relationship to remember for optical fiber communications is 0 dBm = 1 mW.**
- **Therefore, positive values of dBm are greater than 1 mW and negative values are less than 1 mW.**

Table 1.3 *Examples of optical power levels and their dBm equivalents*

Power	*dBm equivalent*
200 mW	23
100 mW	20
10 mW	10
1 mW	0
100 μW	–10
10 μW	–20
1 μW	–30
100 nW	–40
10 nW	–50
1 nW	–60
100 pW	–70
10 pW	–80
1 pW	–90

Decibel Units

<u>*Example 1.3*</u> Consider the transmission path from point 1 to point 4 shown in Fig. 1.7. Here the signal is attenuated by 9 dB between points 1 and 2. After getting a 14-dB boost from an amplifier at point 3, it is again attenuated by 3 dB between points 3 and 4. Relative to point 1, the signal level in dB at point 4 is

dB level at point 4 = (loss in line 1) + (amplifier gain) + (loss in line 2)
= (–9 dB) + (14 dB) + (–3 dB) = + 2 dB

Thus the signal has a 2-dB (a factor of $10^{0.2} = 1.58$) gain in power in going from point 1 to point 4.

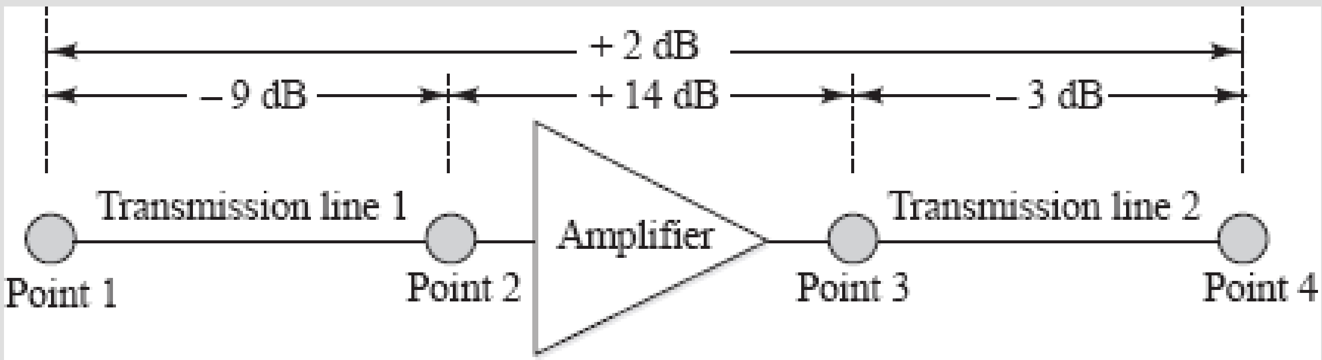
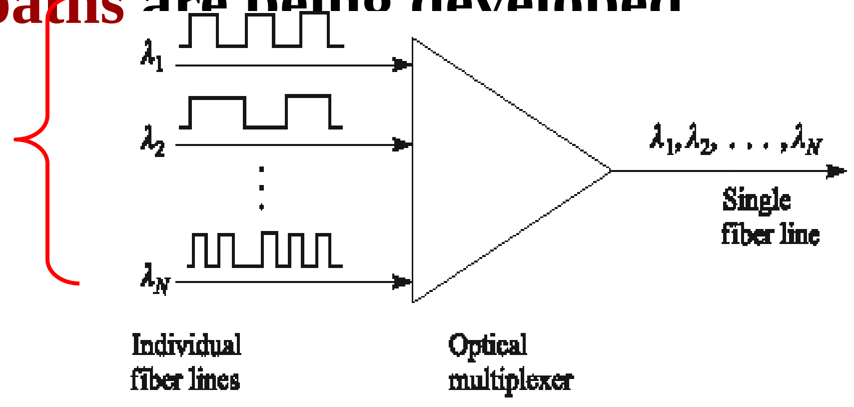


Fig. 1.7 *Example of signal attenuation and amplification in a transmission path*

Power levels differing by many orders of magnitude can be compared easily when they are in decibel form.

