Light as a carrier of information

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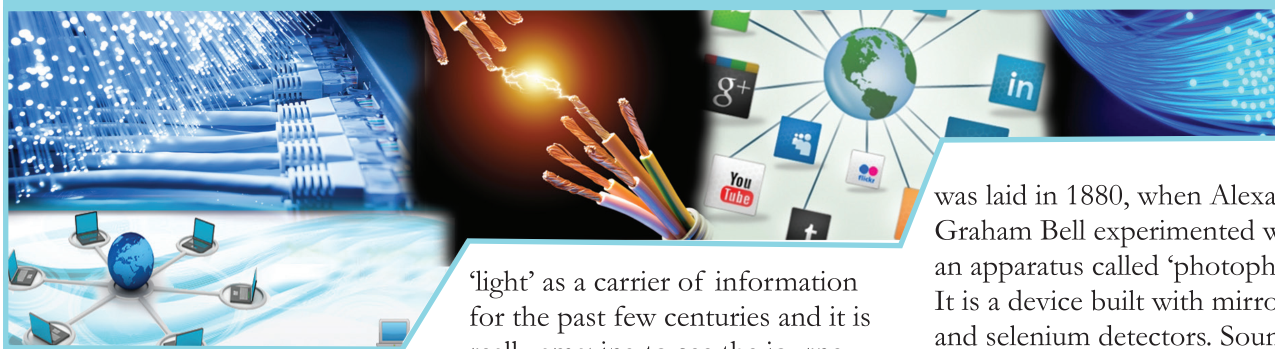
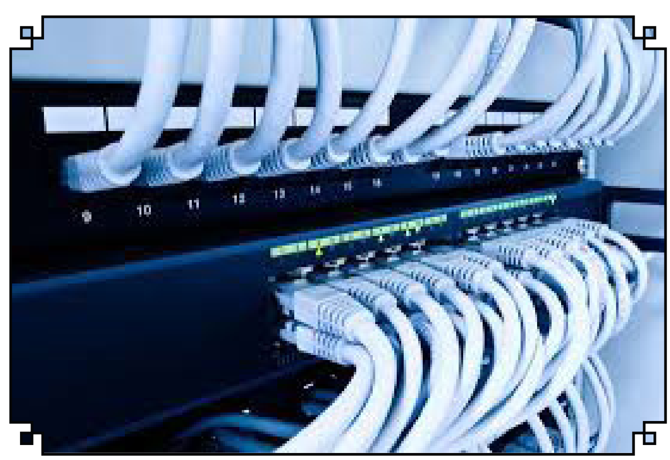


