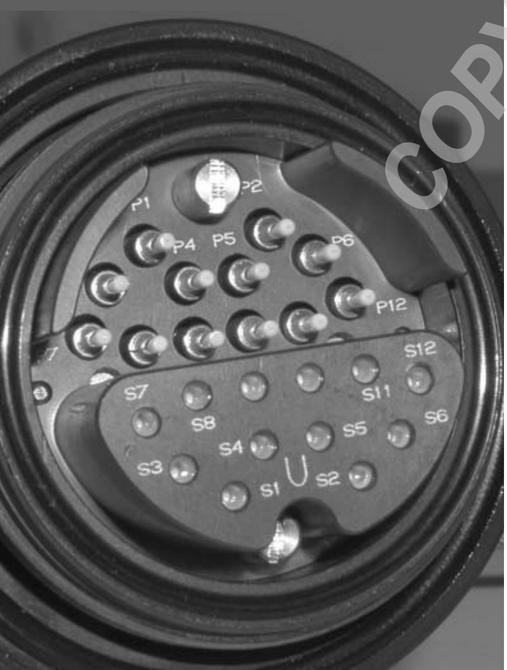
Chapter 1

History of Fiber Optics and Broadband Access

THE FOLLOWING ETA FIBER-OPTICS INSTALLER COMPETENCIES ARE COVERED IN THIS CHAPTER:

- ✓ **Trace the evolution of light in communication.**
- ✓ **Summarize the evolution of optical fiber manufacturing technology.**
- ✓ **Track the evolution of optical fiber integration and application.**
- ✓ **Describe the role of fiber optics in high-speed Internet access.**



Like many technological achievements, fiber-optic communications grew out of a succession of quests, some of them apparently unrelated. It is important to study the history of fiber optics to understand that the technology as it exists today is relatively new and still evolving.

This chapter discusses the major accomplishments that led to the creation of high-quality optical fibers and their use in high-speed communications and data transfer, as well as their integration into existing communications networks.

In this chapter, you will learn to

- Recognize the refraction of light
- Identify total internal reflection
- Detect crosstalk between multiple optical fibers
- Recognize attenuation in an optical fiber

Evolution of Light in Communication

Hundreds of millions of years ago, the first bioluminescent creatures began attracting mates and luring food by starting and stopping chemical reactions in specialized cells. Over time, these animals began to develop distinctive binary, or on-off, patterns to distinguish one another and communicate intentions quickly and accurately. Some of them have evolved complex systems of flashing lights and colors to carry as much information as possible in a single glance. These creatures were the first to communicate with light, a feat instinctive to them but tantalizing and elusive to modern civilization until recently.

Early Forms of Light Communication

Some of the first human efforts to communicate with light consisted of signal fires lit on hilltops or towers to warn of advancing armies, and lighthouses that marked dangerous coasts for ancient ships and gave them reference points in their journeys. To the creators of these signals, light's tremendous speed (approximately 300,000 kilometers per second) made its travel over great distances seem instantaneous.

An early advance in these primitive signals was the introduction of relay systems to extend their range. In some cases, towers were spread out over hundreds of kilometers, each one in the line of sight of the next. With this system, a beacon could be relayed in the time it took each tower guard to light a fire—a matter of minutes—while the fastest transportation might have taken days. Because each tower only needed in its line of sight the sending and receiving towers, the light, which normally travels in a straight line, could be guided around obstacles such as mountains as well as over the horizon. As early as the fourth century A.D., Empress Helena, the mother of Constantine, was believed to have sent a signal from Jerusalem to Constantinople in a single day using a relay system.

NOTE The principle behind signal relay towers is still used today in the form of repeaters, which amplify signals attenuated by travel over long distances through optical fibers.

Early signal towers and lighthouses, for all their usefulness, were still able to convey only very simple messages. Generally, no light meant one state, whereas a light signaled a change in that state. The next advance needed was the ability to send more detailed information with the light. A simple but notable example is the signal that prompted Paul Revere's ride at the start of the American Revolution. By prearranged code, one light hung in the tower of Boston's Old North Church signaled a British attack by land; two lights meant an invasion by sea. The two lamps that shone in the tower not only conveyed a change in state, but also provided a critical detail about that change.

