The Impact of Fibre Optics Technology

Outcomes:

1. Describe how optical technologies have developed through systematic trial-and-error processes constrained by the optical properties of the materials. (109-5)
2. Provide examples of optical technologies that have enabled scientific research. (111-3)
3. Provide examples related to optics that illustrate that scientific and technological activities that take place individually and in group setting. (112-8)

Early Developments in Light Communication

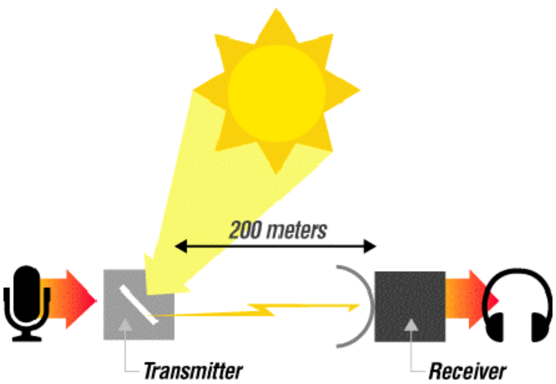
Light has been used as a communication device for centuries and almost every civilization has used light in some form for communication. Around 400 BC the Greeks armies used polished shields to send coded messages by reflecting light in flashes to one another. In the early 1900's the British army developed a more accurate signaling device called the Mance Heliograph that used mirrors and a sighting device which allowed instantaneous light communication from as much as 50 km away. Heliographs were used by the British and Australian armies up to the 1960's and by the Pakistani army as late as 1975. Many modern navies still use lantern signaling devices as a means of ship-to-ship communication.

The word heliograph comes from the Greek *helios* meaning "sun" and *graphein* meaning "write". Photo courtesy of Jithra Adikari, Wikipedia Commons.

How effective do you think the heliograph would be when the sun sets or if it is cloudy or raining? Why do you think these devices were so popular with the military for so long a period?

In 1880, Alexander Graham Bell invented a more scientific light-communicating device called a photophone. Using the photophone a person would speak into a microphone, causing a mirror to vibrate. Sunlight would be allowed to strike this mirror. The vibrating mirror would then reflect the sunlight in a pattern over open space. The target mirror would receive the light and cause a special crystal (made of selenium) to vibrate. This vibration would be converted back to sound.

The photophone was successful but its users could not protect the transmissions from outside interference from such things as clouds. These problems caused Bell to give up on this invention. However, Bell's photophone is often credited with the development of fibre optics which will be discussed later.



Schematic of photophone. The requirement for sunlight limits its use.

The use of light to communicate in this way was not always practical, and the limit of distance that could be used made getting a message across continents difficult and time consuming.

With the advent of the telegraph and telephone in the late 1800's and early 1900's, which used wire to transmit signals, the heliograph started to fall from wide-spread use. It was still popular with militaries, but its use in the commercial world declined.

The Impact of Lasers on Light Communication

The next advancement in light communication came in the late 1950's, when the laser was invented. The laser is a device that transmits a concentrated beam of light over long distances. As a communication device, this concentrated beam could carry information, using the vibrations of the light itself. In fact lasers could be changed to carry a lot of information, much more than in the heliograph or the photophone. While the laser could be used at night it experienced similar problems to the photophone. Fog, rain, or obstructions such as buildings or hills between sender and receiver still prevented it from working effectively.

> **Did you know?**
> Lasers are found in many devices in your home. Some are obvious, such as in a laser printer. Other common uses of lasers, that are less obvious, are in CD players, computers, and many other items used for electronic entertainment.

Scientists and inventors around the world were then presented with a question: "how do I communicate with a laser so that it won't be interfered with by fog or rain or line of sight problems?"

When scientists are asked questions, they work and experiment to find solutions. By this time, lasers had started to be used in other communication fields, such as the barcode reader in supermarkets which were introduced in 1974.