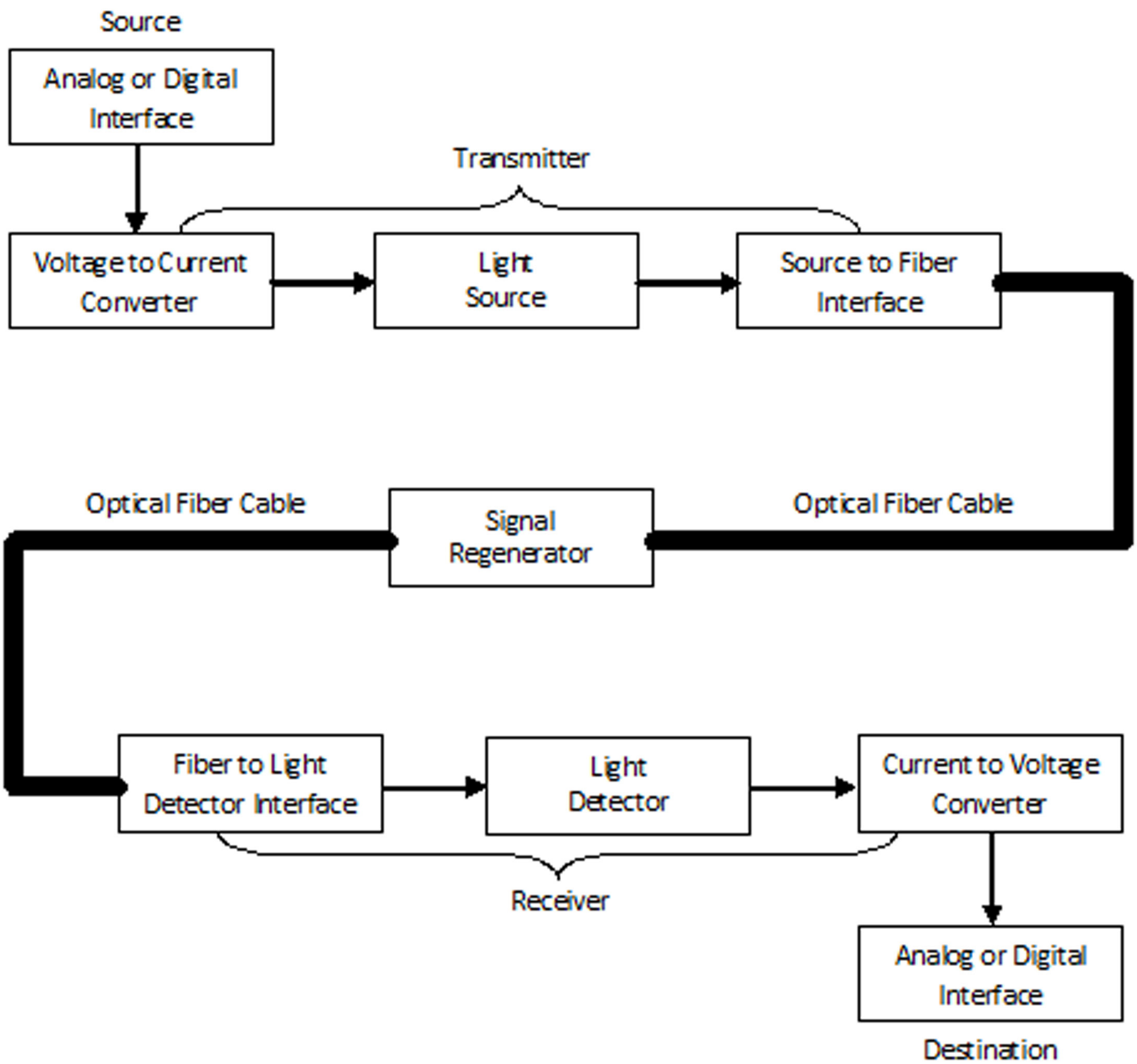
Light as a Carrier of Information

The word 'Information' has gained prime importance in the rapidly evolving technological world nowadays, simply because of the fact that it is information which enables every single task of every process. The scenario is not so different as for a human being: we do every action based on the information we receive from the surroundings. Likewise, every system performs its operations based on the information they received as the inputs. Thus, we can obviously understand that transmission of information from one place to another is to be used in productive manner. In the vast technical fields ranging from spacecraft technology to Nano technology, information transmission plays a vital role. Now that we know how impactful this 'transmission of information' could be to any technocrat, it is important for us to identify the currently available methods to transmit information from one place to another. We use various media to transmit information and this article focuses on how light is used to carry information from place to place. Yes, you read it correct, the world has been using 'light' as a carrier of information for the past few centuries and it is really amazing to see the journey as to how this technology evolved through the years.

History of Evolution

It is very correct to state that the history of the use of light, or more scientifically 'optics', to transmit information from one place to another goes back to hundreds of years. If you do not agree think of ancient people living in a village using smoke signals or fire beacons to communicate with people living in another village. That signal came to our eyes via visible light. Imperial armies were using different colors of flags to indicate the victory or defeat. People identified the different colours with the aid of light. Another instance was the use of mirrors to reflect light and send signals beyond several miles away. All these things simply depict that 'light' is not a new technique used to send information. The aforementioned ones are the most basic and ancient examples of 'light' as a carrier of information. The technological foundation for this concept was laid in 1880, when Alexander Graham Bell experimented with an apparatus called 'photophone'. It is a device built with mirrors and selenium detectors. Sound waves were transmitted using it over a light beam. However, this did not have the potential to be deployed in a real world application, because the effect from water vapor, oxygen and other particles in the air obstruct the transmission at light frequencies through the atmosphere to a great extent. Thus, the very first practical application of optical communication system was invented in 1930 by J.L. Baird (British) and C.W. Hansell (USA). The special feature is that, they were using a medium called 'fiber cable' to guide the light. It is at this point that the concept of fiber cables for the use in optical communication came into discussion, and that marks the inception of optical fiber communication systems.
Since 1930, there were major





