# OPTICAL GLASS COMPONENTS CONTRIBUTION TO GLOBAL TELECOMMUNICATION DEVELOPMENT

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## ABSTRACT

*Optical glass components have contributed in the development of laser devices with the potential of using light as the carrier wave in communications systems. Laser-generated light in the visible or near-infrared regions is now widely used to provide greater band width and hence higher rates of information transmittal. It has been estimated that a single optical system could simultaneously carry 500million telephone conversations. Fundamental to all of this has been the excellent work in Research and Development by Materials Scientists (Glass Technologist) and Telecommunication Engineering Specialists. By controlling the properties and providing reliable manufacturing techniques, possibilities have been opened up which will have a major impact and will provide advanced optical communication systems such as Silicon All-Optical Integrated Circuit Switch system and chalcogenide glass lasers.*

## INTRODUCTION

Telecommunication is the science of communicating over distances where the basic modes of communication, such as speech and vision, are no longer feasible. The use of light signals carried over optical fibres has become a practical alternative, with considerable implications for future of telecommunication. For efficient long-distance (trunk) communication, several signals are combined together, or multiplexed, so that they may be carried simultaneously by a single cable of appropriate quality rather than large bundle of separate wire pairs. For transmission to geographical inaccessible places, radio channels are used. Over difficult terrain it is often better to use microwave links than to have to lay cables in the grounds. For uninterrupted international communication, laying of submarine cable on the ocean bed acts as an insurance cover for satellites telecommunication interference problem.

Optical fibre transmission of light is really an extremely high frequency electromagnetic wave. It is possible to modulate it and transmit it like any other electromagnetic wave. Because of it extreme high frequency, between about $2 \times 10^{14}$ and $5 \times 10^{14}$Hz, enormous band-width are possible and an almost unlimited number of telephone conversation could be modulated into the frequency band-width of a single optical fibre; the transmission of speech, data, video and other information by means of the visible and the infrared portion of the electromagnetic spectrum. A communication system consists of a transmitter, a transmission medium and a receiver. Optical communication is one of the newest and most advanced forms of communication by electromagnetic waves. In one sense, it differs from radio and micro communication only in that the wave length employed are shorter (or equivalently, the frequencies employed are higher). However, in another very real sense, it differ markedly from these older technologies because, for the first, the wave lengths involved are much shorter than the dimensions of the devices which are used to transmit, receive, and otherwise handle the signals. The advantages of optical communication are three fold.

(1) The high frequency of the optical carrier (typically of the other of 300,00GHz) permits more information to be transmitted over a single channel than is possible with a conventional radio or microwave system.

(2) The very short wave length of the optical carrier (typically of the order of 1 micrometer) permits the realization of very small compact components.

(3) The highest transparency for electromagnetic radiation yet achieved in any solid material is that of silica glass in the wave length region 1-1.5 m. This transparency is orders of magnitude higher than that of any other solid material in other part of the spectrum

## OPTICAL COMMUNICATION

Communication by means of light is not a new concept. A.G. Bell patented the "photophone" in 1880. In this device, the sound waves from a speaker's voice caused a mirror to vibrate and this in turn caused a beam of sunlight to be modulated. At the receiver, a selenium detector converted the sunlight into electronic current to recreate the speech. Nevertheless, optical communication in the modern sense of the term dates from about 1960, when the advent of laser and light-emitting diodes (LEDs) made the exploitation of the wide-bandwidth capabilities of the light wave practical. During the 1960s much effort was devoted to utilizing light waves which were propagating through the atmosphere. But in 1970 an optical fibre which was orders of magnitude more transparent than any of its predecessors was made.

The advent of this low-loss fibre stimulated a worldwide effort in what is now known as fibre optics. The result has been a tremendous increase in the transparency of silica fibres. (In the best fibre available prior to 1970, light waves retained only about 1% of their energy after traveling a distance of 65ft or 20m. By 1984 light waves in the best fibres retained about 10% of their energy after traveling over 12 miles or 20km). Although the majority of the effort in optical communication is now in the area of optical fibre systems considered or used. Other optical channels which have been considered include light beams in free space (between satellites, light beams through the atmosphere, and light beams through tubes which control the atmosphere.) In addition to categorizing optical communication systems by the type of transmission medium, it is possible to categorize them by wave length, by the characteristics of the signal transmitted, and by the types of sources.