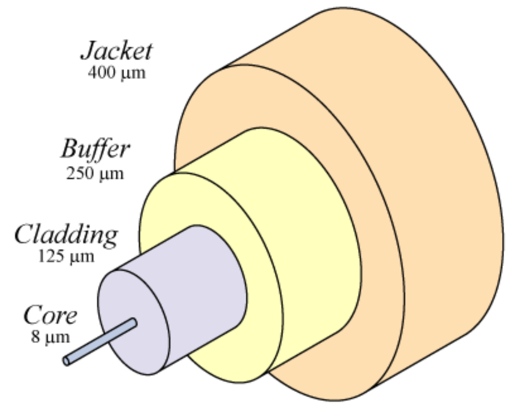
However, trying to find a practical way to allow lasers to be used in communication was not so easy. The first issue was to find a way to stop things from interrupting the signal. The answer to this was to direct the laser's light into a shielded tube or cable so light can travel without interference from the outside. However, this solution raised another question: "how can you get the light to travel in the cable?" The answer to this question came from two things that were already know about the properties of light: while it can pass through glass it can also reflect off glass if it hits it at the correct angle. The answer to the problem of how to get light to travel through a long cable was to put glass inside the shielded cable! The result was the invention of the fibre optic cable.

Fibre Optic Cables

The first fibre optics cable was the result of joint work between the Corning and Siemens Corporations in 1977. Corning provided the fibre technology and Siemens the cabling technology to produce a cable that transmitted information by using light.

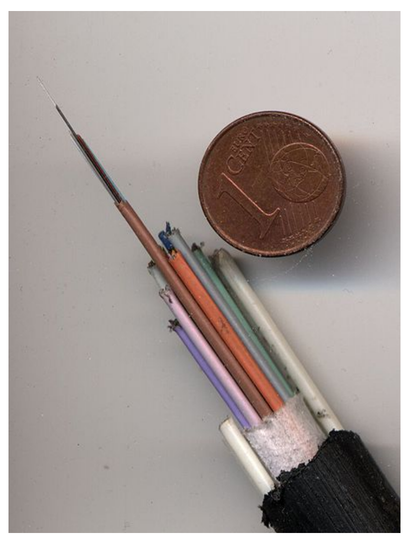
A Fibre optic is a long, thin strand about the size of human hair, made up of a very pure glass. This strand, called the **core**, is the material that the light travels through.

Surrounding the core is a dark flexible material called the **cladding**; it reflects back any light that escapes the core. Finally, on the outside of each cladding there is a plastic coating, called a **buffer**, which protects the fibre from damage and moisture.



The fibre optic is made up of 5 distinct layers. Courtesy of Wikipedia Commons.

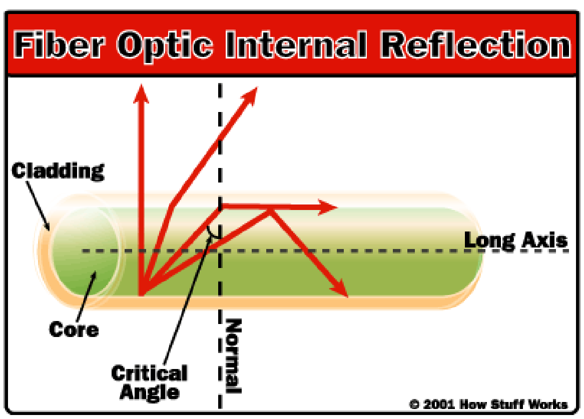
Commonly, hundreds or thousands of these optic fibers are placed together in one optical cable which is protected by an outside covering called a **jacket**.



The penny in this photograph of a bundle of fiber optics gives us an idea of the size of a fibre optic. Photo courtesy of Christophe Merlet, Wikipedia Commons.

