UNIT–3 : Satellite and Optical Communication (PYQ Solution)

PART–A Answers (≈70 Words Each)

Q1. What is the main difference between Geostationary Earth Orbit (GEO) and Low Earth Orbit (LEO) satellites? (2025)

GEO	LEO
Height **35,786 km** above the equator	Height **160–2,000 km**
Period 24 h — looks **fixed** in the sky	Period ~90–120 min — moves fast
3 satellites cover the whole Earth	Hundreds needed (constellation)
Delay ~250 ms one way	Delay ~5–20 ms
TV/DTH, weather	Starlink, ISS, imaging

Q2. Give the 3 different types of application with respect to satellite system. (2022)

1. **Communication: TV broadcasting (DTH), telephone trunks, Internet (VSAT, Starlink), disaster communication.**
2. **Navigation: GPS, NavIC (IRNSS), Galileo — position and time.**
3. **Remote sensing and weather: earth imaging, crop and forest monitoring, weather forecasting (INSAT), defence surveillance.**

Also: scientific research and astronomy.

Q3. Mention the three regions to allocate the frequency for satellite services. (2022)

The ITU (International Telecommunication Union) divides the world into three regions for frequency allocation:

- **Region 1: Europe, Africa, Middle East, Russia and Mongolia.**

- **Region 2: North and South America and Greenland.**
- **Region 3: Asia (including India) and Australia / Oceania.**

Each region has its own frequency plan to avoid interference.

Q4. Mention two advantages of using fiber-optic cables over copper cables for communication. (2025)

1. **Huge bandwidth and speed: carries Tbps of data, far more than copper.**
2. **Very low loss: about 0.2 dB/km, so signals travel 50–100 km without repeaters.**

Also: immune to electromagnetic interference, no crosstalk, more secure (hard to tap), thin and light, no electrical shock or spark risk.

Q5. How the signal is amplified in fiber optic cable? (2022)

Over long distances the light gets weaker, so it is amplified directly in optical form using an optical amplifier, mainly the EDFA (Erbium-Doped Fiber Amplifier).

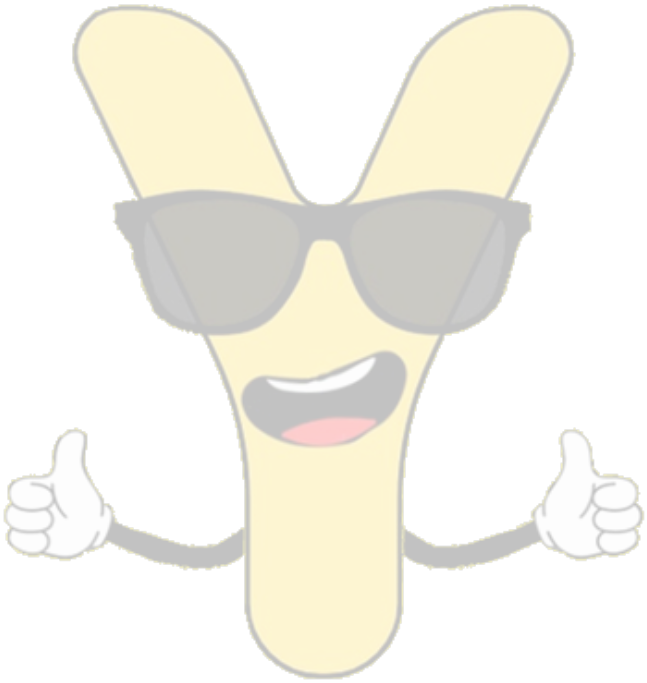
A short fiber doped with erbium is pumped by a 980/1480 nm laser. The excited erbium ions release extra photons at 1550 nm (stimulated emission), boosting all signal wavelengths together. Older systems used electronic repeaters (light → electrical → light).