### OPTICAL TELECOMMUNICATION SYSTEMS TRANSMISSION MEDIUM

***Free-Space Optical Communications:*** A free-space optical channel exists, for example, between orbiting satellites. A free-space channel between satellites is in some sense, ideal. It does not distort or attenuate the light beam. For this application the laser is the best source because it's spatially coherent radiation can be confined to a much smaller angle of divergence than can the incoherent radiation from other sources. Laser particularly well suited to this application are the carbon dioxide gas laser and the neodymium yttrium-aluminium-garnet (Nd: YAG) solid state laser. The beam can be launched at the transmitter and picked up at the receiver by telescopes with apertures limited only by the weight and by the precision with which they can be pointed at each other. Pointing is a severe limitation since light beam less than 1 second of arc wide may be required, a beam width attainable with a 4 inch (10cm) telescope at visible wavelength. For this reason, light wave systems have had difficulty competing with millimeter-wave systems for satellite to satellite communication.

***Atmospheric Optical Communication:*** For satellite-to-Earth Communication and terrestrial communication through the air, the Earth's atmosphere strongly influences the light transmission. In the visible wavelength band and in a few narrow windows in the near-infrared, transmission losses are low in clear weather. However, minute temperature gradients along the path of the light beam cause the beam to broaden and bend so that even in clear air the degradation can be severe over longer paths. Rain, fog, and snow cause even more severe transmission degradations. Attenuation of the light beam power to less than 1/1000 the clear weather value occur in 2 - miles (3 - km) path. The primary source of excess attenuation in an Earth-to-satellite path is clouds. Fog and snow, rather than rain, are the most serious offenders on terrestrial paths. In neither case would the transmission reliability be considered satisfactory for most communication purposes. But for very short transmission paths the probability of outage may be low enough to be acceptable. For example, it is sometimes feasible to provide data links between nearby buildings over optical beams.

In a shielded atmosphere (such as in a room or in a pipe) the effect is quite low. Optical communication systems which guide light beams along a path inside a pipe with the help of lenses and mirrors have been studied. Even in a confined atmosphere, however, thermal effects must be very well controlled to prevent degradation of the light beams. The information carrying capacity of a pipe carrying many such light beams could be very high; perhaps a few million telephone conversations. But the installation and maintenance cost would be very high, and the demand for a system may never be sufficient to justify the expense of it development.

***Optical Fibre Communication:*** Optical fibre boundless had been used to transmit light and even images for many years when the use of silica-based optical fibres to transmit data was proposed in 1966. With the development of extremely low-loss optical fibres during the 1970s, optical fibre communication became a very important form of telecommunicate almost instantaneously. For fibres to become useful as light wave guides (or light guides) for communications applications, transparency and control of signal distortion had to be improved dramatically and a method had to be found to connect separate lengths of fibre together.

The transparency objective was achieved by making glass rods almost entirely of silica. These rods could be pulled into fibres at temperatures approaching 3600oF (2000$^{o}$C). Reducing distortion over long distances required modification of the method of guidance employed in early fibres. These early fibres (called step-index fibres) consisted of two coaxial cylinders (called core and cladding) which were made of two slightly different glasses so that the core glass had a slightly higher index of refraction than the cladding glass. Light rays that strike the core-cladding interface at a grazing angle are reflected into the core by means of a theoretically lossless process called total internal reflection, and thus are confined there. Depending on the angle of incidence, therefore, the rays follow different paths and hence required different lengths of time result in distortion of the signal - a broadening and overlapping of the pulses in a digital signal, for example. Because of the propagation time increases with path length, this effect places a limit on the transmission distance for a given pulse rate.

Two modifications of the step-index fibre have led to large improvements in the transmission of high data rates over large distances:

1. By causing the index of refraction to decrease continuously according to a particular formula, the effect of this delay distortion can be greatly reduced. This happens because in a properly designed fibre the light which travels the greatest distance spends more time farther from the axis in a region of lower index and therefore travels at a great velocity. These graded-index fibres were widely used in first generation optical fibre transmission systems, and they will continue to be used in certain applications in the future. However, an alternative approach is more attractive and the method of choice in most long distances system.
2. By reducing the core size and the index differences in a step-index fibre, it is possible to reach a point at which only axial propagation is possible. In this condition, only one mode of propagation exists and determines the travel time. These single mode fibres are capable of transmitting rates in excess of $10^9$ pulses per second over distances of 75miles (120km). In fact, it will become feasible in the near future to provide individual offices and even individual homes with the capability of receiving and sending data at rates in excess of $2 \times 10^9$ bits per second.

