A SHORT PRIMER ON OPTICAL NETWORKING

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and

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In 1880, Alexander Graham Bell invented the photophone, which transmitted voice signals via beams of light. This device failed because of too many disruptions of the light beam—when the weather was cloudy, it didn't work. Today, however, technologies that generate and transmit light, commonly referred to as photonics, have completely altered the telecommunications infrastructure. The old network, through which communications were transmitted electrically over copper wires, increasingly has given way to systems built of optical components and fibers.

Most telecommunication systems today are not completely optical yet. They rely on optoelectronic devices that convert electrical energy to light energy that is transmitted over a fiber optic line. It is then converted back to electrical energy by another optoelectronic device. The advent of fully optical networks is several years away.

As is frequent in technological innovation, the advent of optical networks has resulted in new terms and phrases. In this article, we will provide explanations of some of the more common terms that have resulted from, and some older terms associated with, information dancing the light fantastic.

Generating the Signal: What is a LASER?

The acronym "laser" means "**L**ight **A**mplification by **S**timulated **E**mission of **R**adiation." Lasers produce narrow, finely focused beams of light. In a beam of such energy, all the waves have the same phase and frequency. A laser beam is very pure, with the light approaching a single wavelength.

A laser consists of a chamber, or "cavity," in which atoms, ions or molecules of a solid, liquid or gas are amplified or "pumped" with electricity or light. Mirrors at each end of the cavity allow energy to reflect back and forth and resonate, continually increasing in intensity. The energy emerges from the cavity as a continuous beam or as a series of pulses of light. The type of the material in the cavity of a laser determines the wavelength of the output.

Lasers create the light pulses that travel through optical fibers. In optical networks, the lasers are semiconductors about the size of a grain of salt. They are typically known as laser diodes, semiconductor lasers or laser chips.

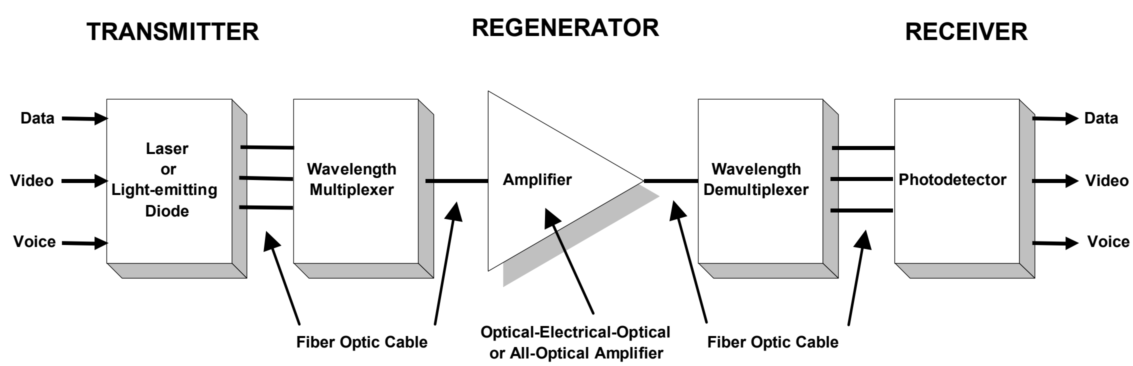
Optical networks can use light sources other than laser beams for transmission of information along optical fibers. The "LED" or light emitting diode is a semiconductor device that emits light when electricity passes through it. It differs from a laser in that it produces waves that do not have the same phase and frequency.

<u>Organizing the Signal</u>: What is DWDM?

DWDM or "dense wave division multiplexing" also is called "WDM" or "wave division multiplexing." This technology allows two or more optical signals having different wavelengths to be transmitted simultaneously in the same direction over one optical fiber. Because optical fibers can carry many wavelengths of light simultaneously without interaction between each of them, DWDM greatly increases the amount of information that a fiber can carry.

