Optics and Wireless Media

CS158a
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Feb 12, 2007.

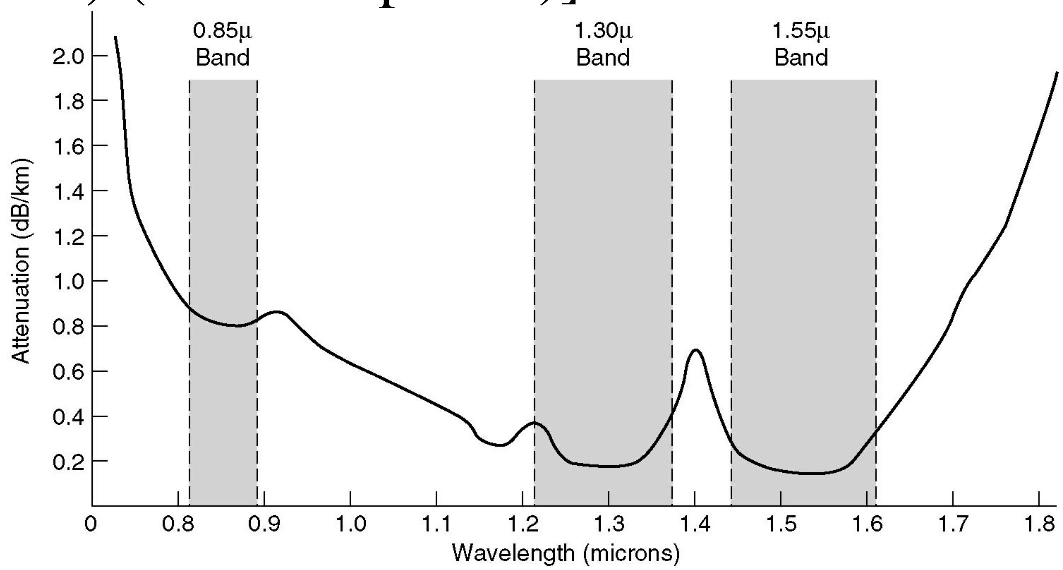
Outline

- More on Optical Fiber
- Wireless Transmission

More on Optical Fiber

- Optical fiber is made from highly transparent glass, which in turn is made from essentially sand
- Attenuation of light through glass depends on the wavelength of light.
- It is calculated using the equation:

Attenuation in decibel/km = 10 $\log_{10}$[(transmitted power)/(received power)].

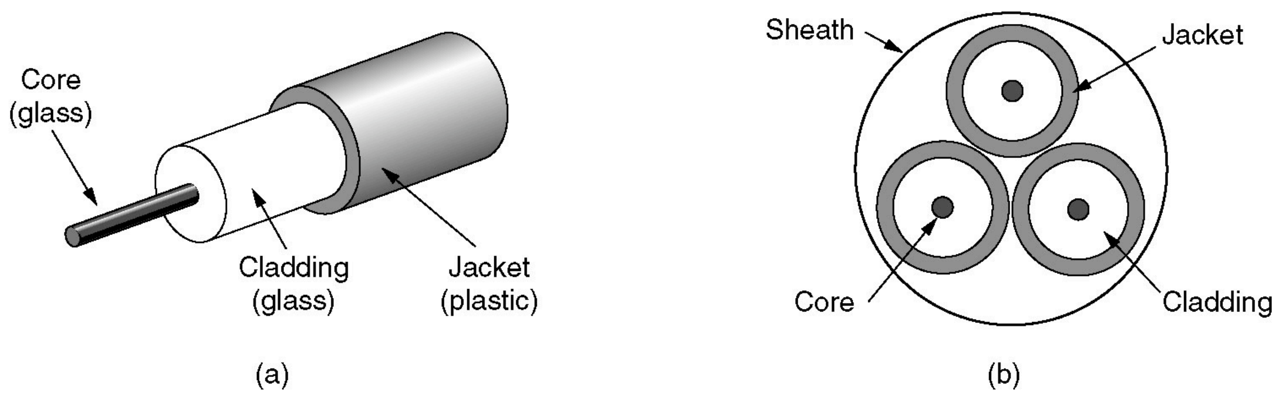


Still More Fiber

- Three wavelengths of light are used for optical communication: .85, 1.3, and 1.55 microns.
- The latter two have better attenuation properties; the first one though is easier to produce electronics for (gallium arsenide).
- Each has a bandwidth between 25,000 and 30000 GHz.
- Light pulses sent down a fiber tend to spread out with distance in a process called **chromatic dispersion**.
- To prevent two pulses from overlapping one typically needs to separate them by a longer time gap, reducing the bandwidth.
- Currently, there is a lot of research into pulse based on the inverse of the hyperbolic cosine function **(solitons)** which do not suffer from this problem.

Fiber Cables

- A typical fiber cable looks like:



- Fibers can be connected in three different ways: they can terminate in connectors (10 to 20% light loss), they can be spliced mechanically (10% light loss), or they can be melted together (best).
- Reflections can occur at the point of splice further interfering with the signals.

