An Introduction to Fiber Optics as a Medium of Recent Communication Technology

Ravindra Sharma

Abstract— **In this paper an introduction to fiber optics as an advanced medium of recent communications has been provided. The Romans must have been particularly satisfied with themselves the day they invented lead-pipes around 2000 years ago for the purpose of an easy way to carry their water from one place to another place. It can be imagined what they'd make of modern fiber-optic cables—"pipes" that can carry telephonic calls and e-mails right around the world in a fraction of a second. Fiber optics works a third way. It sends information coded in a beam of light down a glass or plastic pipe. It was originally developed for endoscopes in the 1950s to help doctors see inside the human body without having to cut it open first. In the 1960s, engineers found a way of using the same technology to transmit telephone calls at the speed of light (186,000 miles or 300,000 km per second).**

INTRODUCTION

Optical fiber technology: A fiber-optic cable is made up of incredibly thin strands of glass or plastic known as optical fibers; one cable can have as few as two strands or as many as several hundred. Each strand is less than a tenth as thick as a human hair and can carry something like 25,000 telephone calls, so an entire fiber-optic cable can easily carry several million calls [1,2,3].

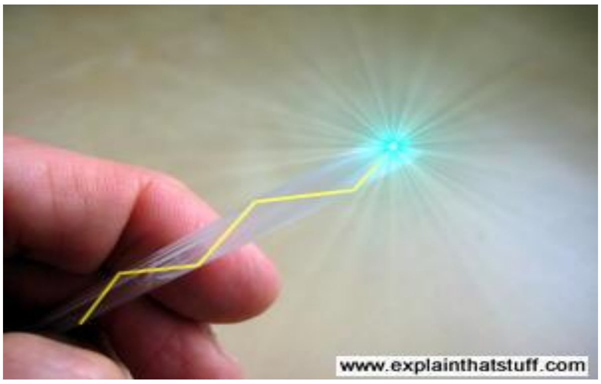
Figure 1. Image of a section of 144 strand optical fibers cable. Each strand is made of optically pure glass and is thinner than a human hair.
(Picture by Tech. Sgt. Brian Davidson; courtesy of US Air Force).

Fiber-optic cables carry information between two places using entirely optical (light-based) technology. It is supposed that to send information from a computer to other's house down the street using fiber optics. When computer is hooked up to a laser that converts electrical information from the computer into a series of light pulses [4,5,6]. Then the laser is fired down the fiber-optic cable. After traveling down the cable, the light beams would emerge at the other end. Other user would need a photoelectric cell (light-detecting component) to turn the pulses of light back into electrical information his or her computer could understand. So the whole apparatus would be like a really neat, hi-tech version of the kind of telephone, one can make out of two baked-bean cans and a length of string [7,8,10].

A dielectric fiber with a refractive index higher than its surrounding region is a form of dielectric waveguide which represents a possible medium for the guided transmission of energy at optical frequencies. This form of structure guides the electromagnetic waves along the definable boundary between the regions of different refractive indexes [14,15,19]. The associated electromagnetic field is carried partially inside the fiber and partially outside it. The external field is evanescent in the direction normal to the direction of propagation, and it decays approximately exponentially to zero at infinity. Such structures are often referred to as open waveguides, and the propagation is known as the surface-wave mode. The particular type of dielectric-fiber waveguide to be discussed is one with a circular cross-section [14,15,16,22].

MATERIALS AND METHODS

Functions of fiber optics: It has been supposed to use the idea of information traveling in different ways. When one speaks into a landline telephone, a wire cable carries the sounds from our voice into a socket in the wall, where another cable takes it to the local telephone exchange. Cell-phones work a different way: they send and receive information using invisible radio waves—a technology called wireless because it uses no cables [3,5].



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Ravindra Sharma, Assistant Professor, Dept. of ECE.

Figure 2. Photo of Light-pipe: fiber optics means sending light beams down thin strands of plastic or glass by making them bounce repeatedly off the walls. This is a simulated image.
(Ref. www.explainthat stuff.com).