The problem of joining fibres together was solved in two ways. For permanent connection, fibres can be spliced together by carefully aligning the individual fibres and then epoxying them together or fusing them together. In fact, permanent connection of fibre ribbons - linear arrays of several fibres - can be achieved by splicing the entire ribbon as a single unit. Fusion splices have been made with losses of less than 3% while expoxied splices typically have losses of about 12%. For temporary connection, or for applications in which it is not desirable to make splices, fibre connectors have been developed. Connector losses for good connectors are typically less than 12%.

## APPLICATION OF OPTICAL CABLE IN TELECOMMUNICATION

***Terrestrial Systems:*** It is anticipated that light-wave systems will gradually be installed in the telephone loop plant - that is the portion of the telephone plant which connect the individual subscribers to the telephone central office. It will then become feasible to provide high-speed digital services such as digital video, high-speed facsimile, and high-speed data transfer for business and eventually residential customers.

***Undersea Cable:*** The globacom transatlantic optical cable that landed in Nigeria in 2009 is an improved version of optical telephone cable laid in 1988, funning from Tuckerton, New Jersey (USA), to a branch point near the European coast. From this branch point, two fibre cables will run, one to Widemouth in Great Britain and the other to Penmarch in France. Each cable will contain two active fibre pairs and one standby pair. The fibre at that time uses pulse-code modulation and transmits at a rate of 295.6Mb/s which is lower to what is now obtained. By means of highly efficient coding, each fibre can carry up to 20,000 voice circuits. The fibre will be single-mode fibre operating at wavelength of 1.3μm. The transmitters will be indium gallium arsenide-phosphide lasers and the receiver will be Indium gallium arsenide detectors. Avalanche photodetectors will not be used because of the reasons cited below, as well as the fact that they are not yet proven sufficiently reliable. Reliability is the overriding consideration in an undersea system, where repair of a faulty component is extremely expensive. The reliability target for the system is three repairs over the 25-years life time of the system. All new components are protected by the third fibre pair which can be switch into service as required. In addition, there is a cold standby backup for every laser in the system. The distance between repeaters in the system varies from 24 miles (39km) on the continental shelf to 39 miles (63km) in the deep ocean.

A novel system continuously monitors selected critical voltages and current in the repeaters and predicts failures before they become service-affecting.

Process of Optical Transmission

***Optical Transmitters:*** In principle any light source could be used as an optical transmitter. In modern optical communication systems, however, only lasers and light-emitting diodes are generally considered for use. The simplest device is the light-emitting diode which emits in all directions from a fluorescent area located in the diode junction. Since optical communication systems usually require well-collimated beams of light, light-emitting diodes are relatively efficient. In particular, since optical fibres accept only light entering the core in a relative narrow solid angle about the axial, only a small portion of the emitted light is capture and transmitted by the fibre. In fact, the acceptance angle for single-mode fibre is so small that light-emitting diodes are not suited for use with them unless a high loss can be tolerated. On the other hand, light-emitting diodes are less expensive than lasers and, at least until recently, have exhibited longer life times. Another device, the semiconductor laser, provides comparatively well-collimated light. In this device, two ends of the junction plane are furnished with partially reflecting mirrors surfaces which form an optical resonator. (In practical semiconductor laser the partially reflecting mirrors, are formed by simply cleaving the two sides of the junction). The device enhances the light bouncing back and forth between these mirrors by means of stimulated emission. As a result of cavity resonance, the light emitted through the partially reflecting mirrors is well collimated within a narrow solid angle, and a large fraction of it can be captured and transmitted by an optical fibre. Both light-emitting diodes and laser diodes can be modulated by varying the forward diode current. Typically, the messages are a digital sequence of pulses which are used to turn the diode on and off. The light injected into the optical channel is a faithful representation of the information sequence. It is also possible to fabricate a laser directly into an optical fibre by doping the core glass with ions of an element such as neodymium and pumping this active medium with light-emitting diodes of the proper wavelength. Lasers of this type required external modulators which make them less attractive than the diode lasers described above. Such lasers are still in the early experimental stages, but the show potential for use as amplifiers in long-haul systems. Green lasers are the current technology used in this direction.