Source: Advanced Electronic Communication Systems – Wayne Tomasi

breakthroughs which eventually created high-quality, high-capacity and efficient light wave systems that we experience today. In fact, optical fiber cables are now considered as the most promising type of guided transmission medium for most types of communication applications.

These optical fiber systems generally operate in the infrared band of the electromagnetic frequency spectrum which has longer wavelengths than the visible light. The most typical wavelengths being used include, 850 nm, 1300 nm and 1550 nm.

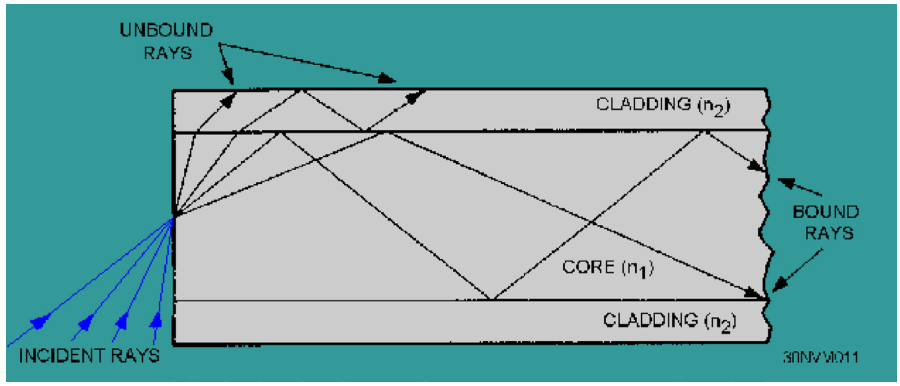
Overview of an Optical Fiber Communication System

The above figure indicates a simplified version of a light wave communications link. The basic building blocks of this system include a transmitter, a receiver and the optical fiber cable.

The transmitter comprises a voltage to current converter, a light source and a source to fiber interface.

The purpose of the voltage to current converter is to act as an electrical interface between the input circuitry (Eg: a computer) and the light source. A typical light sources could be an IR LED (Infrared Light Emitting Diode) or a Laser Diode. The amount of light emitted by the light source is controlled by the current received by the source. So in simple terms, the voltage to current converter converts an input signal voltage to a current that could drive the light source, and the output light of the source is directly proportional to

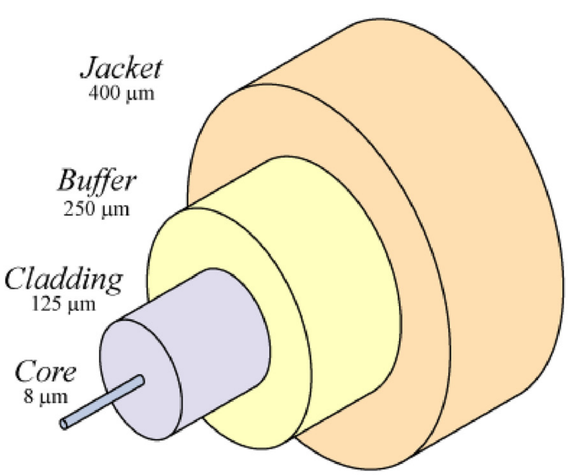
the magnitude of the input signal. Then this output light beam is coupled to the optical fiber cable for transmission.
Once the light enters the optical fiber cable (either glass or plastic), it propagates along the cable. The fiber to light detector coupling device is also as same as the previous coupler and optimize the amount of input light to detector. Even though the best known light detector is human eyes, in communication the same principle is used in devices such as a PIN (p-type-intrinsic-n-type) diode, an APD (Avalanche Photo Diode) or a phototransistor. All these devices perform the same function of converting light energy to current. In order to obtain the transmitted signal, a current to voltage converter is used.
The reason to add a signal regenerator in between the transmitter and receiver is to regenerate the light signal because as the distance increases, the signal strength decreases due to various losses (attenuation), and to get rid of noise. The signal need to be regenerated in the propagation path in order to ensure that the original signal is properly received at the destination.



