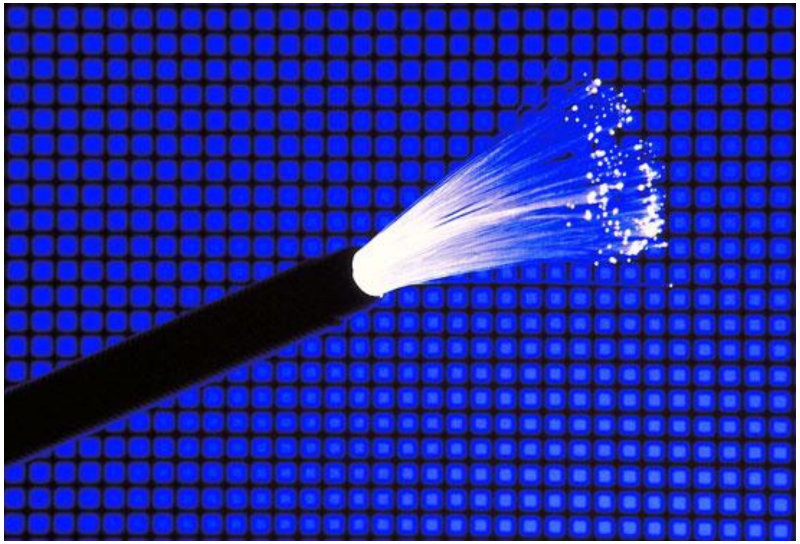
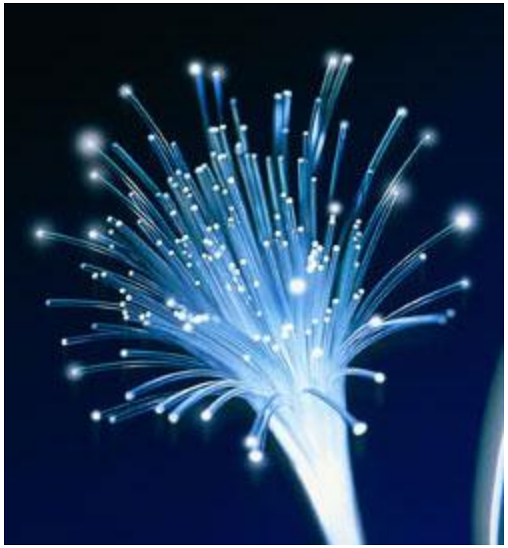
Optical fibre

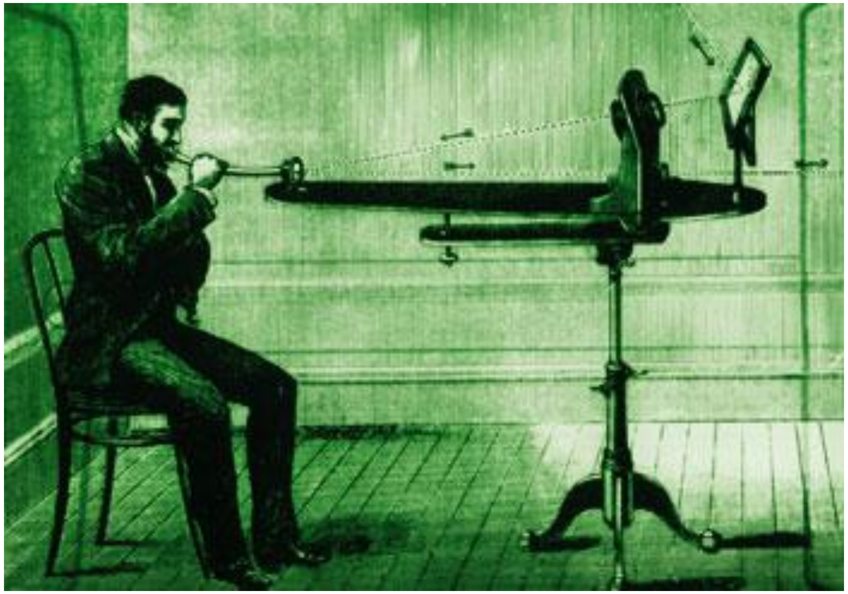
Principle and applications






Circa 2500 B.C. Earliest known glass
Roman times-glass drawn into fibers
Venice Decorative Flowers made of glass fibers
1609-Galileo uses optical telescope
1626-Snell formulates law of refraction
1668-Newton invents reflection telescope
1840-Samuel Morse Invents Telegraph
1841-Daniel Colladon-Light guiding demonstrated
in water jet
1870-Tyndall observes light guiding in a thin water jet
1873-Maxwell electromagnetic waves
1876-Elisha Gray and Alexander Bell Invent Telephone
1877-First Telephone Exchange
1880-Bell invents Photophone
1888-Hertz Confirms EM waves and relation to light
181936-1940 Communication 80-1920 Glass rods used for illumination
1897-Rayleigh analyzes waveguide
1899-Marconi Radio Communication
1902-Marconi invention of radio detector
1910-1940 Vacuum Tubes invented and developed
1930-Lamb experiments with silica fiber
1931-Owens-Fiberglass using a waveguide

1951-Heel, Hopkins, Kapany image transmission using fiber bundles
1957-First Endoscope used in patient
1958-Goubau et. al. Experiments with the lens guide
1958-59 Kapany creates optical fiber with cladding
1960-Ted Maiman demonstrates first laser in Ruby
1960-Javan et. al. invents HeNe laser
1962-4 Groups simultaneously make first semiconductor lasers
1961-66 Kao, Snitzer et al conceive of low loss single mode fiber communications and develop theory
1970-First room temp. CW semiconductor laser-Hayashi & Panish
April 1977-First fiber link with live telephone traffic-
GTE Long Beach 6 Mb/s
May 1977-First Bell system 45 mb/s links
GaAs lasers 850nm Multimode -2dB/km loss
Early 1980s-InGaAsP 1.3 µm Lasers
- 0.5 dB/km, lower dispersion-Single mode
Late 1980s-Single mode transmission at 1.55 µm - 0.2 dB/km
1989-Erbium doped fiber amplifier
1 Q 1996-8 Channel WDM
4th Q 1996-16 Channel WDM
1Q 1998-40 Channel WDM



1880 - Photophone Receiver

1880 - Photophone
Transmitter

- An **optical fiber** is a thin, flexible, transparent fiber that acts as a **wave guide** , or "light pipe", to transmit light between the two ends of the fiber
- It is a cylindrical wave guide made up of dielectric material that transmits light along its axis, The fiber consists of

1. **Core** :- diameter from 1 µm to 100 µm

Made of **pure** silica (SiO_2) ,refractive index n1

2. Surrounded by a **cladding** layer, also made of doped silica or plastic. Diameter from 100 to 125 µm

the R.I n2 such that **n1 > n2**

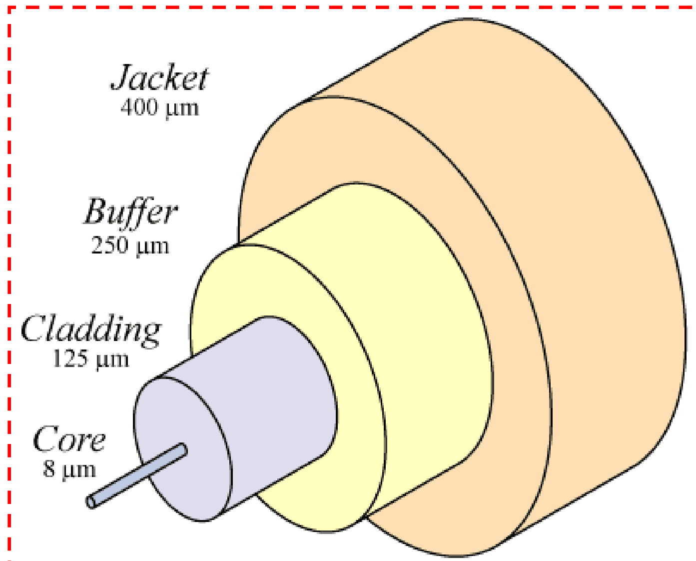
3. Outermost layer called **Protective jacket**

