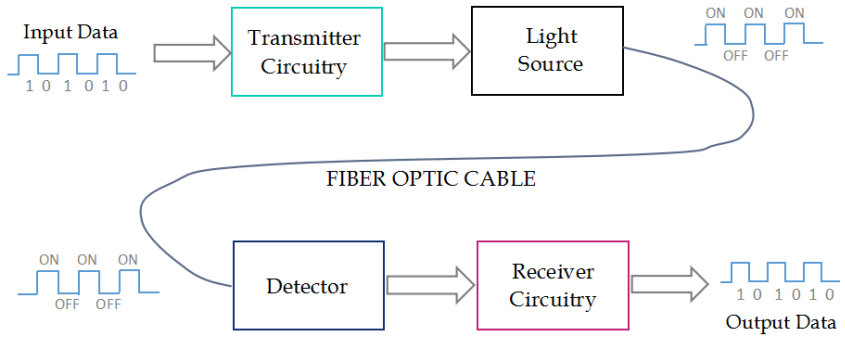
INTRODUCTION TO FIBRE OPTIC CABLE COMMUNICATION

EEN 464 – DIGITAL COMMUNICATION

Friday, 10 April 2026

BRIEF HISTORY

1. By the late 1960s, PCM signals could be transmitted without using repeaters for a distance of 1 km and there was growing need to have optical communication.
2. The challenge then was to develop fibre which could retain light over the PCM repeater distance, i.e 1 km

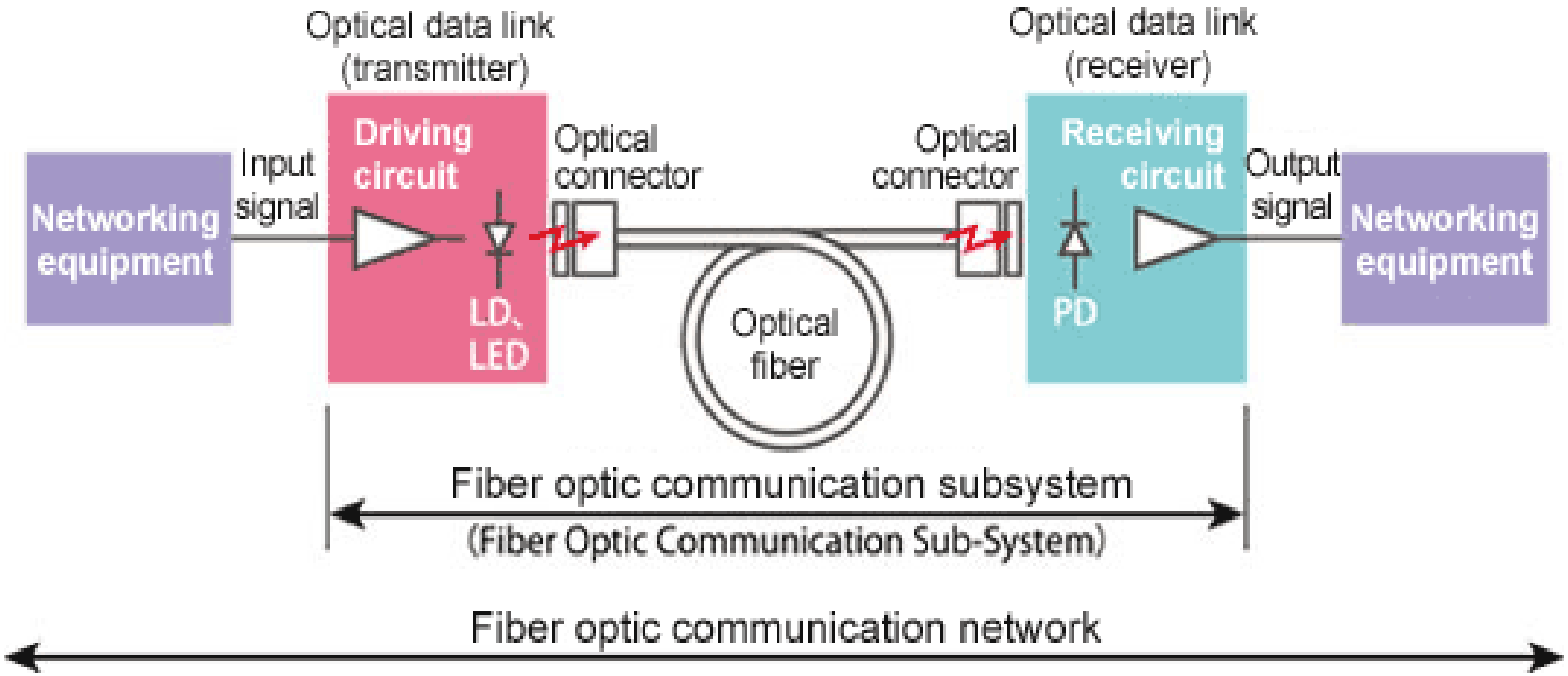


3. **In 1970, Dr. Robert Maurer developed such fibre with attenuation of less than 20dB/Km** thus paving way for commercialization of the fibre technology.
4. **Today, Fibre optic cables has achieved attenuation of less than 0.35dB/Km** which has made fibre the technology of choice for long-distance digital transmission.