Source: http://www.tpub.com/neets/tm/106-9.htm

Construction of the Optical Fiber Cable

The main parts of an optical fiber cable are called the core and the cladding. The core and the cladding are constructed out of either glass or plastic. The important characteristic of these two parts is that their refractive indices are different to each other. However to ensure the strength of the cable and to protect the core and the cladding, a number of protective coatings are applied around the cladding. The diagram below shows the construction of a practically used optical fiber cable.
The diameter of the core will decide the possible number of patterns of allowable light energy in fiber, and we define this property as the 'mode' of the optical fiber cable. If it only allows a single pattern of light energy, it is called single mode and the others called multi-mode.

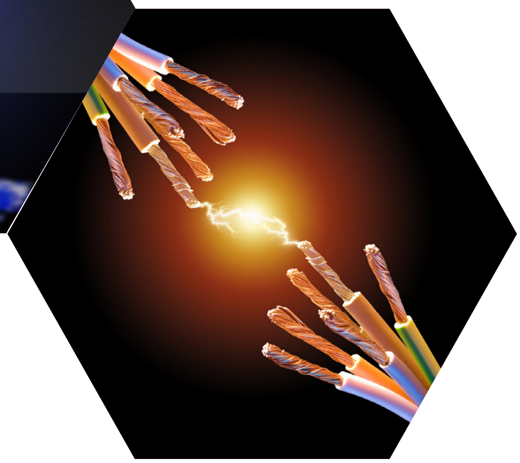


Source: http://www.openoptogenetics.org/images/7/7d/Singlemode_fibre_structure.png

How does Light Propagate in an Optical Fiber Cable?

As stated earlier, the core and cladding refractive indices are different from each other. Precisely, the core has a higher refractive index when compared to the cladding to enable the total internal reflection inside the core. Once the light ray enters the optical fiber cable at an angle (i.e. not perpendicular to the surface) it will not take a direct path to the end. The ray will definitely hit the internal interface between the core and the cladding. Our objective is to always keep the light only in the core and thus we need to ensure the light rays do not go out to the cladding. The only possibility to ensure this is to let the core with a higher refractive index and allow the total internal reflection for a larger amount of received light angles.

The important thing is that, not every light ray that is being launched into the fiber optic cable will undergo total internal reflection. To ensure this, there is an angle being defined as the acceptance angle, which states the maximum angle in which external light rays may strike the air/glass interface and still propagate down the fiber.



Pros and Cons of Optical Fiber Cables

Before moving forward, it is important for us to understand the essence of the previous section of this article. In very simple words, light-wave systems use glass or plastic fiber cables to contain and guide the light waves to reach the desired destination.
The major advantage of optical fiber cables is the greater information capacity when compared to the conventional transmission media like copper cable. Optical fibers have a wider bandwidth (up to several thousand gigahertzes) available at optical frequencies. As a result of this, now we have the ability to allow millions of individual voice and data channels to be sent over a single optical fiber cable.
Because optical fiber cables are nonconductors of electric current, the possibility of the natural interference problems (e.g. lightning) are rare and thus, hardly vulnerable to the crosstalk issue. Due to the same reason, these cables are immune to static interference as well.
The next biggest benefit is the very low amount of transmission losses uncovering in optical fiber cables. In fact, the present day optical fiber cables have only a few tenths of a decibel loss per kilometer. As a result, the distance between the signal regenerators are high and can reach for longer distances, which on the other hand reduce the cost as well. On a negative remark, the optical components incur huge investment costs at the beginning, and thus careful consideration needs to be paid when designing an optical fiber communication system. The cost is further increased because of the requirement of specialized tools, equipment and training to deal with the optical fiber cables. Also, the strength of the cables is questionable to a certain extent and losses could be induced even at the slightest bending of the cable.

