OPTICAL FIBERS: MATERIALS & FABRICATION

By

Dr Neena Gupta
Asstt. Prof
E& EC Deptt
PEC ,Chd

Introduction

Optical fiber communication systems are more advantageous over metallic communication Systems because

- Cost effectiveness & Stable over long distances
- Available in different sizes ,refractive indices, index profiles, material and operating wavelength for different system applications.
- Can be handled in a more efficient manner than conventional electrical transmission cables without degradation of the characteristics or damage.
- The fibers and fiber cables may be terminated and connected together (jointed) without excessive practical difficulties.

Optical Fibers

An optical fiber contains three layers:

- **Core - made of highly pure glass with a high refractive index for the light to travel**
- **Cladding- a middle layer of glass with a lower refractive index**
- **And an outer polymer jacket to protect the fiber from damage.**

Optical Fiber

Types of Optical Fiber

- On the basis of Refractive Index
  - ❖Step Index Fiber
  - ❖Graded Index Fiber
- On the basis of Modes
  - ❖Single mode Fiber
  - ❖Multimode Fiber

Optical Fiber

Points to be Discussed

- Various materials used for making fibers
- Various methods of preparation for silica based optical fibers (both liquid and vapour phase) with characteristics suitable for telecommunication applications.
- Developments in the area of fiber about polymeric fibers for lower bandwidth, very short haul applications.
- The requirements for optical fiber cabling in relation to fiber protection, and
- Finally, cable design strategies and their influence upon typical fiber cable construction.

Fiber Materials

In selecting materials for optical fibers, a number of requirements must be satisfied:

- It must be possible to make long, thin, flexible fibers from the material.
- The material must be transparent at a particular wavelength for the fiber to guide light efficiently.
- Physically compatible materials having slightly different indices for the core and cladding must be available.

Materials satisfying these requirements are glasses and plastics

- The majority of fibers are made of glass consisting either of silica (SiO_2) or a silicate.
- The variety of available glass fibers ranges from high-loss glass fibers with large cores used for short transmission distances to very transparent (low loss) fibers employed in long haul applications.
- Plastic fibers are less widely used because of their substantially higher attenuation than glass fibers.
- The main use of plastic fibers is in short distance applications and in abusive environments, where the greater mechanical strength of plastic fibers offers an advantage over the use of glass fibers.

Glass Fibers

- Glass is made by fusing mixtures of metallic oxides, sulphides or selenides. The resulting material is a randomly connected molecular network rather than a well defined orderly structure as found in crystalline materials.

- The largest category of optically transparent glasses from which optical fibers are made consists of the oxide glasses. Of these, the most common is silica, which has a refractive index of 1.458 at 850 nm.

- To produce two similar materials having slightly different indices of refraction for the core and cladding, either fluorine or various oxides (referred to as dopants) such as B_2O_3, GeO_2 or P_2O_5 are added to the silica. The addition of GeO_2 or P_2O_5 increases the refractive index whereas doping the silica with fluorine or B_2O_3 decreases it.

Since the cladding must have a lower index than the core, examples of fiber composition are:

1. GeO_2 – SiO_2 core; SiO_2 cladding
2. P_2O_5 – SiO_2 core; SiO_2 cladding
3. SiO_2 core; B_2O_3 – SiO_2 cladding
4. GeO_2 – B_2O_3 – SiO_2 core; B_2O_3 – SiO_2 cladding

Here the notation GeO_2 – SiO_2, e.g., denotes a GeO_2 doped silica glass.

The principle raw material for silica is sand. Glass composed of pure silica is called silica glass, fused silica, or vitreous silica. Some of its desirable properties are:

- A resistance to deformation at temperatures as high as 1000°C.
- A high resistance to breakage from thermal shock because of its low thermal expansion.
- Good chemical durability, and high transparency in both the visible and infrared regions of interest to fiber optic communication systems.
- Its high melting temperature is a disadvantage if the glass is prepared from the molten state. This problem is partially avoided when using vapour deposition techniques.