FIBRE OPTIC COMMUNICATION SYSTEM

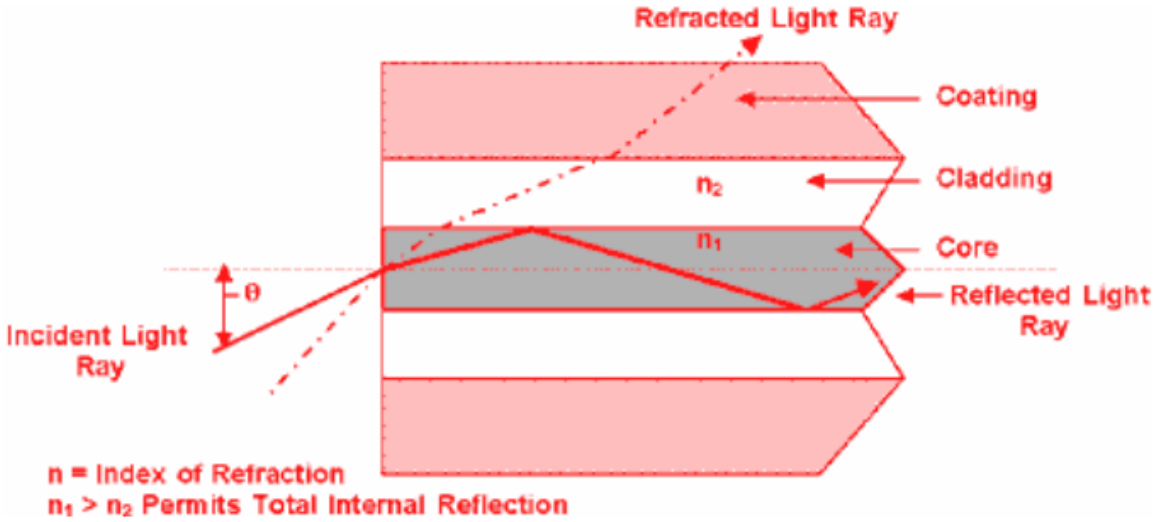
- Fiber optic telecommunication systems transmit data as light pulses through thin strands of glass or plastic (optical fibers).

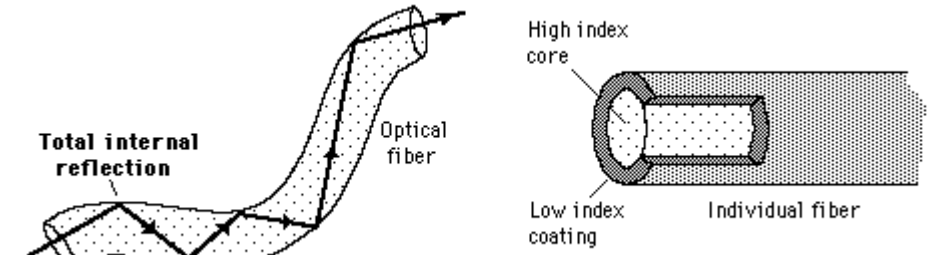
OPTICAL COMMUNICATION NETWORK



DESIGN OF FIBER OPTIC CABLE

1. A fibre optic cable consists of two pure glass materials (core and cladding) of different refraction index and a coating which is applied to the cable during the final stages of manufacturing.



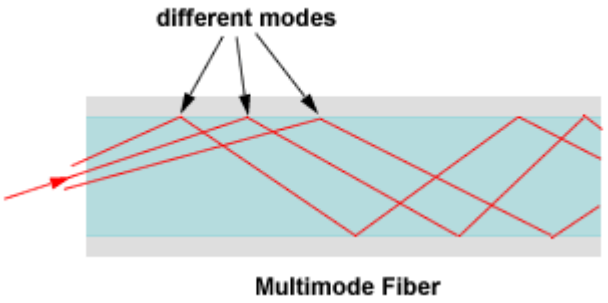


2. Total internal reflection of light in the core is assured when its refractive index n_1 is greater than that of the cladding n_2.
3. The coating protects the cables from scratches and dust.

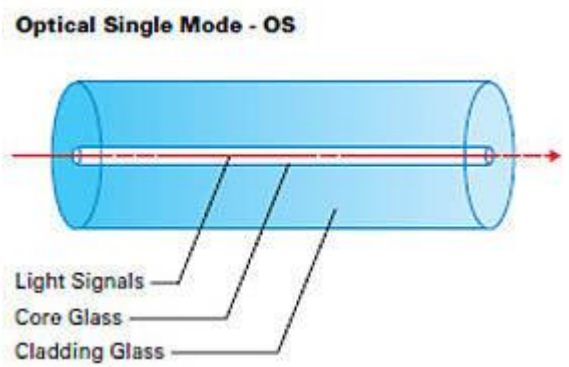
GENERAL CATEGORIES OF FIBER OPTIC CABLE

There are two general categories of fibre optic cables:

(a) Multi-mode: Allows multiple paths of light to propagate through the core simultaneously. The core is much larger which allows the use of low-cost optical transmitters (e.g Light emitting diodes) and connectors.



(b) Single Mode: Has a core with a much smaller diameter which only allows single mode of light. Single mode cables are designed for higher spectral integrity of the optical signal thus allowing more information to be transmitted over longer distances.



Single mode cables are therefore used for long distance high bandwidth applications while multi-mode are used for low-capacity private data networks, e.g LANS.

SINGLE MODE VS MULTIMODE

- **Multi-mode fibres** have multiple modes of propagation for the rays of light. These range from low order modes which take the most direct route straight down the middle, to high order modes which take the longest route as they bounce from one side to the other all the way down the fibre.
- This has the effect of scattering the signal because the rays from one pulse of light, arrive at the far end at different times, this is known as **Intermodal Dispersion.**

- We get rid of Intermodal Dispersion by using a smaller core size which allows higher bandwidth and ability to travel greater distances with low attenuation.