The Science Behind the Fibre Optic Cable

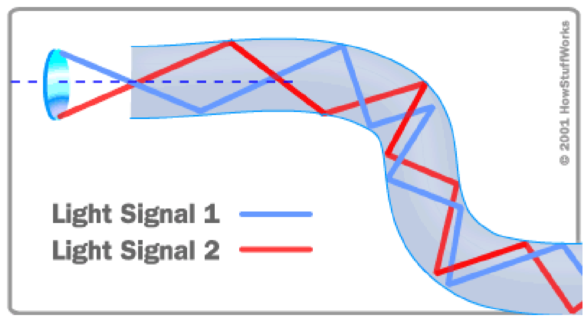
The fibre optic cable works by applying the principles of **reflection** and **refraction**. When light strikes a shiny or mirrored object it "bounces" off it, just like a ball bounces off the ground. When light travels between two substances that are of different thickness or density, it bends (refracts), depending on the angle at which it strikes the substance. At a certain angle, light no longer travels between the substances, but reflects back into the original substance completely. The boundary now acts like a mirror, keeping the light inside. This is called **total internal reflection** and is the basis of the fibre optic cable.



The angle at which the light hits the wall of the fibre optic will determine whether it continues along the fibre or not. Photo courtesy of How Stuff Works (http://electronics.howstuffworks.com/fiber-optic6.htm)

When a light ray is sent into a fibre optic, it is sent at an angle towards the side of the fibre that will reflect. The light reflects and then strikes the opposite side of the fibre, again at an angle that will reflect. This light ray will reflect from side to side, traveling through the whole length of the fibre. The angle that the light will reflect at is called the **critical angle**. The diagram above shows what happens.

An added bonus to the principle of total internal reflection is that light rays can pass through each other without causing any destruction or interference. The light signals will be unaffected, resulting in the ability of being able to send more than one signal through the fibre at the same time.



Total internal reflections allows more than one signal to be transmitted along the fibre at the same time. Photo courtesy of How Stuff Works (http://electronics.howstuffworks.com/fiber-optic2.htm)

Because of this, each fibre can carry many signals, such as phone calls, at the same time with great clarity to each caller.

Parts of the Fibre Optic System

A fibre optic system has four main components:

1.<u>Transmitter</u>

- converts a signal, for example sound, into a pattern of light.

2. <u>Optical Fibre</u>

- the cable that conducts the light patterns over large distances.

3. <u>Optical Regenerator</u>

- in transmittance, some light energy may be lost. This device boosts the light signal back up to continue its journey. This is used for signals sent over very large distances.

4. <u>Optical Receiver</u>

- converts the light patterns back to an understandable message, (i.e., sound).

Advantages of Fibre Optics

The fibre optic system has enabled the telecommunication industry to rapidly develop new advancements in technology. The systems offer many advantages over the traditional metal (copper) wire form of communications.

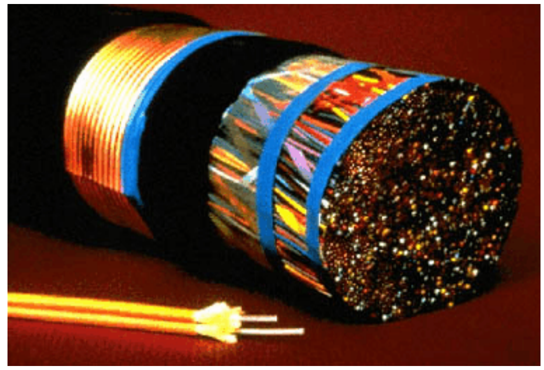
These advantages include:

1.less expensive

- saves the provider and the customer money

2.higher carrying capacity

- because they are thinner, more fibers can be put into the same size cable as the traditional copper cable. This results in more phone lines or TV channels per cable.



A much larger bundle of traditional copper wire is required to transport signals as compared to the much smaller fibre optic (bottom left).

3. less signal break up

- the fibre optic does not lose as much of its signal as the copper wire and a light signal in one fibre will not interfere with the signals of other fibers. These conditions give the customer a clearer phone call, or TV picture and sound.

> **Did you know?**
> Older telephones used electrical signals carried on copper wire. These wires were bunched together in massive cables, with each wire able to carry one signal at a

4. low power requirements

- light signals lose less energy as it is transmitted therefore low powered transmitters can be used instead of the high-voltage transmitters needed for copper wires.

5.digital signals

- optical fibers are capable of transmitting digital signals that are used by computers, such as those connected to the internet.