1.48
1.46
1.44
Refractive index
GeO2
P2O5
B2O3
F
0
5
10
15
20
Dopant addition (mol %)

Halide Glass Fiber

MATERIAL	MOLECULAR %age
ZrF_4	54
BaF_2	20
LaF_3	4.5
AlF_3	3.5
NaF	18

- **Fluoride glasses have extremely low transmission losses at mid infrared wavelengths (0.2 to 8 μm) with the lowest loss being around 2.55 μm.**
- **Heavy metal fluoride glass, which uses ZrF_4 as a major component and glass network former.**
- **Moderate resistance to crystallization by adding more constituents such as ZBLAN (after its elements ZrF_4, BaF_2, LaF_3, AlF_3 and NaF), as shown in table.This material forms the core of the glass fiber.**
- **To make a lower refractive index glass, one partially replaces ZrF_4 by HaF_4 to get a ZHBLAN cladding.**

Although these glasses potentially offer intrinsic minimum losses of 0.01 to 0.001 dB/Km, fabricating long lengths of these fibers is difficult because

- Ultra pure materials must be used to reach this low loss level.
- Fluoride glass is prone to devitrification(becoming opaque and crystalline).
- Fiber making techniques have to take this into account to avoid the formation of micro crystalloids, which have a drastic effect on scattering losses.

Active Glass Fibers

- Incorporating rare earth elements (atomic numbers 57 to 71) into a glass give the resulting material new optical and magnetic properties. These new properties allow the material to perform amplification, attenuation, and phase retardation on the light passing through it. Doping can be done both for silica and halide glasses.

- Two commonly used materials for fiber lasers are erbium and neodymium. The ionic concentrations of the rare earth elements are low to avoid clustering affects.

- By, examining the absorption and fluorescence spectra of these materials, one can use an optical source which emits at an absorption wavelength to excite electrons to higher energy levels in the rare earth dopants. When these excited electrons drop to lower energy levels, they emit light in a narrow optical spectrum at the fluorescence wavelength.

Plastic Clad Glass Fibers

- Optical fibers constructed with glass cores and glass claddings are very important for long distance applications where the very low losses achievable in these fibers are needed.
- For short distance applications (upto several 100 m), where higher losses are tolerable, the less expensive plastic clad silica fibers can be used.
- These fibers are composed of silica cores with the lower refractive index cladding being a polymer (plastic material). These fibers are often referred to as PCS (Plastic Clad Silica Fibers).
- A common material source for the silica core is selected high purity natural quartz. A common cladding material is a silicone raisin having a refractive index of 1.405 at 850 nm.

- Silicon raisin is also frequently used as a protective coating for other type of fibers. Another popular plastic cladding material is perfluoronated ethylene propylene (Teflon FEP). This low refractive index, 1.338, of this material results in fibers with potentially large numerical apertures.

- Plastic claddings are only used for step index fibers. The core diameters are larger (150 to 600 μm) than the standard 50 μm diameter core of all glass graded index fibers, and the larger difference in the core and cladding indices result in a high numerical aperture.

- This allows low cost large area light sources to be used for coupling optical power into these fibers, thereby yielding comparatively inexpensive but lower quality systems which are quite satisfactory for many applications.

PLASTIC FIBERS

- All plastic multimode step index fibers are good candidates for fairly short (up to about 100 m) and low cost links.
- Although they exhibit considerably greater signal attenuations than glass fibers, the toughness and durability of plastic allow these fibers to be handled without special care.
- The high refractive index differences that can be achieved between the core and the cladding materials yield numerical apertures as high as 0.6 and large acceptance angles of up to 70^0.
- In addition, the mechanical flexibility of plastic allows these fibers to have large cores, but typical diameters ranging from 110 – 1400 μm.

- These factors permit the use of inexpensive large area light emitting diodes which in conjunction the less expensive glass fibers, make an economically attractive system. Examples of plastic fiber constructions are:

- A polystyrene core ($n1 = 1.6$) and a methyl methacrylate cladding ($n2 = 1.49$) to give an NA of 0.6.

- A polymethyl methacrylate core ($n1 = 1.49$) and a cladding made of its copolymer to give an NA of 0.5.

FIBER FABRICATION

Two basic techniques are used in the fabrication of all glass optical wave guides. These are the

- Direct Melt Methods
- Vapour Phase Oxidation Process

Precision feed mechanism
Clamp
Preform
Drawing furnace
Bare fiber
Fiber thickness monitor
Elastic coating applicator
Coated fiber
Takeup drum

- The direct melt methods follows traditional glass making procedures in that optical fibers are made directly from the molten state of purified components of silicate glasses.

- In vapour phase oxidation process, highly pure vapours of metal halides (e.g., $SiCl_4$ and $GeCl_4$) react with oxygen to form a white powder of SiO_2 particles.

