Lecture-VI Programme: M. Sc./B.Sc. Physics

Basics of Optical Fiber and its Applications -II

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Types of Optical Fiber

Optical fibers are categorized on the basis of modes carried by the fiber and the refractive index profile of the core and cladding of fiber. These are classified into three categories:

- **Step Index Multimode Fibers (MMF)**
- **Step Index Single Mode or Mono-mode Fibers (SMF)**
- **Graded Index Multimode Fibers (GRIN)**

Step Index Multimode Fiber

❖ In a step index multimode fiber a transparent glass core with a constant index of refraction is enclosed by an additional coaxial glass or plastic cladding of refraction lower than that of the core. The upper and lower interfaces between the core and cladding work as a cylindrical mirror at which the reflection of the transmitted light takes place.

❖ Such type of a fiber is the simplest but poorest in performance. Step index multimode fiber permits more than one mode of wavelength of light to propagate from one end to another as shown in Fig. 1.

❖**The core diameter of multimode fiber is in the range 20 μm–100 μm and the diameter of cladding is in the range 100 μm - 200μm. The standard overall diameter of the MMF is 125 μm.**

❖ **The refractive index of such type of fiber, like to single mode, also suddenly changes at core–cladding surface in steps; so called step index. Being large core diameter, it can contain several rays of light travelling in different paths incident at different angles.**

