M85: What are A1 fiber cables? Discuss types of Optical fiber cables. How intermittently bonded ribbon fibers are revolutionizing the communication industry?

(Answer in 250 words) : 15 Marks

Subtopic M85: Information & Comm Technology

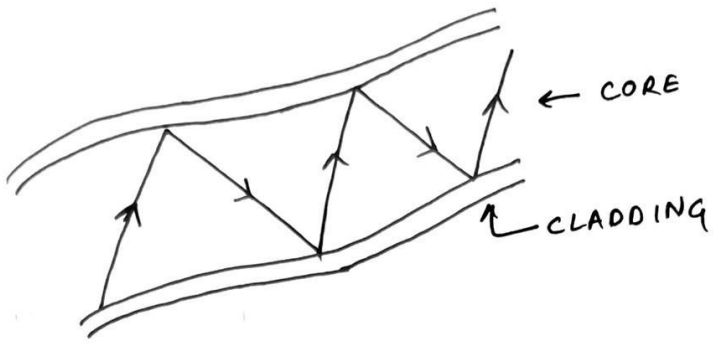
M85

FIBRE OPTICS technology uses light waves to transmit information through a glass or plastic pipe.

FIBRE OPTIC CABLE.

- Is made up of extremely thin strands of glass or plastic.
- It transmits information at the speed of light.
- Glass or plastic does NOT allow light to leak out on propagation.

  Instead, light beams are repeatedly reflected back due to TOTAL INTERNAL REFLECTION.



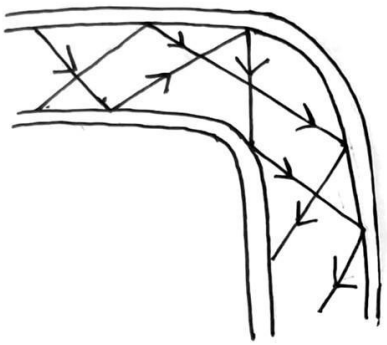
ISSUE OF BENDING

- Deviations from a straight path can cause light to scatter and escape the core.
- This causes loss of signal.
- When cables are used in multiple dwelling units, they need compact distribution cabinets.

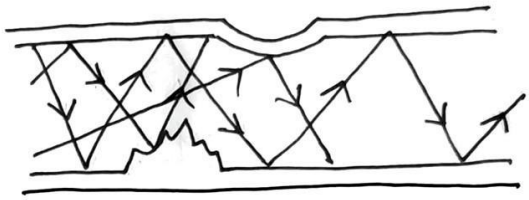
∴ fibre is subjected to greater bending.

- 2 types of bending

MACROBENDING



MICROBENDING



A1 FIBRE CABLES are single-mode optical cables that have the distinction of being "BEND-OPTIMIZED".

- Such cables are capable of making attenuation (signal loss) minimal.
- Can be used in high density applications in offices.
- Can also be used in FTTx (Fibre to the "x") systems to provide last-mile connectivity.

TYPES OF OPTICAL FIBRE CABLES.

i) based on material of cable.

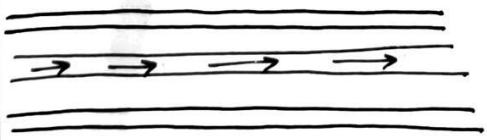
- PLASTIC OPTICAL FIBRE
- GLASS OPTICAL FIBRE

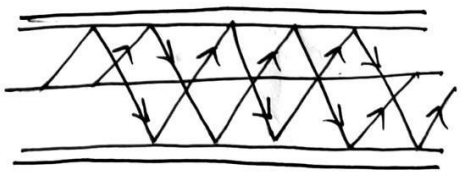
ii) based on refractive index

- STEP-INDEX OPTICAL FIBRE
- GRADED-INDEX OPTICAL FIBRE

iii) based on mode of propagation

- SINGLE-MODE
- MULTIPLE-MODE



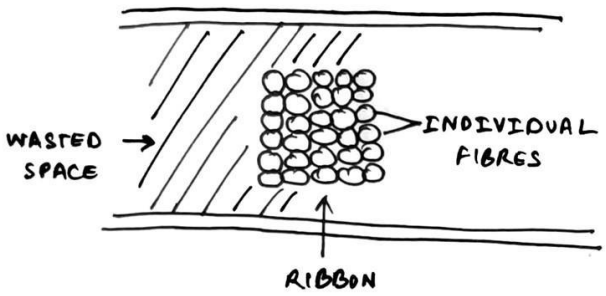


- Signal travels straight down the middle.
- Covers long distances (over 100 km)

- Light beam takes multiple paths.
- Covers short distances.