Q6. What is meant by DOM set? (2022)

DOM (Digital Optical Monitoring), also called DDM, is a feature of optical transceivers (SFP/SFP+ modules). The DOM set is the group of real-time parameters the module reports to the switch or router:

- **Module temperature**
- **Supply voltage**
- **Laser bias current**
- **Transmit (Tx) optical power**
- **Receive (Rx) optical power**

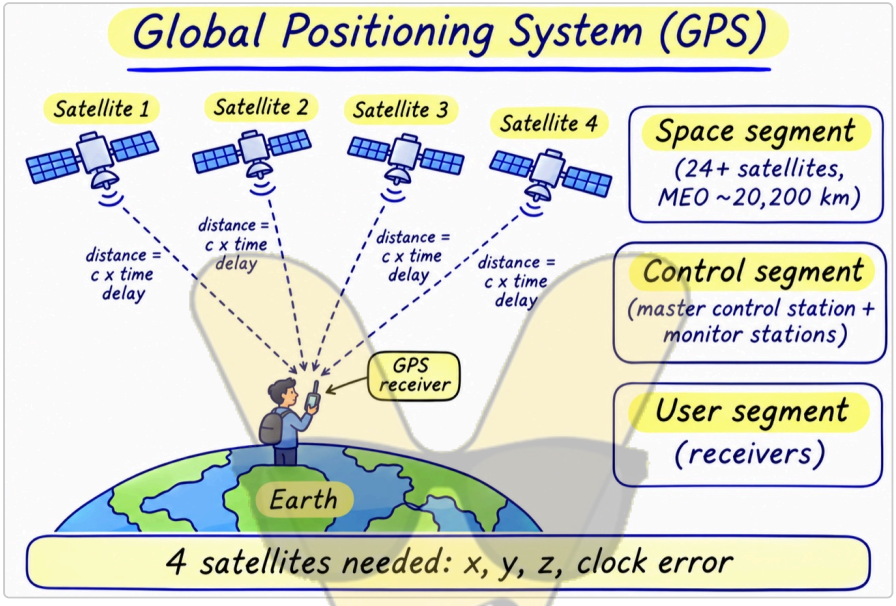
It helps detect link and fiber faults early.



PART–B Answers (≈250 Words Each)

Q1. With a neat diagram, explain the components and working of a Global Positioning System (GPS). (2025)

GPS is a satellite navigation system (USA) that gives **position (latitude, longitude, height), speed and exact time** anywhere on Earth, in any weather.



Components (three segments):

1. **Space segment:** 24+ satellites (31 active) in **MEO at about 20,200 km**, in 6 orbital planes, period ~12 h. Each carries **atomic clocks** and continuously broadcasts its position and time on L-band (L1 = 1575.42 MHz).
2. **Control segment:** a **master control station** (Colorado) and monitor stations around the world that track satellites, correct their clocks and orbit data, and upload it.
3. **User segment:** GPS receivers in phones, cars, aircraft and ships.

Working (trilateration):

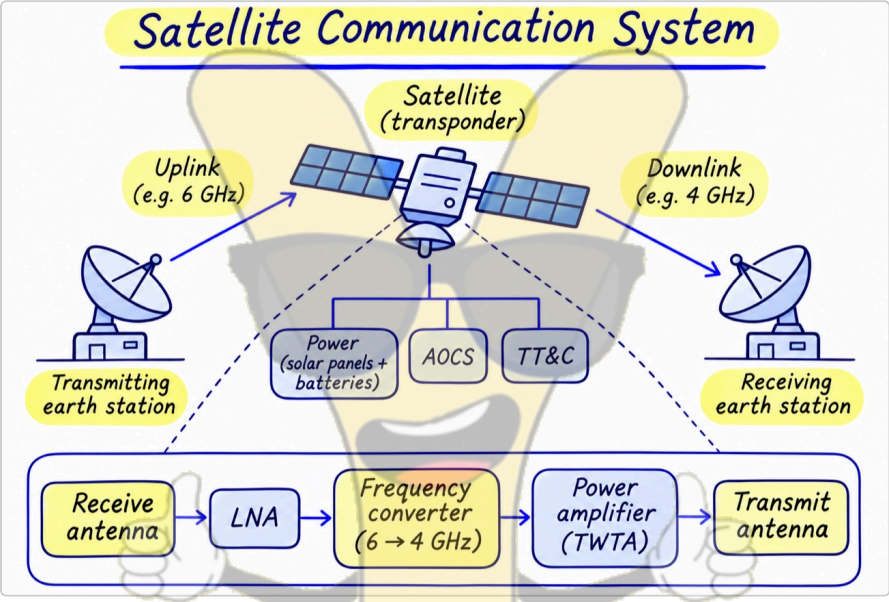
1. Each satellite sends a signal with the **time it was sent** and its position.
2. The receiver notes the **arrival time**. Distance = speed of light × travel time ($d = c \times \Delta t$).
3. With one satellite, the receiver is somewhere on a sphere; with three spheres the intersection gives a point.

4. The phone's clock is not accurate, so a **4th satellite** is used to solve for the clock error. So **4 satellites → x, y, z and time**.