The Quest for Data Transmission

Until the 1800s, light had proven to be a speedy way to transmit simple information across great distances, but until new technologies were available, its uses were limited. It took a series of seemingly unrelated discoveries and inventions to harness the properties of light through optical fibers.

The first of these discoveries was made by Willebrord van Roijen Snell, a Dutch mathematician who in 1621 wrote the formula for the principle of *refraction*, or the bending of light as it passes from one material into another. The phenomenon is easily observed by placing a stick into a glass of water. When viewed from above, the stick appears to bend because light travels more slowly through the water than through the air. Snell's formula, which was published 70 years after his death, stated that every transparent substance had a particular *index of refraction*, and that the amount that the light would bend was based on the relative refractive indices of the two materials through which the light was passing. Air has an approximate refractive index of 1 and water has a refractive index of 1.33.

The next breakthrough came from Jean-Daniel Colladon, a Swiss physicist, and Jacques Babinet, a French physicist. In 1840, Colladon and Babinet demonstrated that bright light could be guided through jets of water through the principle of *total internal reflection*. In their demonstration, light from an arc lamp was used to illuminate a container of water. Near the bottom of the container was a hole through which the water could escape. As the water poured out of the hole, the light shining into the container followed the stream of water. Their use of this discovery, however, was limited to illuminating decorative fountains and special effects in operas. It took John Tyndall, a natural philosopher and physicist from Ireland, to bring the phenomenon to greater attention. In 1854, Tyndall performed the demonstration before the British Royal Society and made it part of his published works in 1871, casting a shadow over the contribution of Colladon and Babinet. Tyndall is now widely credited with discovering total internal reflection, although Colladon and Babinet had demonstrated it 14 years previously.

Total internal reflection takes place when light passing through a material with a higher index of refraction (the water in the experiment) hits a boundary layer with a material that has a lower index of refraction (the air). When this takes place, the boundary layer becomes reflective, and the light bounces off the boundary layer, remaining contained within the material with the higher index of refraction.

Shortly after Tyndall, Colladon, and Babinet laid the groundwork for routing light through a curved material, another experiment took place that showed how light could be used to carry higher volumes of data.

In 1880, Alexander Graham Bell demonstrated his photophone, one of the first true attempts to carry complex signals with light. It was also the first device to transmit signals wirelessly. The photophone gathered sunlight onto a mirror attached to a mouthpiece that vibrated when a user spoke into it. The vibrating mirror reflected the light onto a receiver coated with selenium, which produced a *modulated* electrical signal that varied with the light coming from the sending device. The electrical signal went to headphones where the original voice input was reproduced.

Bell's invention suffered from the fact that outside influences such as dust or stray light confused the signals, and clouds or other obstructions to light rendered the device inoperable. Although Bell had succeeded in transmitting a modulated light signal nearly 200 meters, the photophone's limitations had already fated it to be eclipsed by Bell's earlier invention, the telephone. Until the light could be modulated and guided as well as electricity could, inventions such as the photophone would continue to enjoy only novelty status.

Evolution of Optical Fiber Manufacturing Technology

John Tyndall's experiment in total internal reflection had led to attempts to guide light with more control than could be achieved in a stream of water. One such effort by William Wheeler in 1880, the same year that Bell's photophone made its debut, used pipes with a reflective coating inside that guided light from a central arc lamp throughout a house. As with other efforts of the time, there was no attempt to send meaningful information through these conduits—merely to guide light for novelty or decorative purposes. The first determined efforts to use guided light to carry information came out of the medical industry.

Controlling the Course of Light

Doctors and researchers had long tried to create a device that would allow them to see inside the body with minimal intrusion. They had begun experimenting with bent glass and quartz rods, bringing them tantalizingly close to their goal. These tools could transmit light into the body, but they were extremely uncomfortable and sometimes dangerous for the patient, and there was no way yet to carry an image from the inside of the body out to doctors. What they needed was a flexible substance or *medium* that could carry whole images for about half a meter.

