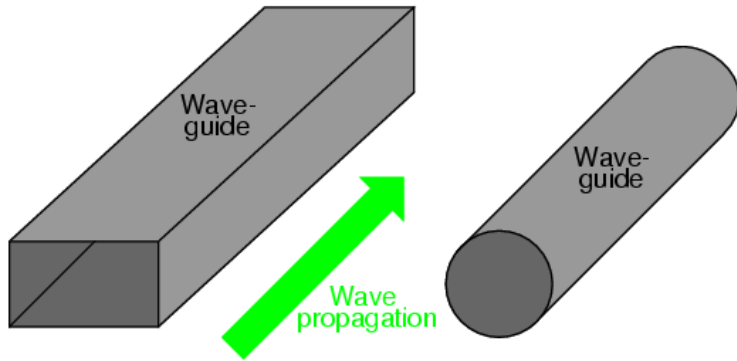


WAVEGUIDE

- A specially constructed hollow metallic pipes or system of conductors and insulators for carrying electromagnetic waves.
- They are used for microwave frequencies for the same purposes as transmission lines were used for lower frequencies.



Reasons for using waveguide rather than coaxial cable at microwave frequency:

- easier to fabricate
- no solid dielectric and I^2R losses

At *microwave* signal frequencies (between 100 MHz and 300 GHz), two-conductor transmission lines of any substantial length operating in standard TEM mode become impractical. Lines small enough in cross-sectional dimension to maintain TEM mode signal propagation for microwave signals tend to have low voltage ratings, and suffer from large, parasitic power losses due to conductor "skin" and dielectric effects

Waveguides do not support TEM waves inside because of boundary conditions.

Waves travel zig-zag down the waveguide by bouncing from one side wall to the other.

RECTANGULAR WAVEGUIDE

Mode of Operation	
Mode Type	Propagation Properties
Transverse Electric (TE)	Electric field is perpendicular to the direction of wave propagation
Transverse Magnetic (TM)	Magnetic field is perpendicular to the direction of wave propagation

DOMINANT MODE OF OPERATION

The most natural mode of operation for a waveguide, this mode is the lowest possible frequency that can be propagated

For a waveguide's mode of operation, the two submodes are:

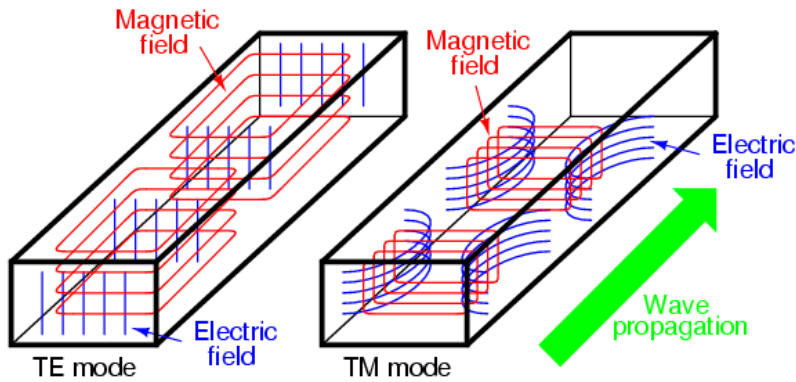
1. TE_{mn} for the transverse electric mode.
2. TM_{mn} for the transverse magnetic mode.

Where: m – number of half-wavelength across waveguide width (the **a** dimension)

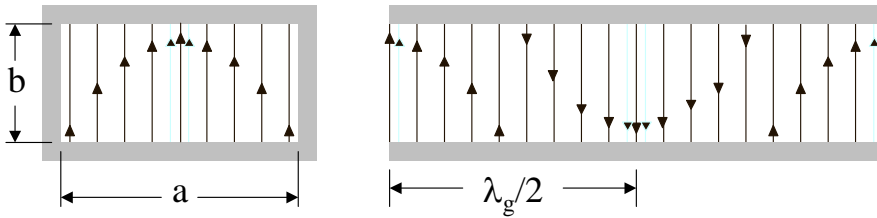
n – number of half-wavelength along waveguide height (the **b** dimension)

TE_{mn} means there are m number of half-wave variations of the transverse E-field along the "a" side and n number of half-wave variations along the "b" side.

The magnetic field forms closed loops horizontally around the E-field



E-I
 Magnetic flux lines appear as continuous loops
 Electric flux lines appear with beginning and end points



Wavelength for TE & TM Modes

Cutoff wavelength

Smallest free-space wavelength that is just unable to propagate in the waveguide under given conditions.

The wavelength of the lowest frequency that can be accommodated in a given waveguide.

$$\lambda_c = \frac{2}{\sqrt{(m/a)^2 + (n/b)^2}}$$

Any signal with $\lambda > \lambda_c$ will not propagate down the waveguide.