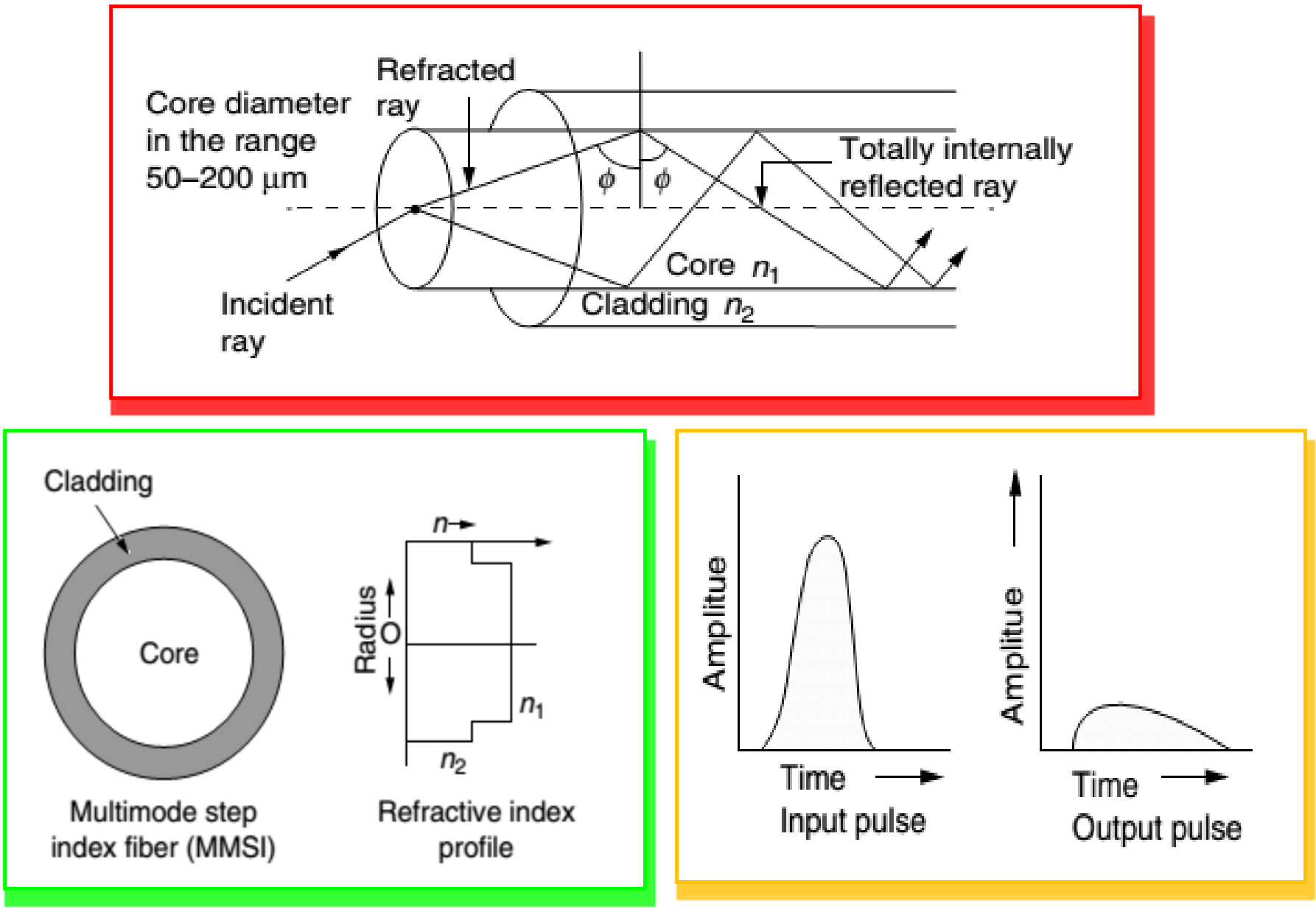


Figure 1: Multimode step index fiber with refractive index profile.

❖ **It is well known that the different modes have different path lengths causing broadening of transmission light pulse, hence dispersion losses increase and the bandwidth length product decreases.**

❖ **Step index multimode fibers usually have a huge diameter core and made without giving up mechanical strength. Multimode fibers are utilized for short distance, shorter than 200 meters, communication links or for application where power must be transmitted.**

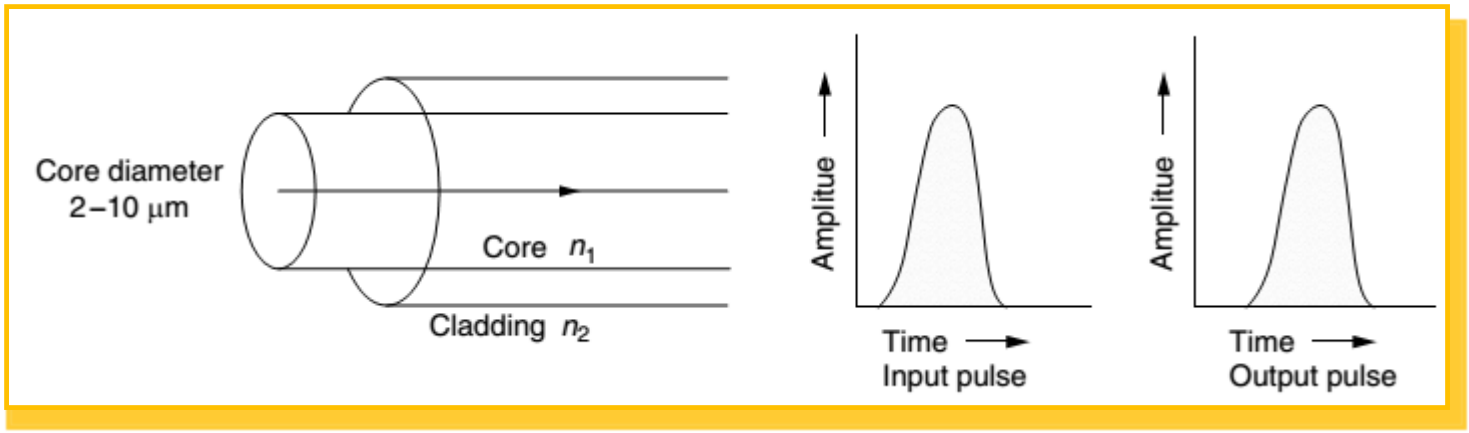
Single-Mode Step Index (SMSI) Fiber

❖ In order to reduce dispersion up to almost zero level and to boost the information carrying ability, a fiber with a core diameter less than about 10 times the wavelength of the propagating light wave is fabricated.

❖The single-mode step index fiber is a mono-mode that can carry only one mode. There is only one path of light to travel down the length. The diameter of the core of such fiber is very lower, less than about 10 times the wavelength of the propagating light, and can be 2−10 mm (see Fig. 2).

❖ If the refractive index of fiber modifies from core to cladding in steps then it is known as a step index. There is an sudden change in the index at core−cladding interface. In such type of single mode fiber the dispersion losses are much less and hence the maximum transmission bandwidth.

