An Insight Into OPTICAL COMMUNICATIONS SYSTEM

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In the wake of accelerated developments in the field of technology new systems of communications are born every few years. From the days of Marconi when the radio waves were trapped, to the current days when solidstate devices and miniaturisation is the order of the day, technicians, scientists and engineers are constantly endeavouring to create new vistas of technology. The reason for this is not one but a combination of many, and most of these have a bearing on the technological infrastructure, trade potential and economy of a country.

Whenever an idea is born, there is an effort to give it a practical form. One such case is of using modulated light guided in glass fiber, used as a media for broad-band communications. The idea initially took shape as an offshoot of analysis of propagation in dielectric guides. The initial experiments showed that it was possible to have a classical waveguide propagation in glass fiber with suitable refractive indices and dimensions.

In this article we will discuss the optical communication system (OCS) which is presently at the threshold of commercial exploitation in the USA and the UK.

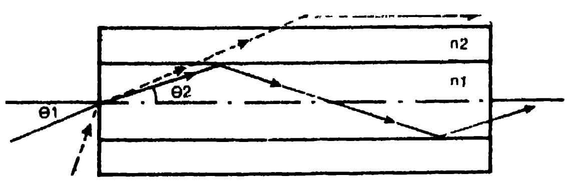

Fig 1. Optical waveguide ray path

Communication system requirements

There are a few basic requirements of a communication system. These are:

1. To convert sound and telegraph signals or both into electrical signals.
2. To convert electrical signals into higher frequency signals, for ease of carrying through the media proposed.
3. A suitable media with the least possible attenuation.
4. Repeatering, in case the transmission losses are high or distances are long.
5. Detectors to convert the signals into the basic form of intelligence at the far end.

These requirements are equally applicable to the OCS as well. The OCS requires transducers to convert the electrical signals into modulated light. It also requires a propagation media, which is glass fiber strand in this case, and a detector to convert light signals back into the electrical signal at the far end. Repeaters may also be necessary when propagation losses are excessive.

System configuration

The building blocks of an OCS are given in Fig. 2. All systems have essentially the same configuration. Where they may differ would be in the nature of the dotted blocks: In a simpler system the blocks shown in dotted lines may not be present at all.

The transmitting source in each case is a laser and receiving device a photodetector. Generally amplitude modulation is used. But where power involved is large, pulse position modulation or pulse code modulation may be used. Where pulse code modulation is used, additional circuits in the form of amplifiers, reshaping and retiming networks would be necessary.

The repeater amplifier is a critical sub-system. Although conceptually it is simple, its construction is extremely difficult. The problem lies in converting light signals into base band for the purposes of repeatering. The devices and circuits which can amplify modulated light signals without going through base band conversions are the subject of investigation today. In the meantime low-loss fibers are being invented to obviate the necessity of repeatering.

Technical details

The optical fiber can be considered as a waveguide media for transmission of wideband signals. The terminations are a source of light at one end and a transducer at the other end to convert light energy into signals. As in a waveguide, the optical signals in a fiber travel by reflection from the medial walls (Fig 1). Total reflection takes place in a fiber media with refractive index n1 which has a boundary with a media of refractive index n2, when n1 is greater than n2. The light signal has to be launched into the fiber at a predetermined angle, or else it will not propagate through it.

An LED is a common source of light. When placed close to the optical fiber it generates signals with multimode properties (Fig. 3).

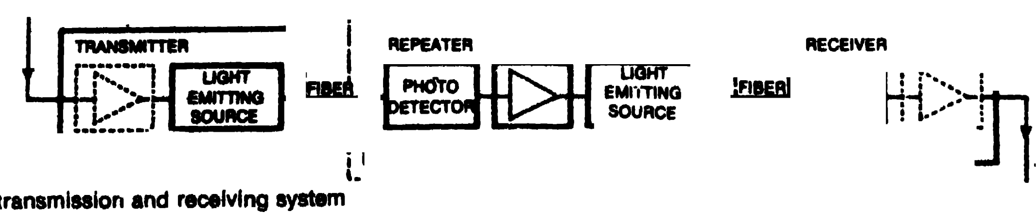

Fig 2. Basic fiber transmission and receiving system

Propagation of light

There are certain basic technical considerations which control propagation of light through an optical fiber. These are:

1.The diameter of active source should not be greater than that of the optical fiber, otherwise losses will occur.