ADVANTAGES OF FIBRE OPTIC CABLE TO COPPER

1. **Distance:** Because of the Low loss and high bandwidth properties of fibre cable they can be used over greater distances than copper cables.
2. **Light Weight:** Their light weight and small size makes them ideal for applications where running copper cables would be impractical.
3. **High Capacity:** By multiplexing many wavelengths, one fibre could replace thousands of copper cables.
4. **Immunity to EM Interefence:** They have immunity to Electro Magnetic Interference.
5. **Non-Conducting**: Because fibre is non-conductive, it can be used where electrical isolation is needed, for instance between buildings where copper cables would require cross bonding to eliminate differences in earth potentials.
6. **Fires caused by Sparks:** Fibres pose no threat in dangerous environments such as chemical plants where a spark electric current for could trigger an explosion.
7. **Difficult to eavesdrop** - It is very difficult to tap into a fibre cable to read or modify the data signals.

DISADVANTAGES OF FIBRE OPTIC CABLE TO COPPER

1. **Fragility: U**sually optical fiber cables are made of glass, which lends to they are more fragile than electrical wires. In addition, glass can be affected by various chemicals including hydrogen gas (a problem in underwater cables), making them need more cares when deployed underground.

2. **Difficult to Install:** it's not easy to splice fiber optic cable. And if you bend them too much, they will break. And fiber cable is highly susceptible to becoming cut or damaged during installation or construction activities. All these make it difficult to install.

3. **Attenuation & Dispersion:** as transmission distance getting longer, light will be attenuated and dispersed, which requires extra optical components like Erbium-Doped Fiber Amplifier (EDFA) to be added.

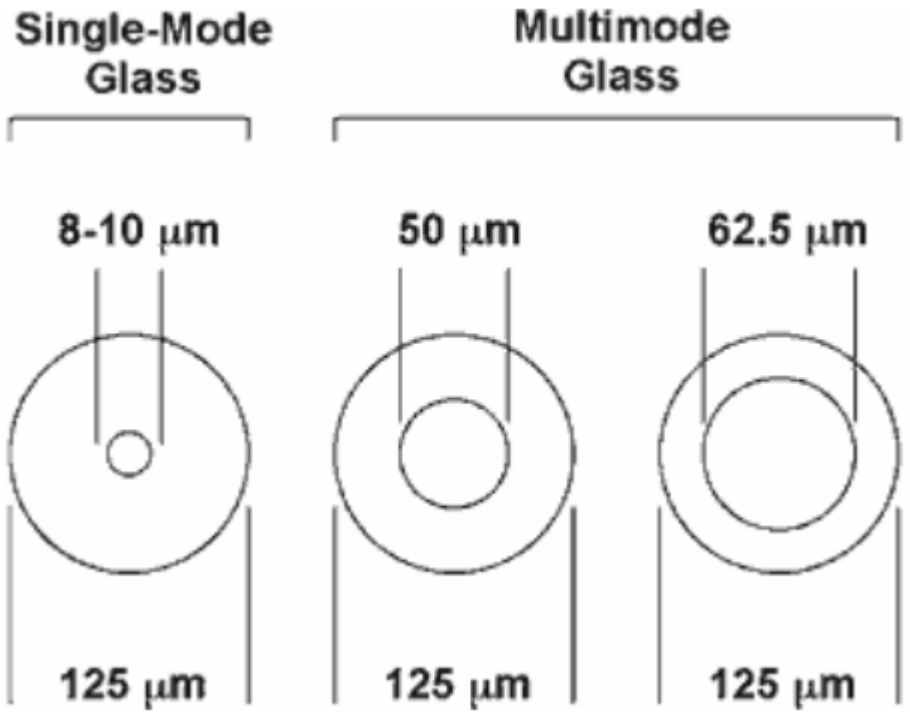
4. **Cost:** Despite the fact that fiber optic installation costs are dropping every year, installing fiber optic cabling is still relatively higher than copper cables mainly because copper cable installation does not need extra care like fiber cables.

COMPARISON OF SINGLE & MULTIMODE FIBRE OPTIC CABLES

CHARACTERISTIC	SINGLE MODE	MULTIMODE
Bandwidth	Virtually Unlimited	Less than single mode
Signal Quality	Excellent over long distances	Excellent over short distances
Primary Attenuation	Chromatic Dispersion	Modal Dispersion
Fibre Types	Step Index & Dispersion Shifted	Step & Graded Index
Typical Applications	Long range and almost anything else (including Ethernet)	Analog Video; Local Area Networks(LAN); Short Range Communications