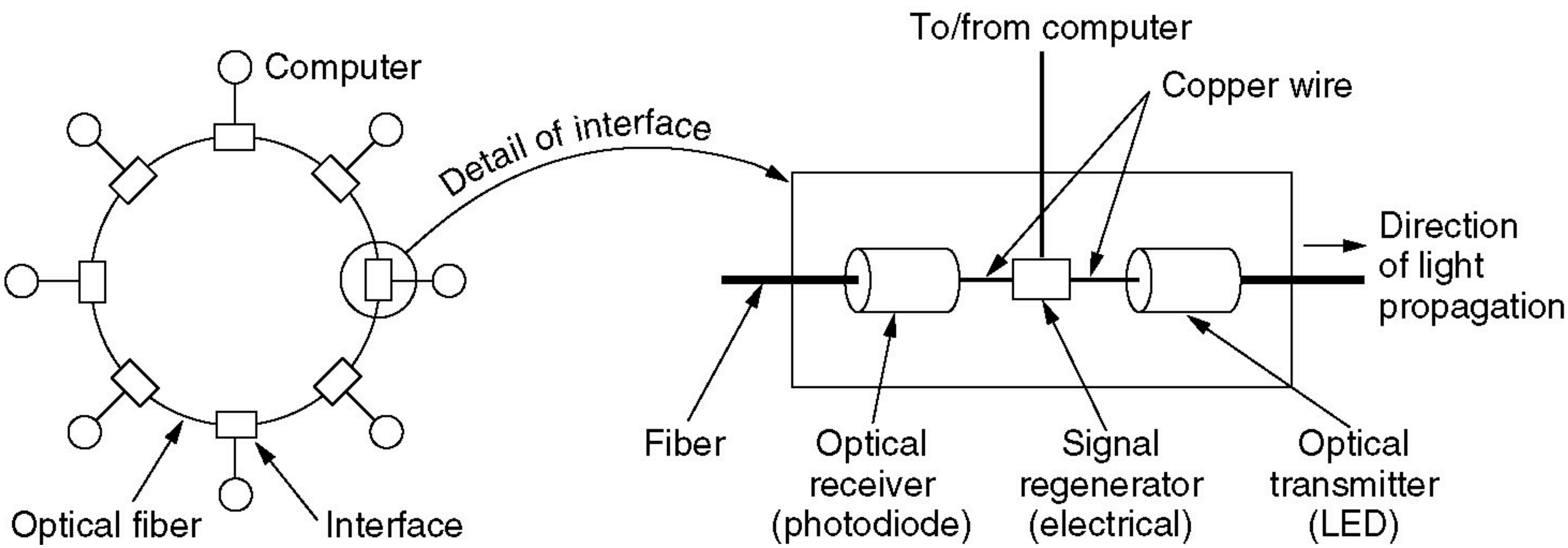
Light Sources

- Two kinds of light sources are typically used: LEDs or semiconductor lasers.

Item	LED	Semiconductor laser
Data rate	Low	High
Fiber type	Multimode	Multimode or single mode
Distance	Short	Long
Lifetime	Long life	Short life
Temperature sensitivity	Minor	Substantial
Cost	Low cost	Expensive