One such material was in fact pioneered for quite a different purpose. Charles Vernon Boys was a British physics teacher who needed extremely sensitive instruments for his continuing research in heat and gravity. In 1887, to provide the materials he needed, he began drawing fine fibers out of molten silica. Using an improvised miniature crossbow, he shot a needle that dragged the molten material out of a heat source at high speed. The resulting fiber—more like quartz in its crystalline structure than glass—was finer than any that had been made to date, and was also remarkably even in its thickness. Even though glass fibers had already been available for decades before this, Boys' ultra-fine fibers were the first to be designed for scientific purposes and were also the strongest and smallest that had been made to date. He did not, however, pursue research into the optical qualities of his fibers.

Over the next four decades, attempts to use total internal reflection in the medical industry yielded some novel products, including glass rods designed by Viennese researchers Roth and Reuss to illuminate internal organs in 1888, and an illuminated dental probe patented in 1898 by David Smith. A truly flexible system for illuminating or conveying images of the inside of the body remained elusive, however.

The next step forward in the optical use of fibers occurred in 1926. In that year, Clarence Weston Hansell, an electrical engineer doing research related to the development of television at RCA, filed a patent for a device that would use parallel quartz fibers to transmit a lighted image over a short distance. The device remained in the conceptual stage, however, until a German medical student, Heinrich Lamm, developed the idea independently in an attempt to form a flexible gastroscope. In 1930, Lamm bundled commercially produced fibers and managed to transmit a rough image through a short stretch of the first fiber-optic cable. The process had several problems, however, including the fact that the fiber ends were not arranged exactly, and they were not properly cut and polished. Another issue was to prove more daunting. The image quality suffered from the fact that the quartz fibers were bundled against each other. This meant that the individual fibers were no longer surrounded by a medium with a lower index of refraction. Much of the light from the image was lost to *crosstalk*. Crosstalk or optical coupling is the result of light leaking out of one fiber into another fiber.

The poor focus and resolution of Lamm's experimental image meant that a great deal more work would be needed, but Lamm was confident enough to write a paper on the experiment. The rise of the Nazis, however, forced Lamm, a Jew, to leave Germany and abandon his research. The dream of Hansell and Lamm languished until a way could be found to solve the problems that came with the materials available at the time.

Also in 1930, the chemical company DuPont invented a clear plastic material that it branded Lucite. This new material quickly replaced glass as the medium of choice for lighted medical probes. The ease of shaping Lucite pushed aside experiments with bundles of glass fiber, along with the efforts to solve the problems inherent in Lamm's probe.

The problems surfaced again 20 years later, when the Dutch government began looking for better periscopes for its submarines. They turned to Abraham van Heel, who was at the time the president of the International Commission of Optics and a professor of physics at the Technical University of Delft, the Netherlands. Van Heel and his assistant, William Brouwer, revived the idea of using fiber bundles as an image-transmission medium. Fiber bundles, Brouwer pointed out, had the added advantage of being able to scramble and then unscramble an image—an attractive feature to Dutch security officials.

When van Heel attempted to build his image carrier, however, he rediscovered the problem that Lamm had faced. The refractive index of adjacent fibers reduced a fiber's ability to achieve total internal reflection, and the system lost a great deal of light over a short distance. At one point, van Heel even tried coating the fibers with silver to improve their reflectivity, but the effort provided little benefit.

At his government's suggestion, van Heel approached Brian O'Brien, president of the Optical Society of America, in 1951. O'Brien suggested a procedure that is still the basis for fiber optics today: surrounding, or "cladding," the fiber with a layer of material with a lower refractive index.

Following O'Brien's suggestion, van Heel ran the fibers through a liquid plastic that coated them, and in April 1952, he succeeded in transmitting an image through a 400-fiber bundle over a distance of half a meter.

Van Heel's innovation—along with research performed by Narinder Singh Kapany, who also coined the term *fiber optics*, and Harold Hopkins—helped make the 1950s the pivotal decade in the development of modern fiber optics.