of diameter 250 µm

Made of polymeric material

Is used to provide strength , support

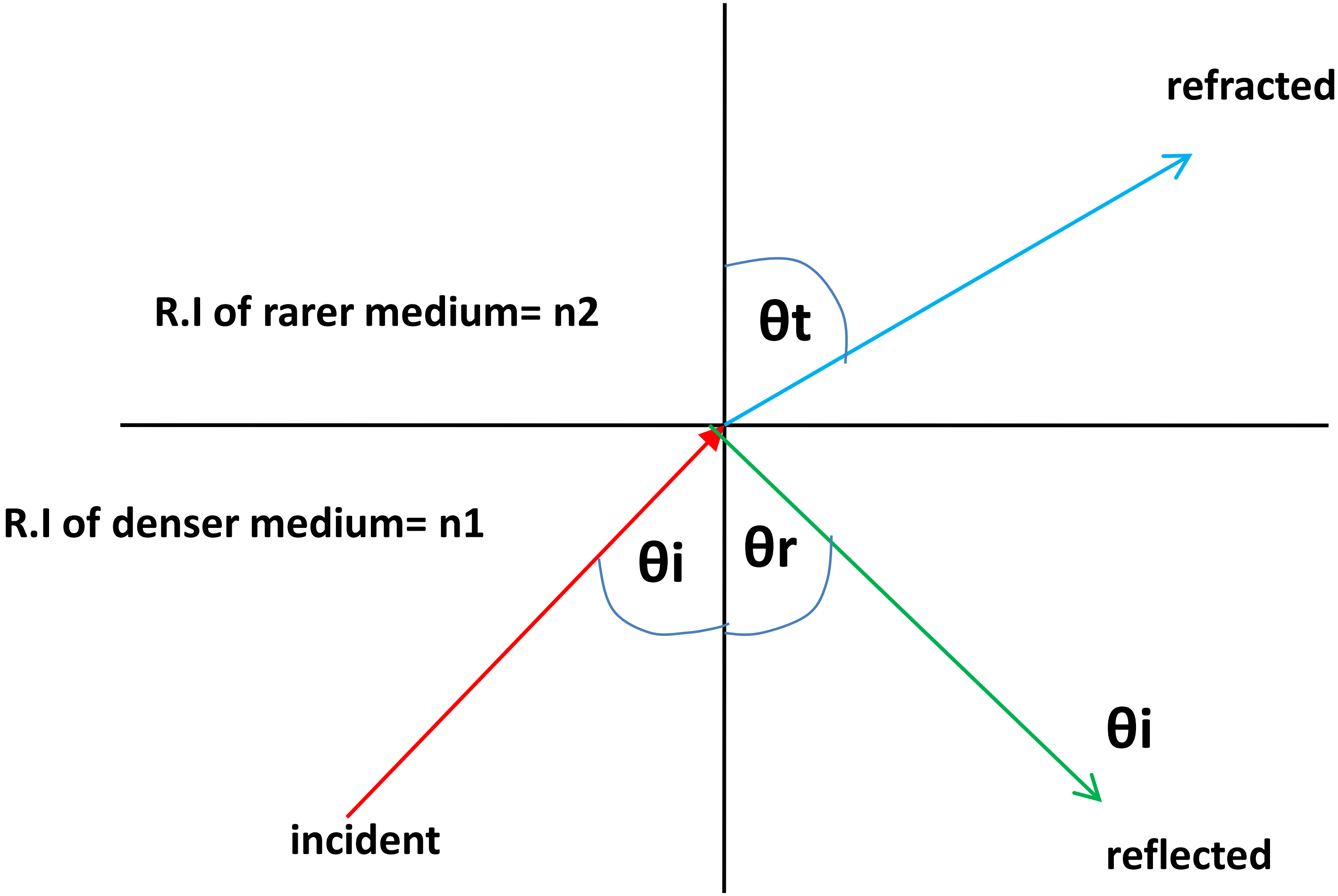
and protection to the fibre



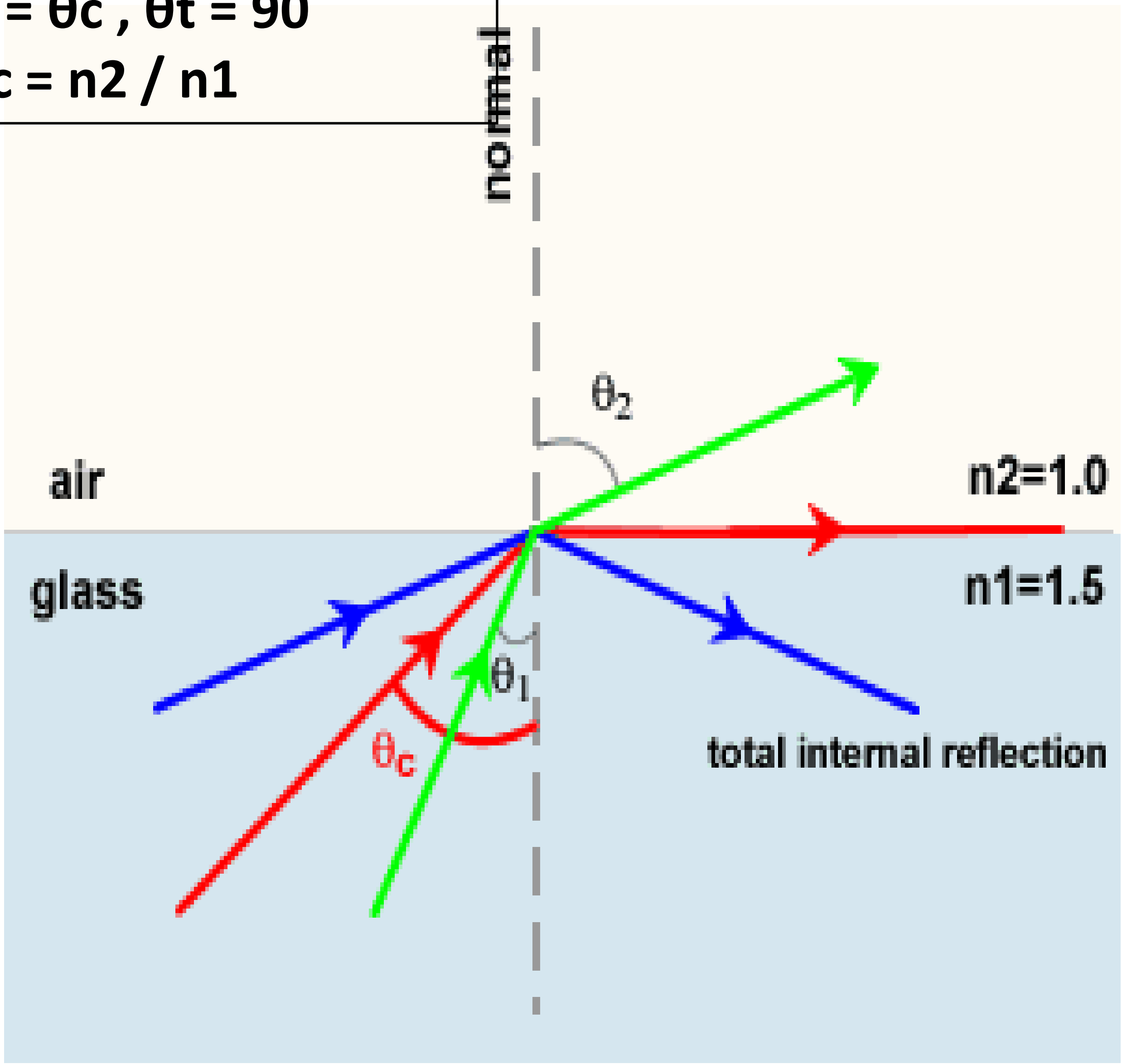
Areas of Application

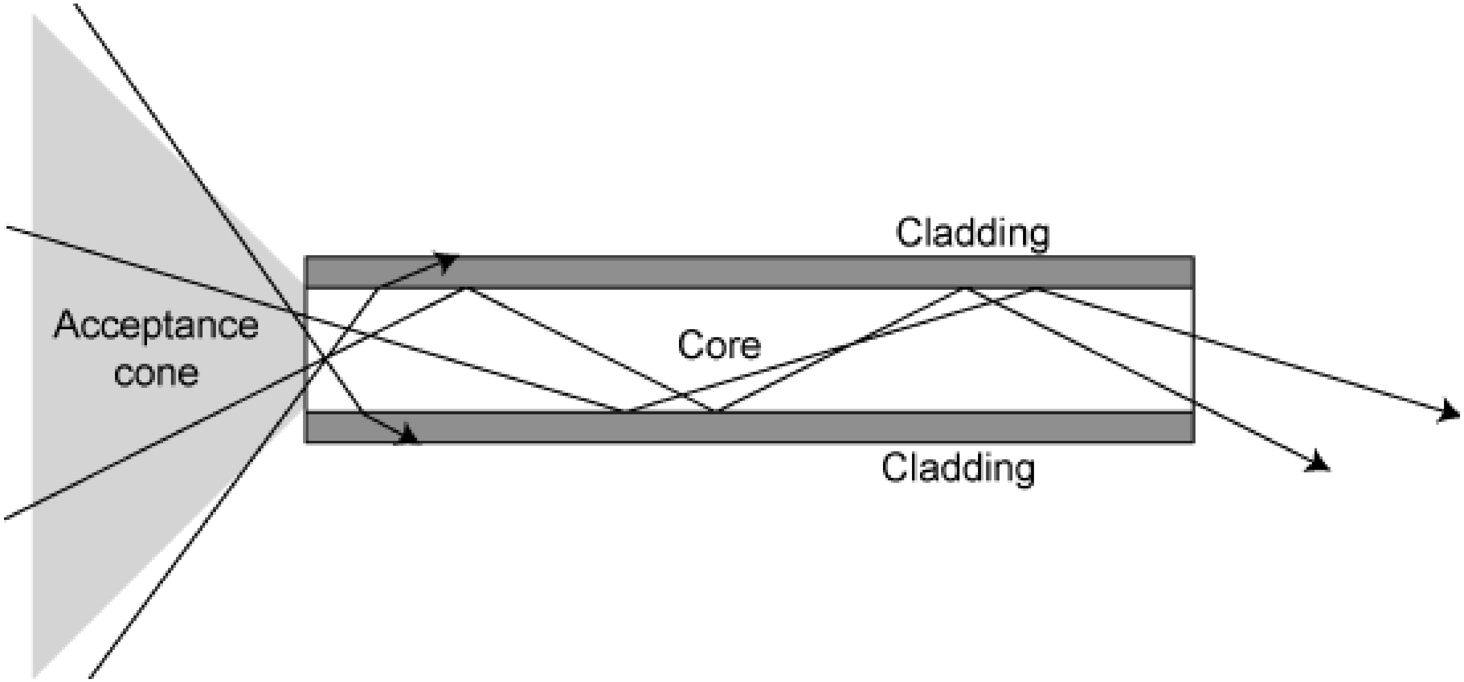
- Telecommunications
- Local Area Networks
- Cable TV
- CCTV
- Optical Fiber Sensors

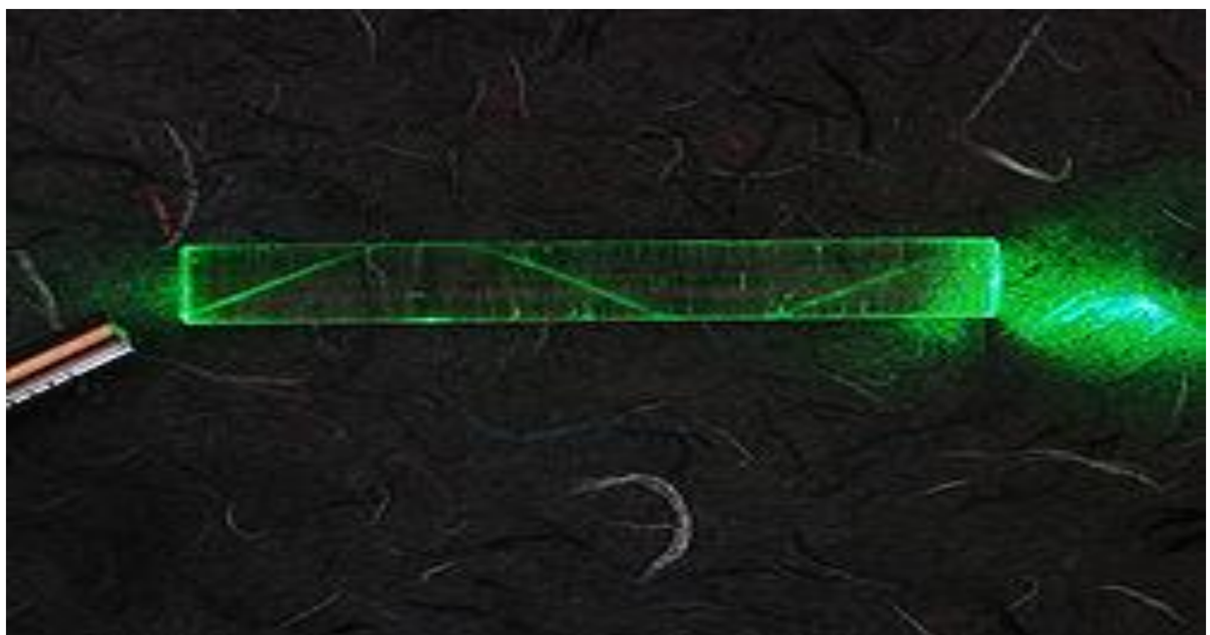
Principle: total internal reflection



We have n1 sin θi = n2 sin θt
When θi = θc , θt = 90
So, sin θc = n2 / n1




Cladding
Acceptance
cone
Core
Cladding



- **Fiber-optic communication** is a method of transmitting information from one place to another by sending pulses of light through an optical fibre.
- The light forms an electromagnetic carrier wave that is modulated to carry information
- optical fibers have largely replaced copper wire communications
- Radio wave –10^6 , microwave –10^{10} , light wave –10^{15} Hz
- Hence more information may be carried
- Signal transmission is photonic, where in copper wires it is electronic
- Transmission speed is high, information density is high, attenuation (loss) is less, error less (reliable), light weight, secured and immune to electromagnetic radiation
- **100gm of optical fibre can replace 33 tons of copper wire**
- **Two optical fibres can transmit the equivalent of 24000 telephone call**

When light passes from air into the fibre $n_0 \sin i = n_1 \sin r$

$= n_1 \sin(90-\theta) = n_1 \cos\theta$

Or, $n_0 \sin i = n_1 (1 - \sin^2\theta)^{½}$

Or, for $i = i_m$ (say), $\theta = \theta c$

and $\sin\theta c = n_2 / n_1$, also n_0 (air) = 1

Putting all the values $\sin i_m = n_1 (1 - n_2^2 / n_1^2)^{½}$

So, **$\sin i_m = (n_1^2 - n_2^2)^{1/2}$** is called the numerical aperature of the fibre, which determines the light gathering capacity of the fibre = **NA**