***Optical Receivers:*** Semi-conductors photodiodes are used for the receivers in virtually all optical communication systems. There are two basic types of photodiodes in use. The most simple comprises a reverse biased junction in which the received light creates electron-hole pairs. These carriers are swept out by the electric field and induce a photo current in the internal circuit. The minimum amount of light needed for correct reconstruction of the received signal, is limited by noise super imposed on the signal by the following circuits. Such a photodiode must collect more than 100 nanowatts of signal in order to receive a signal of 108 pulses per second with sufficient fidelity. Avalanche photodiodes provide some increase in the level of the received signal before it reaches the external circuits. They achieve greater sensitivity by multiplying the photo-generated carriers in the diode junction. This is done by creating an internal electric field sufficiently strong to cause avalanche multiplication of the free carrier. Unfortunately, the avalanche gain process is a random phenomenon and introduces additional noise into the signal. This excess noise becomes the limiting factor in the amount of avalanche gain which can be beneficially obtained.

Nevertheless, the improvement available from avalanche detectors is significant. A reduction is required signal power of between 10 and 100 times (depending on the type of devices used) is routinely realizable. Avalanche photodiodes are used only when the extra sensitivity which they provide is required because they are more expensive than simple photodiodes, they require much more expensive power supplies than simple photodiodes, and they require very carefully temperature stabilization.

## ATTENUATION IN SILICA-BASED FIBRES CABLES

The attenuation or loss of light intensity is an important property of the light guide since its limits the achievable transmission distance, and is caused by light absorption and scattering. Every material has some fundamental absorption due to the atoms or molecules comprising it. In addition, the presence of other elements as impurities can cause strong absorption of light at specific wavelengths. Fluctuations in material on a molecular scale cause intrinsic Rayleigh scattering of light. In actual fibre devices fibre-core diameters variations or the presence of defects such as bubbles can cause additional scattering light loss. The light loss of a material, after traveling a length L, is related to the initial power coupled into the fibre, Po, verses the power at the output end, P, by the equation below:

$$\text{Loss (dB/Km)} = \frac{10}{L(Km)}\ log\left(\frac{P_o}{P}\right)$$

Optical fibres based on silica glass have an intrinsic transmission window at near-infrared wavelengths with extremely low loss. Very special glass making techniques are required to reduce iron and water (OH) to the parts-per-billion level, and have resulted in losses as low as 0.16 dB/Km (0.26dB/min). Such fibres are used with solid-state laser and light-emitting diodes for information transmissions, especially for long distance (greater than 1km or 0.6min). Plastic fibers exhibit much higher intrinsic as well as total losses, and are more commonly used for image transmission, illumination, or very short distance data links. Many other fibre properties are important, and their specification and control are dictated by the particular application. Good mechanical properties are essential for handling: Plastic fibres are ductile, while glass fibres, are intrinsically brittle, and are coated with a protective plastic to preserve their strength. Glass fibres have much better chemical durability and can operate at higher temperatures than plastics. Very tight tolerances on core and outer-diameter control are essential for information transmission fibres, especially to allow long length to be assembled with low-loss joining or splicing.

### *Advantages of Optical Fibre Application in Telecommunication*

- Wide bandwidth
- Low attenuation
- Lightness
- Small cross-section
- Non conductivity to electricity.

## CHALCOGENIDE GLASS COMPONENTS

The term 'Silicon Chip' is well established. One of these is a little-known family of glasses-materials based on sulphur and other group VIA elements - that has been establishing itself as the main materials for many emerging applications. Used as the active layer in billions of rewritable CD's and DVD's, the glasses hold considerable promise as the next generation of memory in ipods, and as highly efficient solar cells. Chalcogenide elements, such as sulphur, selenium or tellurium, act as a substantial constituent. Glass elements are covalently bonded materials and although an amorphous or crystalline solid, may be classified as semi-conductors with a band gap of approximately two electron volts. Chalcogenide glasses are established as passive optical component materials for infrared application.

Market leaders such as intel and ST microelectronics are committed to phase change based on chalcogenide Robust investment in thin-film chalcogenide-based solar cell manufacturers show confidence in these materials. Both memory and photovoltaics are multi-billion dollar industries and offer opportunity for this wide platform technology. Application of chalcogenide materials go beyond thin film devices such as memory chips or solar panels. The original application of chalcogenide glass was as passive infrared transmitting material. Chalcogenide glass can be easily cut and polished, extruded or mould, making it a versatile optical tool. Chalcogenide based sulphur have optimum transmission at wavelength between two and five microcrometers, while those based on selenides and tellurides extend to 10µm and beyond. When use as optical fibres, chalcogenide transmit far beyond the transmission range of conventional silica fibres.