OPTICAL CABLE SIZES

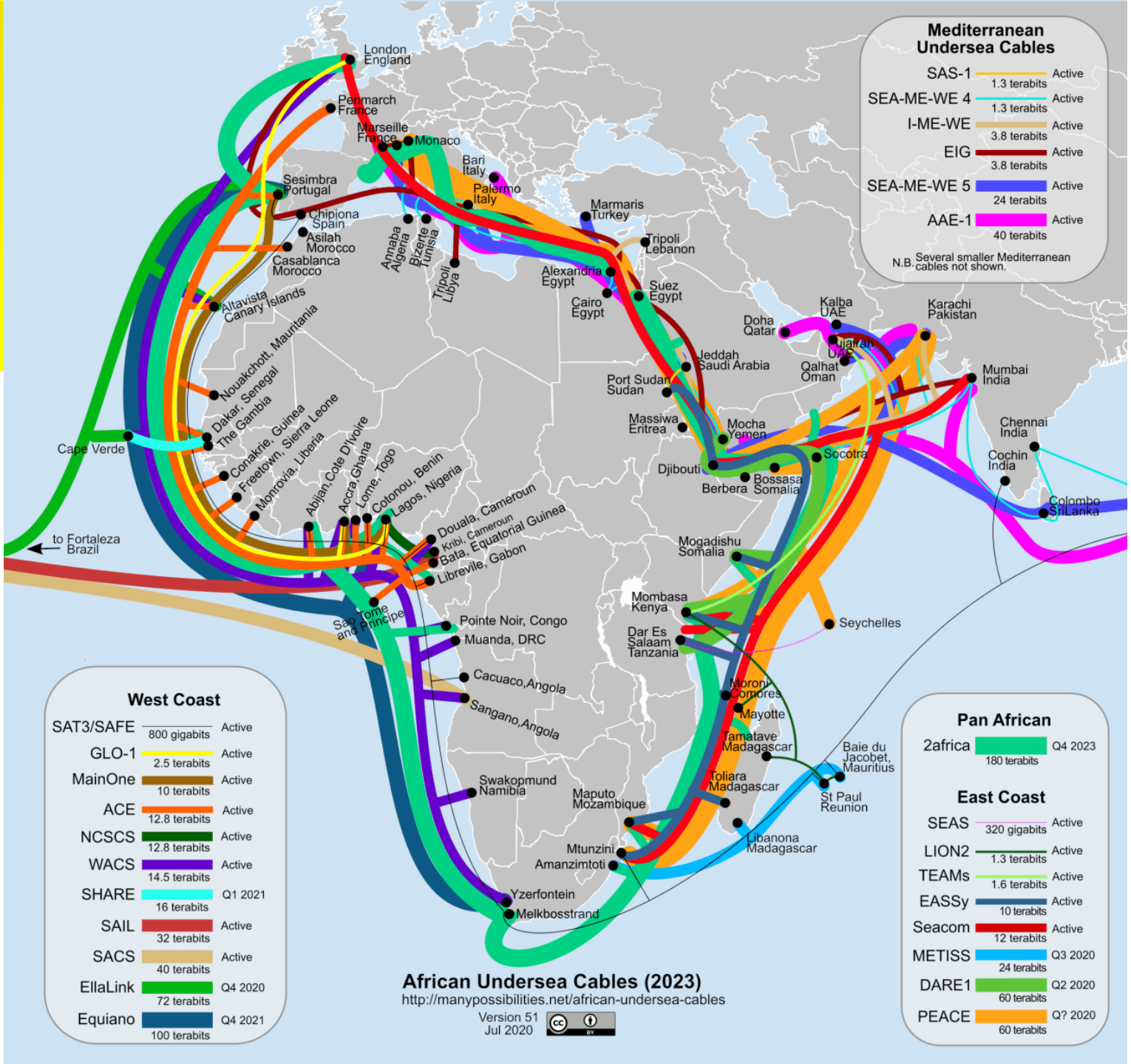
- To ensure compatibility amongst splicers, connectors and other tools used in the industry, all fibre cables are manufactured according to the same international standard shown below.



APPLICATIONS OF FIBRE OPTIC CABLES

1. **National & International** voice and data communication networks
2. **Local voice and local data communication networks**
   a) Traditional leased voice and data lines
   b) Local area networks
3. **Linking distributed computing resources**
   a) Linking Mobile Switching Centres in GSM systems
   b) Linking mirror servers, etc.
4. **Video links**
   a) remote CCTV backup
   b) TV broadcast studio links