INTERMITTENTLY BONDED RIBBON FIBRES.

In recent years, A1 fibres have been used to make ribbon fibre cables, where each individual optical ribbon consists of fibres stacked in a bundle.



The advantage of this structure is that it enhances the fibre-packing density of the cable. However, there is still the limitation of wasted space due to its flat and cuboidal organization of cable fibres.

↳ This is overcome through the new ribbon technology called intermittently bonded ribbon fibres.

Advantages

Ribbons are ROLLABLE

Since fibres are only "intermittently bonded" using matrix material, more flexibility given to structure, along with increased fibre packing density.

Ribbons can undergo MASS FUSION FIBRE CABLE SPLICING

In order to maintain connection between optical fibres permanently.

Together, the use of A1 fibres (with their small bend radius) and intermittently bonded ribbons (with loose fibre bundling and splicing capabilities) has REVOLUTIONIZED the capability to form high density cable connections. Its applicability to

i) provision of broadband services

ii) FTTx systems (especially FTTH)

has taken the communications industry by storm, especially at a time when high data speeds is key.

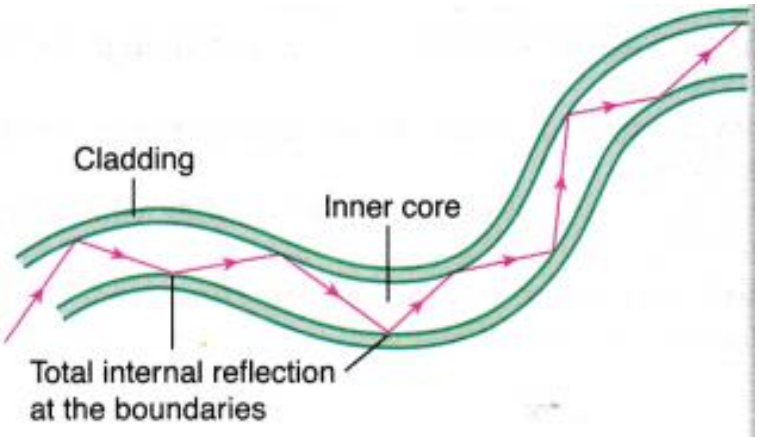
SYNOPSIS

What is fiber optics?

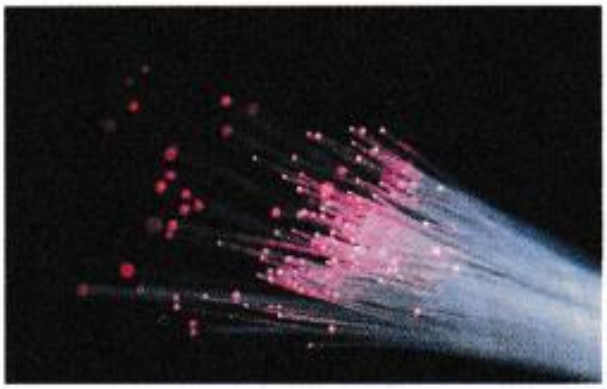
- There are different ways of transmitting information.
- In telephones, wire cables carry sound from the sender to the receiver.
- On the other hand, cell phones are wireless and make use of radio waves to send and receive information.
- A third way is fiber optics. It sends information coded in a beam of light down a glass or plastic pipe.
    - It was originally developed for endoscopes in the 1950s to help doctors see inside the human body without having to cut it open first.
    - In the 1960s, engineers found a way of using the same technology to transmit telephone calls at the speed of light.