These properties allow transmission of infrared laser power, for uses including medical defence, optical sensing and industrial application. When doped with rare earth ions, the optical fibres can amplify light or act as a laser host laser action in chalcogenide glass was first show in 1995, and since then, bulk glass, thin film, optical fibre and, recently, microsphere lasers have been demonstrated. Other properties included acoustical-optic modulation, which is being used by Gooch and Housego Group for laser modulators and Q-switches. Chalcogenides are highly non-linear optical medium and scientists now use this dependence of the refraction index on the applied electric field to produce harmonic generation of frequency shifting. Telecommunications will benefit through a new generation of high-speed all optical switches.

## IMPACT OF FIBRE OPTIC GLASS CABLE ON 3G TELECOMMUNICATION

Telecommunications have seen vast expansion over the last few decades. Today it accepted that one can pick up a phone and within a few seconds be in contact with people on the other side of the world. Improved communications have brought live coverage of events wherever they are being held directly to our homes have transformed news reporting. At the basis of this expansion has been the development and use of optical fibre communications with its capability of transmitting huge amounts of data in both land and undersea cables. The combination of readily available high performance PCs, the expansion of the entertainment market and the development of optical communications is leading rapidly towards the formation of information superhighways. They will give ubiquitous access to high speed data links for business, education, entertainment, personal communication, healthcare, home shopping etc. Optical fibre systems will have a major role in this.

In an optical communications system, light, in the form of short pulses, is launched into the core of a glass fibre. By having a lower refractive index glass surrounding the core, the light is confined by total internal reflection. In mono-mode fibre the core is about 7 m diameter in a total of 125 m. The refractive index is controlled by the addition of small amounts of germanium and phosphorous to the silica. As the light passes along the glass fibre, the intensity decreases due to various loss mechanisms and the signal therefore has to be regenerated periodically. In the 1970s the main thrust of glass fibre development was to obtain low loss fibres to maximize distances between signal regenerators.

The glass fibre acted as a purely passive medium for transmitting the light pulses from one point to another. Suitable silica based glasses were obtained by removing impurities from the source materials and developing techniques such as Modified Chemical Vapour Deposition (MCVD) to produce controlled refractive index profiles within glass pre-forms which were then pulled into ultra-high purity fibres. The simultaneous development of semiconductor optoelectronic lasers and detectors enabled control of the wave-length of the light to take advantage of the low loss windows in the silica glass spectrum, which occur around 1300nm and 1550nm. Typical losses at these wavelengths in current fibres are 0.35 and 0.2dB/km respectively. This is equivalent to light traveling through a block of glass 10 miles thick with only 50% reduction in light intensity.

Considerable work has gone into improving coupling and jointing techniques in the fibres to minimize signal losses and also into the optoelectronic devices used to send and detect the light pulses. The data capacity of one fibre can be increased either by decreasing the length of the individual light pulses (Time Division Multiplexing, TDM >100Gbit/s has been demonstrated) or by using more than one wavelength of light (Wavelength Division Multiplexing, WDM >100 different wavelengths within the 30nm wide window at 1550nm have been demonstrated). As the capacity has increased so issues about signal regeneration for long distances and also wavelength selection and control have been raised. This has led to some interesting new developments in glass fibre technology.

In recent years there have been investigations of different glasses which could offer greater transparency than conventional silica based materials. Where glasses are made up of heavy atoms and which are weakly bonded, the fundamental absorption band is shifted to longer wavelengths. The intrinsic Rayleigh scattering loss mechanism in the glass is inversely proportional to the fourth power of the wavelength; hence glasses with a longer wavelength absorption band offer the potential of very low loss. Much work has gone into studying fluoride based glasses (fluorides of zirconium, barium, lanthanum, aluminium - ZBLAN) which should give an order of magnitude lower loss than silica but at the longer wavelength of 2.5 m. Overcoming problems of purity, scattering and durability in the fluoride glasses has proved formidable and the best results are no better than conventional silica. Attention has therefore shifted to techniques for amplifying the signal in the glass, rather than seeking lower intrinsic losses.

Where signal regeneration by an electronic amplifier is used, the photons from the fibre impinge on a detector which converts the signal from optical to electronic. It is then amplified electrically, converted back to a light pulse using a laser and then relaunched into the fibre, fig 5a.