And **$i_m = \sin^{-1} (n_1^2 - n_2^2)^{½}$** is called the acceptance angle

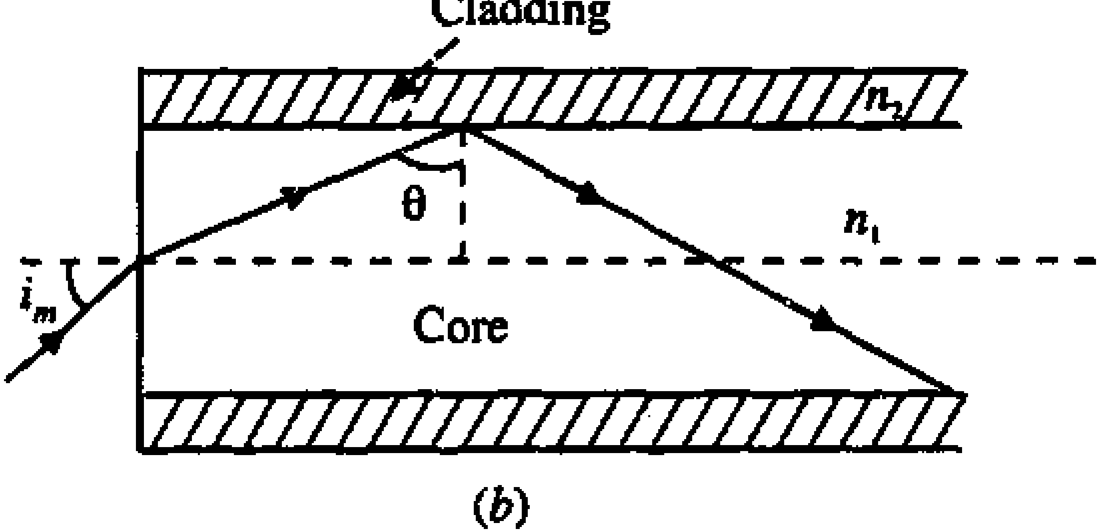
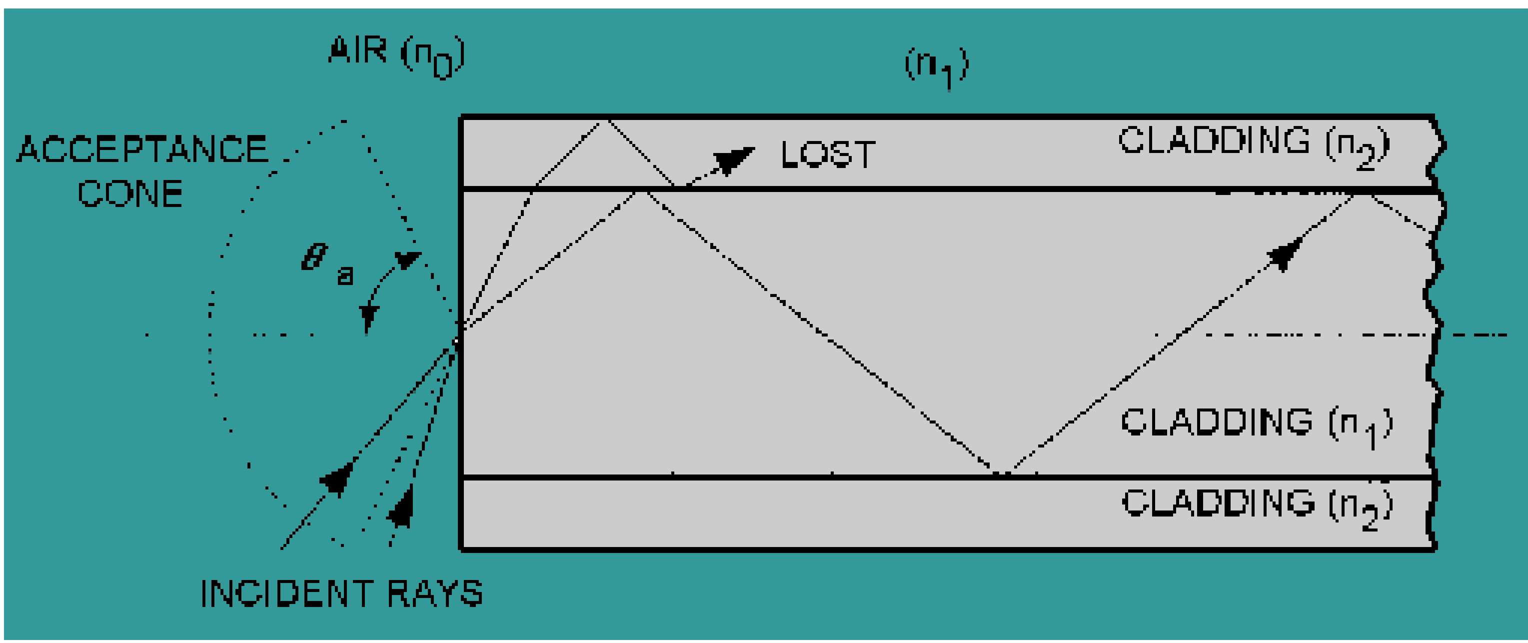
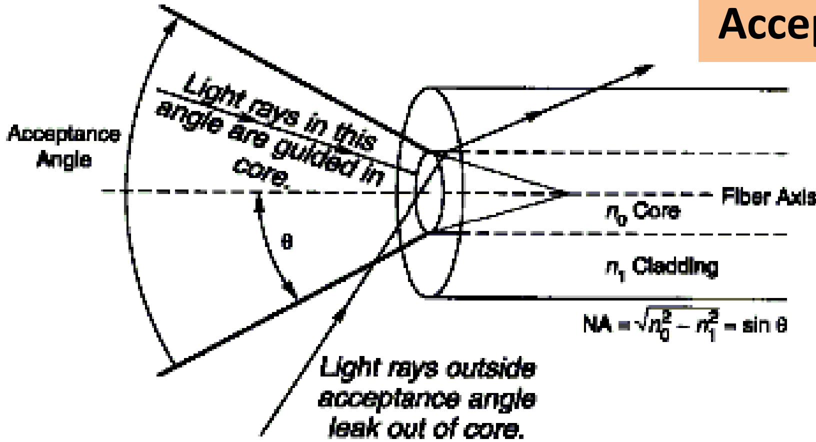
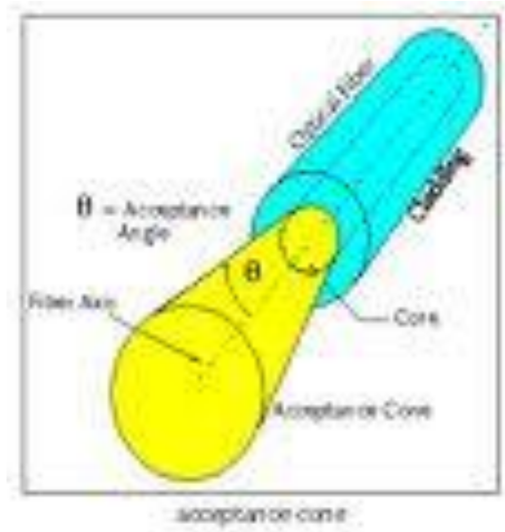

Cladding
n_2
θ
n_1
i_m
Core
(b)