Optical Technology

- A fiber-optic cable is made up of extremely thin strands of glass or plastic known as **optical fibers**
    - One cable can have as few as two strands or as many as several hundred.
    - Each strand is less than a tenth as thick as a human hair and can carry something like 25,000 telephone calls.
    - This means that an entire fiber-optic cable can easily carry several million calls.
- fiber-optic cables carry information between two places using entirely optical (light-based) technology.
- Electrical information from the computer is first converted into a series of light pulses.
- These light beams then travel down the cable by bouncing repeatedly off the walls.
- The fiber-optical cable, made out of glass or plastic, does not allow light to leak out on propagation. Instead, the glass acts like a mirror and the light beams are repeatedly reflected back. This phenomenon is called **total internal reflection**.
- Repeated reflection takes place due to the structure of the cable, which is made up of two separate parts.
    - The **core**: where light travels
    - The **cladding**: wrapped around the outside of the core, it is another layer of glass. Its job is to keep the light signals inside the core.
    - Both are made of different types of glass, the cladding having a lower refractive index than the core.

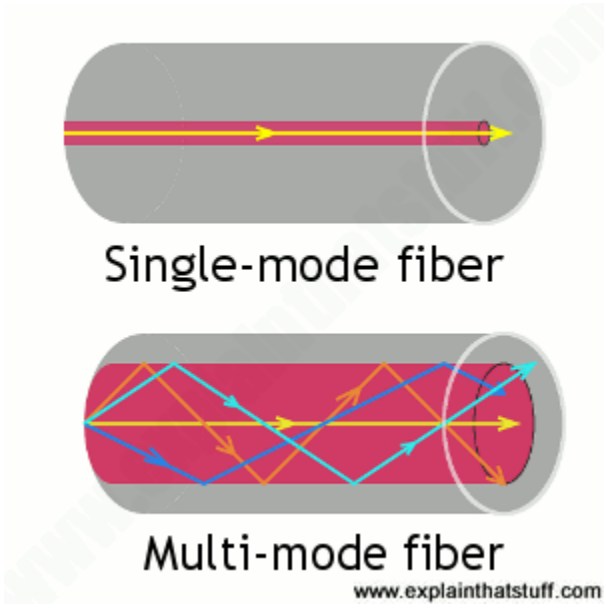


(a)



(b) Optical fibres

Types of optical fiber cables



(i) Two main types based on mode of propagation: single-mode fiber and multiple-mode fiber

- **Single-mode fiber**
  - It is the simplest type.

    - All signals travel straight down the middle without bouncing off the edges.
    - Cable TV, Internet, and telephone signals are generally carried by single-mode fibers, wrapped together into a huge bundle.
    - Cables like this can send information over 100 km.
- **Multiple-mode fiber**
    - Each optical fiber in a multi-mode cable is about 10 times bigger than one in a single-mode cable.
    - This means light beams can travel through the core by following a variety of different paths.
    - Multi-mode cables can send information only over relatively short distances and are used (among other things) to link computer networks together.
- Even thicker fibers are used in a medical tool called a **gastroscope** (a type of endoscope), which doctors poke down someone's throat for detecting illnesses inside their stomach.

(ii) Two main types based on material of the cable: plastic and glass optical fiber

- **Plastic optical fiber**
    - It has an acrylic or polycarbonate core with a resin cladding that is typically made with silicone.
    - It can withstand environments that have a lot of vibrations and are more flexible and bendable in comparison to glass optical fibers.
    - However, it does not suit harsh environments and degrades over time.
    - It is mainly used in decorative and illumination appliances. It is also used in medical instruments where a narrow spectrum of light needs to be transmitted.
- **Glass optical fiber**
    - It has a glass core with a glass or plastic cladding
    - It is the most common type of optical fiber cable.
    - It allows more light to travel, along with having the ability to withstand extremities in temperature and a corrosive environment
    - The overall loss applicable to this variant is lesser compared to other variants.
    - However, it is prone to breakage unless handled with care. Sensors and measurement systems typically opt for a glass optical fiber.