- The particles are then collected on the surface of a bulk glass by one of 4 different commonly used processes and are sintered (transformed to a homogeneous glass mask by heating without melting) by one of a variety of techniques to form a clear glass rod or tube (depending on the process).

- This rod or tube is called a preform. It is typically around 10 to 25 mm in diameter and 60 to 120 cm long. Fibers are made from perform by using the equipment shown in the figure 2.

- The perform is precision-fed into a circular heater called the drawing furnace. Here the preform end is softened to the point where it can be drawn into a very thin filament, which becomes the optical fiber.

- The turning speed of the take up drum at the bottom of the draw tower determines how fast the fiber is drawn. This, in turn, will determine the thickness of the fiber, so that a precise rotation rate must be maintained.

- An optical fiber thickness monitor is used in a feedback loop for this speed regulation.

- To protect the bare glass fiber from external contaminants such as dust and water vapour, an elastic coating is applied to the fiber immediately after it is drawn.

String materials

Outside Vapour Phase Oxidation

- The first fiber to have a loss of less than 20 dB/Km was made at the Corning Glass Works by the Outside Vapour Phase Oxidation (OVPO process).
- First, a layer of SiO_2 particles called a suite is deposited from a burner onto a rotating graphite or ceramic mandrel. The glass suite adheres to this bait rod and, layer by layer ≈200 layers , a cylindrical, porous glass perform is built up.
- Refractive index modification is achieved through the formation of dopants from non-silica materials (TiO_2, GeO_2, P_2O_5, Al_2O_3 etc.).
- By properly controlling the constituents of the metal halide vapour stream during the deposition process, the glass compositions and dimensions desired for the core and cladding can be incorporated into the perform. Either step or graded index performs can thus be made.

O_2 + metal halide vapors
Burner
Glass particles
Bait rod (Mandrel)
Soot preform
(a) Soot deposition
Core
Cladding
(b) Soot preform cross section
Soot preform
Furnace
Glass preform
(c) Preform sintering
Glass preform
Furnace
Fiber
(d) Fiber drawing

METAL HALIDE VAPORS IN OXYGEN-HYDROGEN FLAME
BURNER
PARTICLES OF SOOT
ROTATING
MANDREL
MANDREL TRANVERSES BACK AND FORTH PAST BURNER

- When the deposition process is completed, the mandrel is removed and the porous tube is then vitrified in a dry atmosphere at a high temperature (above 1400^0 C) to a clear glass preform.

- This clear perform is subsequently mounted in a fiber drawing tower and made into a fiber. The central hole in the tube preform collapses during this drawing process. Several Km $\approx$ 10 Km of 120 μm core diameter fiber have been produced.

- Bandwidth x Length = 3 GHz.Km can be produced. Losses $\approx$1 dB/Km and 1.8 dB/Km at 1.2 and 1.55 μm are possible.

Vapour Phase Axial Deposition

- Another OVPO type process is the Vapour Phase Axial Deposition method (VAD).
- In this method the SiO_2 particles are formed in the same way as the OVPO process. A porous preform is grown in the axial direction by moving the rod upward.
- The rod is also continuously rotated to maintain cylindrical symmetry of the particle deposition.
- As the porous preform moves upward, it is transformed into a solid, transparent rod preformed by zone melting (heating a narrow localized zone).
- The resultant preform can then be drawn into a fiber by heating it in another furnace.

MOTOR
ROTATING SEED ROD
SINTERED GLASS
CARBON FURNACE
POUROUS PREFORM
REACTION CHAMBER
PARTICLES OF SOOT
REACTANTS

Both step and graded index fibers in either multimode or single mode varieties can be made by the VAD method. The advantages of the VAD method are:

- The preform has no central hole as occurs in the OVPO process.
- The preform can be fabricated in continuous lengths which can effect process costs and product yields.
- The fact that the deposition chamber and the process melting ring heater are tightly connected to each other in the same enclosure allows the achievement of a clean environment.
- The fiber of length 100 Km can be drawn. Attenuation of 0.7 to 2 dB/Km at a wavelength 1.181 μm has been reported.

Modified Chemical Vapour Deposition

- The modified chemical vapour deposition (MCVD) process was pioneered at Bell labs and widely adopted elsewhere to produce very low loss graded index fibers.
- The glass vapour particles arising from the reaction of the constituent metal halide gases and oxygen flow through the inside of a revolving silica tube.
- As the silica particles are deposited, they are sintered to a clear glass layer by an oxy-hydrogen torch which travels back and forth along the tube.