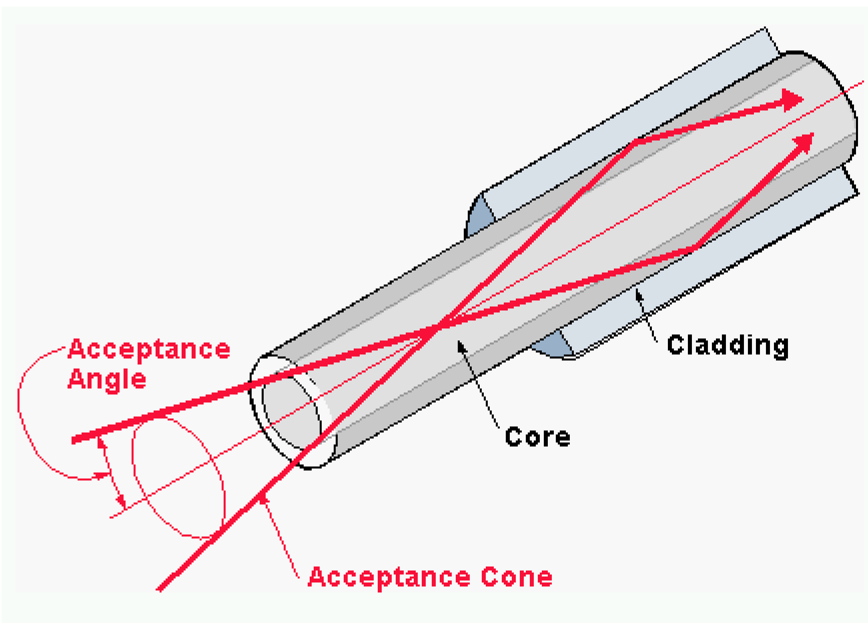
Fig. 23.23

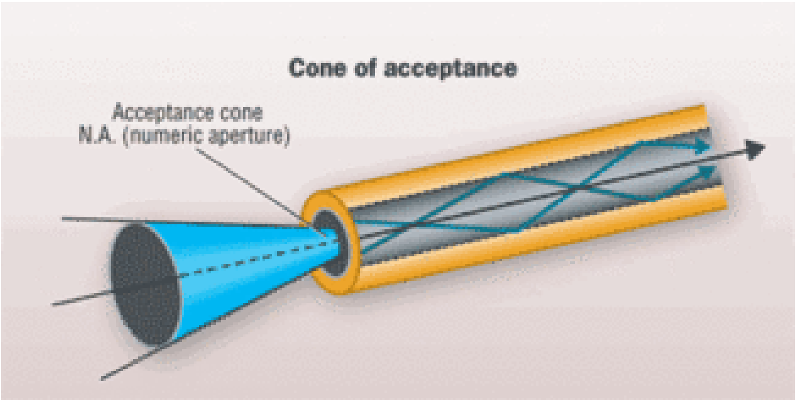

AIR (n_0)
(n_1)
ACCEPTANCE
CONE
LOST
CLADDING (n_2)
θ_a
CLADDING (n_1)
CLADDING (n_2)
INCIDENT RAYS

Acceptance cone

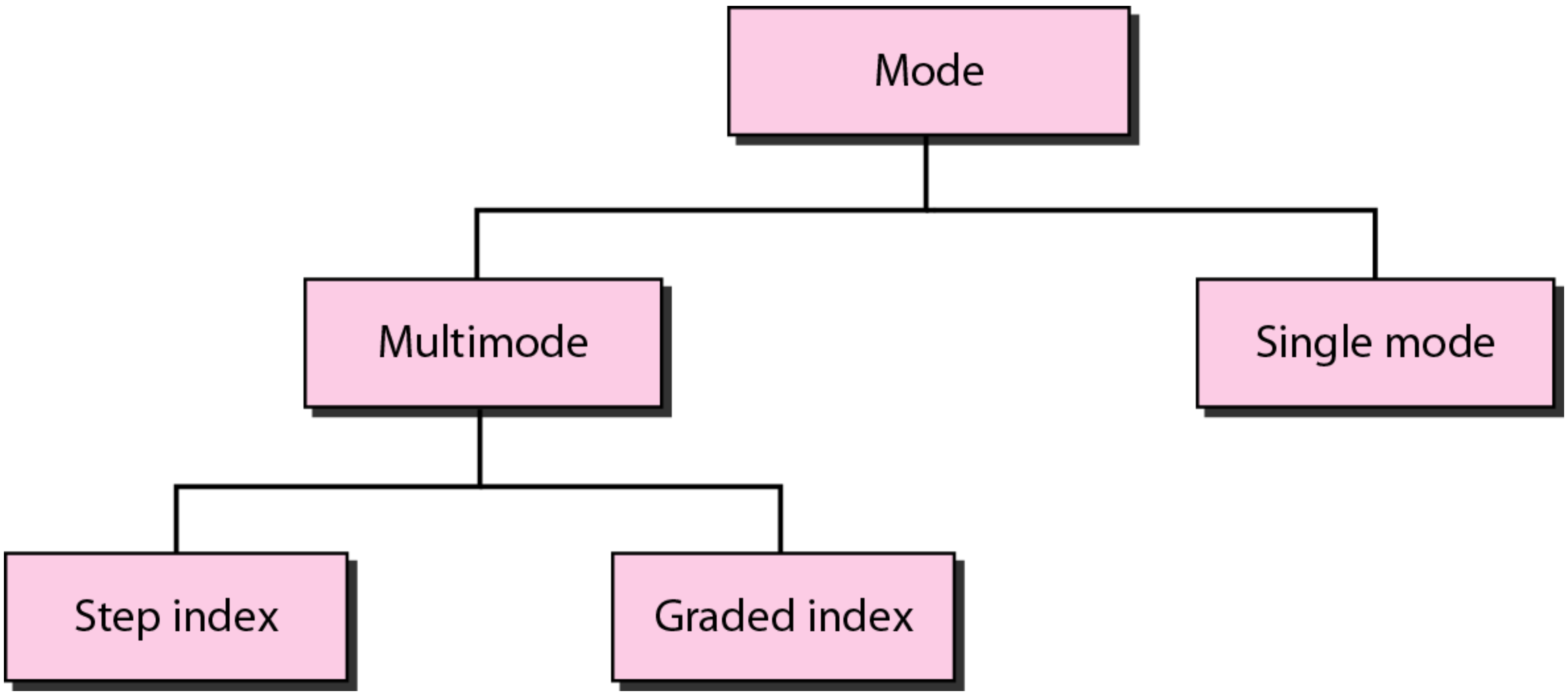








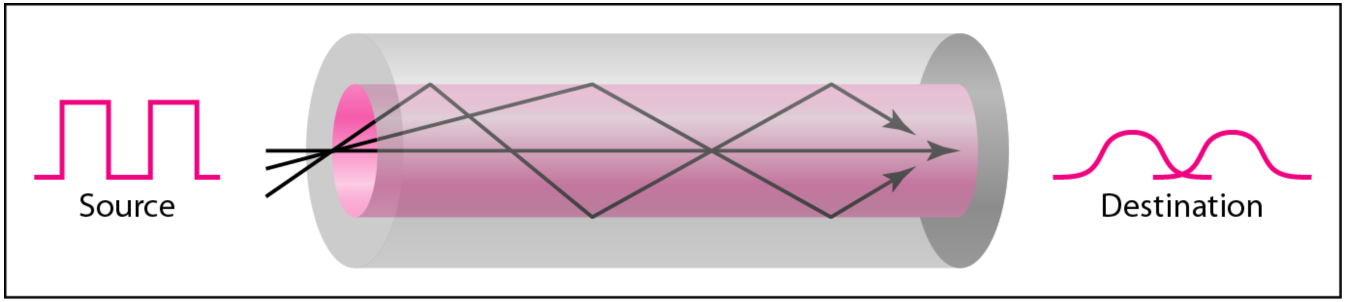
Types of propagation (mode)



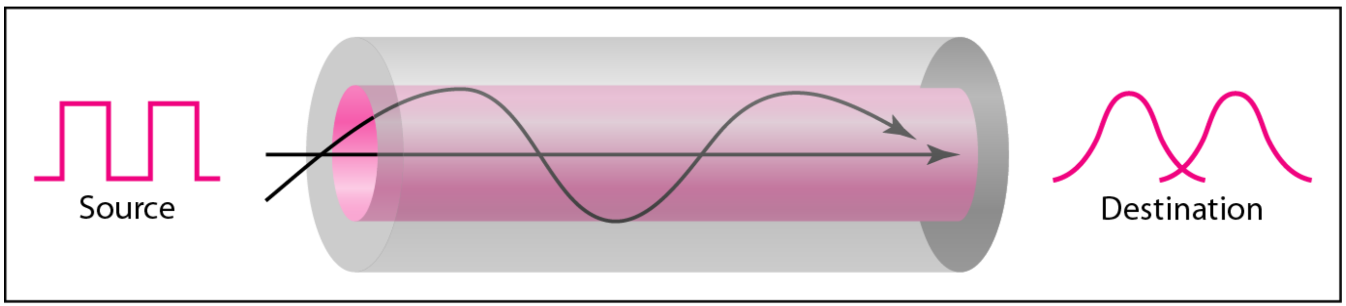
Type of Fibers

Optical fibers come in two types:

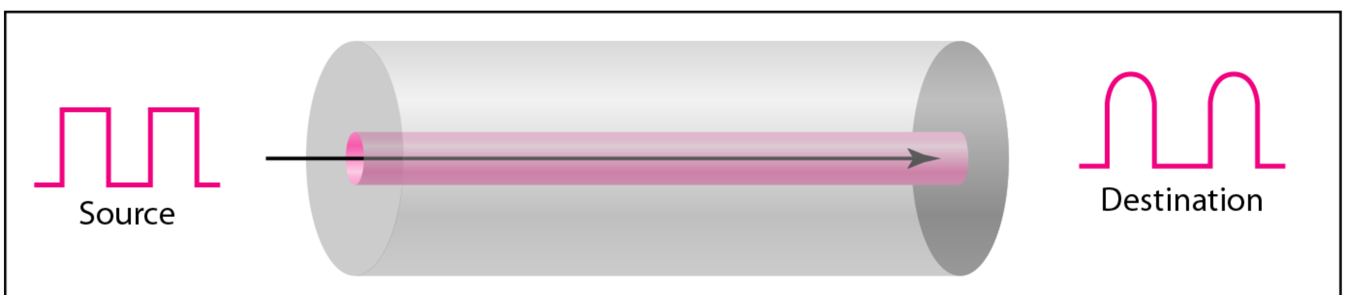
- **Single-mode fibers** – used to transmit one signal per fiber (used in telephone and cable TV). They have small cores(9 microns in diameter) and transmit infra-red light from laser.
- **Multi-mode fibers** – used to transmit many signals per fiber (used in computer networks). They have larger cores(62.5 microns in diameter) and transmit infra-red light from LED.