(iii) Two main types based on refractive index: Step and graded index optical fiber

- **Step index optical fiber**
    - In this fiber, the refractive index is the same across both the centre of the core as well as at the extremes.
    - The traveling light is slightly uncontrolled in the beginning but eventually all the light rays travel at the same speed.
- **Graded index optical fiber**

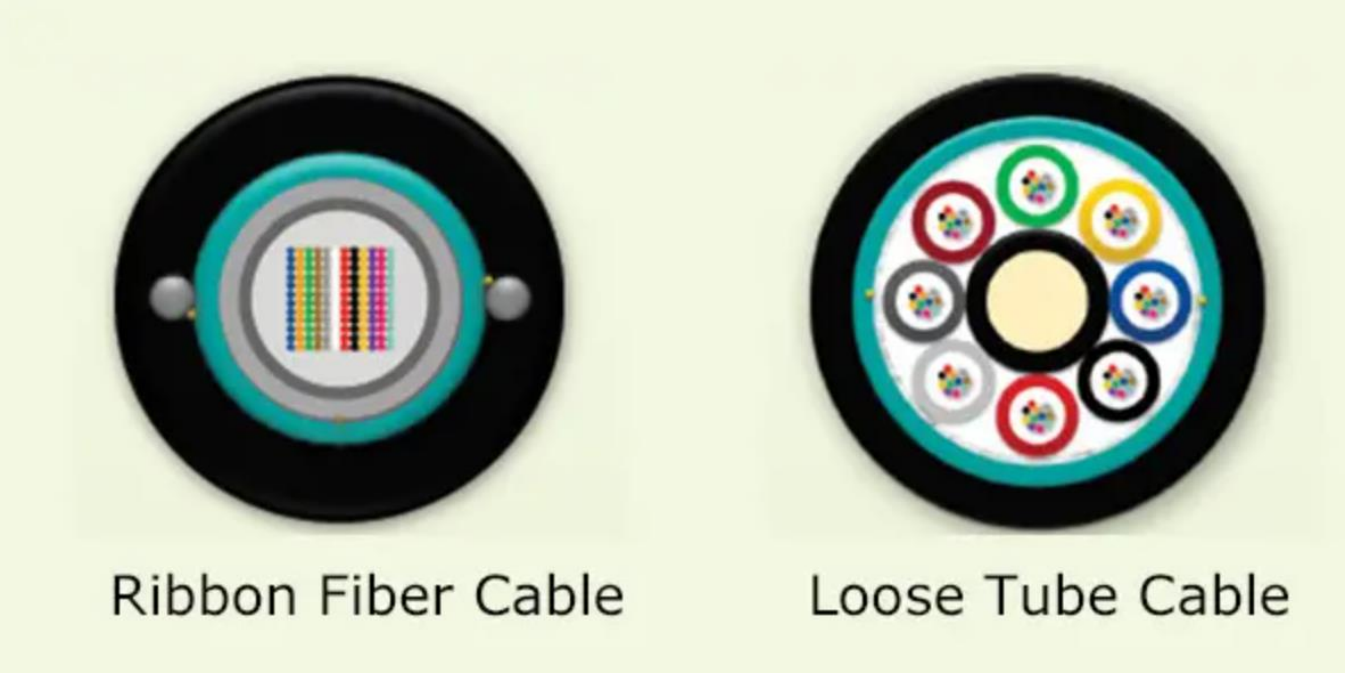
- In this type of fiber, there is a lot of variation in the refractive index at the center of the core to what it is at the extremes near the cladding.
- In the center, light travels slowest, as the refractive index there is the highest compared to the other areas.
- However, the optical fiber price for the graded variant is on a slightly larger scale than the step variant.