- When the desired thickness of glass has been deposited, the vapour flow is shut off and the tube is heated strongly to cause it to collapse into a solid rod preformed.

- The fiber that is subsequently drawn from this preformed rod will have a core that consists of the vapour deposited material and the cladding consisting of the original silica tube.

- Loss: Approximately 0.2 dB/Km at wavelength 1.55 µm.
- Approximately 0.34 dB/Km for multimode fiber at wavelength 1.55 µm.
- Large scale batch production can give 30,000 Km of 50 µm core graded index fiber at wavelength 0.825 and 1.3 µm.
- Normally 100 to 200 Km of fiber is produced.

Reactants
(metal halides + O_2)
Soot formation
Exhaust
Bait tube
Sintered glass
Soot deposit
Traversing burner

Plasma Activated Chemical Vapour Deposition

- Scientists at Philips Research invented the plasma activated chemical vapour deposition process (PCVD). The PCVD method is similar to the MCVD process in that deposition occurs within a silica tube.However, non-isothermal microwave plasma operating at low pressure initiates the chemical reaction.

- With the silica tube held at temperatures in the range of 1,000 to 1,200^0 C to reduce mechanical stresses in the growing glass films, a moving microwave resonators operating at 2.45 GHz generates a plasma inside the tube to activate the chemical reaction.

- This process deposits clear glass material directly on the tube wall; there is no soot formation. Thus, no sintering is required. When one has deposited the required glass thickness, the tube is collapsed into a perform just as in the MCVD case. Over 200 Km of fiber can be produced.

- Losses are: 0.3 dB/Km at 1.55 μm.

Fused
silica tube
Reactants
($SiCl_4$ + O_2 + dopants)
Plasma
Exhaust
Glass layers
Moving microwave resonator

TYPES OF OPTICAL FIBERS

- It is necessary to consider the various optical fibers currently available.
- It is interesting to note, however, that although the high performance values quoted are for fibers produced and tested in the lab, the performance characteristics of commercially available fibers in many cases are now very close to these values indicating improvements made over recent years in the fiber materials preparation technologies.
- In particular, high performance silica based fibers for operation in 3 major wavelength regions (0.8 to 0.9, 1.3 & 1.55 μm) are now widely commercially available.

- Moreover, complex refractive index profile single mode fibers, including dispersion modified fibers and polarization maintaining fibers are also commercially available and in the former case are starting to find system application within communications.

- Another relatively new area of commercial fiber development is concerned with mid infrared range (2 to 5 μm) often employing heavy fluoride glass technology. However, the fiber products that exist for this region tend to be multimode with relatively high losses and hence at present are only appropriate for specialized applications.

Multimode Step Index Fibers

- Multimode step index fibers may be fabricated from either multi-component glass compounds or doped silica. These fibers can have reasonably large core diameters and large NAs to facilitate efficient coupling to incoherent light sources such as LEDs.
- The performance characteristics of this fiber type may vary considerably depending on the material used and the method of preparation.
- The doped silica fibers exhibit the best performance. Multi-component glass and doped silica fibers are often referred to as multi-component glass/glass (Glass clad glass) and silica/silica respectively.
- Although the glass clad glass terminology is sometimes used vaguely to denote both types.

Typical structure for a glass multimode step index fiber

Performance Characteristics

- **ATTENUATION:**

  2.6 to 50 dB/Km at wavelength of 0.85 µm, limited by absorption or scattering. The wide variation in attenuation is due to the large difference both within and between the two overall preparation methods (melting and deposition).

- **BANDWIDTH APPLICATIONS:**

  6 to 50 MHz.Km. these fibers are best suited for short haul, limited bandwidth and relatively low cost applications.

Performance Characteristics

- **ATTENUATION : 2.6 to 50 dB/Km at wavelength of 0.85 µm, limited by absorption or scattering.**

  The wide variation in attenuation is due to the large difference both within and between the two overall preparation methods (melting and deposition).

- **BANDWIDTH APPLICATIONS: 6 to 50 MHz.Km.**

  These fibers are best suited for short haul, limited bandwidth and relatively low cost applications.

Multimode Graded Index Fibers

- These multimode fibers which have a graded index profile may also be fabricated using multi-component glasses or doped silica. However, they tend to be manufactured from materials with higher purities than the majority of multimode step index fibers in order to reduce fiber losses.
- The performance characteristics of these fibers are therefore generally better than multimode step index fibers due to index grading and lower attenuation.
- These fibers tend to have smaller core diameters, although the overall diameter including the buffer jacket is usually about the same.