a. Multimode, step index



b. Multimode, graded index



c. Single mode

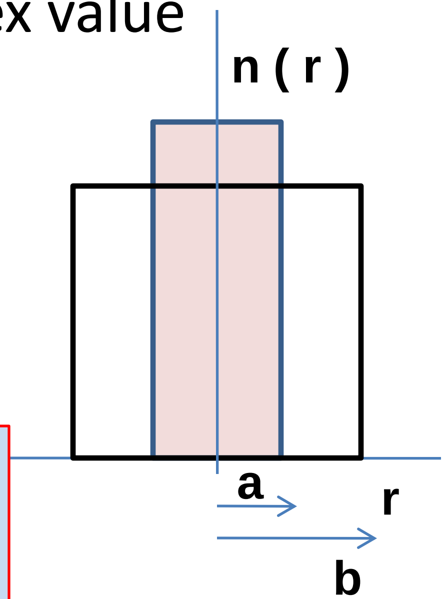
Refractive index profile and types of fibre

- Two types of fibre depending on the refractive index value

1. step-index profile

is a refractive index profile characterized by a uniform refractive index within the core and a sharp decrease in refractive index at the core-cladding interface

$n(r) = n1$ for $r < a$
$\quad = n2$ for $r > a$

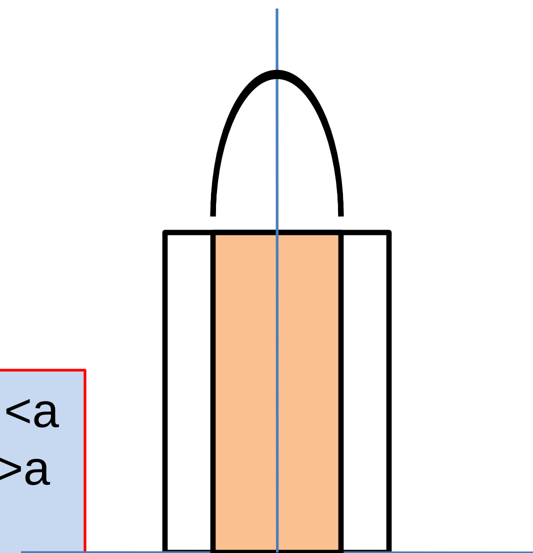


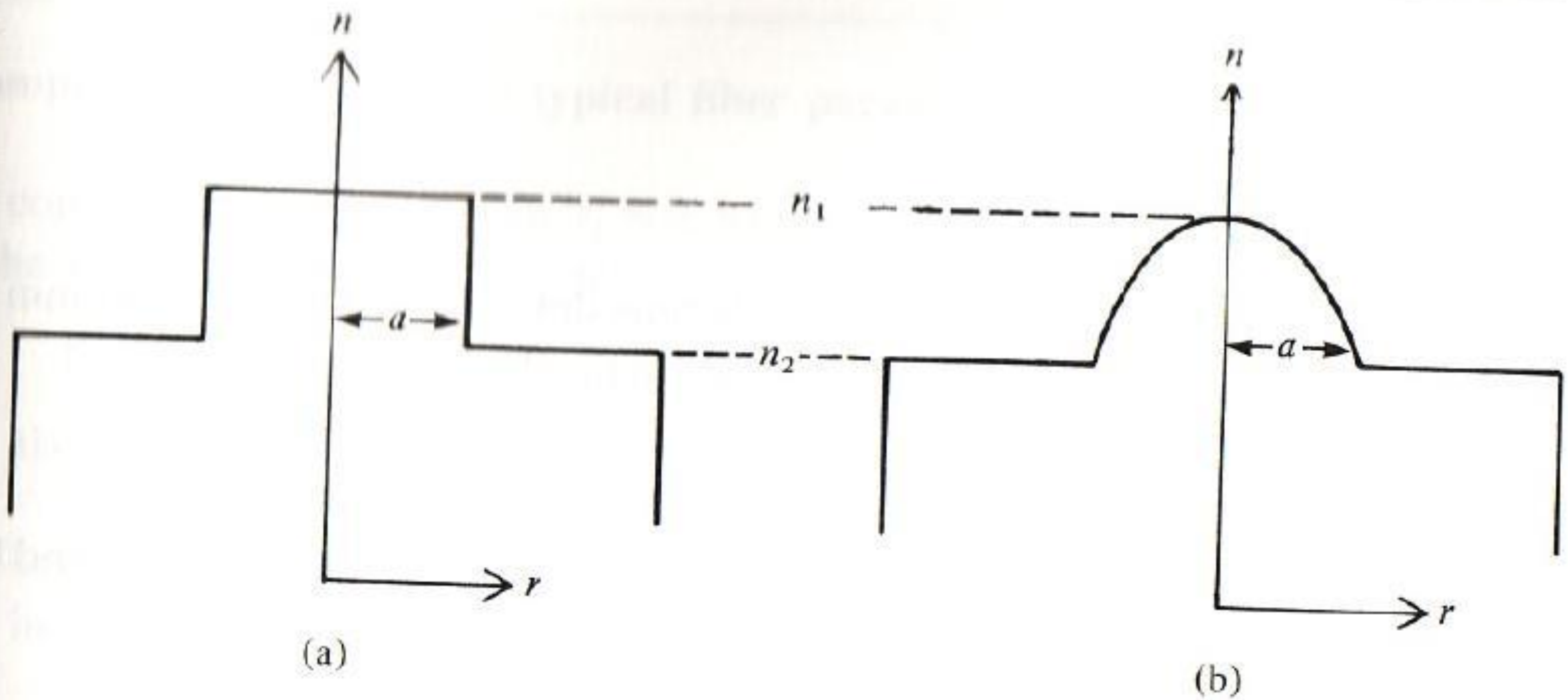
2. graded index profile.

is a refractive index profile characterized by non uniform refractive index within the core And decrease in refractive index at the core-cladding interface

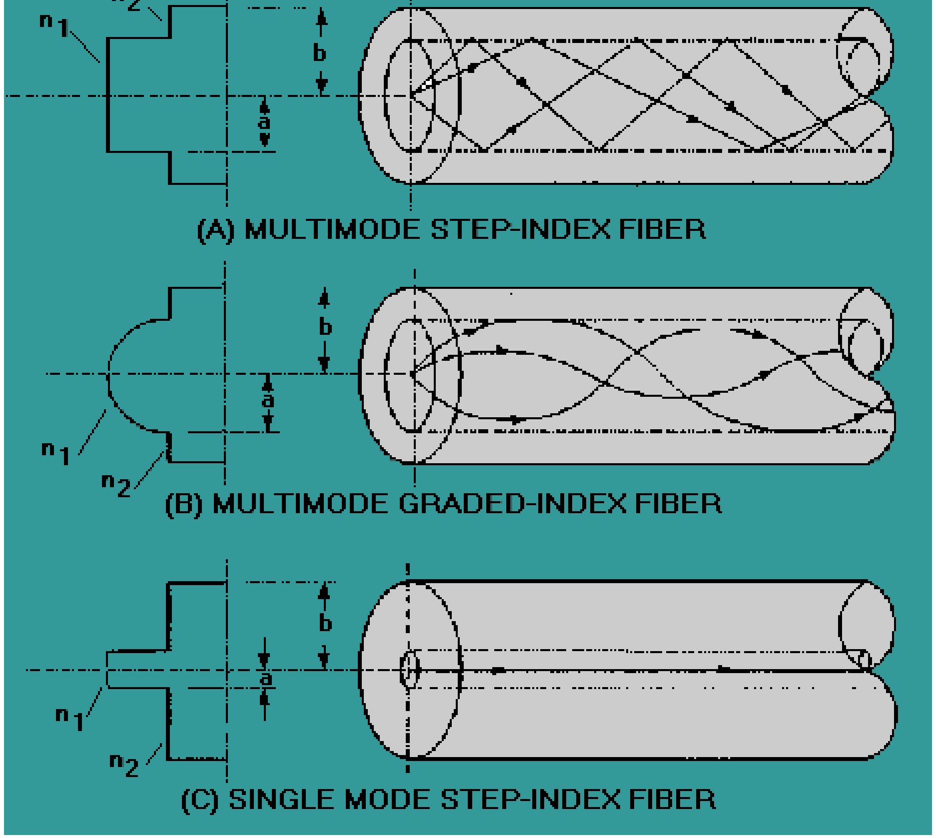
$n(r) = n1\,[1- 2\Delta(r/a)]^{1/2}$ for $r < a$
$\quad = n2$ for $r > a$