INTERNATIONAL FIBRE OPTIC COMMUNICATION LINKS – AFRICA 2022



FIBRE OPTIC COMMUNICATION SYSTEMS

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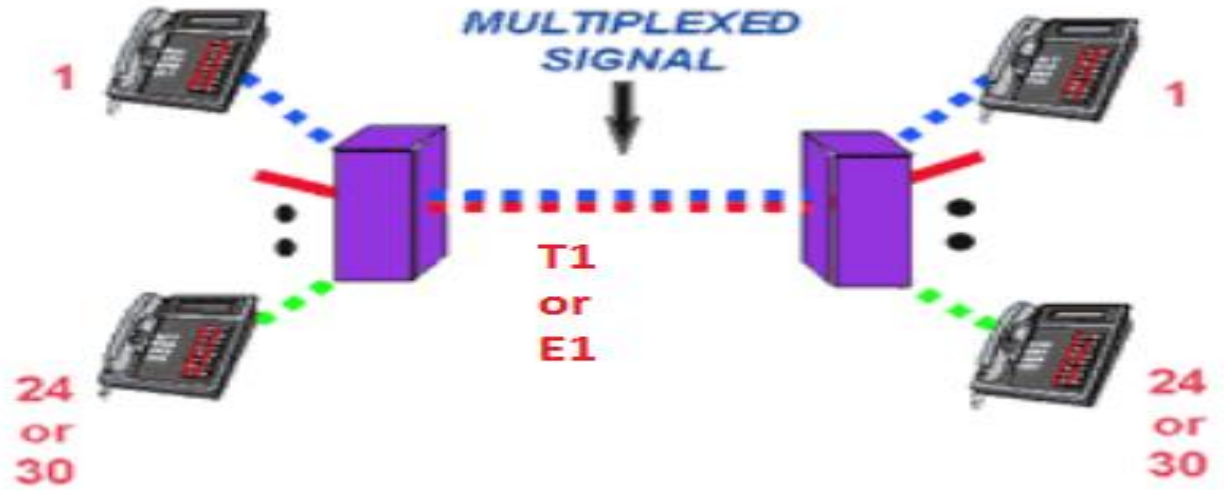
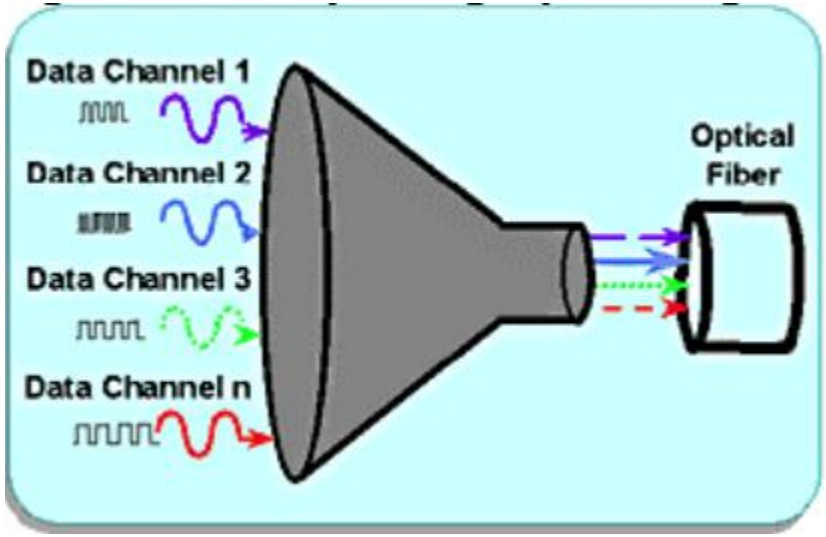
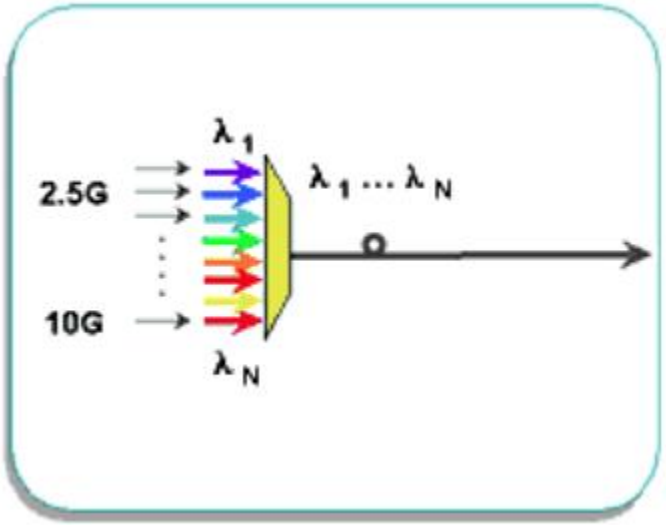
OVERCOMING LIMITATIONS OF TDM USING WDM

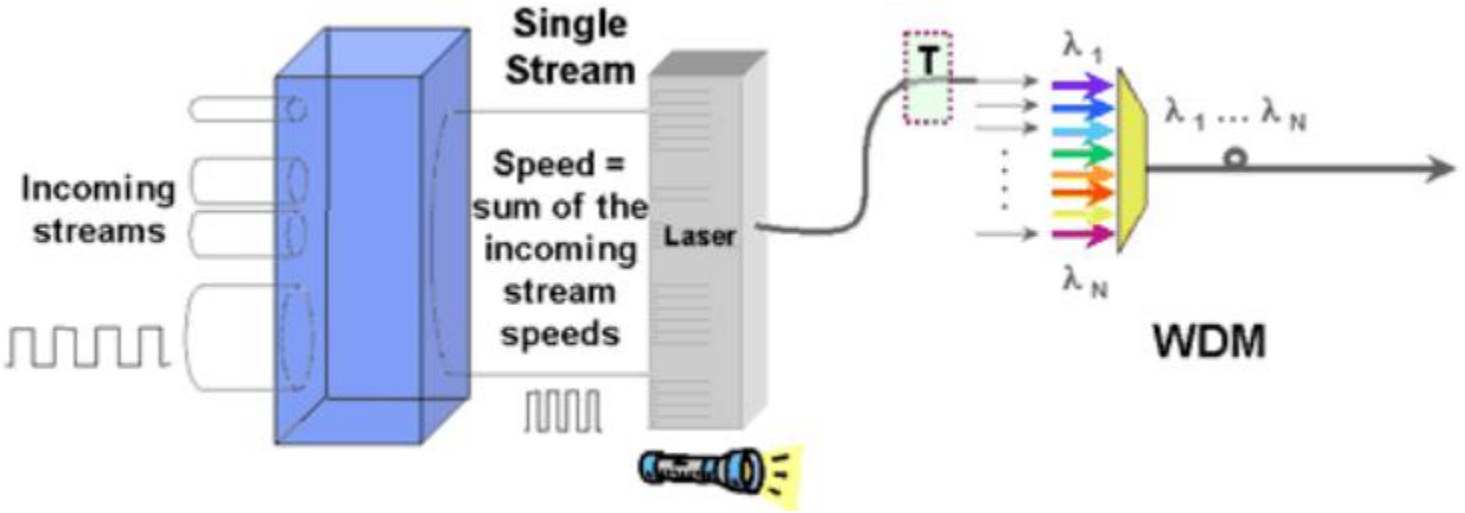
- In TDM systems, information transmission rate is increased by increasing the bit rate.
- The fastest TDM bit rate is currently 10GB/s.
- Therefore other transmission media must be used to transmit data at over 10GB/s without laying a parallel transmission system.
- This is usually achieved by feeding the TDM signal into a Wave Division Multiplex (WDM) system.