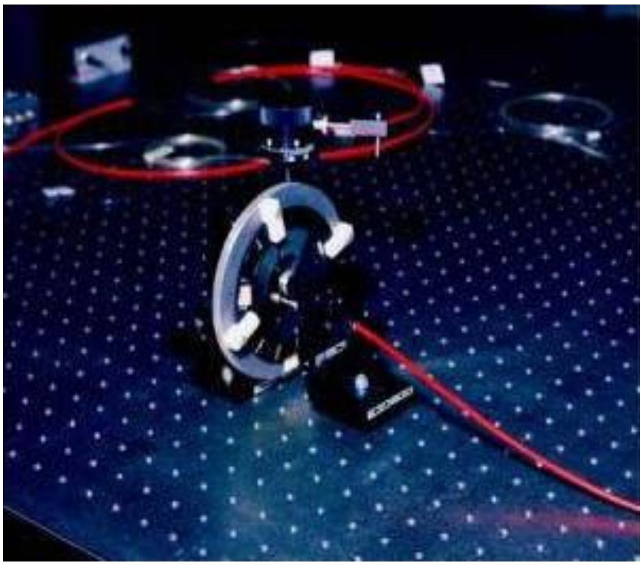

Figure 3. Fiber-optic cables are thin enough to bend, taking the light signals inside in curved paths too. (Picture courtesy of NASA Glenn Research Center: NASA-GRC).

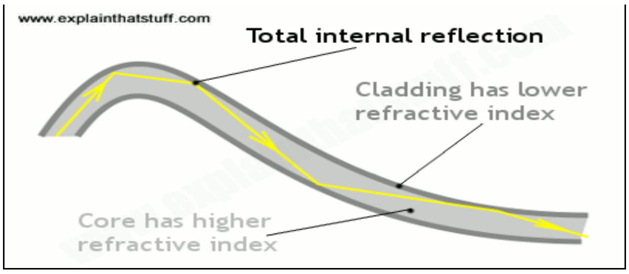

Figure 4. Artwork of total internal reflection keeps light rays bouncing down the inside of a fiber-optic cable (Ref. www.explainthat stuff.com).

Light travels down a fiber-optic cable by bouncing repeatedly off the walls. Each tiny photon (particle of light) bounces down the pipe like a bobsleigh going down an ice run. Now you might expect a beam of light, traveling in a clear glass pipe, simply to leak out of the edges. But if light hits glass at a really shallow angle (less than 42 degrees), it reflects back in again—as though the glass were really a mirror. This phenomenon is called total internal reflection. It's one of the things that keep light inside the pipe [5,7,9].

The other thing that keeps light in the pipe is the structure of the cable, which is made up of two separate parts. The main part of the cable—in the middle—is called the **core** and that's the bit the light travels through. Wrapped around the outside of the core is another layer of glass called the cladding. The cladding's job is to keep the light signals inside the core. It can do this because it is made of a different type of glass to the core. (More technically, the cladding has a lower refractive index) [8,11,12].

Types of fiber-optic cables

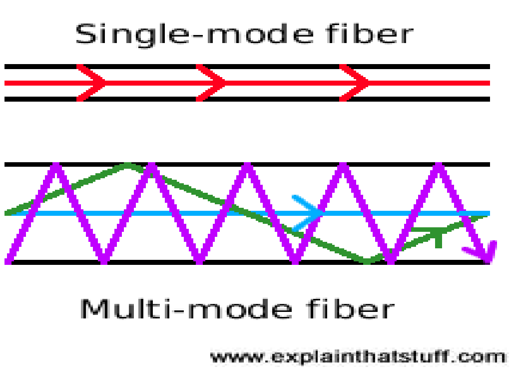

Figure 5. Artworks for light-travelling in different ways in single-mode and multi-mode fibers. Below: Inside a typical single-mode fiber cable (not drawn to scale). The thin core is surrounded by cladding roughly ten times bigger in diameter, a plastic outer coating (about twice the diameter of the cladding), some strengthening fibers made of a tough material with a protective outer jacket on the outside (Ref. www.explainthat stuff.com).

Optical fibers carry light signals down them in what are called modes. That sounds technical but it just means different ways of traveling: a mode is simply the path that a light beam follows down the fiber. One mode is to go straight down the middle of the fiber. Another is to bounce down the fiber at a shallow angle. Other modes involve bouncing down the fiber at other angles, more or less steep [14,17].

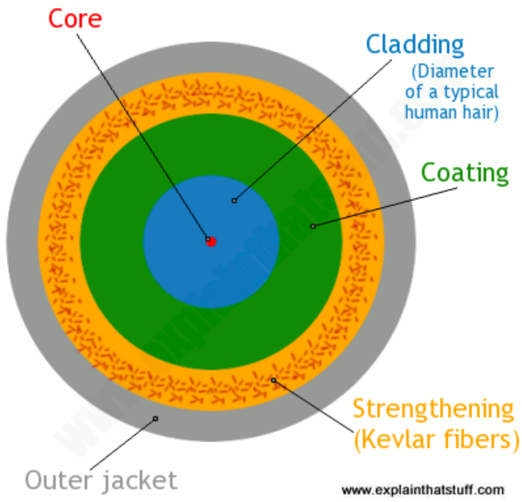

Figure 6. Sectional view of fiber optics cable.