Applications: navigation (Google Maps), aviation and shipping, surveying, vehicle tracking, time sync for mobile towers and banks, defence. India's own system is **NavIC**.

Q2. Draw a block diagram of a basic Satellite Communication System, labeling its main components. (2025)

A **satellite communication system** uses a satellite as a **repeater in the sky** to link two distant earth stations.



Main components:

1. **Transmitting earth station:** takes baseband signal (TV, data), modulates it, up-converts it to the uplink frequency (e.g. **6 GHz** in C-band), amplifies it with a high power amplifier (HPA) and sends it through a large dish antenna. This path is the **uplink**.
2. **Satellite (space segment):** its main communication part is the **transponder**:
   - **Receive antenna** picks up the weak uplink signal.
   - **LNA (Low Noise Amplifier)** amplifies it with little added noise.
   - **Frequency converter** (mixer + local oscillator) shifts 6 GHz → **4 GHz**, so uplink and downlink do not interfere.
   - **Power amplifier (TWTA or SSPA)** boosts the signal.
   - **Transmit antenna** sends it back to Earth.

3. **Receiving earth station:** dish antenna → LNA/LNB → down-converter → demodulator → user. This path is the **downlink**.

Supporting satellite subsystems: power (solar panels + batteries), **AOCS** (keeps antennas pointed), **TT&C** (telemetry, tracking and command), thermal control and propulsion.

Why uplink frequency > downlink: high frequency needs more power to generate; power is plentiful on the ground but limited in space, so the higher frequency is used for the uplink. Common bands: C (6/4 GHz), Ku (14/12 GHz), Ka (30/20 GHz).

Q3. Explain the Attitude and Orbit Control System (AOCS) regarding satellite subsystems. (2022)

The **AOCS** keeps the satellite **pointing in the right direction (attitude)** and **in the correct orbital position (orbit)**. Without it antennas would drift away from Earth and the satellite would slowly leave its slot.

1. Attitude control (orientation about roll, pitch, yaw axes):

- **Sensors:** earth sensors (infrared horizon), sun sensors, star trackers and gyroscopes measure the current orientation.
- **Actuators:**
- **Spin stabilisation:** the whole body (or a drum) spins like a top and stays stable.
- **Three-axis stabilisation: momentum/reaction wheels** inside the body speed up or slow down to turn the satellite; **magnetorquers** and small **thrusters** dump extra momentum.
- An on-board computer compares sensor readings with the required attitude and drives the actuators (closed loop).

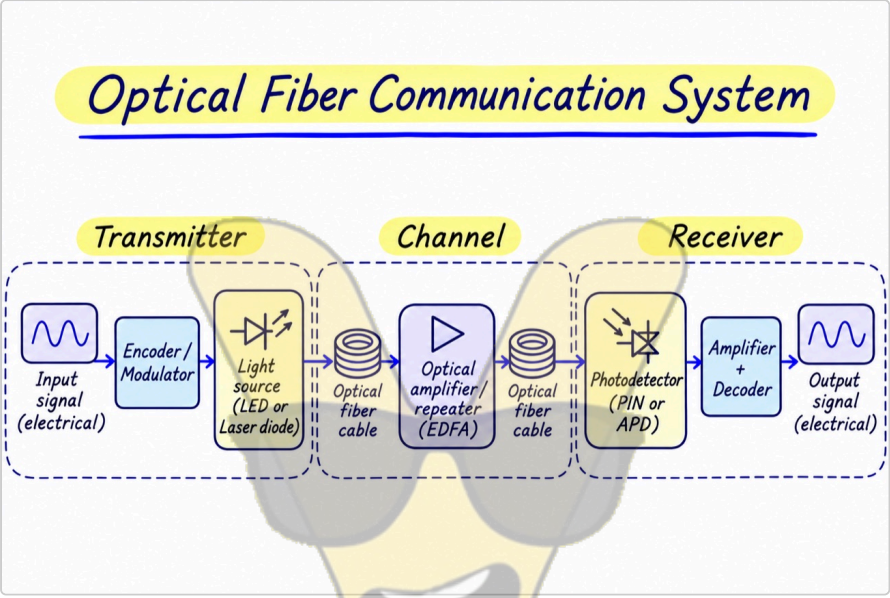
2. Orbit control (station keeping):

- The Sun and Moon's gravity and Earth's uneven shape slowly push a GEO satellite north–south and east–west.
- Small **gas jets / ion thrusters** fire periodically to correct it, keeping it within about ±0.05° of its slot.
- **North–south** correction uses most of the fuel; the **satellite's life (10–15 years) usually ends when station-keeping fuel runs out.**

Simple idea: attitude control = "face the right way", orbit control = "stay in the right place".