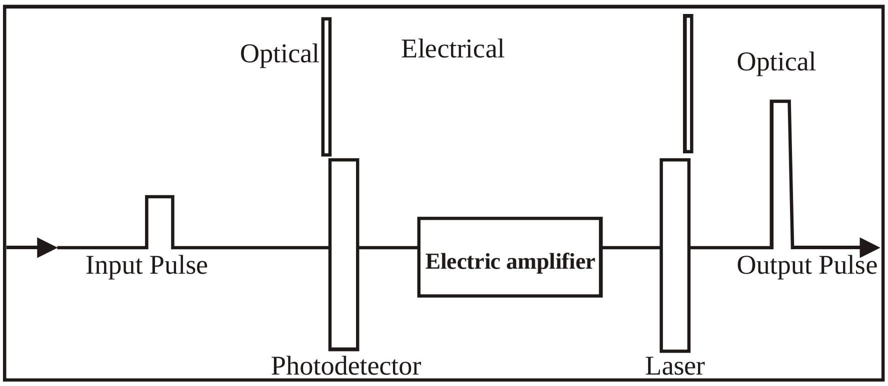

**Fig. 5a:** Signal regeneration by an electronic amplifier

If more than one wavelength is involved then it is necessary to separate, amplify individually and then recombine the different wavelengths for re-launch into the fibre. Optical amplification in fibres is achieved by the optical signal extracting power indirectly from an optical pump, which is light launched into the fibre but at a different wavelength from the signal, fig 5b.

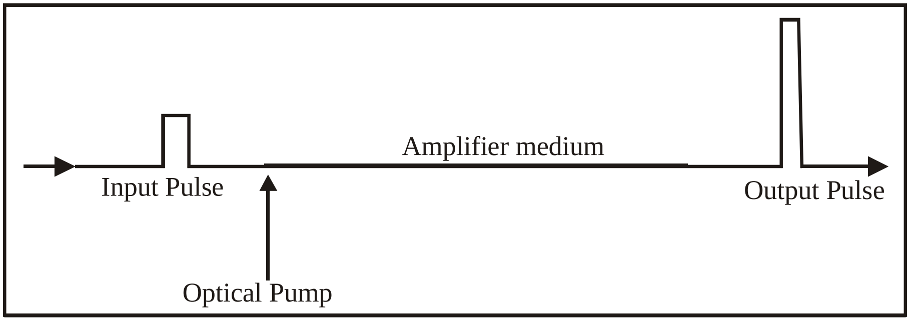

**Fig. 5b:** Optical amplification in fibres

Such a process obviates the need for conversion to and from electrical signals and is also capable of amplifying several wavelengths simultaneously. The amplifying medium consists of 20m of fibre doped with a few hundred ppm of the rare earth ion, erbium (Er3+). The ions are excited by light from an optical (pump) laser and transfer power to the optical signal as fibre.

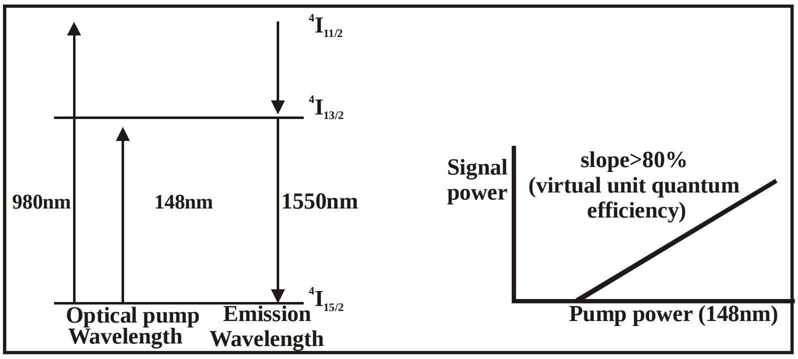

**Fig. 6:** Erbium ion transitions(Courtesy of material world Journal)

Fig. 6 shows part of the energy level diagram for Er3+ with the associated adsorption bands. There are two suitable pump wavelengths: the one at 980nm excites electrons from the ground state (4I15/2) to the 4I11/2 level and the one at 1480nm to the 4I13/2. Due the closeness of the 4I11/2 and the 4I13/2 levels, when 980nm pump light is used, electrons excited to the higher level rapidly decay to the 4I13/2 level. The electrons are held at this level for several milliseconds before decaying radioactively back to the ground state. As light pulses at 1500nm pass through the doped fibre, emission by the decay from the 4I13/2 level is stimulated thus amplifying the signal as it passes. The 1500nm wavelength corresponds to the energy difference between the two levels. The amplification achieved increases with pump power and for just 11mW of launched pump power gains of 30dB (1000 fold increase) are possible.