> **Did you know?**
> Digital signals consist of patterns of bits of information. The pattern produces a code. In computers the code is made up of "on" and "off" pulses of electricity. The specific sequence of the on's and off's are decoded by computer software to produce sounds, graphics, and text.

6.non-flammable

- the fibre uses no electricity and therefore there is no danger of an electrical fire as with copper wires.

7.flexibility

- the fibre optic cable is very flexible, and, therefore can be used in places that require repeated bending and shape changing, such as in the flexible digital camera in your school science lab.

Applications of Fibre Optic Technology

The previously mentioned the advantages with the fibre optics cable has lead to almost daily leaps forward for the telecommunication industry. However, the advantages of fibre optics go well beyond the communication or data transmittance sectors. The fibre optic cable has been used for the advancement in such diverse areas as Medicine, Mechanics, and Plumbing.

Medicine

The properties of the fibre optic have allowed medical personnel to see places in the human body with greater ease and comfort for the patient.

i) bronchoscopes allow doctors to examine the inside of the respiratory tract (your lungs and throat); so doctors are able to detect or rule out tumors of the lungs or airways and to get tissue samples for analysis.

ii) endoscopes allow doctors to evaluate the interior surfaces of an organ by inserting a small tube into the body through a small cut. The procedures are relatively painless with the patient being sedated.

The long coiled portion of the endoscope is inserted into the person. The doctor can view teh interior of the body through the viewing lens (top left). The image can be directed to a television monitor through the larger tube that extends from the viewing section. Photo courtesy of Wikipedia Commons.

iii) laparoscopes allow doctors to perform surgery on growths within the abdomen or pelvic areas, to examine the female organs, stomach, liver, appendix, or gallbladder, and remove the appendix or gallbladder if necessary. When compared to the traditional abdomen surgery, laparoscopy usually involves less pain, less risk, less scarring and faster recovery time.

All of these tools make use the fibre optics' ability to carry light, the small size of a single fibre as well as the flexibility of each fibre.

Inspection of Manmade Materials

Mechanics

The use of fibre optics as part of imaging systems allows engineers to inspect mechanical welds in pipes and engines. Engines of planes, rockets, space shuttles and cars can now be examined both externally and internally after use. This increased safety feature has allowed for the prevention of previously un-preventable accidents. Potential problems can now be detected and thus corrected before they occur.

Plumbing

Again, the use of fibre optics in imaging systems and as well as its flexibility allow us to inspect water and sewer lines without the high cost or interruption in their operation. Inspection can now be done more quickly and with greater accuracy. The whole system can be examined, not just the section of pipe that was dug up.

Conclusion

Fibre optics systems have allowed scientists to make many important advances in the telecommunication, mechanical and medical fields. Sound, video, and computer communications are more reliable than in the past. Engineers are able to monitor and maintain safer modes of transportation. And doctors can perform less dramatic life-improving procedures. The world of fibre optics has opened many possibilities for solving technological problems and has improved human civilization.

Questions

1. Describe how a fibre optics cable carries telephone conversations.
2. What are the advantages of using fibre optic technology in medicine?
3. What problems made Bell's invention, the photophone, unreliable to use?

4. Describe the advantages of the fibre optic cable over the copper cable.

5. Why are fibre optics important in the transportation industry?

6. Describe the principle of total internal reflection.

For Further Research or Discussion

1. An alternative to the glass fibre optic is plastic. What are the advantages and uses of plastic fibre optics?

2. Describe how a laser works. Where are lasers used in society today?

3. Another form of communication is through microwave use. Compare microwave and fibre optic communications. What are advantages of each?

4. Write a diary for a day (week, month) list down when and how many times you use a device that involves fibre optics. Discuss how important or not important it is to our daily lives.

References

http://www.www-fibreoptics.com

http://www.lungdiseases.about.com

http://www.corningcablesystems.com

http://www.tyndall.ie/learning/optic_fibres.html

http://shoutfind.net/medical/Endoscopes.htm

http://www.answers.com/topic/laparoscopy

http://www.tyndall.ie/learning/plastic_optic_fibre.html

http://www.howstuffworks.com/