2.Monochromatic laser sources are very few.Therefore, the optical fiber should be such that it is capable of multimode propagation.

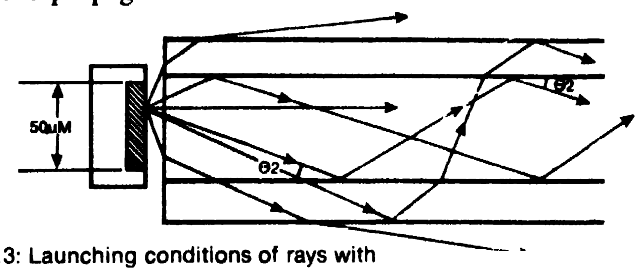

Fig.3: Launching conditions of rays with a LED into multimade fiber

3.Bandwidth capability of a high numerical operture fiber is less than that of one which is able to have fewer modes.

GaAs laser is another light source. The optical fiber material for single-mode propagation uses doped silical for core and pure silical for cladding.

Types of lasers used

Semiconductor lasers are ideally suited as source for wideband optical communication systems. These lasers are known to give 10,000 hours of continuous wave (CW) operation. Lasers which can work up to 10^5 hours are under development. The basic considerations for laser design are wideband, high-power output, high modulation efficiency, narrow spectral line width, and narrower emission pattern.

The geometry of a SiO_2 laser is shown in Fig. 4. The conventional junction structure is double layers with Ga,

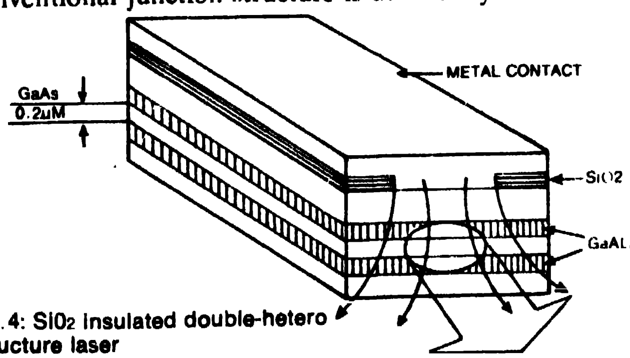

Fig.4: SiO_2 Insulated double-hetero structure laser

Al, As passive layers with 35% Al and an active region with 5% Al. With this type of junction structure CW operation is attainable at 353 k.

As regards reliability of lasers, their short life is mainly due to the formation and growth of dark line defects or related effects.The dark line defects are areas which appear dark when the laser is operated spontaneously. These can be viewed with an infra-red microscope. Efforts are on to rid the laser of defects and improve its reliability.

Design of an optical fiber cable

The nore important components of an optical fiber cable are:

- Coated optical fibers
- Tensile reinforcement
- Radial reinforcement
- Sheath
- Moisture barriers
- Insulated metallic conductors and screens
- Core wraps
- Filters

The simplest structure is of course a single coated fiber with sheath. For tensile and radial reinforcement, additional components are necessary. This can be achieved by adding filling material all around the coated fibers. Control power is inserted by including metallic conductors, whereas core wraps are meant to maintain the geometric uniformity in groups of fibers and conductor.