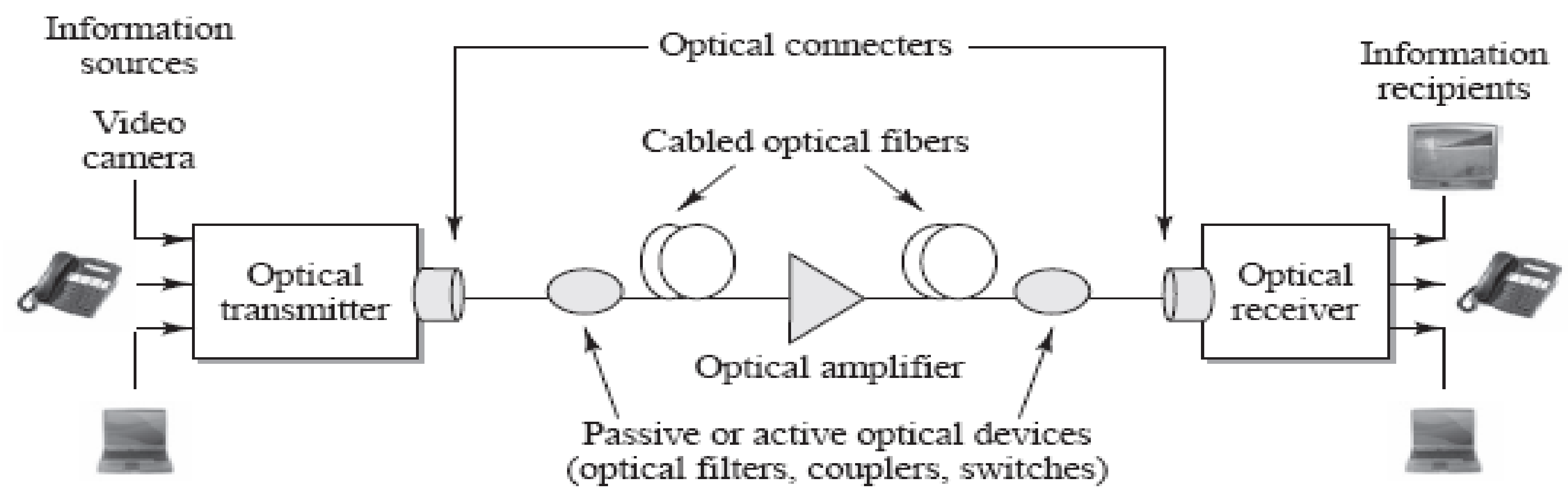
WDM Concepts

- Many independent information-bearing signals are sent along a fiber simultaneously
- Independent signals are carried on different wavelengths
- Data rates or formats on each wavelength may be different
- Coarse WDM (CWDM) and dense WDM (DWDM) are the two major wavelength multiplexing techniques
- Wavelength routing and switching techniques based on lightpaths are being developed



Key Elements of Optical Fiber Systems

- **Transmitter: a light source and signal-formatting circuitry**
- **A cable offering mechanical and environmental protection to the optical fibers contained inside**
- **A receiver consisting of a photodetector plus amplification and signal-restoring circuitry**
- **Other components: Optical amplifiers, connectors, splices, couplers, regenerators, and passive and active devices.**



Standards

The three basic classes for fiber optics are *primary* standards, *component testing* standards, and *system* standards.