Working in England, Kapany and Hopkins developed a method for ensuring that the fibers at each end of a cable were in precise alignment. They wound a single fine strand several thousand times in a figure-eight pattern and sealed a section in clear epoxy to bind the fibers together throughout the bundle. They then sawed the sealed portion in half, leaving the fiber ends bonded in exact alignment. The image transmitted with this arrangement was clearly an improvement, but the brightness degraded quickly since the fibers were unclad.

Extending Fiber's Reach

In January 1954, the British journal *Nature* chanced to publish papers on the findings of van Heel as well as Kapany and Hopkins in the same issue. Although their placement in the journal was apparently coincidental, the two advancements were precisely the right combination of ideas for Professor Basil Hirschowitz, a gastrosurgeon from South Africa who was working on a fellowship at the University of Michigan. Hirschowitz assembled a team to study the uses of these new findings as a way to finally build a flexible endoscope for peering inside the body. Assisting Hirschowitz were physicist C. Wilbur Peters and a young graduate student named Lawrence Curtiss.

Curtiss studied the work of Kapany and Hopkins and used their winding method to create a workable fiber bundle, but his first attempt at cladding used van Heel's suggestion of cladding glass fibers with plastic. The results were disappointing.

In 1956, Curtiss began working with a new type of glass from Corning, one with a lower refractive index than the glass he was using in his fibers. He placed a tube made of the new glass around a core made from the higher refractive index glass and melted the two together. The cladded glass fiber that he drew from this combination was a success. On December 8, 1956, Curtiss made a fiber with light-carrying ability far superior to that of any fiber before it. Even when he was 12 meters away from the glass furnace, he could see the glow of the fire inside the fiber that was being drawn from it. By early 1957, Hirschowitz and Curtiss had created a working endoscope, complete with lighting and optics. This event marked the first practical use of optical fibers to transmit complex information.

Curtiss' fibers were well suited for medical applications, but their ability to carry light was limited. Suffering a signal loss of one *decibel* per meter, the fibers were still not useful for long-distance communications. Many thought that glass was inherently unusable for communications, and research in this area remained at a minimal level for nearly a decade.

In the meantime, the electronic communications industry had been experimenting with methods of improving bandwidth for the higher volumes of traffic they expected to carry. The obvious choice for increasing the amount of information a signal could carry was to increase the frequency, and throughout the 1950s, researchers had pushed frequencies into the tens of *gigahertz*, which produced *wavelengths* of only a few millimeters. Frequencies in this range—just below the lowest infrared frequencies—required hollow pipes to be used as *waveguides*, because the signals were easily disturbed by atmospheric conditions such as fog or dust.

With the invention of the laser in 1960, the potential for increasing communication bandwidths literally increased exponentially. Wavelengths had been slashed from the millimeter range to the micrometer range, and true optical communications seemed within reach. The problems of atmospheric transmission remained, however, and waveguides used for lower frequencies were proving inadequate for optical wavelengths unless they were perfectly straight. Optical fibers, too, were all but ruled out as a transmission medium because of the loss of light or *attenuation*. The loss of 1,000 decibels per kilometer was still too great.

One researcher did not give up on fiber, however; Charles K. Kao, working at Standard Telecommunications Laboratories, began studying the problems encountered in optical fibers. His conclusions revived interest in the medium after he announced in 1966 that signal losses in glass fibers were not caused by inherent deficiencies of the material, but by flaws in the manufacturing process. Kao proposed that improved manufacturing processes could lower attenuation to levels of 20 decibels per kilometer or better, while providing the ability to carry up to 200,000 telephone channels in a single fiber.

Kao's pronouncement sparked a race to find the lower limit of signal loss in optical fibers. In 1970, Corning used pure silica to create a fiber with a loss that achieved Kao's target of only 20 decibels per kilometer. That was just the beginning. Six years later, the threshold had dropped to just half a decibel per kilometer, and in 1979 the new low was 0.2 decibel per kilometer. Optical fiber had passed well into the realm of practicality for communications and could begin showing its promise as a superior medium to copper.