Applications of Fiber Optics

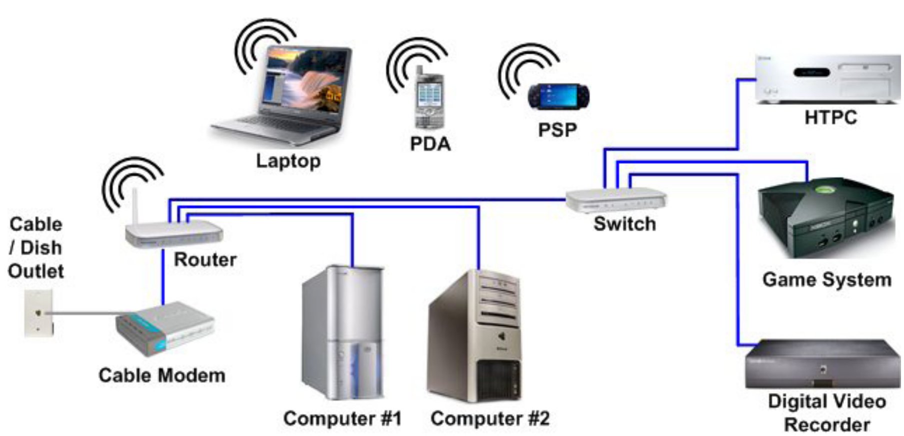
Due to the very advantages qualities in light, its applications could be found on various fields. Light-wave systems have broadened the scope of helping to achieve tremendous targets which were not even imagined a few decades ago. Some of the popular applications are briefly described below but definitely not limited to this.

Fiber Optic Interconnects

This is a widely used application of optical communication. An interconnect is the physical connection of two or more fixtures through which communication happens. A broad range of interconnects are available such as simple, simplex patch cords to multi-channel distribution and backbone cables etc.

Networking

Nowadays, networking applications (Facebook, YouTube, twitter, etc) play an important role. Service providers and network operators face a huge challenge with the increasing bandwidth requirement,



and optical systems are a definite solution to expand and extend their networks. Trunk cables, distribution cables, high-density interconnect cables, and standard patch cords are just a few of the many types of products under this category.

Gigabit Ethernet

With the accelerated LAN traffic, gigabit Ethernet comes as a solution to increased data speed and more bandwidth expectations. Due to the immune nature for EMI (Electromagnetic Interference) and RFI (Radio Frequency Interference), fiber optics is a more flexible and suitable option for Gigabit and multi-wavelength transmission in both long and short distances.

In Harsh Environments

Due to their favorable properties, optical fibers could be used in extreme adverse/harsh environments such as conditions in which these products are exposed to extreme high/low temperatures, shock, vibration, radiation, corrosive conditions, high electromagnetic interference (EMI), high radio-frequency interference (RFI), and/or pressure extremes.

Military Applications

Due to the very precise nature of light, optics play a highly specialized role, and cater to specific requirements, and rigorous testing is done to ensure the reliability and performance in the field. Fiber optic technology is used for wide variety of air, sea, ground and space military applications.

Aerospace and Avionics

These applications too are customized to serve different kinds of purposes. As a results of deploying fiber optic technology in this field, sizes and weight requirements are reduced while increasing the performance and bandwidth.

Unmanned Aerial Vehicles (UAV)

This is a growing application for light-wave communication. Optical fiber is used as the primary communication mode between ground control and the antenna controlling the UAV due to its fast and efficient transmission of large amount data over long distances.

Data Storage Equipment

In this context, fiber optics provide the communication link between multiple devices on a network and/or part of a storage system. This connectivity offers very high bandwidth over longer distances, thus could be used for device-to-device connections with faster simultaneous information access even across different geographical locations.

Carrier Networks

These are also known to be the backbone networks, and are used to distribute very large amounts of bandwidth over longer distances. All communications and broadband services offered at the end residential, commercial or institutional level are offered through these. With the FTTx concept, fiber cables usage has enabled network operators to move for higher bandwidth and additional value added services. Through these methods, every household will get a direct fiber termination, thus enabling a high capacity access.

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