- ***Primary standards*** **deal with *physical parameters*: attenuation, bandwidth, operational characteristics of fibers, and optical power levels and spectral widths.**
- ***Component testing standards*** **define tests for fiber-optic component performance and establish equipment-calibration procedures.**
  - **The main ones are *Fiber Optic Test Procedures (FOTP)***
- ***System standards*** **refer to measurement methods for optical links and networks.**

Electromagnetic Spectrum

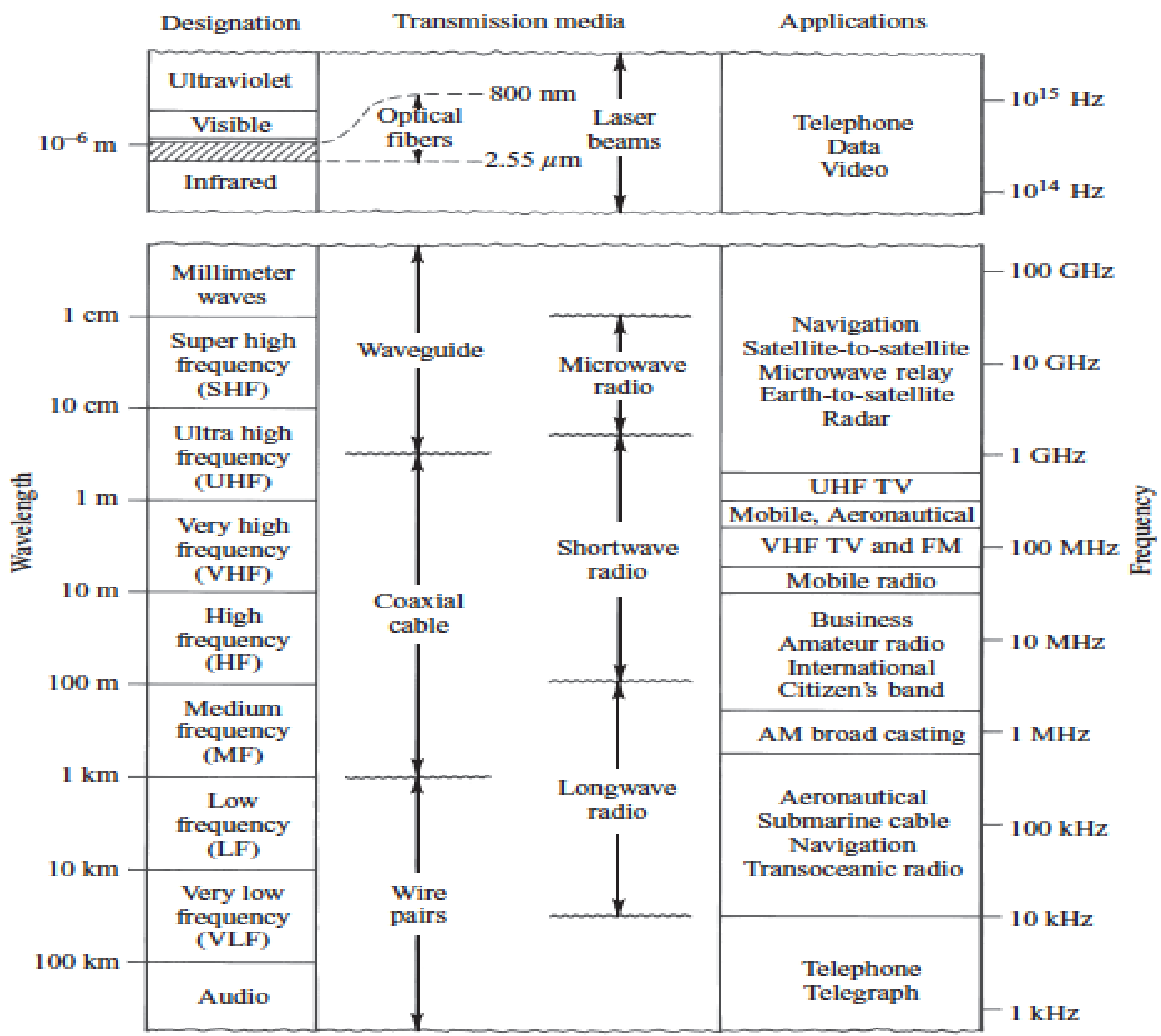


Fig. 1.1 *The regions of the electromagnetic spectrum used for radio and optical fiber communications. (Used with permission from A. B. Carlson, Communication Systems, © 1986, McGraw-Hill Book Company.)*