Semiconductor lasers are readily available to provide compact pump sources. Erbium fibre amplifiers thus provide a convenient way for boosting decaying signals both in land and undersea systems. They are also important for providing power to compensate for splitting losses in distribution networks. At BT laboratories, the multiplexing of 16 different wavelengths each modulated at 2.4Gbit/s onto one fibre has been demonstrated in a laboratory simulation. This huge data rate is equivalent to hundreds of simultaneous video channels. The signals were then broadcast via a number of splitters over 527 km so that 43.8 million customers could receive the data. The fibre and splitter losses were compensated for by gain from erbium amplifiers.

In order to amplify at other wavelengths and thus extend the wavelength window of silica fibres, it is possible to select transitions in other rare-earth ions to provide amplification at different wavelengths. It is necessary to change the host glass where lattice vibrations of the host material provide loss mechanisms for transitions in the ions. Praseodymium has been used in the fluoride glass system to provide amplification in the 1300nm silica window. A section of the doped fluoride fibre is coupled into the silica fibre to amplify as the signal passes through. By selecting the rare earth element and the host glass, amplification can be achieved at wavelengths from 400nm to 2000nm and beyond. This opens up the possibility of increased bandwidth in the fibre and total optical transparency in a network.

While the rare earth doped fibre amplifiers have opened up the possibility of transparent optical networks, another materials property of silica frbres has provided the potential for increased functionality - that of photosensitivity. If a standard silica fibre is exposed to UV light from a laser, then a permanent refractive index change is observed in the germania doped core glass. By exposing the fibre to focused UV through a phase grating, it is possible to form a holographic grating in the fibre core defined by the refractive index change. The increase in the refractive index is best obtained by UV light at about 240nm wavelength. Studies have shown that the change is related to oxygen deficient germania defects in the glass; the UV causes a stress relaxation which results in compaction and hence a refractive index change locally.

For a regular pitch grating the transmission spectrum shows a minimum corresponding to the wavelength reflected back by the grating. Practically 100%

reflection can be achieved. Changing the pitch of the grating alters the reflection wavelength. Using such a grating coupled to a semiconductor laser produces an external cavity which enables one mode of specific wavelength to be selected.

By making the fibre grating detachable from the laser module, the wavelength of the light used in the fibre can be altered, without having to replace the laser. One advantage of the fibre grating laser is its wavelength temperature stability (<1nm over 70oC). Semiconductor lasers are significantly worse (1nm per 12oC) for a laser with a built-in semiconductor grating. Wavelength stability and referencing are key issues for WDM systems. Gratings may be normal to the fibre or out of plane. The transmission characteristics vary accordingly, fig 7.

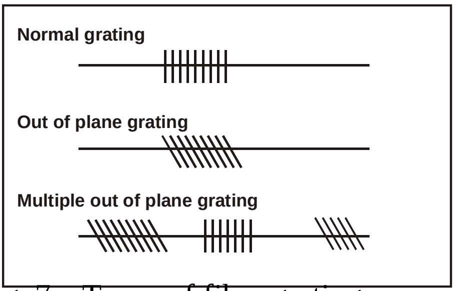

Fig. 7a: Types of fibre gratings

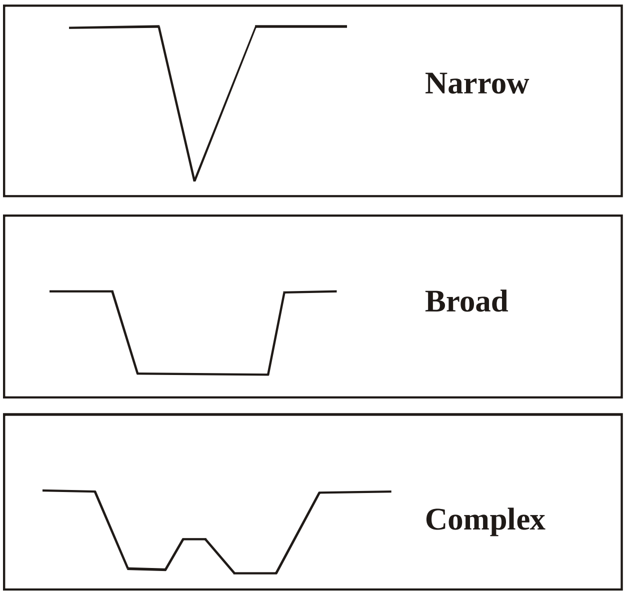

**Fig. 5:** Transmission characteristics of fibre gratings (Courtesy of Material World Journal)

By using these on their own or in conjunction with each other a number applications have been demonstrated. One example is the use of several gratings to flatten the gain profile of an erbium fibre amplifier, fig 8.