Evolution of Optical Fiber Integration and Application

Once signal losses in fiber dropped below Kao's projected figure of 20 decibels per kilometer, communications companies began looking seriously at fiber optics as a new transmission medium. The technology required for this fledgling medium was still expensive, however, and fiber-optic communications systems remained in closed-circuit, experimental stages until 1973. In that year, the U.S. Navy installed a fiber-optic telephone link aboard the *USS Little Rock*. Fiber optics had left the lab and started working in the field. Further military tests showed fiber's advantages over copper in weight and information-carrying capacity.

The first full-scale commercial application of fiber-optic communication systems occurred in 1977, when both AT&T and GTE began using fiber-optic telephone systems for commercial customers. During this period, the U.S. government breakup of the Bell Telephone system monopoly ushered in a boom time for smaller companies seeking to market long-distance service. A number of companies had positioned themselves to build microwave towers throughout the country to create high-speed long-distance networks. With the rise of fiber-optic technology, however, the towers were obsolete before they had even been built. Plans for the towers were scrapped in the early 1980s in favor of fiber-optic links between major cities. These links were then connected to local telephone companies that leased their capacity from the operators. The result was a bandwidth feeding frenzy. The fiber-optic links had such high capacities that extra bandwidth was leased to other local and long-distance carriers, which often undercut the owners of the lines, driving some out of business.

Following the success of fiber optics in the telecommunications industry, other sectors began taking advantage of this medium. During the 1990s, fiber-optic networks began to dominate in the fields of industrial controls, computers, and information systems. Improvements in lasers and fiber manufacturing continued to drive data rates higher and bring down operating costs.

Today, fiber optics have become commonplace in many areas as the technology continues to improve. Until recently, the transition to fiber optics was cost effective only for business and industry; equipment upgrades made it too expensive for telephone and cable companies to run fiber to every home. Manufacturing improvements have reduced costs, however, so that running fiber to the home is now an affordable alternative for telephone and cable companies.

Broadband since the Turn of the Century

A search on the Internet for the definition of broadband will yield many different results. Which result is correct? For this chapter, the definition published by the Federal Communications Commission (FCC) is correct. The FCC states that the term broadband commonly refers to high-speed Internet access that is always on and faster than the traditional dial-up access.

Broadband can be accessed using different high-speed transmission technologies over different mediums. Typical broadband connections include:

- Fiber optics
- Wireless

- Cable modem
- Satellite
- Digital Subscriber Line (DSL)
- Broadband over Power Lines (BPL)

In June of 2013, the United States Office of Science and Technology Policy and The National Economic Council published a report entitled *Four Years of Broadband Growth.* Many of the facts and definitions presented in this section of the chapter were obtained from that report.

The Role of Fiber Optics in Broadband

Today broadband can be accessed using different transmission technologies over different mediums. On the road, you may access the Internet using your cell phone and *fourth-generation* (4G) technology. At your local coffee shop, that same phone may access the Internet using the coffee shop's *Wi-Fi* connection. When you arrive home, your phone connects to your wireless router that provides Internet access over a *cable modem*. Later in the day, you place the phone on the charger and turn on a high-definition television with Internet capabilities that connects to your router with a cable. While your favorite show is playing in the background, you turn on your laptop and check email over your wireless connection.

The state of broadband technology today makes all this connectivity relatively easy, and to most users it is completely transparent. In other words, you do not need to understand anything about the infrastructure that supports the global telecommunications system to communicate and share information with nearly anyone in the world.

Without fiber optics, broadband as we know it today would not exist. Fiber optics is the backbone of the global telecommunications system. No other transmission medium can move the high rates of data over the long distances required to support the global telecommunications system. This technology works so well that the typical user may not be aware that it even exists.

Cell phone towers like the one shown in Figure 1.1 are everywhere. From a distance, you can see the antennas at the top of the tower. As you get closer to the tower, you can see the copper cables running up the tower to the antennas. However, what you do not see are the optical fibers typically buried underground moving the data to and from the cell tower.

Broadband Speed and Access at the Turn of the Century and Today

As stated in the Four Years of Broadband Growth Report, at the turn of the century broadband speed was considered 200,000 bits per second or 200 kilobits per second (kbps), while dial-up Internet connections were typically 28.8kbps or 56kbps. Only 4.4 percent of the households in America had a broadband connection to their home. However, 41.5 percent had a dial-up Internet connection.