Typical structure for a glass multimode graded index fiber

Structure

Core diameter:	**30 to 100 µm.**
Cladding diameter:	**100 to 150 µm.**
Buffer Jacket diameter:	**250 to 1,000 µm**
Numerical Aperture:	**0.2 to 0.3**

Although the above general parameters encompass most of th commonly available multimode graded index fibers, in particular the following major groups have now emerged:

- 50 μm/125 μm (core/cladding) diameter fibers with typical NA between 0.2 & 0.24. These fibers were originally developed and standardized by the CCITT for telecommunication applications at wavelengths of 0.85 and 1.3 μm. But now they are mainly utilized within data links and LANs.

- 62.5 μm/125 μm (core/cladding) diameter fibers with optical NA between 0.26 and 0.29. Although these fibers were developed for longer distance, subscriber loop applications at operating wavelengths of 0.85 and 1.3 μm, they are mainly used with LANs.

- 85 μm/125 μm (core cladding) diameter fibers with typical NA 0.26 and 0.30. These fibers were developed for operation at wavelengths of 0.85 and 1.3 μm in low cost, short distance applications.

- They can, however, be utilized at the 1.3 µm operating wavelength and have. Therefore. Also found application within LANs.

- 100 µm/125 µm (core/cladding) diameter fibers with NA of 0.29. These fibers were developed to provide high coupling efficiency to LEDs at a wavelength of 0.85 µm in low cost, short distance applications.

- They can, however, be utilized at the 1.3 µm operating wavelength and have, therefore, also found application within LANs.

Performance Characteristics

- **ATTENUATION: 2 to 10 dB/Km at a wavelength of 0.85 µm with generally a scattering limit. Average losses of around 0.4 and 0.25 dB/Km can be obtained a wavelengths of 1.3 and 1.55 µm respectively.**

- **BANDWIDTH APLICATIONS: 300 MHz.Km to 300 GHz.Km.**

  These fibers are best suited for medium haul, medium to high bandwidth applications using incoherent and coherent multimode sources (i.e., LEDs and injection lasers respectively).

Single Mode Fibers

- Single mode fibers can have either a step index or graded index profile. The benefits of using graded index profile are to provide dispersion modified single mode fibers.
- The more sophisticated single mode fiber structures used to produce polarization maintaining fibers make these fibers quite expensive at present and thus they are not generally utilized within optical fiber communication systems. Therefore, at present, commercially available single mode fibers are still usually step index.
- They are high quality fibers for wideband, long haul transmission and are generally fabricated from doped silica (silica clad silica) in order to reduce attenuation.
- Although single mode fibers have small core diameters to allow single mode propagation, the cladding diameter must be at least 10 times the core diameter to avoid losses from evanescent field.
- Hence with a buffer jacket to provide protection and strength, single mode fibers have similar overall diameters to multimode fibers.

Typical structure for a silica single mode step index fiber

Structure

Core diameter:	5 to 10 µm, typical around 8.5 µm
Cladding diameter:	generally 125 µm
Buffer Jacket diameter:	250 to 1,000 µm
Numerical Aperture:	0.08 to 0.15, usually around 0.10

Performance Characteristics

- **ATTENUATION: 2 to 5 dB/Km with a scattering limit of around 1 dB/Km at a wavelength of 0.85 µm. In addition, average losses of 0.35 and 0.21 dB/Km at wavelengths of 1.3 and 1.55 µm can be obtained in a manufacturing environment.**
- **BANDWIDTH: Greater than 500 MHz.Km.**
- **In theory, the bandwidth is limited by waveguide and material dispersion to approximately 40 GHz.Km at a wavelength of 0.85 µm.**
- **However, practical bandwidths in excess of 10 GHz.Km are obtained at a wavelength of 1.3 µm.**
- **APPLICATIONS: These fibers are ideally suited for high bandwidth, very long haul applications using single mode injection laser sources.**

Plastic Clad Fibers

- Plastic clad fibers are multimode and have either a step index or a graded index profile.
- They have a plastic cladding (often a silicone rubber) and a glass core which is frequently silica (i.e., plastic and silica PCS fibers).
- The PCS fibers exhibit lower radiation-induced losses than silica clad silica fibers and, therefore, have an improved performance in certain environments.
- Plastic clad fibers are generally slightly cheaper than the corresponding glass fibers, but usually have more limited performance characteristics.