MULTIPLEXING TDM ON FIBER (TDM TO WDM)



1. **Wave Division Multiplexing (WDM)** takes optical signals (carrying information at a certain bit rate) and gives them colour (wavelength).
2. Each equipment in the WDM system has an illusion of having its own cable.
3. Wavelength used in WDM systems is called a window and is usually in the range of 1,300nm - 1,550 nm.

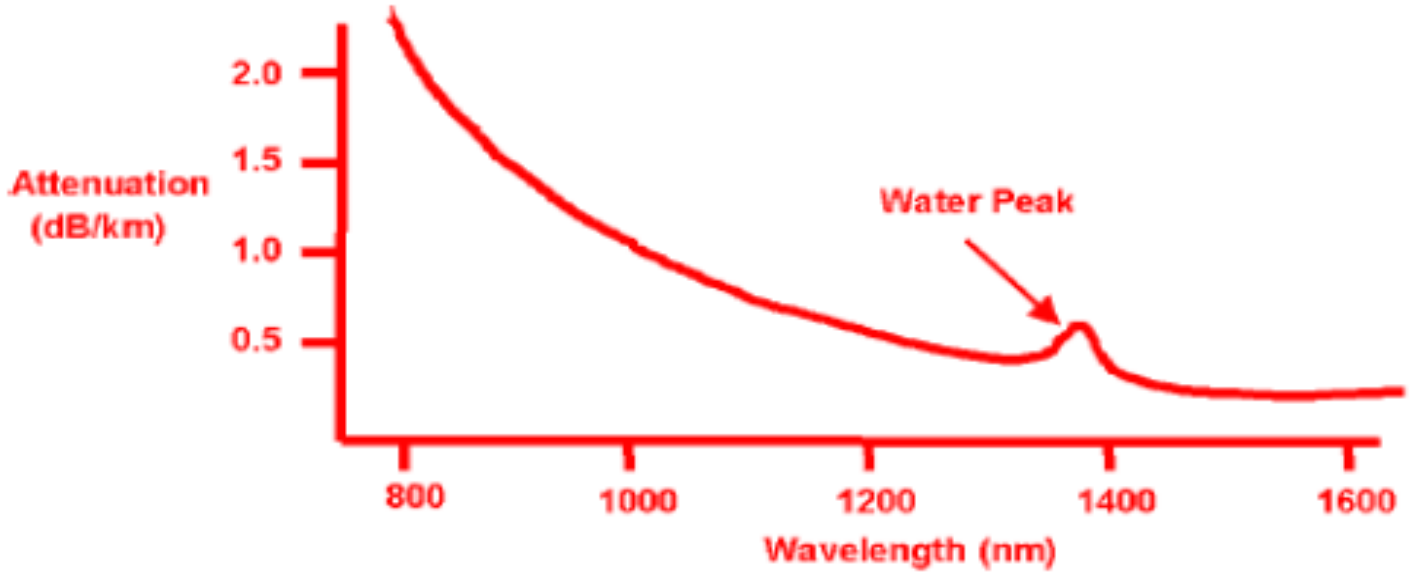
ATTENUATION IN FIBRE OPTIC CABLES

1. Attenuation is a measure of the reduction in signal strength or light power over the length of the cable.
2. Attenuation in fibre optic cables is measure in dB/Km.

3. Scattering and absorption are the main causes of attenuation in fibre optic cables.
4. Absorption is mainly caused by residual materials such as metals and water ions is the fibre core.

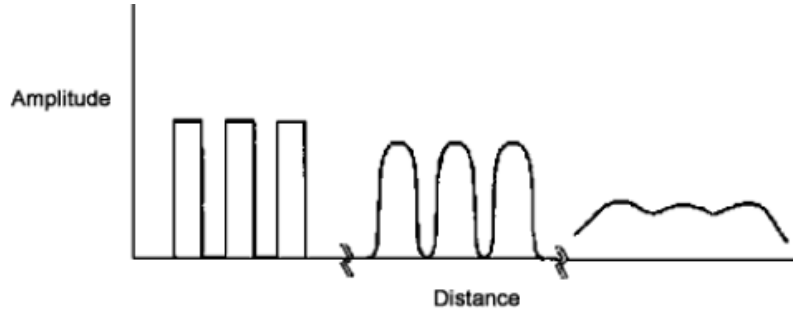
ATTENUATION CURVE

- Water ions cause a water peak in the attenuation curve at around 1400nm.
- Removal of water ions is of specific interest to fibre cable manufacturers in an attempt to minimize its broadening effect and effect to neighbouring wavelengths.



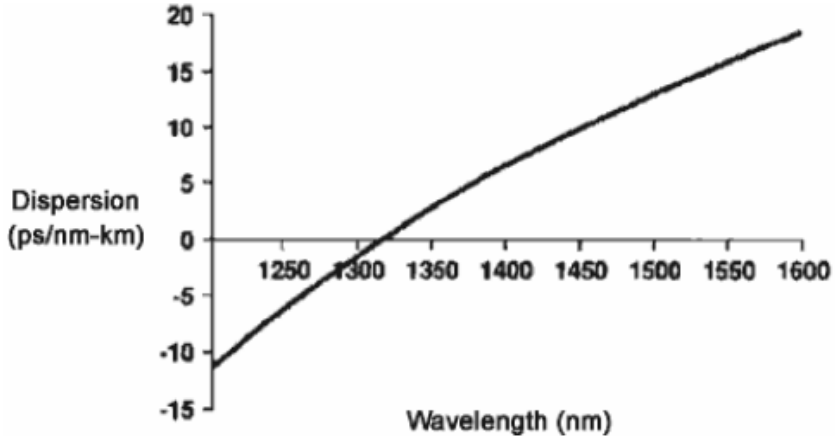
DISPERSION

1. Dispersion is the time distortion of an optic signal resulting from many discrete wavelength components travelling at different rates.
2. Dispersion results in the broadening of the pulses.