The simplest type of optical fiber is called single-mode. It has a very thin core about 5-10 microns (millionths of a meter) in diameter. In a single-mode fiber, all signals travel straight down the middle without bouncing off the edges (red line in diagram). Cable TV, Internet, and telephone signals are generally carried by single-mode fibers, wrapped together into a huge bundle. Cables like this can send information over 100 km (60 miles).

Another type of fiber-optic cable is called multi-mode. Each optical fiber in a multi-mode cable is about 10 times bigger than one in a single-mode cable. This means light beams can travel through the core by following a variety of different paths (purple, green, and blue lines)—in other words, in multiple different modes. Multi-mode cables can send information only over relatively short distances and are used (among other things) to link computer networks together [11,13,16].

Even thicker fibers are used in a medical tool called a gastro-scope (a type of endoscope), which doctors poke down someone's throat for detecting illnesses inside their stomach. A gastro-scope is a thick fiber-optic cable consisting of many optical fibers. At the top end of a gastro-scope, there is an eyepiece and a lamp. The lamp shines its light down one part of the cable into the patient's stomach. When the light reaches the stomach, it reflects off the stomach walls into a lens at the bottom of the cable. Then it travels back up another part of the cable into the doctor's eyepiece. Other types of endoscopes work the same way and can be used to inspect different parts of the body. There is also an industrial version of the tool, called a fiberscope, which can be used to examine things like inaccessible pieces of machinery in airplane-engines [15,17,20].

An easy experiment to understand fiber-optics

The little but very good experiment is a modern-day recreation of a famous scientific demonstration carried out by Irish physicist John Tyndall (in 1870).

Figure 7. If seen from below the water bottle will look like this when it is wrapped in an aluminum foil. The foil stops light leaking out from the sides of the bottle. The bottom should not be covered of the bottle or light won't be able to get in. The black object on the right is the flashlight, just before pressing it against the bottle. It can already be seen some of its light shining into the bottom of the bottle.

It's best to do it in a darkened bathroom or kitchen at the sink or washbasin. An old clear, plastic drinks bottle, the brightest flashlight (torch) some aluminum foil, and some sticky tape are needed.

1. A plastic bottle is taken and wrapping aluminum foil tightly around the sides, leaving the top and bottom of the bottle uncovered, if it is needed to hold the foil in place with sticky tape
2. The bottle is filled with water
3. The flashlight is switched on and presses it against the base of the bottle so the light shines up inside the water. It works best if you press the flashlight tightly against the bottle. It is needed as much light to enter the bottle as possible, so use the brightest flashlight as find.
4. Standing by the sink, tilt the bottle so the water starts to pour out. The flashlight is kept pressed tightly against the bottle. If the room is darkened, it can be seen the spout of water lighting up ever so slightly. Notice how the water carries the light, with the light beam bending as it goes! If you can't see much light in the water spout, try a brighter flashlight

Uses of fiber optics

Shooting light down a pipe seems like a neat scientific party trick, and you might not think there'd be many practical applications for something like that. But just as electricity can power many types of machines, beams of light can carry many types of information—so they can help us in many ways. We don't notice just how commonplace fiber-optic cables have become because the laser-powered signals they carry flicker far beneath our feet, deep under office floors and city streets. The technologies that use it—computer networking, broadcasting, medical scanning, and military equipment (to name just four)—do so quite invisibly.

Fiber optics for computer networks

Fiber-optic cables are now the main way of carrying information over long distances because they have three very big advantages over old-style copper cables:

Less attenuation: (signal loss) Information travels roughly 10 times further before it needs amplifying—which makes fiber networks simpler and cheaper to operate and maintain.

No interference: Unlike with copper cables, there's no "cross-talk" (electromagnetic interference) between optical fibers, so they transmit information more reliably with better signal quality.

Higher bandwidth: As it has already been seen, fiber-optic cables can carry far more data than copper cables of the same diameter.