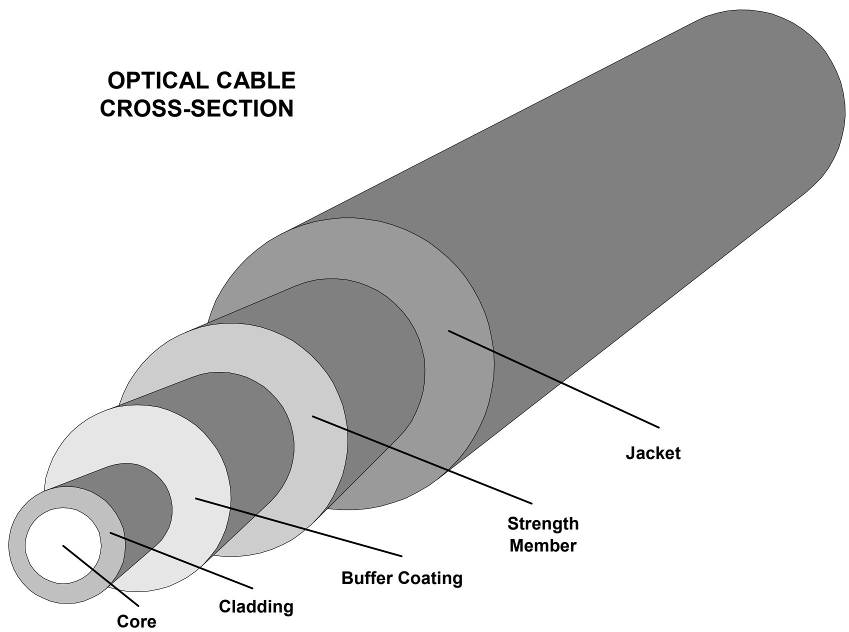
DWDM combines up to 160 wavelengths of light per strand of fiber. The technology breaks white light into multiple colors (wavelengths). Each signal travels within its own wavelength, modulated by the information (e.g., data, voice, video) it is carrying. The signals are then separated by wavelength, or demultiplexed, at the end of the fiber.

DWDM FIBER OPTIC COMMUNICATIONS SYSTEM



<u>Carrying the Signal</u>: What is Fiber Optic Cable?

Fiber optic cable, designed to transmit light, is a thin plastic tube that consists of several layers of materials. At its heart is the "core," which in telecommunications applications is a hair-thin strand of pure silica glass or multiple strands that are bundled together. In some specialized industrial and automotive control applications, the core may be made of plastic. The "cladding," which also is made of glass, surrounds the core. The core and cladding are bonded together during the glass extrusion process when the fiber is made and are inseparable. The core has a slightly higher refractive index than the cladding. This causes the cladding to act as a mirror. Thus, when light is guided down the core, it reflects off the cladding and back into the core. A plastic "buffer coating" surrounds the cladding and protects it from moisture or damage. A "strength member" covers the buffer and prevents stretching problems when the fiber is pulled through conduits. An outer covering, called a "jacket," surrounds the strength member. Despite being made of glass, optical fibers are flexible and strong.



In fiber optic networks, information travels as light pulses through these optical fibers. Optical fiber can carry much more information than copper wire. Most telecommunications networks now are built of optical fiber.

In addition to the increased capacity, or "bandwidth," of optical fiber networks, communicating by light over optical fibers offers other advantages over communicating by electricity over copper wires. Photons travel through optical fibers several times faster than electrons travel through copper wires, thus reducing transmission times. Light, unlike electricity, is not affected by electromagnetic or radio frequency interference. The error rate of information transmitted via light is significantly lower than that transmitted by electricity. Information can be sent over longer distances without the need to retransmit signals. Information also can be transmitted more securely because taps in fiber lines can be detected. Fiber cable carries no current and therefore, poses no danger, unlike live electrical wires. Finally, fiber cable weighs dramatically less than copper cables.

On the downside, fiber is more difficult to splice and thus, to install and repair. Its inability to carry current has forced network designers to adopt new strategies to power remote equipment when replacing copper with fiber.

<u>Regenerating the Signal</u>:

What is an Optical Repeater?

A repeater or regenerator is a device that amplifies or regenerates a signal in order to extend the distance it may accurately be transmitted. This is necessary because a signal weakens or erodes as it travels further from its source. In an optical system, a repeater receives the signal, cleans it up by removing noise and pulse deterioration, and then amplifies and retransmits it. A signal may travel through one or more repeaters.

Two types of optical repeaters exist: Optical-Electrical-Optical (OEO) and Optical-Optical-Optical (OOO). OEO repeaters convert photons into electrical signals before regenerating and retransmitting them optically. OOO repeaters are known as fiber amplifiers.