❖A very high quality, focused, almost monochromatic light source is applied for communication. The numerical aperture and acceptance angle of such type of fiber are small due to which coupling of light is hard. Even then because of superior transmission characteristics, these fibers are widely used for long distance communication.



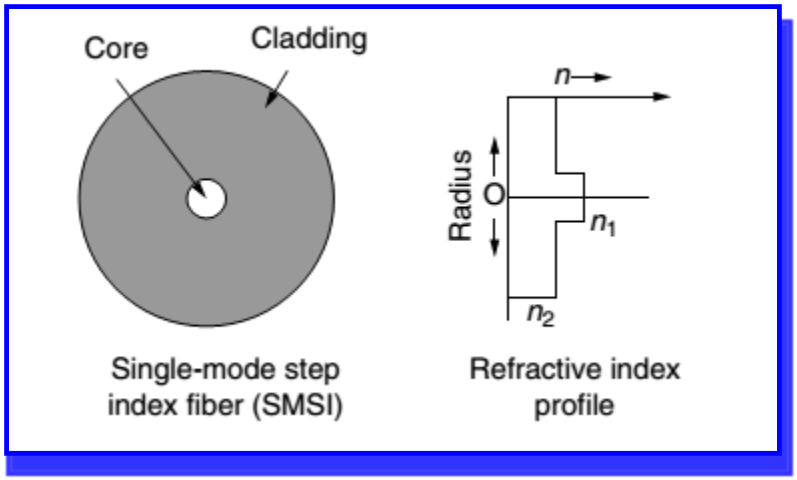
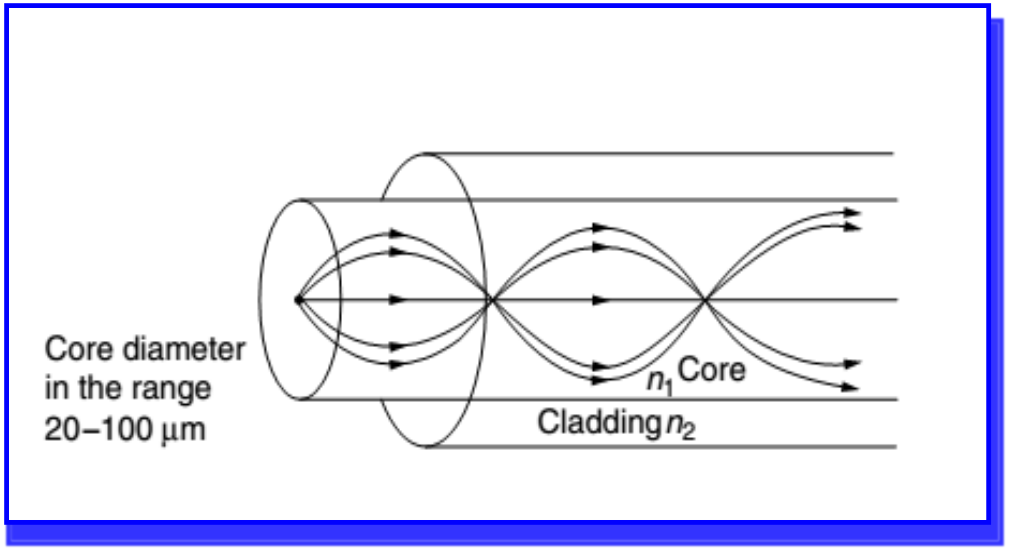


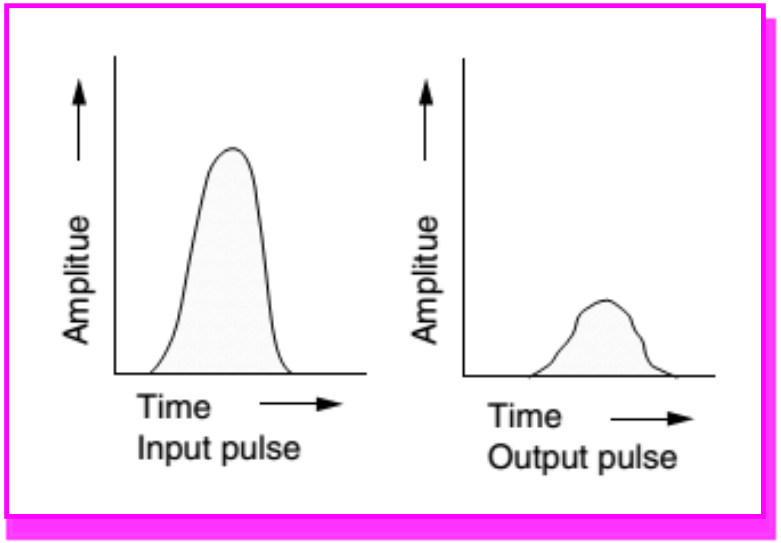
Figure 2: Single mode Step index fiber with refractive index profile