A1 fiber cables

- A1 fiber cables are of the single-mode and especially renowned for being reliable and high-performing.
- They are compatible with existing networks and have improved bending properties.
- They are excellently suited for bridging longer distances in LAN cabling and in FTTx systems.
  - **LAN – Local Area Network**
    - It is an assembly of computers and associated devices which are interconnected.
    - Used in schools, workplaces etc.
  - **FTTx – fiber to the "x" systems**
    - FTTx is a collective term that is used to describe various types of broadband network architectures, depending on wherever they terminate.
    - The 'X' in 'FTTx' represents a particular object: fiber to the *Home* (FTTH), fiber to the *Building* (FTTB), fiber to the *Premises* (FTTP) and fiber to the *Curb* (FTTC)
    - FTTx utilises optical fiber for some or all of their **last mile connectivity.**
- Benefits
  - As fiber gets closer to the residence, there are a variety of uses of optical fiber where a **bend-optimized A1 fiber** can help the system function better.
  - Low-count cables: As the number of fibers in a cable drops, it is more likely that it will bend with a radius of 30mm or less.
  - High-density connectivity: A1 fiber cables are excellent for fiber optic patch cords in high-density applications like central offices and distribution cabinets.
    - Patch cords: cable with connectors on each end that is used to connect end devices to power sources.
  - Small enclosures: The capacity to have bends with radii as small as 10mm, has enabled the creation of more compact sections for FTTx applications.
  - Low-temperature applications: Patch cords and cables work better at temperatures as low as -40°C, thanks to increased micro-bending of the bend-optimized fiber.
  - Compact cable designs: The use of bend-optimized A1 fibers results in minimal attenuation (signal loss) after cabling.

Classic ribbon technology

- Optical fiber technology has revolutionized communications technology with its capability of transferring large amounts of data significantly faster than copper cables.
- However, the practical application of these cables required using cables containing several optical fibers
- This can be done in two ways: **loose tube** and **ribbon**.

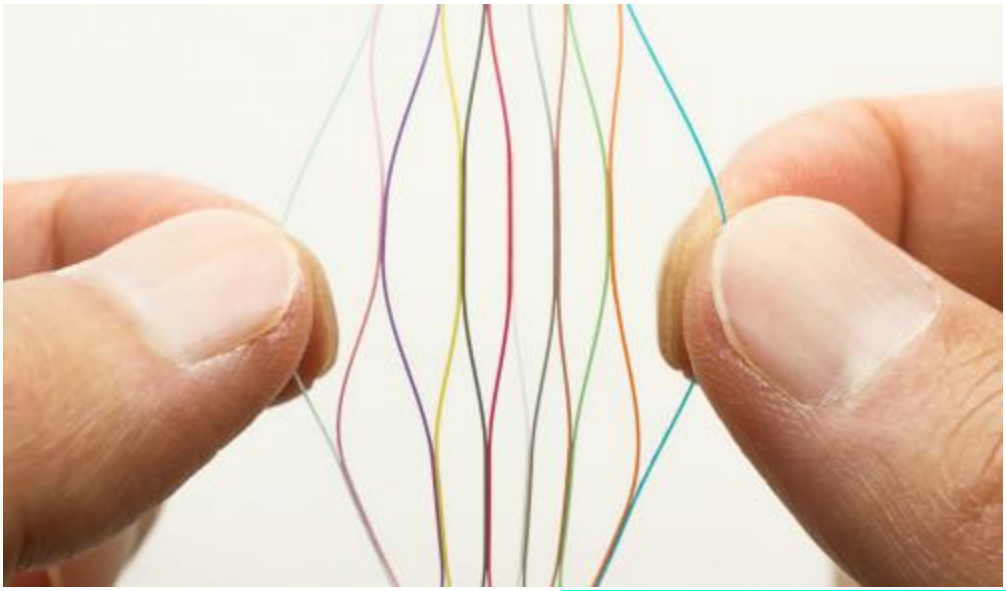


    - The difference between these two types of cables stems from their construction.
    - Optical cables in the ribbon cable are flat like ribbons, while they are round and bundled inside a loose tube cable.
    - The level of optical fiber arrangement is also different inside both.
        - It is consistent and arranged in the order of colour in a banded row in a ribbon cable. This is called a fixed form.
        - In a loose tube cable, it is more random, unarranged, and of independent form.
- Ribbon fiber cables
    - A ribbon fiber cable consists of coated optical fibers which are placed adjacent to each other, aligned in one row.
    - These are individual optical ribbons and they can easily be stacked into a bundle.
    - The ribbons can be stored in two ways: inside a central core tube or in stranded multi-tubes within the cable core.
    - Advantage: By joining multiple optical fibers in ribbon form, one can **optimise the fiber packing density of the cable,** making it suitable for limited space applications.