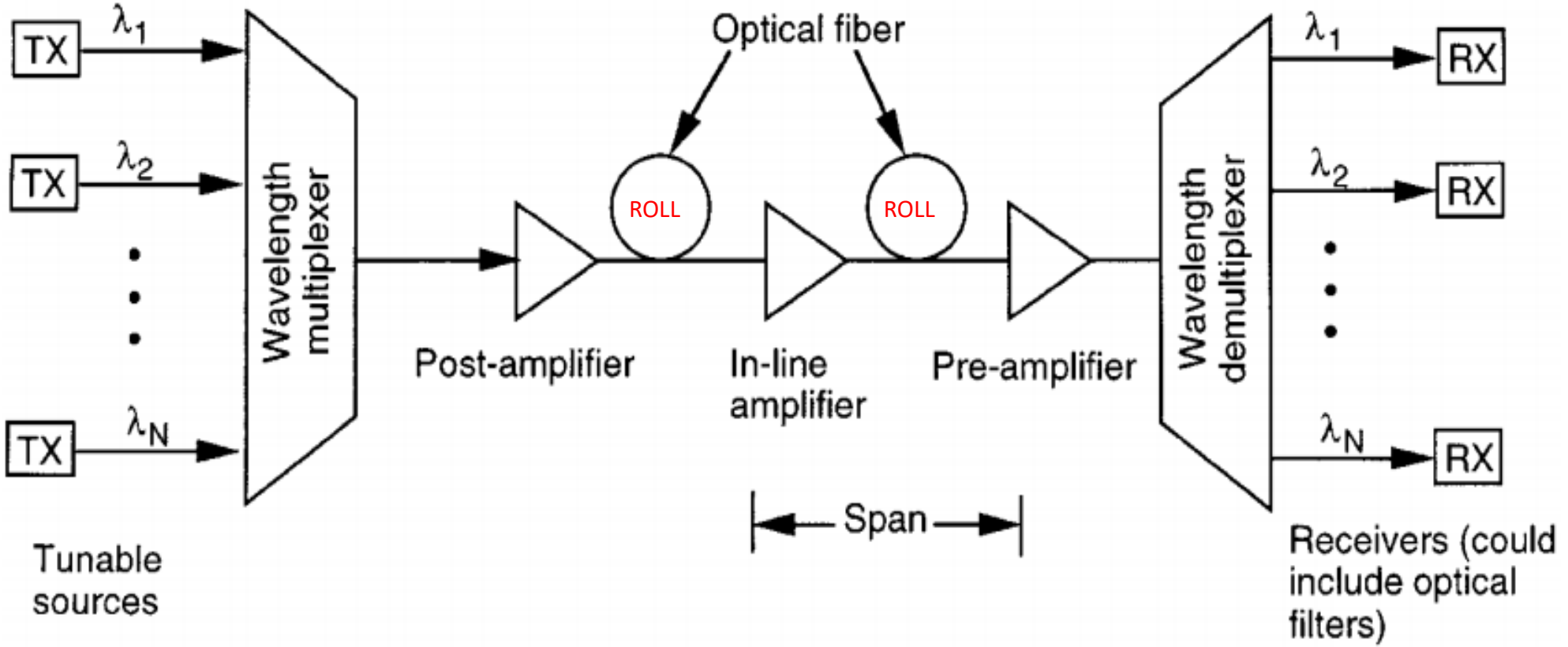


3. Dispersion therefore limits the maximum pulse transmission rate.
4. The wavelength at which dispersion is taken to be zero is called the zero-dispersion wavelength λ_0.

5. Fibre cables are manufactured to have
   a) Zero dispersion point in the 1550 nm band
   b) where attenuation is minimal.