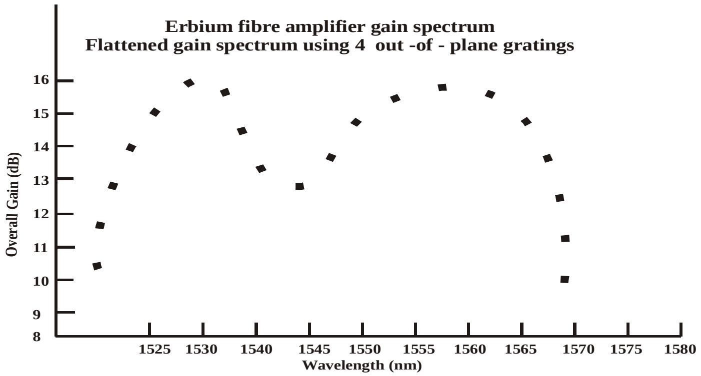

**Fig. 8:** The use of gratings to flatten the gain spectrum of an erbium fibre (Courtesy of Material World Journal)

This enables equal amplification over the whole range of wavelengths for the one amplifier. Another application utilizes the wavelength reflection selectivity in conjunction with a fused fibre couplers to form a transmission filter, the grating allowing all the wavelengths to pass through except the reflected one specific to the chosen grating size. The reflected wavelength can then be directed into another fibre via a fused coupler.

## Silicon All-Optical Integrated Circuit Switch System

All-optical broadband and telecommunications signal processing using silicon may soon be possible at transmission speeds above 100Gbps, according to a European research consortium. The team led by the University of Karlsruhe in Germany has proven the viability of Silicon-Organic Hybrid (SOH) wave guides with highly non-linear and ultra-fast performance. Silicon-based devices are widely used in the electronics industry because they are in-expensive to manufacture. Silicon-based all-optical switching is challenging due to the slow dynamics caused by free-carriers that are generated by two-photo absorption. So far, the data rate achieve using bare silicon wave guides is limited to 40Gbps. The SOH approach overcomes this intrinsic limitation by combining deep-ultraviolent lithography, which is used for mature complementary metal-oxide-semi conductor processing of light waveguides, with molecular beam deposition of the organic polymer DDMEBT.

This molecule has a third-order non-linearity and allows optical switching without introducing significant absorption. A key feature of this material and the deposition process is the ability to homogeneously fill the traditional 100nm wide slot between waveguides. The SOH approach is compatible with existing silicon circuit manufacture as applying DDMEBT can be a back-end processing step. This research is crucial for transforming broadband and 4G telecommunications. Over the next 10 years internet capacity is expected to increase by a factor of 100 and electronics will not be able to cope with the speed and the amount of data transmitted. Mankind need the technology for a petabits network (the equivalent in storage capacity of one million Gigabit), and one route to this goal is optical switching instead of electronic switching, so that optics and electronics work together in an integrated fashion.

However, the relatively slow pace of electrons through silicon-based components reduces the overall efficiency of conventional optoelectronic devices. All-optical processing network switch suitable for 4G systems overcomes this by removing the need for optical-to-electronic and electronic-to-optical conversion, which also reduces energy consumption. To achieve all optical process switching, the researchers have fabricated a four millimeter-long SOH Slot waveguide with a record non-linearity coefficient of $\gamma$ - 105 (wkm)' in the 1.55 m telecommunications window. Based on these waveguides, all-optical de-multiplexing of a 170.8Gbps telecommunication signal to the four data streams of 42.7Gbps each was performed using four-wave mixing. Since the development of the slot waveguide, (fibre optic cable), there have been a number of ideas to add value to silicon in this or other related manner. However, this is a tough field requiring both excellent waveguides (fibre optic cable) and polymer. But a low power all-optical multiplexor taking a large number of 10Gbps channels and combining them, would be very attractive for 4G telecommunication infrastructure development and deployment.

## CONCLUSION

Great progress has been made in the use of glass fibres for optical communications in recent years. From being simply a passive light pipe to providing amplification, routing and filtering of signals, as well as stable wavelength sources in conjunction with semiconductor lasers. Fundamental to all of this has been the excellent work by glass materials scientists (Glass technologists). By controlling the properties and providing reliable manufacturing techniques, possibilities have been opened up which will have a major impact and will provide advanced optical communication systems such as Silicon All-Optical Integrated Circuit Switch System and chalcogenide glass lasers.

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