Specially single mode fibers are utilized for most communication longer than 200 meters. Single mode fibers are frequently used under sea water

Graded Index Optical Fiber

❖The graded index fiber suggests a fewer expensive method of overcoming the modal dispersion . The refractive of the core medium of this fiber is modified in such a way so as to minimize time difference between different modes and hence reduce modal dispersion. The refractive index of the core varies in parabolic form (see Fig. 3). It gradually reduces from the axis of the fiber to the core−cladding interface.





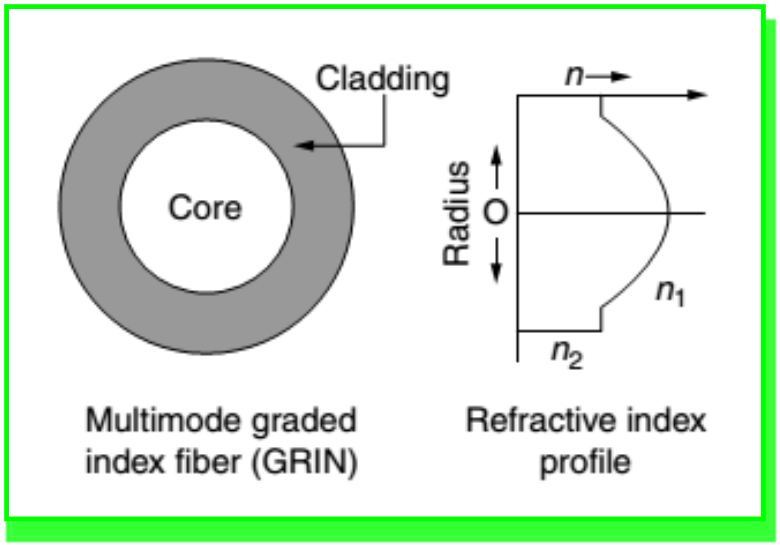


Figure 3: Graded index multimode fiber with refractive index profile

❖ **When light is incident to the fiber it propagates in continuous decreasing refractive index medium from axis to core– cladding interface and in increasing refractive index from core–cladding interface to axis of fiber. So light follows a periodic path in place of straight as in step index fiber. Here the mode having a longer path travels in rare medium with greater speed than a mode having smaller path length in denser medium. Hence, the time difference between modes is decreased which eventually decreases the modal dispersion. Such fiber can be used for moderate distances.**

Numerical Problems

1. The velocity of light in the core of a silica fiber is 2×10^8 m/s and the critical angle at the core cladding interface is 60°. Determine

(a) The refractive index of the core and cladding

(b) The numerical aperture (NA) for the fiber

Assume that the velocity of light in air is 3×10^8 m/s.

2. An optical fiber has NA 0.2 and a cladding refractive index of 1.59. Determine the acceptance angle for the fiber in water which has refractive index of 1.33.

3. In an optical fiber, the core of refractive index is 1.6 and refractive index of cladding is 1.3. Determine the critical angle also calculate the value of angle of acceptance core.

Numerical Problems

4. If the fractional difference between core and cladding refractive indices of a fiber is 0.0135 and NA is 0.2425, Determine the refractive indices of core and cladding materials.

References:

1. **Elements of Electromagnetics, 2nd edition by M N O Sadiku.**
2. **Engineering Electromagnetics by W H Hayt and J A Buck.**
3. **Optics by Ajoy Ghatak**
4. **Optics by Eugene Hecht**
5. **Engineering Physics by A K Katiyar and C K Pandey**

- **For any query/problem/suggestion contact me on whatsapp group or mail on me E-mail: arvindkumar@mgcub.ac.in**
- **Next ***** Basics of Optical Fiber and its Applications–III [dispersion attenuation in fiber, applications and numerical.

Thank you