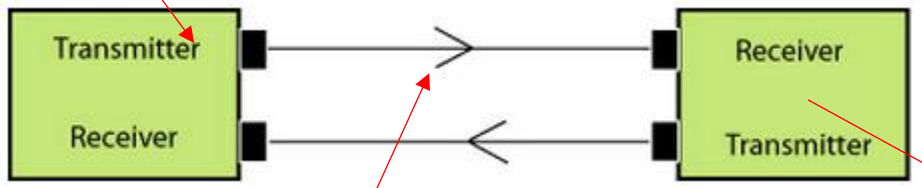
BLOCK DIAGRAM OF WDM LINK



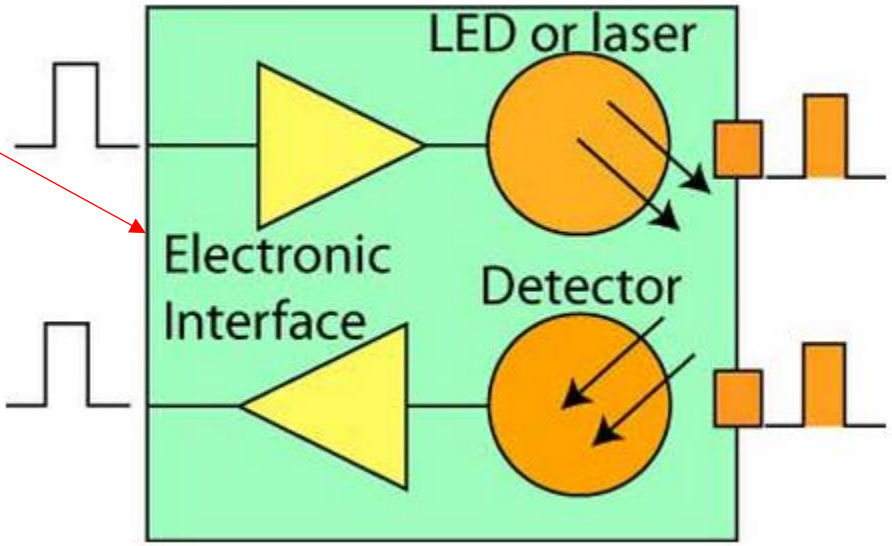
FIBRE OPTIC TRANSMITTERS & RECEIVERS

Transmitter
Takes an electrical input and converts it to an optical output using a laser diode or LED.

Receiver
The light from the end of the fibre is coupled to a receiver where a detector converts the light into an electrical signal

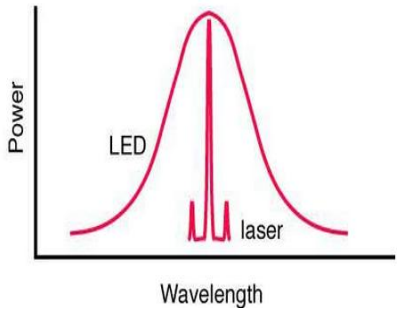


Medium (Fibre Cable)
The light from the transmitter is coupled into the fibre with a connector and is transmitted through the fibre optic cable.



FIBRE OPTIC SOURCES

- There are four sources of fibre optic signal all of which are semiconductor.
  1. **LEDs** are fabricated on semiconductor wafers such that they emit light from the surface of the chip. They have:
     (a) much lower power outputs than lasers and their larger, diverging light output pattern makes them harder to couple into fibres, limiting them to use with multimode fibres.
     (b) much less bandwidth than lasers and are limited to systems operating up to about 250 MHz or around 200 Mb/s.
  2. **Fabry-Perot (FP)** lasers emit from the side of the chip from a laser cavity created in the middle of the chip.
  3. **Distributed Feedback (DFB) Lasers** have the narrowest spectral width which minimizes chromatic dispersion on the longest links and are highly linear (that is the light output directly follows the electrical input) so they can be used applications that require linear modulation such as AM CATV systems.
  4. **Vertical Cavity Surface-Emitting Lasers (VCSELs)** are fabricated on semiconductor wafers in such a way that they emit light from the surface of the chip.

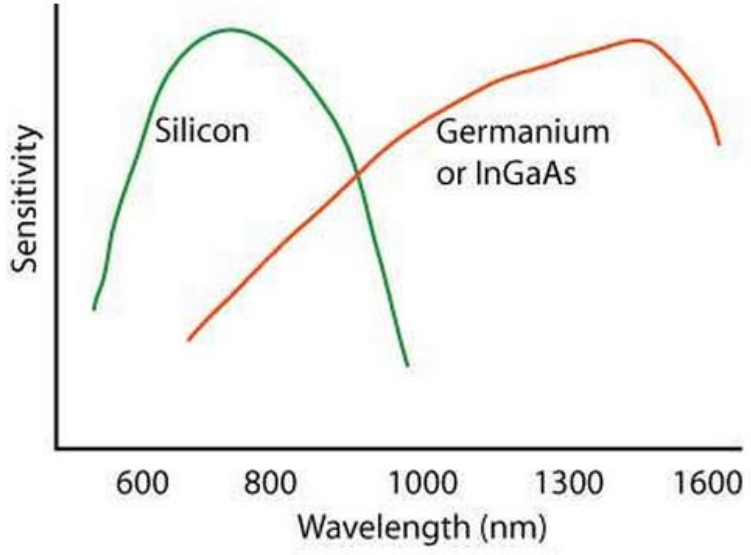


COMPARISON OF VARIOUS SOURCES

DEVICE TYPE	WAVELENGTH (nm)	POWER INTO FIBER (DBm)	BANDWIDTH	FIBER TYPES
LED	850, 1300	-30 to -10	<250 MHz	Multiple Mode
Fabry-Perot Laser	850, 1310 (1280-1330) 1550 (1480-1650)	0 to +10	>10 GHz	Multiple Mode Single Mode
DFB Laser	1550 (1480-1650)	0 to +25	>10 GHz	Multiple Mode Single Mode
VCSE Laser	850	-10 to 0	>10 GHz	Multiple Mode Single Mode

FIBRE OPTIC RECEIVERS

- **Receivers** use semiconductor detectors (photodiodes or photodetectors) to convert optical signals to electrical signals.
- Silicon photodiodes are used for short wavelength links (650 nm for Passive Optical Fibre and 850 nm for glass Multimode fibre).
- Long wavelength systems usually use InGaAs (indium gallium arsenide) detectors as they have lower noise than germanium which allows for more sensitive receivers.



FIBRE OPTIC JUNCTION BOX

- Fibre Optic Junction box is used to terminate fibre cables at the users premises.
- Colour Codes
  - Yellow – Single Mode
  - Orange – Multi-mode
  - Blue – Multi-mode