Fiber Optic Networks

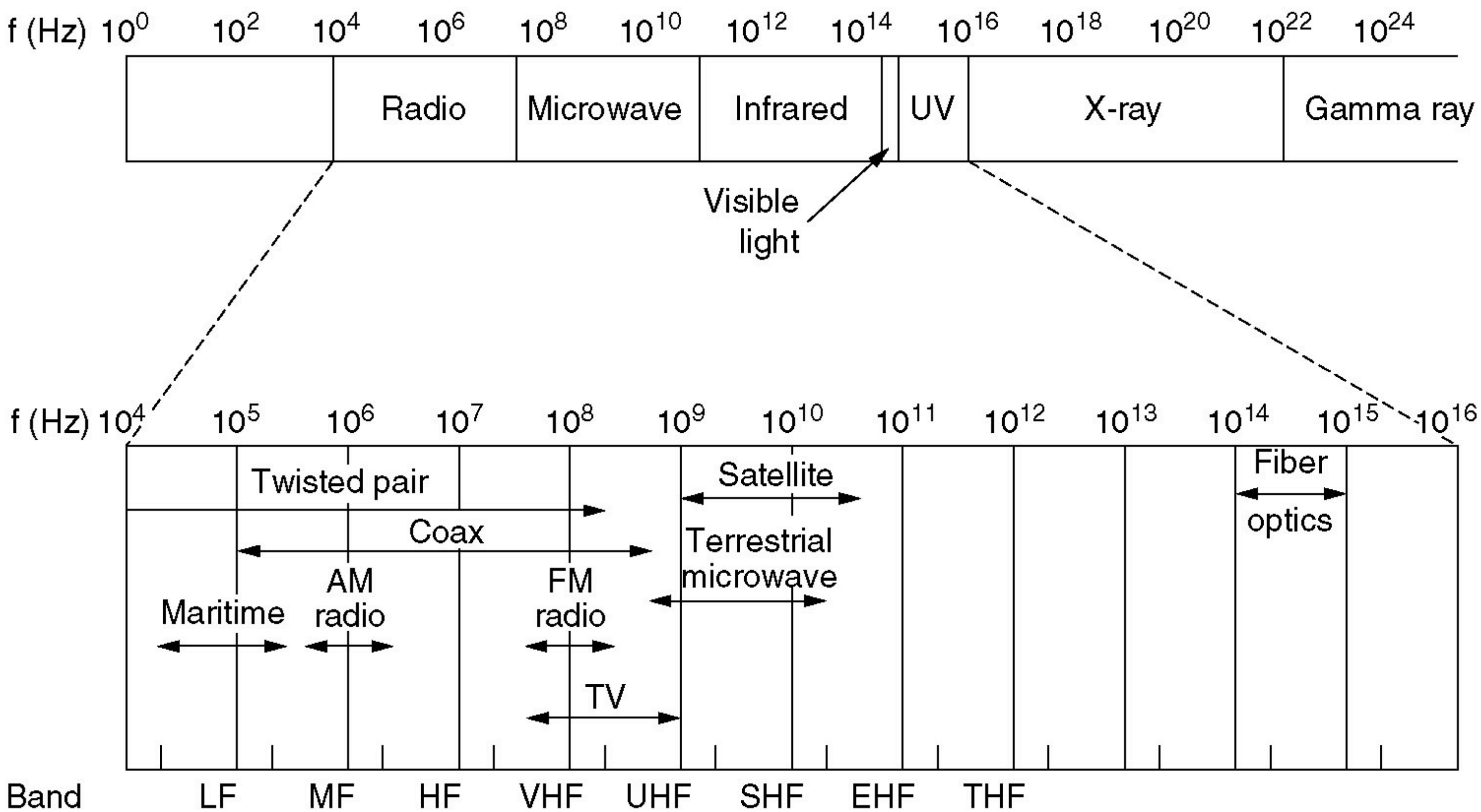
- Fiber Optics can be used either for LANs or for long haul networks.
- In the LAN setting one often connects machines in a ring with point to point connections being given by the fiber.
- The interface at each computer come in two types: a passive interface consisting of two taps fused onto the main fiber (one for receiving, the other for sending), or an **active repeater (**incoming light converted to an electrical signal, then repeated as well as read).



Wireless Transmission

- When electrons move, they create electromagnetic (EM) waves (photons) which can propagate through space.
- The number of oscillations per second of this wave is called its **frequency**, f, (measured in Hertz), the distance (in meters) for a wave to repeat itself is called its wavelength, λ.
- When an antenna of the appropriate size is attached to an appropriate electrical circuit, EM waves can be broadcasts efficiently. At the other end a receiver can pick them up.
- EM waves in a vacuum all travel at the same speed $c = 3x10^8$m/s.(Slower in other media).
- Frequency and wavelength are related by $f\ \lambda=c$
- So a 100MHz wave is about 3m long.

EM Spectrum



f (Hz) 10^0 10^2 10^4 10^6 10^8 10^10 10^12 10^14 10^16 10^18 10^20 10^22 10^24
Radio
Microwave
Infrared
UV
X-ray
Gamma ray
Visible light
f (Hz) 10^4 10^5 10^6 10^7 10^8 10^9 10^10 10^11 10^12 10^13 10^14 10^15 10^16
Twisted pair
Coax
Satellite
Terrestrial microwave
Fiber optics
Maritime
AM radio
FM radio
TV
Band
LF
MF
HF
VHF
UHF
SHF
EHF
THF

Information versus Frequency

- The amount of information that an EM wave can carry is related to its bandwidth.
- At low frequencies one can encode typically a few bits/Hz, at higher frequencies one can encode up to 8 bits/Hz.
- So a 750MHz cable can carry several gigabits/sec.
- Taking the derivative of $f = c/\lambda$ gives $df/d\lambda = -c/\lambda^2$.
- Using finite differences one has $|\Delta f| = c \Delta \lambda / \lambda^2$. So if we use a wavelength band around λ, $\Delta\lambda$, we can compute a corresponding frequency Δf and available data rate.
- For example, if $\lambda = 1.3 \times 10^{-6}$m and $\Delta\lambda = .17 \times 10^{-6}$m, we get a Δf of about 30THz. At 8bits/Hz, one has a theoretical rate of 240Tbps.
- Usually a narrow band around a wavelength is used to get the best power transmission.

Wide-band Techniques.

- Several wide-band techniques are in use:
  - **Frequency hopping spread spectrum** -- the transmitter hops from frequency to frequency hundreds of times per second, transmitting briefly on each frequency (use by 802.11 and Bluetooth). This technique minimizes multipath fading. (Invented by a Hollywood actress)
  - **Direct sequence spread spectrum** -- spreads the signal over a wide frequency band

Radio Transmission

- Radio waves are easy to generate, can travel long distance, and can penetrate buildings easily.
- For low frequency the radio waves pass through obstacles easily but the power falls off quickly.
- Higher frequency waves tend to travel in straight lines and bounce off objects.
- Due to the fact waves can travel long distance, it is easy for two transmitters to end up interfering with each other.
- HF and VHF waves that hit the ionosphere bounce off it greatly extending the range of transmission.

Satellites