Q4. Draw the block diagram of optical fiber communication system and explain it. (2022)

An **optical fiber communication system** sends information as **light pulses** through a glass fiber.

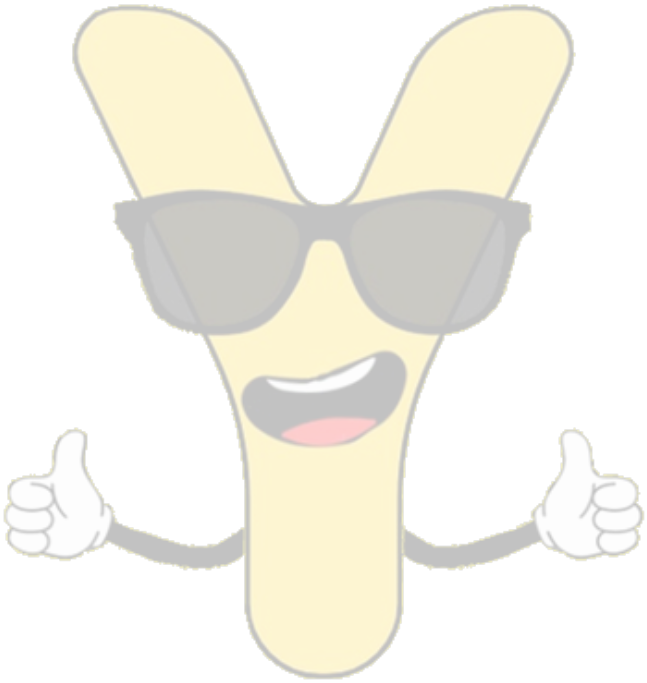


Blocks:

1. **Information source:** voice, video or data as an electrical signal.
2. **Encoder / modulator (driver circuit):** converts the signal into a digital pulse form and drives the light source.
3. **Optical transmitter (light source): LED** (cheap, short distance, multimode) or **laser diode** (narrow spectrum, high power, long distance, single-mode). It turns electrical pulses into light pulses (on = 1, off = 0).
4. **Optical fiber (channel):** carries light by **total internal reflection** in the core. Connectors and splices join sections.
5. **Repeaters / optical amplifiers (EDFA):** placed every 50–100 km to make up for attenuation.
6. **Optical receiver (photodetector): PIN photodiode** or **APD (avalanche photodiode)** converts light back to electric current.
7. **Amplifier, decoder and output:** amplify, regenerate and decode the signal back to its original form.

Wavelength windows used: 850 nm, 1310 nm and **1550 nm** (lowest loss).

Advantages: very high bandwidth, low loss, no EMI, secure, light weight.

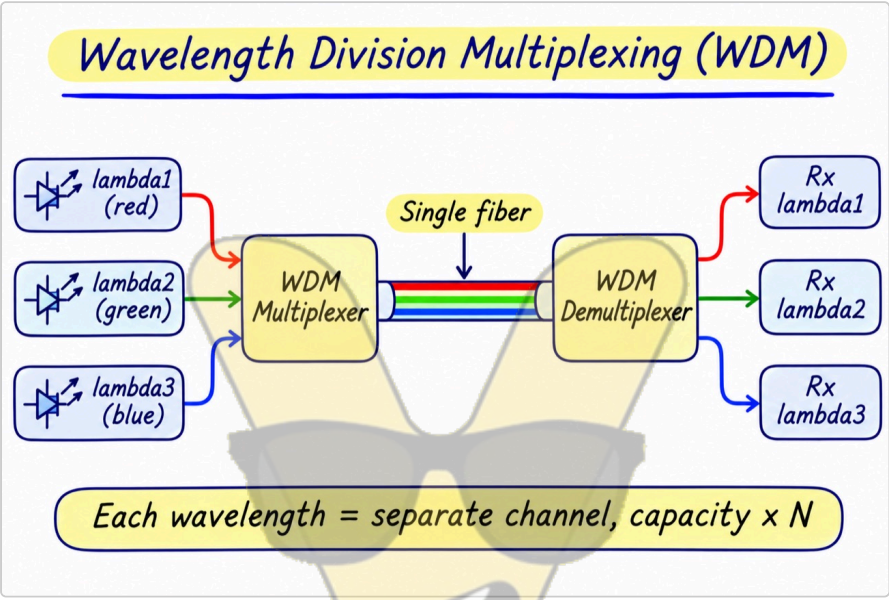


PART–C Answers (≈500 Words Each)

Q1. Explain the following in brief: (a) WDM (b) Fiber optic cables. (2022)

(a) Wavelength Division Multiplexing (WDM)

WDM sends **many signals through one fiber at the same time, each on a different wavelength (colour) of light**. It is like FDM but for light.