One should thank to the Internet media for reading this introductory article. People probably might have chanced upon this page with a search engine like "Google", which operates a worldwide network of massive data centers connected by vast-capacity fiber-optic cables (and is now trying to roll out fast fiber connections to the rest of us). Having clicked on a search engine link, you've downloaded this web page from my web server and my words have whistled most of the way to you down more fiber-optic cables. Indeed, if you're using fast fiber-optic broadband, optical fiber cables are doing almost all the work every time you go online. With most high-speed broadband connections, only the last part of the information's journey (the so-called "last mile" from the fiber-connected cabinet on your street to your house or apartment) involves old-fashioned wires. It's fiber-optic cables, not copper wires, that now carry "likes" and "tweets" under our streets, through an increasing number of rural areas, and even deep beneath the oceans linking continents. If you picture the Internet (and the World Wide Web that rides on it) as a global spider's web, the strands holding it together are fiber-optic cables; according to some estimates, fiber cables cover over 99 percent of the Internet's total mileage and carry over 99 percent of all international communications traffic.

The faster people can access the Internet, the more they can—and will—do online. The arrival of broadband Internet made possible the phenomenon of cloud computing (where people store and process their data remotely, using online services instead of a home or business PC in their own premises). In much the same way, the steady rollout of fiber broadband (typically 5–10 times faster than conventional DSL broadband, which uses ordinary telephone lines) will make it much more commonplace for people to do things like streaming movies online instead of watching broadcast TV or renting DVDs. With more fiber capacity and faster connections, we'll be tracking and controlling many more aspects of our lives online using the so-called Internet of things.

But it's not just public Internet data that streams down fiber-optic lines. Computers were once connected over long distances by telephone lines or (over shorter distances) copper Ethernet cables, but fiber cables are increasingly the preferred method of networking computers because they're very affordable, secure, reliable, and have much higher capacity. Instead of linking its offices over the public Internet, it's perfectly possible for a company to set up its own fiber network (if it can afford to do so) or (more likely) buy space on a private fiber network. Many private computer networks run on what's called dark fiber, which sounds a bit sinister, but is simply the unused capacity on another network (optical fibers waiting to be lit up).

Figure: Fiber-optic networks are expensive to construct (largely because it costs so much to dig up streets). Because the labor and construction costs are much more expensive than the cable itself, many network operators deliberately lay much more cable than they currently need. (Ref. Picture by Chris Willis courtesy of US Air Force)

The Internet was cleverly designed to ferry any kind of information for any kind of use; it's not limited to carrying computer data. While telephone lines once carried the Internet, now the fiber-optic Internet carries telephone (and Skype) calls instead. Where telephone calls were once routed down an intricate patchwork of copper cables and microwave links between cities, most long-distance calls are now routed down fiber-optic lines. Vast quantities of fiber were laid from the 1980s onward; estimates vary wildly, but the worldwide total is believed to be several hundred million kilometers (enough to cross the United States about a million times). In the mid-2000s, it was estimated that as much as 98 percent of this was unused "dark fiber"; today, although much more fiber is in use, it's still generally believed that most networks contain anywhere from a third to a half dark fiber.

Fiber optics for broadcasting

Back in the early 20th century, radio and TV broadcasting was born from a relatively simple idea: it was technically quite easy to shoot electromagnetic waves through the air from a single transmitter (at the broadcasting station) to thousands of antennas on people's homes. These days, while radio still beams through the air, we're just as likely to get our TV through fiber-optic cables.

Cable TV companies pioneered the transition from the 1950s onward, originally using coaxial cables (copper cables with a sheath of metal screening wrapped around them to prevents crosstalk interference), which carried just a handful of analog TV signals. As more and more people connected to cable and the networks started to offer greater choice of channels and programs, cable operators found they needed to switch from coaxial cables to optical fibers and from analog to digital broadcasting. Fortunately, scientists were already figuring out how that might be possible; as far back as 1966, Charles Kao (and his colleague George Hockham) had done the math, proving how a single optical fiber cable might carry enough data for several hundred TV channels (or several hundred thousand telephone calls). It was only a matter of time before the world of cable TV took notice—and Kao's "groundbreaking achievement" was properly recognized when he was awarded the 2009 Nobel Prize in Physics.

Apart from offering much higher capacity, optical fibers suffer less from interference, so offer better signal (picture and sound) quality; they need less amplification to boost signals so they travel over long distances; and they're altogether more cost effective. In the future, fiber broadband may well be how most of us watch television, perhaps through systems such as IPTV (Internet Protocol Television), which uses the Internet's standard way of carrying data ("packet switching") to serve TV programs and movies on demand. While the copper telephone line is still the primary information route into many people's homes, in the future, our main connection to the world will be a high-bandwidth fiber-optic cable carrying any and every kind of information.