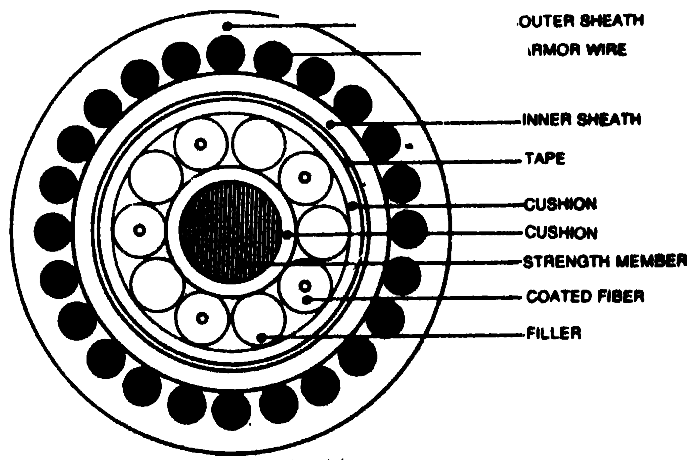

Fig 5: Structure of an optical cable

A typical construction of an optical fiber cable is shown in Fig. 5. It will be seen that with the various components added to the cable structure, it is considered important to retain the fiber in a fixed geometrical condition in spite of stress and strain. The transmission capabilities of optical fibers are such that only a few fibers are required to carry many channels and, therefore, strengthening structures are predominently more in number.

From considerations of channel capacity, the light signals have a frequency of about $3x10^8$ MHz. Therefore, the bandwidth and hence the information carrying capacity is very large as compared to other systems like coaxial cables or waveguides or even the microwave communication systems using space-wave propagation. In order to withstand a possible competition with other systems, the OCS offers certain special features.

First,the OCS, being in the light band of frequencies, has a very large bandwidth of the order of 300 MHz. This bandwidth is adequate to carry up to 1920 speech channels.

Second, the glass fiber used is very thin—sometimes as thin as a human hair. It is formed into cables with protective insulation and other conductors for power supply and order-wire facility. The diameter of the cable, in such a case, does not exceed 7 mm. This gives it the advantages of low weight, small size, flexibility and ease of installation.

Third, the glass fibres have negligible crosstalk levels, and are not affected by external spurious radiations. They are, therefore, immune to interference of any type. Their own radiation level is also low enough. Therefore, they do not cause any interference to nearby systems.

Fourth, the optical cable, once laid, is immune to tapping and interception by unauthorised personnel as it is extremely difficult to cut the cable for this purpose. Also the system uses pulse code modulation and is, therefore, highly secure against evesdropping.

While all this is being said about the OCS, scientists and engineers are making an all out effort to bring down the cost per km per channel of the system. They claim that a system under development cannot be presently compared, costwise, to a well established system like a coaxial cable system. They are quite confident that in case commercial exploitation of the system is resorted to in due course, their costs will be far below the costs of other communication systems.

An experimental system

We have learnt that a 9km experimental OCS route is being laid between Stevenage and Hitchin, about 32 km north of London. The system is capable of carrying 1920 telephone conversations or a mix of telephone, TV, and data traffic between the two stations. The system carried 140 M bits/sec pulse code modulated digital transmissions over a 7mm diameter optical fiber cable. The cable is routed through the already existing ducts of the British Post Office to determine its interference potential. The terminal multiplexing equipment for this route has also been designed and the stream of electrical pulses from the fiber cables is converted into infra-red beams by tiny lasers connected to the end of each fiber. Optical repeaters are sited at 3km intervals down the route.

Although an experimental system, it may prove to be another breakthrough in the technology to solve the system designers' ever increasing problem of clearing high-density traffic within crowded cities and across them.

Other possible applications

Other applications of OCS are in industrial organisations, public utilities, and military users.

In the industrial and public utilities field the OCS can provide colour TV channels and interference-free electromagnetically compatible electronic systems in ships, aircrafts, factories and along railway tracks.

From military users' point of view it can be a lightweight, interference-free, secure long- or short-hop system which can easily replace radio links. Intercommunication systems in areas which need to be safeguarded can also be provided. □