FIGURE 1.1 Cell phone tower

In 2013, the basic broadband speed was defined as 3,000,000 bits per second or 3 megabits per second (Mbps) *downstream* and 768kbps *upstream*. Downstream describes the number of bits that travel from the Internet service provider (ISP) to the person accessing broadband. This is often referred to as *download speed*. Upstream describes the number of bits being sent to the ISP. This is often referred to as *upload speed*.

While the basic broadband speed was defined with a 3Mbps download speed, more than 94 percent of the homes in America exceed 10Mbps. More than 75 percent have download speeds greater than 50Mbps, 47 percent have download speeds greater than 100Mbps, and more than 3 percent enjoy download speeds greater than 1 billion bits, or a gigabit, per second (Gbps).

Summary

This chapter discussed the history of fiber optics in communications, beginning with the first use of light to carry messages. It covered early experiments in the control of light for carrying sound, along with the problems faced by early experimenters.

This chapter also covered the discovery of fundamental principles that are essential to fiber optics and the ways in which they were adapted to control the path of light. It described the invention of processes used to improve the ability of glass fibers to carry light, as well as the refinements that made efficient, long-distance light transmission possible.

This chapter described the growth of fiber optics as an experimental data transmission medium, as a new technology for the telecommunications industry, and in its role in broadband since the turn of the century.

Exam Essentials

Understand the evolution of light in communication. Make sure that you understand the qualities of light that make it a desirable form of communication, the limitations of early communication with light, and some of the ways in which those limitations were overcome. Also, be sure you understand the principles behind early experiments with materials used to modulate and guide light.

Understand the evolution of optical fiber manufacturing technology. Make sure that you understand the problems encountered by researchers looking for more efficient ways to guide light over long distances and the breakthroughs that made modern optical fibers practical.

Understand the evolution of optical fiber integration and application. Make sure that you understand how the drop in signal losses helped optical fiber transition from experiments in guided light to a widespread communication medium. Pay attention to events that first used fiber optics in "real world" applications and proved that the technology could be used practically.

Be able to describe the role played by fiber optics in high-speed Internet access. Be able to explain that without fiber optics, broadband as we know it today would not exist. Know that only fiber optics can move the high rates of data over the long distances required to support the global telecommunications system.

Review Questions

1. What was one of the earliest advantages that light held over other forms of communication?
   - **A.** Ability to communicate complex ideas
   - **B.** Ability to carry messages quickly
   - **C.** Ability to carry messages privately
   - **D.** Ability to carry coded messages

   Hint: Light travels at approximately 300,000 kilometers per second in air.

2. The demonstrations in which light could be seen in water draining from a vessel proved that:
   - **A.** Light could travel through water.
   - **B.** Light was refracted in some materials.
   - **C.** Light could be guided through the principle of total internal reflection.
   - **D.** Light could travel in a straight line.

   Hint: Light can be guided through water because the air around it has a lower index of refraction.

3. Some of the earliest attempts to carry light through glass fibers took place because doctors and researchers were trying to:
   - **A.** View images from inside the human body.
   - **B.** Send messages from one building to another.
   - **C.** Compete with the telephone.
   - **D.** Collect numerous light sources in one area.

   Hint: Doctors and researchers experimented with bent glass and quartz.

4. One of the first goals in creating a fiber that could be used for communications was to:
   - **A.** Make the fibers smaller.
   - **B.** Make the fibers longer.
   - **C.** Reduce signal loss to 40 decibels per kilometer.
   - **D.** Reduce signal loss to 20 decibels per kilometer.

   Hint: In 1966, Charles K. Kao announced that signal losses in glass fibers could be reduced through improved manufacturing processes.

5. The decade that saw the first full-scale commercial application of fiber-optic communication systems was:
   - **A.** The 1880s
   - **B.** The 1920s

C. The 1960s

D. The 1970s

Hint: AT&T and GTE began using fiber-optic telephone systems for commercial customers.

6. Which broadband technology moves the highest rates of data over the greatest distances?

A. Fiber optics

B. Digital Subscriber Line (DSL)

C. Broadband over Power Lines (BPL)

D. Wi-Fi

Hint: No other transmission medium can move such high rates of data over the long distances.