Fiber optics for medicine

Medical gadgets that could help doctors peer inside our bodies without cutting them open were the first proper application of fiber optics over a half century ago. Today, gastro-scopes (as these things are called) are just as important as ever, but fiber optics continues to spawn important new forms of medical scanning and diagnosis.

One of the latest developments is called a lab on a fiber, and involves inserting hair-thin fiber-optic cables, with built-in sensors, into a patient's body. These sorts of fibers are similar in scale to the ones in communication cables and thinner than the relatively chunky light guides used in gastro-scopes. How do they work? Light zaps through them from a lamp or laser, through the part of the body the doctor wants to study. As the light whistles through the fiber, the patient's body alters its properties in a particular way (altering the light's intensity or wavelength very slightly, perhaps). By measuring the way the light changes (using techniques such as interferometry), an instrument attached to the other end of the fiber can measure some critical aspect of how the patient's body is working, such as their temperature, blood pressure, cell pH, or the presence of medicines in their bloodstream. In other words, rather than simply using light to see inside the patient's body, this type of fiber-optic cable uses light to sense or measure it instead.

Uses of fiber optics in military

Photo: Fiber optics on the battlefield. This Enhanced Fiber-Optic Guided Missile (EFOG-M) has an infrared fiber-optic camera mounted in its nose so that the gunner firing it can see where it's going as it travels. (Picture courtesy of U.S. Army).

It's easy to picture Internet users linked together by giant webs of fiber-optic cables; it's much less obvious that the world's hi-tech military forces are connected the same way. Fiber-optic cables are inexpensive, thin, lightweight, high-capacity, robust against attack, and extremely secure, so they offer perfect ways to connect military bases and other installations, such as missile launch sites and radar tracking stations. Since they don't carry electrical signals, they don't give off electromagnetic radiation that an enemy can detect, and they're robust against electromagnetic interference (including systematic enemy "jamming" attacks). Another benefit is the relatively light weight of fiber cables compared to traditional wires made of cumbersome and expensive copper metal. Tanks, military airplanes, and helicopters have all been slowly switching from metal cables to fiber-optic ones.

CONCLUSION

From the era of prehistoric time to recent time of nano technology, communications have always been pioneer in the development of culture as well as basic human needs. Optical fibers have become most versatile communication medium are inexpensive, thin, lightweight, high-capacity, robust against attack, and extremely secure, so they offer perfect ways to connect military bases and other installations, such as missile-launch-sites and radar tracking stations. Partly it's a matter of cutting costs and saving weight (fiber-optic cables weigh nearly 90 percent less than comparable "twisted-pair" copper cables). It also improves reliability; for example, unlike traditional cables on an airplane, which have to be carefully shielded (insulated) to protect them against lightning strikes, optical fibers are completely immune to that kind of problem.

Acknowledgement

The author wish to acknowledge the contribution of the inventors of fiber optics:

- 1840s: Swiss physicist Daniel Colladon (1802–1893) discovered he could shine light along a water pipe. The water carried the light by internal reflection.
- 1870: An Irish physicist called John Tyndall (1820–1893) demonstrated internal reflection at London's Royal Society. He shone light into a jug of water. When he poured some of the water out from the jug, the light curved round following the water's path. This idea of "bending light" is exactly what happens in fiber optics. Although Colladon is the true grandfather of fiber-optics, Tyndall often earns the credit.
- 1930s: Heinrich Lamm and Walter Gerlach, two German students, tried to use light pipes to make a gastro-scope—an instrument for looking inside someone's stomach.
- 1950s: In London, England, Indian physicist Narinder Kapany (1927–) and British physicist Harold Hopkins (1918–1994) managed to send a simple picture down a light pipe made from thousands of glass fibers. After publishing many scientific papers, Kapany earned a reputation as the "father of fiber optics."
- 1957: Three American scientists at the University of Michigan, Lawrence Curtiss, Basil Hirschowitz, and Wilbur Peters, successfully used fiber-optic technology to make the world's first gastro-scope.
- 1960s: Chinese-born US physicist Charles Kao (1933–) and his colleague George Hockham realized that impure glass was no use for long-range fiber optics. Kao suggested that a fiber-optic cable made from very pure glass would be able to carry telephone signals over much longer distances and was awarded the 2009 Nobel Prize in Physics for this ground-breaking discovery.
- 1960s: Researchers at the Corning Glass Company made the first fiber-optic cable capable of carrying telephone signals.
- 1977: The first fiber-optic telephone cable was laid between Long Beach and Artesia, California.
- 1997: A huge transatlantic fiber-optic telephone cable called FLAG (Fiber-optic link around the Globe) was laid between London, England and Tokyo (Japan).

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