- Disadvantage: the stacked ribbon forms a cuboidal structure inside the cylindrical tubes, which wastes significant space.

New ribbon technologies

- Classic ribbon technology has been replaced with new ribbon technologies. One of them that is making waves big time in the industry: Intermittently Bonded Ribbon.
- Ribbon fibers, mainly **intermittently bonded ribbon fibers**, have become the current industrial trend due to their capability to form high-density cable connections. They use **A1 fibers** that have a small bend radius.
- Intermittently bonded ribbon fibers have the appearance of a spider's web [see the picture below], therefore they are also called spider web ribbon fiber.



- Advances over classical ribbon technologies: ribbons are **rollable** and they can undergo ribbon **fiber splicing** (i.e. joining together).
- Doing away with the disadvantage of wasted space associated with classical ribbon technologies, here the ribbons are rollable and can therefore be bundled together [instead of staying structurally flat].
    - An intermittently bonded ribbon fiber cable consists of fibers bonded using matrix material.
    - 'Intermittently bonded' means ribbons have bonded and unbonded regions.
    - In bonded parts, adjacent optical fibers stick together.
    - In unbonded areas, the adjacent fibers can move independently.
    - And because the optical fibers near the unbounded region can move, ribbons can be rolled without causing strain.
    - Due to their **loose fiber bundling**, intermittently bonded ribbon cables are perfect for making optic fiber cables with **higher packing density.**

- Additionally, they can also undergo mass fusion fiber cable splicing – which is another advantage for manufacturers.
    - Splicing of optical fibers is used to maintain permanent connections between two optical fiber cables.
    - In mass fusion, cores of two fiber cables are joined together thermally or electrically to create a long-lasting connection.

Advantages of bonded ribbon fibers

- **Easier to handle**: Ribbon fibers are easier to manoeuvre because they weigh less than traditional fibers of a similar count because of packing efficiency. Less sheathing material is required.
- **High density**: Since ribbon cables have high packing efficiency, ten times more fibers can be packed in a tube with only twice the radius.
- **Splicing Efficiency**: An entire ribbon can be spliced simultaneously, making the splicing process quicker.
- **Cost efficiency**: Ribbon cables can be cost-efficient for higher fiber counts as the higher cost of purchasing the cables can be offset by the lower cost of installing them.

Advantages of intermittently bonded ribbon fibers

- **Higher Fiber Count**: The intermittently bonded fibers can be rolled, presented in bundles, and inserted into cylindrical tubes. These bundled structures have a higher packing efficiency in these tubes than the stacked standard ribbons, giving more fibers in the same volume.
- **Less bonding material**: The fibers in the ribbon need to be bound together only intermittently. Therefore, less adhesive materials are required to bond these types of cables.
- **High Strength**: A central material is required for delivering these ribbon fiber types in loose tube configuration; this makes the fiber cables very strong.
- **Mid-Span Access Protection**: When only a few fibers from the cable have to be spliced (mid-span access), these fibers offer extra layers of protection. During this operation, only the loose tube in the cable can be used. This can be seen in FTTH networks where one loose tube from the fiber cable goes to the customer's home.
- **Used in tighter bends**: The intermittently bonded ribbon fibers are inherently flexible, and the fibers used are bend-resistant A1 fibers. That means they can be installed in small spaces where high fiber is needed.

Conclusion

- Intermittently bonded ribbon cables have more fibers than the corresponding regular ribbon fiber cables of similar size.
- High-density fiber cables are necessary because the need for higher-volume data transmission is increasing daily.
- Reasons include 5G deployment and a general increase in demand for high-speed internet. New digital products also often have high data needs.
- Intermittently bonded ribbon fibers are revolutionizing the communication industry by enabling high data speeds.