For air-filled waveguide, cutoff freq., $f_c = c/\lambda_c$

TE₁₀ is called the dominant mode since $\lambda_c = 2a$ is the longest wavelength of any mode.

Guide wavelength

$$\lambda_g = \frac{\lambda}{\sqrt{1 - (\lambda/\lambda_c)^2}} \quad \text{or} \quad \frac{\lambda}{\sqrt{1 - (f_c/f)^2}}$$

Group Velocity

The speed of transmission of a signal along a waveguide

$$v_g = c \frac{\lambda}{\lambda_g} \quad \text{or} \quad c \sqrt{1 - (\lambda/\lambda_c)^2}$$

Phase Velocity

The apparent speed of propagation along a waveguide based on the distance between wavefronts along the walls of the waveguide.

$$v_p = c \frac{\lambda_g}{\lambda} \quad \text{or} \quad \frac{c}{\sqrt{1 - (\lambda/\lambda_c)^2}}$$

Waveguide Impedance

$$Z_{TE} = \frac{Z_o}{\sqrt{1 - (\lambda / \lambda_c)^2}}$$

$$Z_{TM} = Z_o \sqrt{1 - (\lambda / \lambda_c)^2}$$

Where: $Z_o = 120\pi$ or 377Ω for air-filled waveguide

Circular/Cylindrical Waveguides

A waveguide having a circular cross-section, used whenever a rotating element (radar antenna) must be attached to the transmitter/receiver.

Differences versus rectangular waveguides :

$$\lambda_c = 2\pi r / B_{mn}$$

where: r = waveguide radius

B_{mn} = Bessel function solution for a particular m, n mode being propagated
 = 1.84 for the dominant mode of operation.

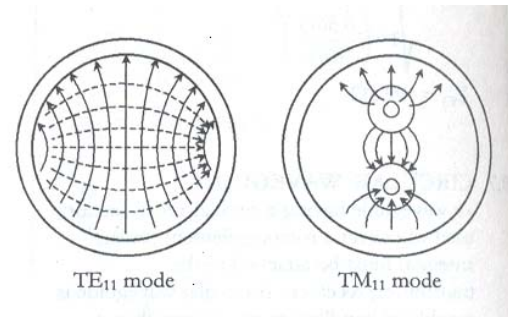
All TE_{mn} and TM_{mn} modes are supported since m and n subscripts are defined differently.

Dominant mode is **TE₁₁**.

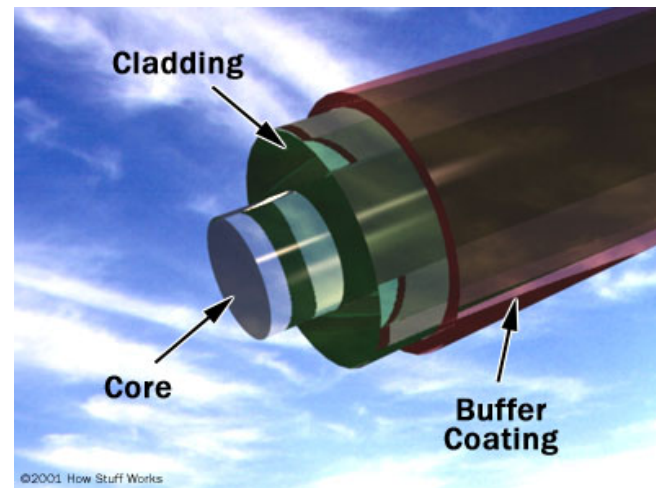
Advantages: higher power-handling capacity, lower attenuation for a given cutoff wavelength.

Disadvantages: larger and heavier.

FIELD PATTERN FOR CIRCULAR WAVEGUIDE



Optical Fibre Communications



- **Core** - Thin glass center of the fiber where the light travels
- **Cladding** - Outer optical material surrounding the core that reflects the light back into the core
- **Buffer coating** - Plastic coating that protects the fiber from damage and moisture

Compared to conventional metal wire (copper wire), optical fibers are:

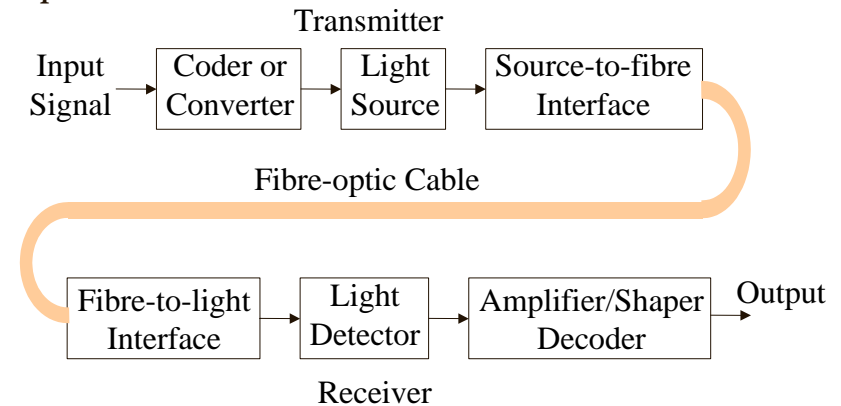
- **Less expensive** - Several miles of optical cable can be made cheaper than equivalent lengths of copper wire. This saves your provider (cable TV, Internet) and you money.
- **Thinner** - Optical fibers can be drawn to smaller diameters than copper wire.
- **Higher carrying capacity** - Because optical fibers are thinner than copper wires, more fibers can be bundled into a given-diameter cable than copper wires. This allows more phone lines to go over the same cable or more channels to come through the cable into your cable TV box.
- **Less signal degradation** - The loss of signal in optical fiber is less than in copper wire.
- **Light signals** - Unlike electrical signals in copper wires, light signals from one fiber do not interfere with those of other fibers in the same cable. This means clearer phone conversations or TV reception.
- **Low power** - Because signals in optical fibers degrade less, lower-power transmitters can be used instead of the high-voltage electrical transmitters needed for copper wires. Again, this saves your provider and you money.
- **Digital signals** - Optical fibers are ideally suited for carrying digital information, which is especially useful in computer networks.
- **Non-flammable** - Because no electricity is passed through optical fibers, there is no fire hazard.

- **Lightweight** - An optical cable weighs less than a comparable copper wire cable. Fiber-optic cables take up less space in the ground.
- **Flexible** - Because fiber optics are so flexible and can transmit and receive light, they are used in many flexible [digital cameras](#) for the following purposes:
 - **Medical imaging** - in bronchoscopes, endoscopes, laparoscopes
 - **Mechanical imaging** - inspecting mechanical welds in pipes and engines (in [airplanes](#), [rockets](#), [space shuttles](#), [cars](#))
 - **Plumbing** - to inspect [sewer lines](#)

•Disadvantages:

–higher initial cost in installation & more expensive to repair/maintain

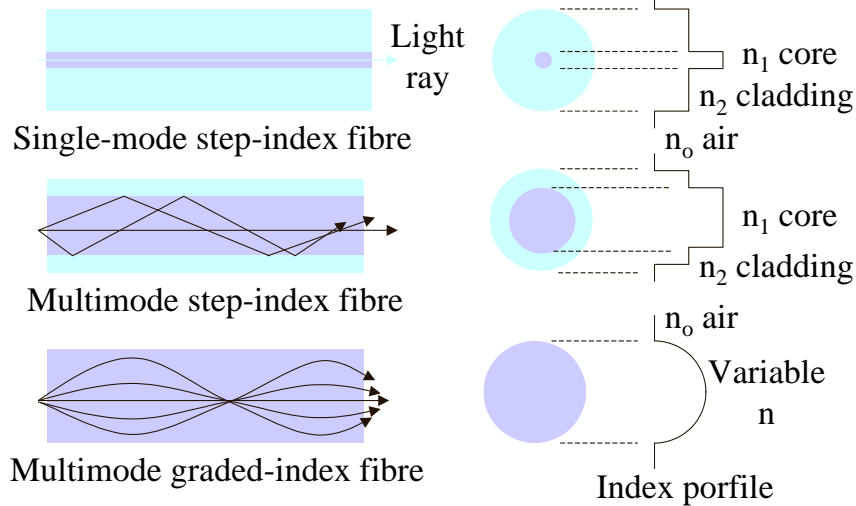
Optical Fibre Link



- **Transmitter** - Produces and encodes the light signals
- **Optical fiber** - Conducts the light signals over a distance
- **Optical regenerator** - May be necessary to boost the light signal (for long distances)
- **Optical receiver** - Receives and decodes the light signals

Optical fibers come in two types:

- Single-mode fibers
- Multi-mode fibers



•Single-mode step-index fibre:

- minimum signal dispersion; higher TX rate possible
- difficult to couple light into fibre; highly directive light source (e.g. laser) required; expensive to manufacture

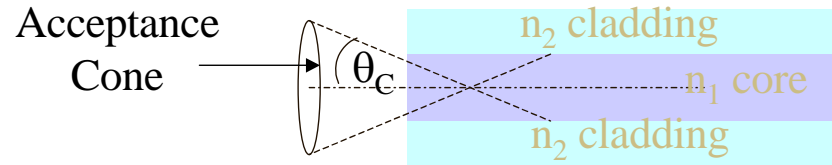
•Multimode step-index fibres:

- inexpensive; easy to couple light into fibre
- result in higher signal distortion; lower TX rate

•Multimode graded-index fibre:

- intermediate between the other two types of fibres

Acceptance Cone & Numerical Aperture



Acceptance angle, θ_c , is the maximum angle in which external light rays may strike the air/fiber interface and still propagate down the fiber with <10 dB loss.

$$\theta_c = \sin^{-1} \sqrt{n_1^2 - n_2^2}$$

Numerical aperture:

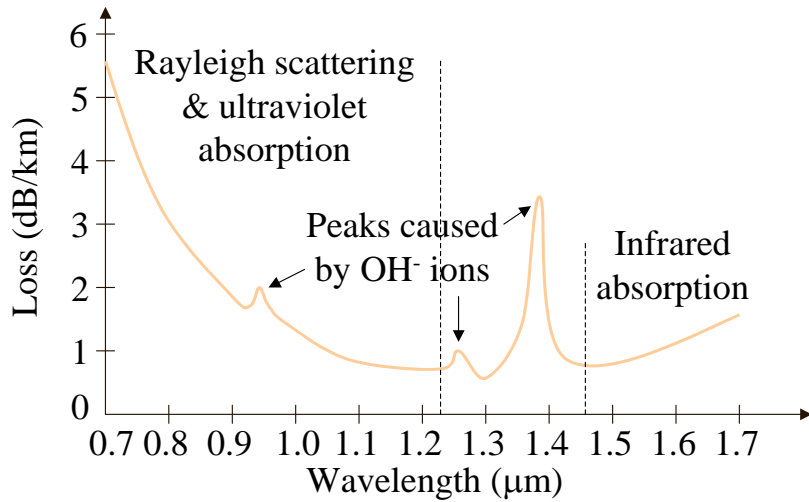
$$NA = \sin \theta_c = \sqrt{n_1^2 - n_2^2}$$

Losses In Optical Fibre Cables

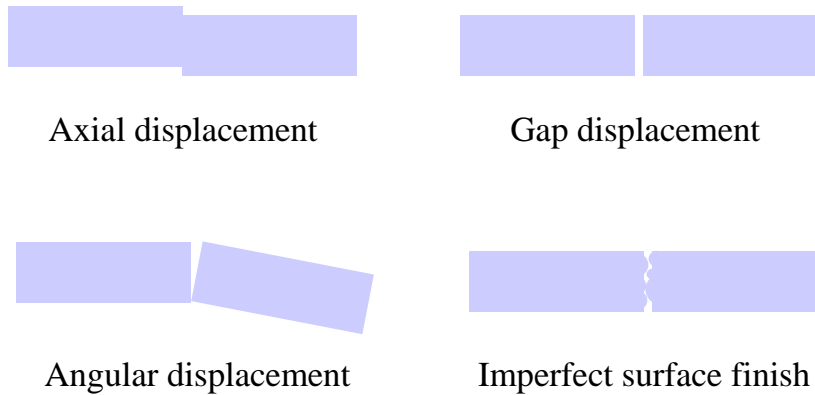
•The predominant losses in optic fibres are:

- absorption losses due to impurities in the fibre material
- material or Rayleigh scattering losses due to microscopic irregularities in the fibre
- chromatic or wavelength dispersion because of the use of a non-monochromatic source
- radiation losses caused by bends and kinks in the fibre
- modal dispersion or pulse spreading due to rays taking different paths down the fibre
- coupling losses caused by misalignment & imperfect surface finishes

Absorption Losses In Optic Fibre



Fibre Alignment Impairments



Light Sources

•**Light-Emitting Diodes (LED)**—made from material such as AlGaAs or GaAsP
 —light is emitted when electrons and holes recombine
 —either surface emitting or edge emitting

• **Injection Laser Diodes (ILD)**—similar in construction as LED except ends are highly polished to reflect photons back & forth

ILD versus LED

- Advantages:*
- more focussed radiation pattern; smaller fibre
 - much higher radiant power; longer span
 - faster ON, OFF time; higher bit rates possible
 - monochromatic light; reduces dispersion

- Disadvantages:*
- much more expensive
 - higher temperature; shorter lifespan

Light Detectors

•**PIN Diodes**

- photons are absorbed in the intrinsic layer
- sufficient energy is added to generate carriers in the depletion layer for current to flow through the device

•**Avalanche Photodiodes (APD)**

- photogenerated electrons are accelerated by relatively large reverse voltage and collide with other atoms to produce more free electrons
- avalanche multiplication effect makes APD more sensitive but also more noisy than PIN diodes.