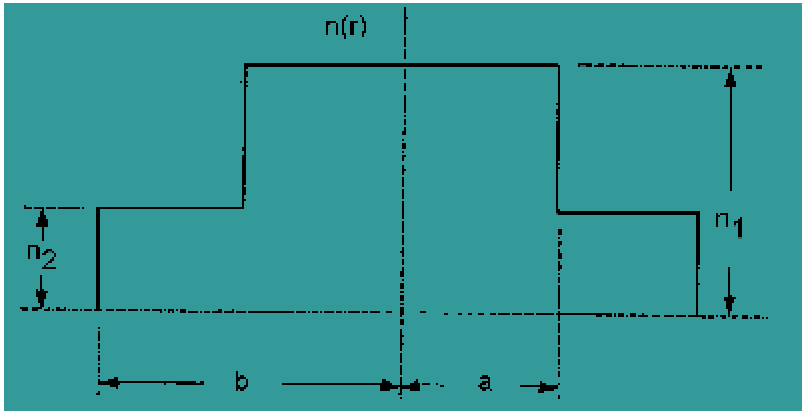
$\Delta = (n1-n2) / n1$





n
n
n_1
n_2
a
a
r
r
(a)
(b)





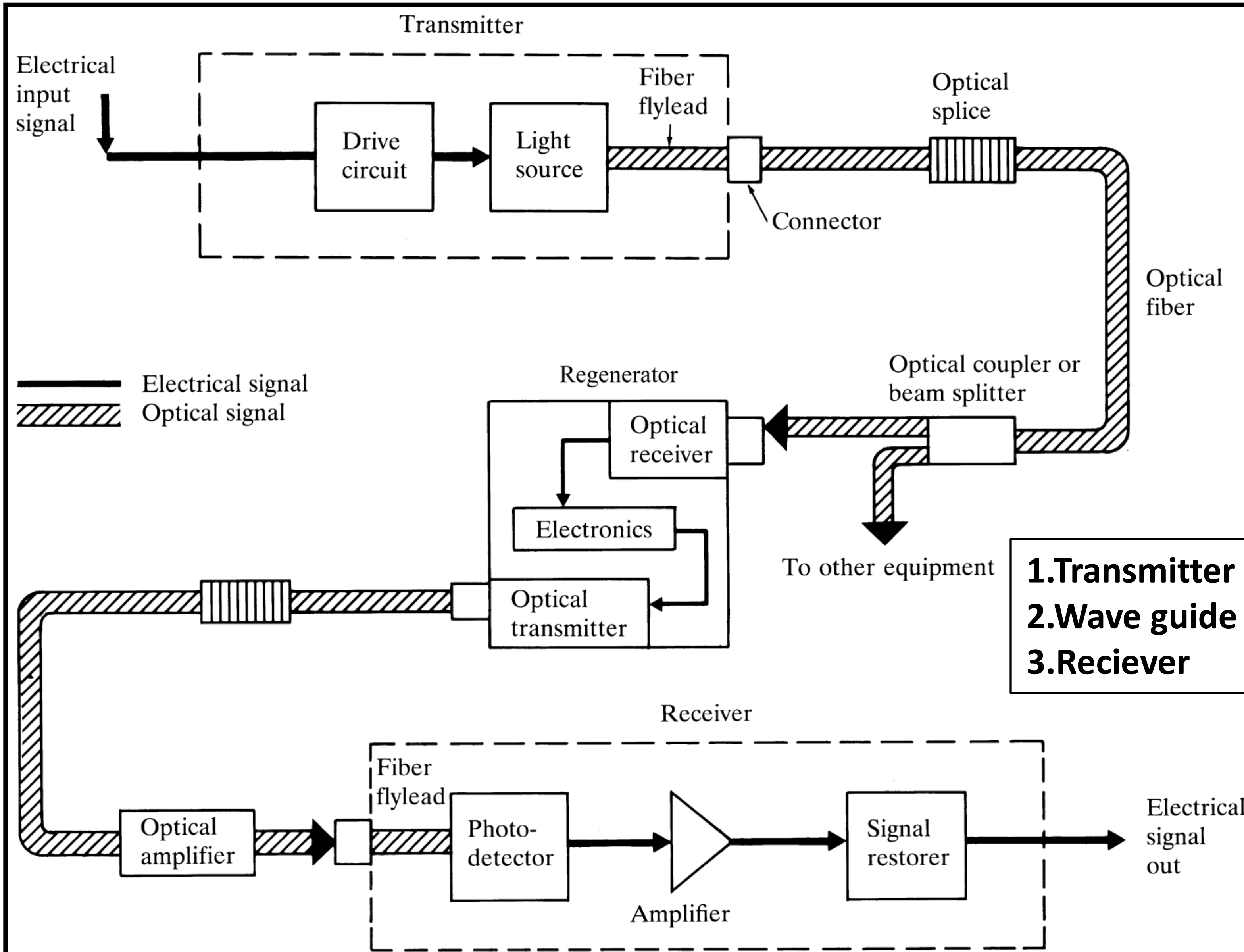
$$n(r) = n_1\left[1 - 2\Delta\left(\frac{r}{a}\right)^{g}\right]^{1/2}$$

$$\Delta = \frac{n_1^2 - n_2^2}{2n_1^2} \approx \frac{n_1 - n_2}{n_1}$$

Image Transmission by Fiber Bundle

Type	*Core (μm)*	*Cladding (μm)*	*Mode*
50/125	50.0	125	Multimode, graded index
62.5/125	62.5	125	Multimode, graded index
100/125	100.0	125	Multimode, graded index
7/125	7.0	125	Single mode

Fibre Optics Communication Link (FOCL)



1.Transmitter
2.Wave guide
3.Reciever

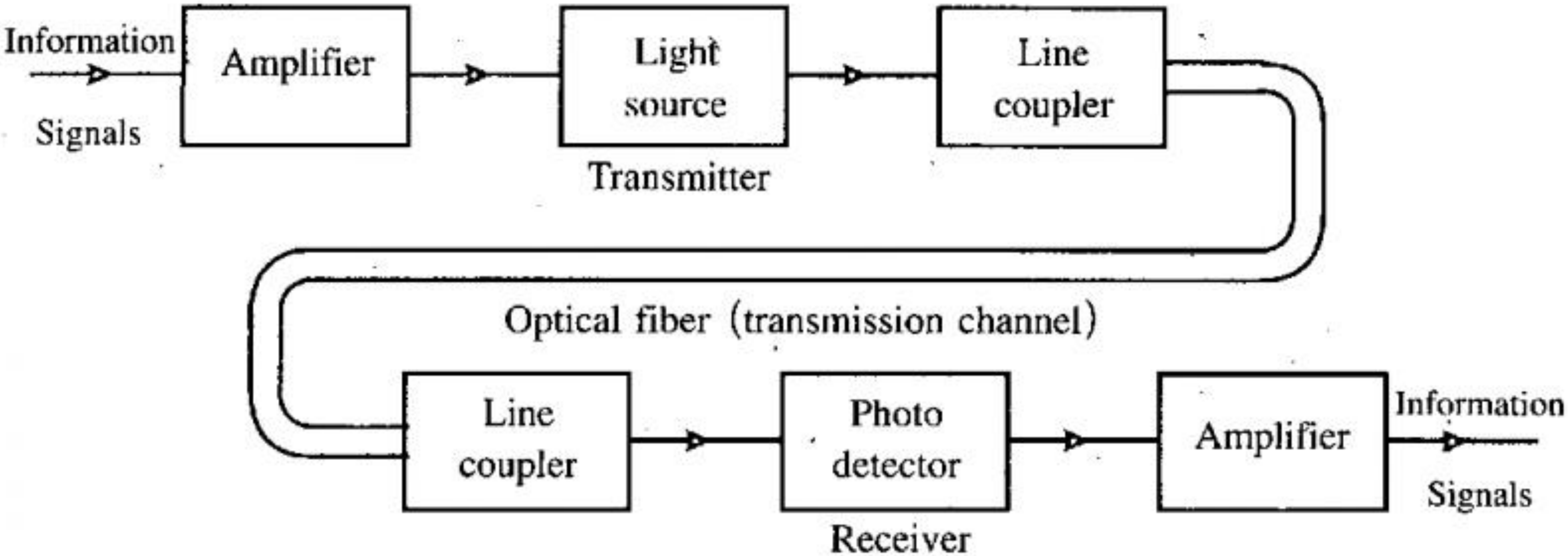


Fig. 16.20

The process of communicating using fiber-optics involves the following
basic steps:

1.Creating the optical signal involving the use of a transmitter,
2.relaying the signal along the fiber,
3.ensuring that the signal does not become too distorted or weak,
4.receiving the optical signal,
5.and converting it into an electrical signal

Proper light source for optical fibre communication

- Must be small to fit with the light source
- Durable
- Intense to overcome the losses
- Monochromatic with small bandwidth
- Capable of modulation

Befitting source with all above characteristic is **LD/ LED**

Attenuation in fiber optics, also known as transmission loss, is the reduction in intensity of the light beam (or signal) with respect to distance traveled through a transmission medium.

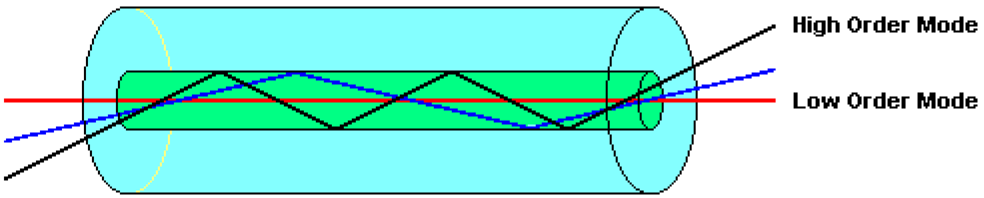
Attenuation coefficients in fiber optics usually use units of dB/km through the medium due to the relatively high quality of transparency of modern optical transmission media.

The medium is usually a fiber of silica glass that confines the incident light beam to the inside.

Attenuation is an important factor limiting the transmission of a digital signal across large distances.

Thus, much research has gone into both limiting the attenuation and maximizing the amplification of the optical signal.

Research has shown that attenuation in optical fiber is caused primarily by both scattering and absorption



- Causes of attenuation:
- 1. absorption by lattice vibration of ions in the glass
- 2. absorption and scattering by impurities
- 3. non uniformity of fibre cross section diameter
- 4.Microscopic variation in R.I of fibre material scatters the signal
- 5. dispersion

Since all these depends on the wavelength, hence attenuation can be minimized by selecting a proper wavelength of light signal, such that absorption and scattering is minimum

Best suitable wavelength for maximum use ---

1310nm to 1550nm

- **Repeaters** are used in the path where optical signal is converted to electrical signal, then amplified and again converted to optical signal for further propagation

Advantages of optical fibres over wires

- low loss, so repeater-less transmission over long distances is possible
- large data-carrying capacity (thousands of times greater)
- immunity to electromagnetic interference, including nuclear electromagnetic pulses (except for alpha and beta radiation)
- High electrical resistance , so safe to use near high-voltage equipment
- light weight

or between areas with different earth potentials

- signals contain very little power

Disdvantages of optical fibres compared to wires

- higher cost
- need for more expensive optical transmitters and receivers
- more difficult and expensive to splice than wires
- cannot carry electrical power to operate terminal devices

Applications:

- **A. Communication**:

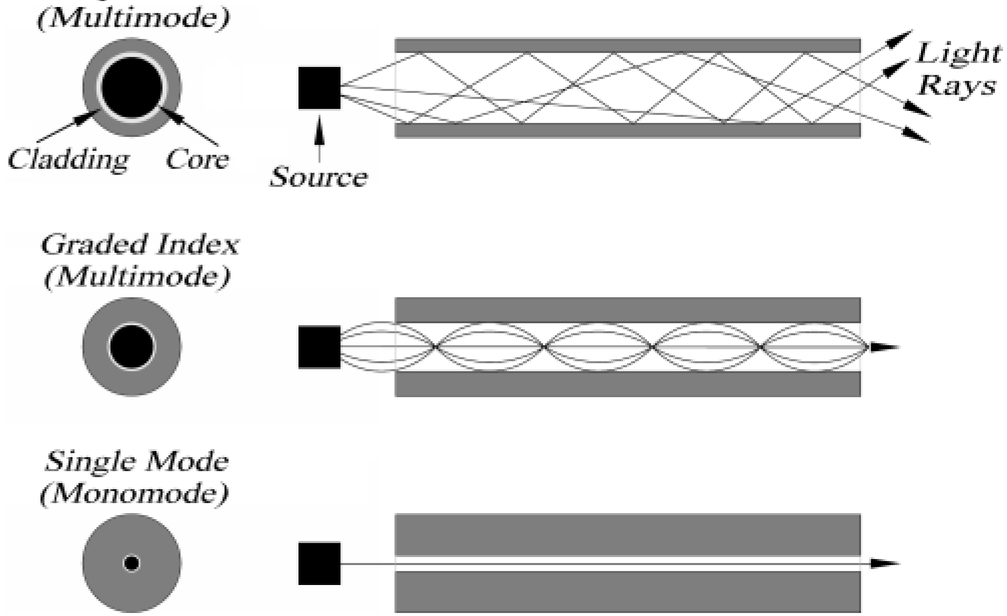
telecommunication, broadband service, LAN in power plants to transmit information for system protection, supervision& control

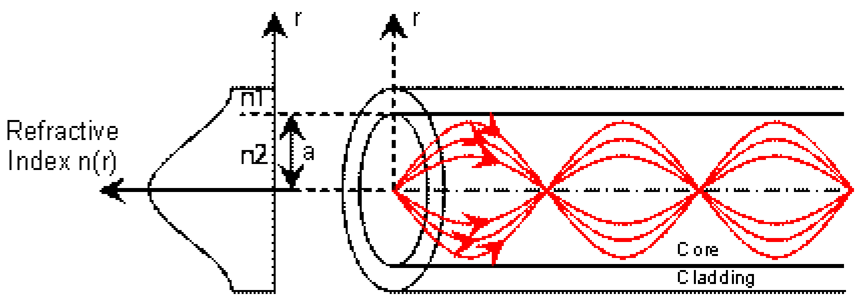
In military for communication, command and fibre guided missiles

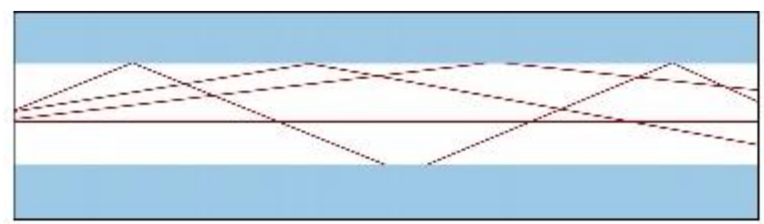
- **B. medical**:

Endoscopy, angioplasty, cancer treatment

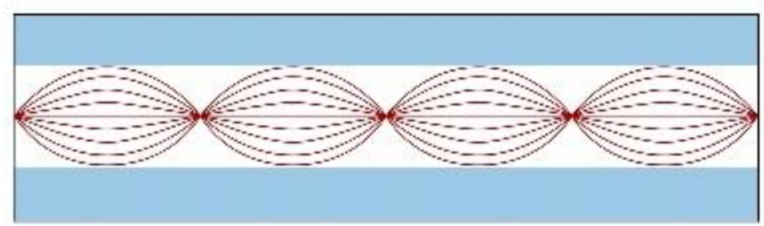
- **C. Sensors**







Multimode, Step-Index



Multimode, Graded Index