Typical structure for a plastic clad silica multimode step index fiber

Structure and Performance Characteristics

Structure

Core diameter:	**Step Index:**	**100 to 500 µm**
	Graded Index:	**50 to 100 µm**
Cladding diameter:	**Step Index:**	**300 to 800 µm**
	Graded Index:	**125 to 150 µm**
Buffer Jacket diameter:	**Step Index:**	**500 to 1,000 µm**
	Graded Index:	**250 to 1,000 µm**
Numerical Aperture:	**Step Index:**	**0.2 to 0.5**
	Graded Index:	**0.2 to 0.3**

Performance Characteristics

ATTENUATION:	**Step Index:**	**5 to 50 dB/Km**
	Graded Index:	**4 to 15 dB/Km**

All Plastic Fibers

- All plastic fibers or polymeric fibers are exclusively of the multimode step index type with large core and cladding diameters. Hence there is a reduced requirement for a buffer jacket for fiber protection and strengthening.

- These fibers are usually cheaper to produce and easier to handle than the corresponding silica based glass variety. However, their performance (especially for optical transmission in the infrared) is restricted, giving them limited use in communication applications.

- All plastic fibers, however, generally have large NA, which allow easier coupling of light into the fiber from a multimode source.

- Early plastic fibers fabricated with a polymethyl methacrylate (PMMA) and a fluorinated acrylic cladding exhibited losses around 500 dB/Km.

- Subsequently, a continuous casting process was developed for PMMA and losses as low as 110 dB/Km were achieved in the visible wavelength region the loss mechanisms in PMMA and polystyrene core fibers are similar to those in glass fibers.

Typical structure for an all plastic fiber

Structure and Performance Characteristics

Structure

Core diameter:	200 to 600 µm
Cladding diameter:	450 to 1,000 µm
Numerical Aperture:	0.5 to 0.6

Performance Characteristics

- ATTENUATION: 50 to 1,000 dB/Km at a wavelength of 0.65 µm
- BANDWIDTH: This is not usually specified as transmission is generally limited to only tens of meters.
- APPLICATIONS: these fibers can only be used for very short haul (i.e. in house) low cost links. However, fiber coupling and termination are relatively easy and do not require sophisticated techniques.

Many Optical Fibers In The Market

- There are several types of fibers based both on the transmission modes and the refractive index profile. It is important to know that the design of an optical fiber depends on the needs it is supposed to meet.

- Key parameters like *attenuation*, *bandwidth*, *dispersion*, and *tensile strength* are the most considered.

- Also the protection of the fiber from external factors like humidity, heat, cold, and water is contemplated. That's why plastic sheaths where the fiber is enclosed in, are used. The whole material comprising the single fiber or bundle of fibers, the sheaths, and the jacket, is usually referred as a *fiber cable*.

- Obviously these cables also must satisfy requirements such as high flexibility, resistance to kinks and crushing, and light weight.

OPTICAL FIBER CABLES

- They can be safely installed and maintained in all the environments (e.g. underground ducts) in which metallic conductors are normally placed. Therefore, when optical fibers are to be installed in a working environment, their mechanical properties are of prime importance.

- In this respect, the unprotected optical fiber has several disadvantages with regard to its strength and durability. Bare glass fibers are brittle and have small cross sectional areas which make them very susceptible to damage when employing normal transmission line handling procedures.

- It is, therefore, necessary to cover the fibers to improve their tensile strength and to protect them against external influences. This is usually achieved by surrounding the fiber with a series of protective layers, which is referred to as coating and cabling.

- The initial coating of plastic with high elastic modulus is applied directly to the fiber cladding. It is then necessary to incorporate the coated and buffered fiber into an optical cable to increase its resistance to mechanical strain and stress as well as adverse environmental conditions.

The functions of the optical cable may be summarized into four main areas. These are

- **Fiber Protection:** The major function of the optical cable is to protect against fiber damage and breakage both during installation and throughout the life of the fiber.

- **Stability of the fiber transmission characteristics:** the cabled fiber must have good stable transmission characteristics which are comparable with the uncabled fiber. Increases in optical attenuation due to cabling are quite usual and must be minimized within the cable design.

- **Cable strength:** optical cables must have similar mechanical properties to electric transmission cables in order that they may be handled in the same manner. These mechanical properties include tension, torsion, compression, bending, squeezing and vibration. Hence the cable strength may be improved by incorporating a suitable strength member and by giving the cable a properly designed thick outer sheath.