Working:

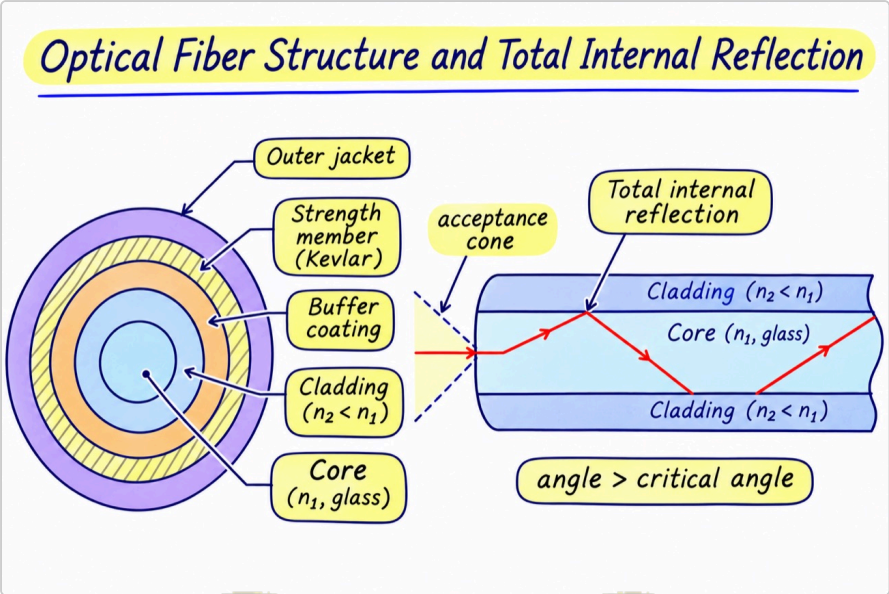
1. Each channel has its own laser at a different wavelength (λ1, λ2, λ3 …).
2. A **multiplexer** (prism, grating or thin-film filter) combines all wavelengths into one fiber.
3. All wavelengths travel together without disturbing each other, and an **EDFA** amplifies them all at once.
4. At the far end, a **demultiplexer** separates the wavelengths and sends each to its own photodetector.

Types:

- **CWDM (Coarse):** 18 channels, 20 nm spacing, cheap, short distance.
- **DWDM (Dense):** 40–160 channels, 0.8 nm (100 GHz) spacing, long-haul and undersea.

Benefits: multiplies fiber capacity (80 channels × 100 Gbps = 8 Tbps on one fiber), uses existing fiber (no new cables), each channel can carry a different format, easy upgrade.

(b) Fiber optic cables



Structure:

1. **Core:** central glass (or plastic) with higher refractive index n_1; light travels here.
2. **Cladding:** glass around the core with lower index n_2; causes total internal reflection.
3. **Buffer coating:** plastic layer that protects from moisture and bending.
4. **Strength members:** Kevlar yarn for pulling strength.
5. **Outer jacket:** protective PVC/PE cover.

Principle — Total Internal Reflection (TIR): when light goes from a denser (core) to a rarer (cladding) medium at an angle larger than the **critical angle** $\theta_c = \sin^{-1}(n_2/n_1)$, it is fully reflected and stays inside the core. **Numerical aperture** $NA = \sqrt{n_1^2 - n_2^2}$ tells how much light the fiber can accept.