Chapter Exercises

Recognize the Refraction of Light

Refraction is the bending of light as it passes from one material into another.

You are cleaning your pool with a small net at the end of a pole when you notice a large bug that appears to be 2' below the surface. You place the net where you believe the bug to be and move it through the water. When you lift the net from the pool, the bug is not in the net. Why did the net miss the bug?

Remember refraction is easily observed by placing a stick into a glass of water. When viewed from above, the stick appears to bend because light travels more slowly through the water than through the air. The same is true for the bug. The bug was viewed from above the water and refraction bent the light so the bug appeared to be in a different location than it actually was.

Identify Total Internal Reflection

In 1840, Colladon and Babinet demonstrated that bright light could be guided through jets of water through the principle of total internal reflection.

You just removed your fish from a dirty 10-gallon aquarium you are preparing to clean when a friend shows up with a laser pointer. Your friend energizes the laser pointer and directs the light into the side of the tank. The laser light illuminates the small dirty particles in the tank and you and your friend observe the light entering one end of the tank and exiting the other. As you friend aims the laser pointer at an angle toward the surface of the water, the light does not exit; instead it bounces off the surface of the water at an angle. Why did this happen?

Remember that Colladon and Babinet demonstrated that bright light could be guided through jets of water through the principle of total internal reflection. In their demonstration, light from an arc lamp was used to illuminate a container of water. You essentially re-created their experiment. Instead of an arc lamp and a small barrel of water, you had a laser pointer and a 10-gallon aquarium full of dirty water. The light reflected off the surface of the tank because of total internal reflection. You were able to see this happen, because the water was cloudy. Had you attempted this after the tank was cleaned the laser would be very difficult to view because there would be no particles to scatter the light. Scattering will be covered in detail in Chapter 5, "Optical Fiber Characteristics."

Detect Crosstalk between Multiple Optical Fibers

Crosstalk or optical coupling is the result of light leaking out of one fiber into another fiber.

You have bundled six flexible clear plastic strands together in an effort to make a fiber-optic scope that will allow you to look into the defroster vent in your car in hope of locating your missing Bluetooth headset. You insert your fiber-optic scope into the defroster vent and are disappointed with the image you see. What is one possible cause for the poor performance of your fiber-optic scope?

Remember that in 1930, Lamm bundled commercially produced fibers and managed to transmit a rough image through a short stretch of the first fiber-optic cable. The process had several problems, including the fact that the fiber ends were not arranged exactly, and they were not properly cut and polished. Another issue was to prove more daunting. The image quality suffered from the fact that the quartz fibers were bundled against each other. This meant that the individual fibers were no longer surrounded by a medium with a lower index of refraction. Much of the light from the image was lost to crosstalk. Crosstalk or optical coupling is the result of light leaking out of one fiber into another fiber.

Recognize Attenuation in an Optical Fiber

In 1960 after the invention of the laser, optical fibers were all but ruled out as a transmission medium because of the loss of light or attenuation.

You are troubleshooting a clog in a drainpipe and because of the size of your flashlight and the location of the drain, you cannot illuminate the drain adequately to see the clog. You decide to modify a flashlight to illuminate the inside of drainpipe in hope of identifying the source of the clog. You purchase a small diameter flexible clear plastic rod approximately 12" in length and secure one end over the bright LEDs in the center of the flashlight. After powering up the flashlight, you are disappointed that the light exiting the optical fiber is much dimmer than you expected; however, you still attempt to identify the clog. Why did the fiber-optic flashlight fail to illuminate the inside of the drainpipe?

Remember that in 1960 optical fibers were all but ruled out as a transmission medium because of their attenuation. However, in 1966 Charles K. Kao announced that flaws in the manufacturing processes caused signal losses in glass fibers. The plastic rod purchased for the flashlight was not engineered to transmit light and experienced the high attenuation that limited the use of optical fibers prior to 1970 when Corning developed an optical fiber that achieved Kao's target of only 20 decibels per kilometer. Decibels are covered in Chapter 2, "Principles of Fiber-Optic Transmission."