- **Identification and jointing of the fibers: This is specially important for cables including a large number of optical fibers. If the fibers are arranged in a suitable geometry, it may be possible to use multiple jointing techniques rather than jointing each fiber individually.**

- **In order to consider the cabling requirements for fibers with regard to (1) & (2), it is necessary to discuss the fiber strength and durability as well as any possible sources of degradation of the fiber transmission characteristics, which are likely to occur due to cabling.**

CABLING

- The design of optical fiber cables must take account of the constraints discussed in previous section. In particular, the cable must be designed so that the strain on the fiber in the cable does not exceed 0.2%.

- Alternatively, it is suggested that the permanent strain on the fiber should be less than 0.1%. In practice, these constraints may be overcome in various ways, which are to some extent, dependent on the cable's application.

- Nevertheless, cable design may generally be separated into a number of major considerations. These can be summarized into the categories of fiber buffering, cable structural and strength members, and cable sheath and water barrier.

- An approach commercialized by AT & T is the loose fiber bundle design . In this, cable up to 12 fibers are assembled into a bundle, which is identified with a colour-coded binder. Several of the fiber bundles are then placed inside a core tube.

- This design does not employ a central strength member but relies upon an armored design using a reinforced sheath with a polyethylene inner jacket.

- Moreover, the core construction provides for compact, low weight cables with diameters of only 10 mm 13 mm for fiber counts up to 50 and 96 fibers respectively.

Telecommunication Fiber Links

- An important application of fiber –optic light wave system is for telecommunication. Indeed, it is this application that started the optical fiber communications and has propelled it by demanding higher and higher capacity light-wave systems.

- Terrestrial light-wave systems became available commercially beginning in 1979. The first generation operated near 0.85 μm and used multimode graded-index fiber as the transmission medium.

- A commercial light-wave system, operating at 90 M b/s with a repeater spacing about 12 km, realized a BL product of nearly 1 (Gb/s)-km.

- The operating wavelength moved to 1.3 μm in second-generation lightwave systems to take advantage of low loss and low dispersion near this wavelength.

- Many commercial systems operate near this wavelength. The BL product of 1.3 μm lightwave systems is limited to about 100(Gb/s)-km when multimode semiconductor lasers are used inside the transmitter.

- A commercial 1.3m lightwave systems in 1987 provided data transmission at 1.7 Gb/s with a repeater spacing of about 45 km.

- The third-generation light wave systems became available commercially in 1990. the operate near 1.5 m at bit rates I excess of 2 G b/s(typically at 2.88 Gb/s because of SONET specifications).

- Undersea transmission systems are used for innterconnection communication.

- Reliability is of major concern for such systems , as repair are expensive. Generally, undersea systems are designed for a 25 years service life with most three failure during operation.

- The first fiber-optics undersea transmission system was installed in 1988 in the Atlantic Ocean (TAT-98). It operates near 1.3μm at a bit rate of 295 Mb/s with repeater spacing of about 40 km.

- Several other transatlantic transmission system (TAT-9 to TAT-12) have been designed to meet the traffic demands.

- The TAT-9 system is designed to operate near 1.55 μm (a third generation system) at a bit rate of 590 Mb/s with a repeater spacing of about 80 km; it would operate at a bit rate in excess of 1Gb/s and are expected to become operational by 1994.

- The TAT-12 system is planned for 1995 and would operate at a bit rate of 2.4 Gb/s. Furthermore, it would make use of optical amplifiers rather than electronic regenerators.

- Similar lightwave systems are being planned for transmission across the Pacific ocean.
- The fourth and fifth generation of fiber-optic telecommunication systems are in the development stage.
- The fourth generation makes use of the coherent-detection techniques and is particularly suitable for transmission of multiple digital channels across the same fiber by using frequency division multiplexing.
- The fifth generation makes use of the nonlinear effects in optical fibers and uses optical solutions for data transmission.

- LTK Cables offers simplex and duplex cable designs for voice, data, image and video
  transmission equipment interconnection. Construction are rugged,
  flexible, easy handling, stripping and termination. They optimize for ease of cable assemblies and utilize as jumper for intra-building distribution wiring applications.

LTK Cables has developed up to 12 tight-buffered fibers, both light and heavy duties, distribution cables. Construction are designed for voice, data, image and video super-high-way-transmission.