Types:

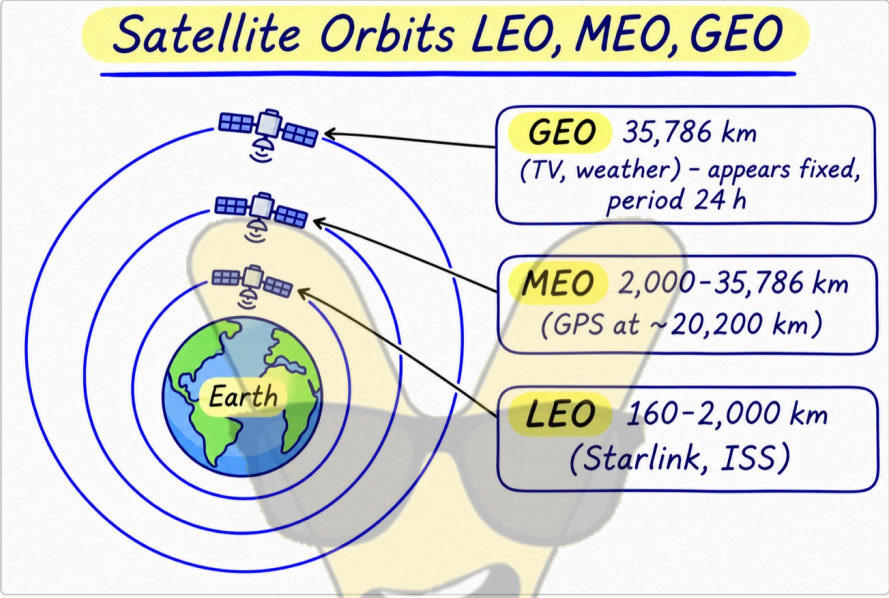
Type	Core size	Use
Single-mode	~9 μm, one light path	Long distance, very high speed (laser)
Multimode step-index	50–100 μm	Short links (LED)
Multimode graded-index	50/62.5 μm, index falls gradually	LANs, less dispersion

Losses: absorption, scattering (Rayleigh), bending loss, connector/splice loss; **dispersion** spreads pulses and limits speed.

Advantages: huge bandwidth, low loss, EMI immunity, security, light weight.
Disadvantages: costly installation, fragile, needs skilled splicing.

Q2. Explain satellite subsystems and the ground (earth) station. (Expected)

A satellite has a **payload** (does the job: transponders and antennas) and a **bus** (supporting subsystems).



Satellite subsystems:

1. **Communication subsystem:** transponders (LNA, frequency converter, power amplifier) and antennas (dish, horn, spot-beam).
2. **Power subsystem: solar panels** generate power; **batteries** supply it during eclipse.
3. **AOCS:** keeps correct orientation and orbital position (sensors, momentum wheels, thrusters).
4. **TT&C (Telemetry, Tracking and Command):** sends health data to ground, allows tracking and receives commands from ground control.
5. **Thermal control:** heaters, radiators and insulation blankets keep equipment within safe temperature.
6. **Propulsion:** thrusters and fuel for orbit raising and station-keeping.
7. **Structure:** body that holds everything and survives launch.

Earth station (ground station):

- **Antenna:** large parabolic dish with tracking system.

- **Transmit chain:** baseband → modulator → **up-converter** → **HPA (high power amplifier, e.g. TWTA/klystron)** → antenna.
- **Receive chain:** antenna → **LNA** → **down-converter** → demodulator → baseband.
- **Diplexer:** lets one antenna transmit and receive together.
- **Power supply, monitoring and control** equipment.

Simple idea: the satellite is a relay tower in space; the earth station is the gateway that talks to it.

Q3. Explain optical transmitters (LED, laser) and optical receivers (PIN, APD). (Expected)

Optical transmitters convert electrical signals into light. Two sources are used:

Point	LED	Laser diode (LD)
Light emission	Spontaneous emission	**Stimulated** emission
Light	Incoherent, wide spectrum (30–60 nm)	Coherent, narrow (<1 nm)
Power into fiber	Low (μW)	High (mW)
Speed	Low (up to ~100 Mbps)	Very high (Gbps)
Fiber	Multimode, short links	Single-mode, long distance
Cost / life	Cheap, long life	Costly, temperature-sensitive

Optical receivers convert light back into electrical current using **photodiodes**:

Point	PIN photodiode	APD (Avalanche photodiode)
Structure	P – Intrinsic – N layers	Extra high-field gain region
Internal gain	None (gain = 1)	Yes (10–100) by avalanche multiplication
Sensitivity	Lower	Higher (for weak signals)
Bias voltage	Low (5–10 V)	High (50–300 V)
Noise / cost	Low noise, cheap	More noise, costly

Receiver chain: photodiode → preamplifier → equalizer → decision/regeneration circuit → output data.

Simple idea: laser = strong, pure, fast light for long distances; LED = cheap light for short links; APD = sensitive ear, PIN = simple ear.