Transmission Characteristics

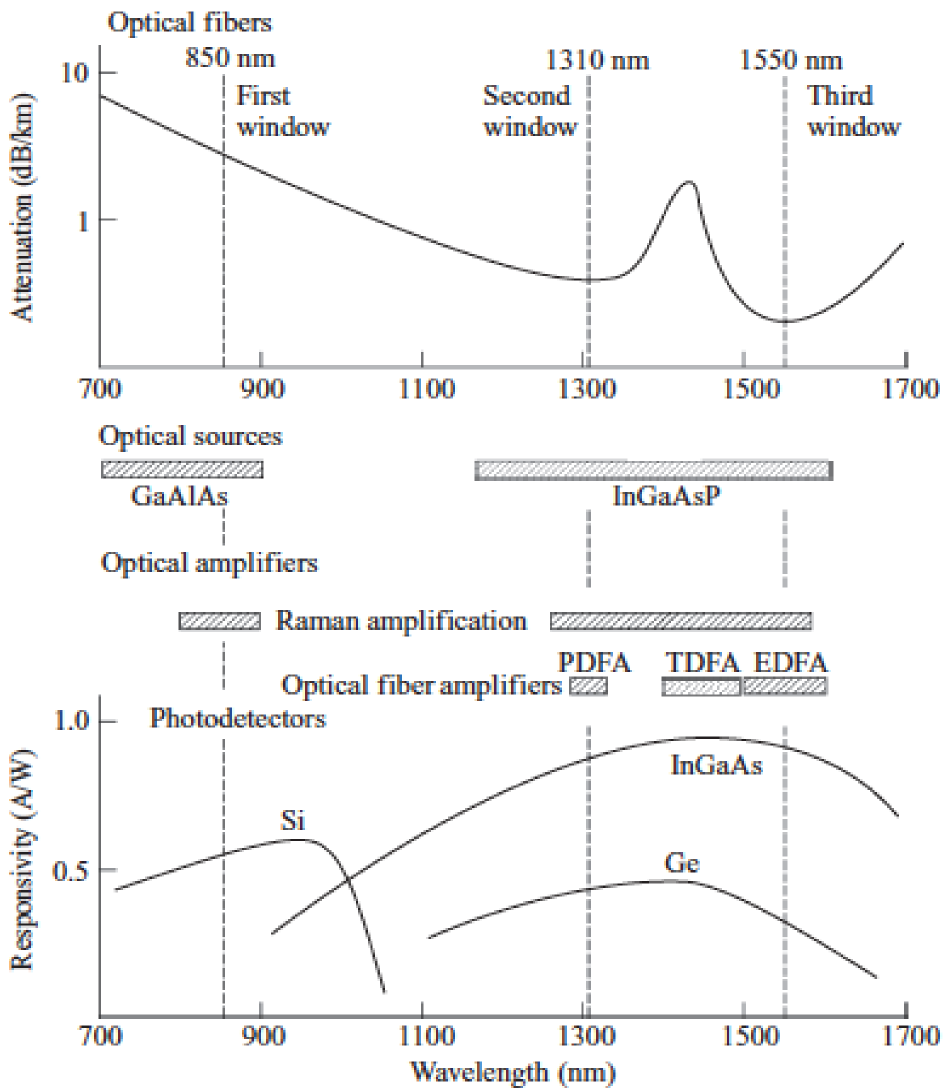
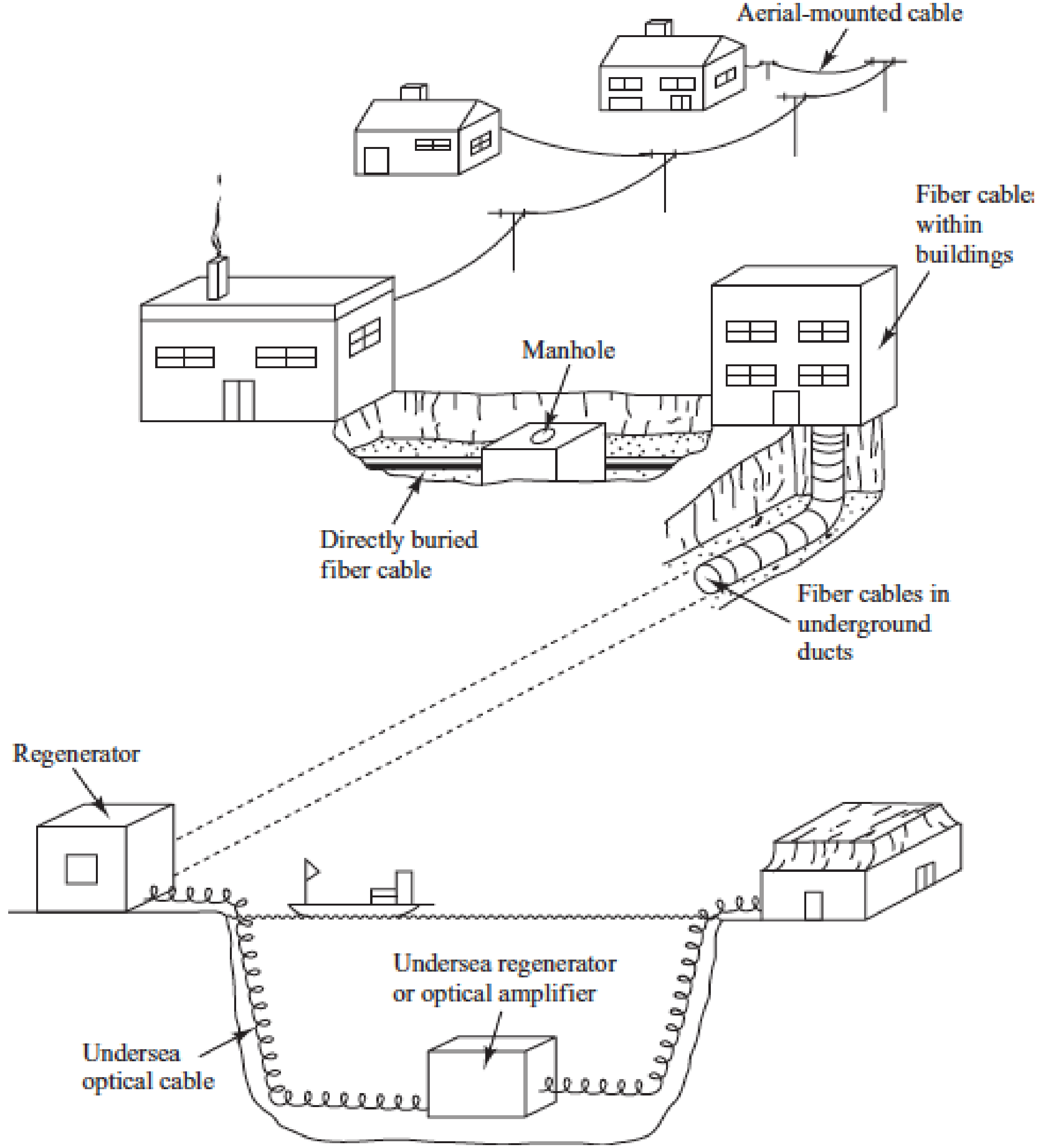


Fig. 1.4 *Characteristics and operating ranges of the four key optical fiber link components*

Application in different scenarios



Plowing operation for direct burial of optical fiber cables. (Photo © Vermeer Corporation. All Rights Reserved; www.vermeer.com.)

Ship used to lay optical fiber cables across a sea or an ocean. (Photo courtesy of TE SubCom: www.SubCom.com.)