Distribution cables contain several tight buffered fibers bundled under the same jacket, with aramid yarn reinforcement. These cables are small in size, and typically used in intra-building backbone cabling, horizontal cabling and computer
room wiring that requires OFNR rating (UL1666).

- LTK Cables has developed both light and heavy duties BREAKOUT optical cables that are typically designed for voice, data, image and video super-high-way-transmission. BREAKOUT Cables are made of several simplex cables bundled together by SZ stranding, which provide strong, rugged support and OFNR rated (UL1666) for riser applications.

- Applications extend from intra-building backbone cabling, horizontal and computer room wiring.

Plastic Optical Fiber Cable

PRODUCT DESCRIPTION

- For short distance (5m) and low speed (6Mb/s) communication
- Immune to electromagnetic noise
- Links with 650nm plastic-packaged LED's and silicon photodiodes for transmitter and receiver
- Lower total system cost over glass fibers series

Plants of Optical Fiber

Ceyba	Core optical transmission systems. (Formerly known as Solinet Systems)
Corning	Optical fiber, cable and photonic products
Crstal/Fiber A/S	Designs, manufactures and markets photonic crystal fibers
Cypress industries	Fiber optic and copper cables, connector products, and custom manufacturing

Plants of Optical Fiber

SKOE,Inc	Fiber optic components, modules and sub-systems
Suncall	Components for fiber optic networks
Samsung Fiberoptic	Optical solutions including optical fiber, cables, and optical components
S& L Telekommunications	Fiber optic products

Latest Discoveries

Optical Fibers Found in Deep-Sea Sponges

- MURRAY HILL, N.J., August 21 -- Scientists from Lucent Technologies' Bell Labs have found that a deep-sea sponge contains optical fiber that is remarkably similar to the optical fiber found in today's state-of-the-art telecommunications networks.
- The deep-sea sponge's glass fiber, designed through the course of evolution, may possess certain technological advantages over industrial optical fiber, the scientists report in today's issue of the journal Nature.
- "We believe this novel biological opticl fiber may shed light on new bio-inspired processes that may lead to better fiber optic materials and networks," said Joanna Aizenberg, the Bell Labs materials scientist who led the research team. "Mother Nature's ability to perfect materials is amazing, and the more we study biological organisms, the more we realize how much we can learn from them."

The discovery of marine optical fiber is the latest Bell Labs contribution in the emerging field of science known as biomimetics, which takes engineering principles from the natural world and applies them to manmade materials and technologies.

Holey Fiber Supports Megawatt Pulses

- Scientists at Corning Inc. in Corning, N.Y., have developed a hollow-core photonic bandgap fiber that supports ultrashort pulses of infrared radiation with peak powers more than 100 times greater than those tolerated by conventional optical fiber. Such fibers promise applications across a variety of fields, including telecommunications.

- The researchers produced the fiber by the stack-and-draw method, bundling capillaries to create a preform that they draw into a fiber while monitoring the exterior diameter of the pulled product.

- The fiber in cross section features a 12.7-µm-diameter central hole surrounded by eight rings of hexagonal airholes with a pitch of 4.7 µm, a structure that offers a transmission window from 1395 to 1510 nm and an attenuation of 13 dB/km at 1500 nm.

Origin of 'Fiber Fuse' Is Revealed

- In the argot of fiber optics engineers, a "fiber fuse" occurs when a fiber, overloaded with optical power, fails catastrophically.
- In a fiber fuse, a brilliant, highly visible intrafiber burn propagates backward from the original damage site toward the optical source at speeds that can reach several meters per second.
- Measurement of the burn's color temperature indicates that the fiber core reaches temperatures as high as 5400 K, sufficient to vaporize the glass.

OFS multimode fiber coating gives lower attenuation

- Enhanced coating reduces attenuation, enables outstanding performance at extreme temperatures

- 52nd IWCS / Focus - PHILADELPHIA, Nov. 19, 2003- OFS, designer, manufacturer, and supplier of leading edge fiber optic products, today introduced Flex-10™ coating, an enhanced multimode fiber coating that results in lower attenuation, especially in tight-buffer cable; improved cable performance in extreme temperature environments; and excellent mechanical stripping.

- Flex-10 coating will be used with all OFS multimode products, including the company's line of LaserWave™ fibers designed for 1 Gb/s and 10 Gb/s premises networks, as well as OFS laser-optimized 62.5um fibers.

Thank You