Research Paper Physics

The Origin of Fiber Optic Systems

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ABSTRACT

To guide light in a waveguide initially metallic and non-metallic wave guides were fabricated. But they have enormous losses. So they were not suitable for telecommunication. In optical fibers light could be transmitted by the phenomenon of total internal reflection and refraction to overcome dispersion.

KEYWORDS light, total internal reflection and Optical fibers.

1.1.1: INTRODUCTION:

Tyndall discovered that through optical fibers, light could be transmitted by the phe-nomenon of total internal reflection. During 1950s, the optical fibers with large diameters of about 1 or 2 millimetre were used in endoscopes to see the inner parts of the human body[3].

Kao and Hockham published a paper about the optical fiber communication system in 1966. But the fibers produced an enormous loss of 1000 dB/km. But in the atmosphere, there is a loss of few dB/km. Immediately Kao and his fellow workers realized that these high losses were a result of impurities in the fiber material. Using a pure silica fiber these losses were reduced to 20 dB/km in 1970 by Kapron, Keck and Maurer. At this attenuation loss, repeater spacing for optical fiber links become comparable to those of copper cable systems. Thus the optical fiber communication system became an engineer-ing reality.

1.1.2: Different types of fibers

We know that the light or the optical signals are guided through the silica glass fibers by total internal reflection. A typical glass fiber consists of a central core glass (50 *m*m) sur-rounded by a cladding made of a glass of slightly lower refrac-tive index than the core's refractive index. The overall diameter of the fiber is about 125 to 200 *m*m. Cladding is necessary to provide proper light guidance i.e. to retain the light energy within the core as well as to provide high mechanical strength and safety to the core from scratches[5].

2.1.1: Discussion:

Based on the refractive index profile we have basically two types of fibers

Step index fiber : In the step index fiber, the refractive index of the core is uniform throughout and undergoes an abrupt or step change at the core cladding boundary[1]. The light rays propagating through the fiber are in the form of meridional rays which will cross the fiber axis during every reflection at the core cladding boundary and are propagating in a zig-zag manner as shown in figure 1a.

Graded index fiber : In the graded index fiber, the refractive index of the core is made to vary in the parabolic manner such that the maximum value of refractive index is at the centre of the core. The light rays propagating through it are in the form of skew rays or helical rays which will not cross the fiber axis at any time and are propagating around the fiber axis in a hel-ical (or) spiral manner as shown in figure 1b[6].

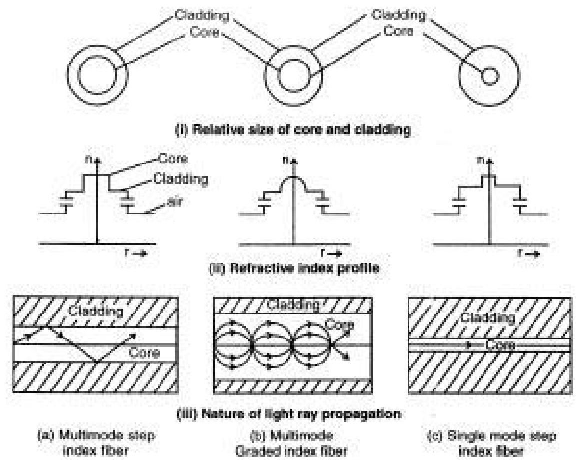

Figure 1. Different types of fibers.

Based on the number of modes propagating through the fib-er, there are multimode fibers and single mode fibers. Mode is the mathematical concept of describing the nature of propa-gation of electromagnetic waves in a waveguide. Mode means the nature of the electromagnetic field pattern (or) configura-tion along the light path inside the fiber[4]. In metallic wave-guides there are transverse electric (TE) modes for which E_z = 0 but H_z =6 0 and transverse magnetic (TM) modes for which H_z = 0 but E_z =6 0 when the propagation of micro-waves is along the *z*-axis. In optical fibers, along with TE and TM modes, there are also hybrid modes which have both axial electric and magnetic fields E_z and H_z. The hybrid modes are further classified into EH and HE modes. In EH modes, the ax-ial magnetic field H_z is relatively strong whereas in HE modes, the axial electric field E_z is relatively strong. Based on the lin-early polarized nature of light, today these modes are desig-nated as linearly polarized (LP) modes. For example LP_{01} mode corresponds to HE_{11} mode. LP_{11} mode is the combination of HE_{21}, TE_{01} and TM_{01} modes[7].

(c) ***Single mode fibers*** : In a single mode fiber, only one mode (LP_{01} mode) can propagate through the fiber (figure 1c). Normally the number of modes propagating through the fiber is proportional to its V-number where

$$\text{V-number} = \frac{2\pi}{\lambda} n_1 a \sqrt{2\Delta}$$

Here a = radius of the core of the fiber; n_1 = refractive index of the core, λ = wavelength of light propagating through the fiber; Δ = relative refractive index difference =

$$\frac{n_1^2 - n_2^2}{2n_1^2} \approx \frac{n_1 - n_2}{n_1}$$, where n_2 = refractive index of cladding.

In the case of single mode fiber, V-number 2.405. The single mode fiber has a smaller core diameter (10 *m*m) and the difference between the refractive indices of the core and the cladding is very small. Fabrication of single mode fibers is very difficult and so the fiber is expensive. Further the launching of light into single mode fibers is also difficult. Generally in the single mode fibers, the transmission loss and dispersion or degradation of the signal are very small. So the single mode fibers are very useful in long distance communication[2].

(d) ***Multimode fibers*** : Multimode fibers allow a large number of modes for the light rays traveling through it. Here the V-number is greater than 2.405. Total number of modes `N' propagating through a given multimode step index fiber is

$$N \approx \frac{V^2}{2} = 4.9\left(\frac{d n_1 \sqrt{2\Delta}}{\lambda}\right)^2$$

where ***d*** is the diameter of the core of the fiber. For a multimode graded index fiber having parabolic refractive index profile core,

$$N = \frac{V^2}{4}$$

Which is half the number supported by a multimode step index fiber.

CONCLUSION:

Generally in multimode fibers, the core diameter and the relative refractive index dif-ference are larger than in the single mode fiber. In the case of multimode graded index fiber, signal distortion is very low because of self-focusing effects. Here the light rays travel at different speeds in different paths of the fiber because of the parabolic variation of refractive index of the core. As a result, light rays near the outer edge travel faster than the light rays near the centre of the core. In effect, light rays are continuously refocused as they travel down the fiber and almost all the rays reach the exit end of the fiber at the same time due to the helical path of the light propagation. Launching of light into the fiber and fabrication of the fiber are easy. These fibers are generally used in local area networks.

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