What is a Fiber Amplifier?

A fiber or optical amplifier is a device that boosts a light signal in an optical network without first converting it to an electrical signal. In other words, it acts on the light directly. Common kinds of fiber amplifiers include erbium-doped fiber amplifiers (also known as erbium amplifiers or EDFA), Raman fiber amplifiers and silicon optical amplifiers (SOA).

<u>Sorting out the Signals</u>: What is an Optical Switch?

A switch is a device for making, breaking or changing the connections in or among communications pathways. An optical switch, also known as a "photonic switch" or "optical cross-connect," performs this function with light as it travels through an optical network.

The two broad categories of optical switches are hybrid optical switches with electrical cores (OEO switches) and all-optical (OOO) switches. OEO switches convert light pulses into electrical signals to switch them between fibers, then convert them back to light. OEO switches are subject to the speed limitations of electrical switching.

An all-optical switch maintains a signal as light from input to output. This greatly increases network speed. The prevailing all-optical technology is micro-electro-mechanical systems or "MEMS." MEMS switch light by using tiny mirrors to reflect a light beam from one fiber to another.

<u>A Look Into the Future</u>: What is wireless optical networking?

Wireless networking has emerged as an efficient means for delivering data, voice and video. In general, fiber optic cabling or traditional copper plant is used for long-range transport. In office local area networks (LANs), wireless networking based on conventional radio frequency (RF) technology is now commonplace, due to the proliferation of laptop computers and handheld devices. To link buildings and campuses together, wireless optical networking is emerging as an alternative solution to RF and conventional copper or optical fiber-based links. Instead of sending beams of light along a glass fiber, wireless optical networking sends laser beams over-the-air. This is known as atmospheric laser transmission, "free space optics" (FSO) or "free space photonics" (FSP).

RF wireless technology offers longer-range transmission capabilities than FSO, but FSO provides much greater bandwidth capacity. Additionally, RF-based networks require significantly greater capital investment because spectrum licenses must be purchased.

FSO functions by optically aligning two or more laser transceivers with a clear line of sight between them. A transceiver both transmits and receives signals, so there is full duplex (bi-directional) capability.

Four different FSO configurations exist. The first type is a dedicated point-to-point link between two terminals, such as two buildings. In the second, a point-to-multipoint architecture, a hub is placed on a tall building. The hub transmits to and receives signals from either the roofs or windows of surrounding buildings. The third kind of configuration is a series of transceivers connecting building roofs in a ring. The fourth method consists of short, redundant links connecting building roofs in a mesh configuration.

The great advantage of FSO is that it eliminates the lengthy regulatory process and associated costs of obtaining permits for and digging trenches and laying fiber optic cable. Further, there is no cost for acquiring spectrum licenses, important as the RF spectrum has become crowded and license fees have risen. FSOs are highly directional, offering transmission security. Finally, an FSO system can be set up in a matter of hours and can operate over a distance of several kilometers. An example of this occurred in September, 2001 after the World Trade Center tragedy, when FSO vendor Terabeam deployed a system linking Merrill Lynch & Company's offices in lower Manhattan and northern New Jersey across the Hudson River, a distance of 1.5 miles.

A number of problems are associated with FSO systems. The leading concern is that atmospheric conditions may impact performance. While rain, snow, dust and smog can block light transmission and thus, disrupt service, fog presents the greatest problem. Dense fog disrupts and dissipates laser signals because its small, dense moisture particles act like billions of tiny prisms. While technological advances have helped to minimize this concern, weather issues can limit the distance between transceivers. Another problem is that laser beams may misalign when buildings move because of solar and wind loading or small earthquakes, although systems with auto-alignment capabilities resolve this issue. Additionally, very small pockets of turbulent air may disrupt transmission, but the use of multiple transmitters and receivers solves this problem. Finally, flying objects, such as birds, can disrupt communications and require retransmission of information, although this is not a concern for redundant mesh configurations.

Wireless optical networking offers an exciting opportunity to increase communications options and decrease connectivity bottlenecks in dense urban areas. The potential combination of generally reliable performance, low-costs, bandwidth scalability, and rapid and flexible deployment, points to a bright—and light-filled—future.

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