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Tel: +86-755-8981 8866 Fax: +86-755-8427 6832
Email & Skype: info@chipsmall.com Web: www.chipsmall.com
Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China

# Fiber Optic Demonstration System

Industrial Fiber Optics

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IF 120026 Teacher's Manual Revision A

Printed in the United States of America

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**INDUSTRIAL FIBER OPTICS, INC.**
1725 WEST 1ST STREET
TEMPE, AZ 85281-7622
U. S. A.

# BEFORE YOU BEGIN . . .

The Industrial Fiber Optics IF-DS100G, *Fiber Optic Demonstration System* is a modular 10-day introduction to fiber optics. It is designed for science, physics, industrial technology, and vocational education classrooms for grades 6-12. This module is a complete curriculum—no additional manuals or books are required except in completing homework assignments, where the library and Internet are adequate.

This manual is an integral part of the IF-DS100G module. It will guide instructors and students through 10 separate activities each of which has reading assignments containing background knowledge and fiber optic theory, lab exercises where one works with fiber optics, worksheets containing questions and homework assignments. At the rear of this manual is an operational and reference guide for the equipment.

As you complete this module, you may be surprised with what constitutes fiber optics. In fact, some of this material contained herein, you may have learned about in other classes or modules. You will learn that fiber optics is not an entirely new technology but rather a combination of three technologies: optics, lasers and electronics. A fiber optic communication system is composed of an optical fiber, transmitter and receiver. The optical fiber is a spin-off of classical optical study. Transmitters and receivers are made from semiconductor materials and technology, making them part of the electronics field. The transmitters of most fiber optic systems use light emitting diodes (LED's) or semiconductor laser diodes. The semiconductor laser is also laser technology and therefore is part of the both electronic and laser field. The curriculum in this manual will cover all the above aspects and have you working with the elements in the matching fiber optic hardware.

Everyone who samples or completes these activities will see fiber optics applied to everyday things and will have a much better appreciation of this new and exciting technology. Please take time to browse through this manual carefully. It contains a wealth of information such as reference materials, vocabulary, advance courses, etc.

Industrial Fiber Optics makes every effort to incorporate state-of-the-art technology, highest quality, and dependability in its products. We constantly explore new ideas and products to best serve the rapidly expanding needs of industry and education. We encourage comments that you may have about our products, and we welcome the opportunity to discuss new ideas that may better serve your needs. For more information about our company and products refer to **http//www.i-fiberoptics.com** on the Worldwide Web.

Thank you for selecting this Industrial Fiber Optics product. We hope it meets your expectations and provides many hours of productive activity.

# *Table of Contents*

## Teacher's Manual Only

# Section Guide

# *INTRODUCTION*
## *ACTIVITY #1:*

This activity is intended to get you acquainted with **Industrial Fiber Optics'** *Introduction to Fiber Optics* modular training curriculum. In it you will begin your studies of the fascinating world of fiber optics and familiarize yourself with fiber optic equipment.

## Equipment Needed:

- Television monitor and VCR suitable for 1/2" VHS tape
- Laser Technology: Fiber Optics videotape*
- All the components that are part of this module. Please refer to the parts list on page 7 or the detailed description on system components beginning on page 121, Tab 11.

## *To complete this activity you must:*

1. Complete the **Pretest** on pages 2 through 4.
2. Read pages 5 and 6 concerning safety and laser classification.
3. Complete **Lab Demonstration #1 - Equipment Familiarization** on page 9 and take inventory of all the equipment in this module. If you are missing any equipment or parts, let your instructor know before continuing. You may refer to the parts list on page 7 to help describe the components.
4. Watch the videotape entitled Laser Technology: Fiber Optics. (*The tape is an optional item available for purchase with this curriculum.)
5. Answer all Questions on **Worksheet #1** if watched the video tape.
6. Complete **Homework Assignment #1**.

## Homework Assignment #1:

Complete **Reading Assignment #1**, which begins on page 10.

## Pretest Student: ______________________________

1. What do the letters in the acronym **LED** stand for?
   a) Laser emission by defect
   b) Light emission by diodes
   c) Light emitting device
   d) Light emitting diode

2. When light passes from one material to another with a different refractive index, bending of the light rays occurs. This phenomenon was first mathematically described by:
   a) Howard Maxwell
   b) Galilei Galileo
   c) Fred Fresnel
   d) Willebrord Snell

3. Fiber optics is best known for its application in long-distance telecommunications.
   a) True
   b) False

4. Circle the three basic components in a fiber optic communications system.
   a) Telescope
   b) Transmitter
   c) Receiver
   d) Surveillance satellites
   e) Maser fiber
   f) Optical fiber
   g) Alternator

5. Information (data) is transmitted over optical fiber by means of:
   a) Light
   b) Radio waves
   c) Cosmic rays
   d) Acoustic waves

6. Which is a modern-day application of fiber optic illumination?
   a) Borescopes
   b) Intersection "Walk" and "Wait" signs
   c) Microscope specimen lighting
   d) All of the above

7. What type of materials can be used as a lasing medium?
   a) Solid
   b) Liquid
   c) Gas
   d) All of the above

8. The basic particle of light is:
   a) A photon
   b) A quark
   c) An electron
   d) A neutron
   e) A positron

9. Lasers are too dangerous to be used in fiber optics.
   a) True
   b) False

10. Silicon is the most commonly used detector material in fiber optic applications for wavelengths between 400 and 1050 nm.
    a) True
    b) False

11. List two advantages of using optical fiber.

    ______________________________________

    ______________________________________

12. Planck's Constant has been a tremendous benefit to the timber and wooden shipbuilding industries.
    a) True
    b) False

13. The replacement of copper wiring harnesses with fiber optic cabling increases the weight of an aircraft.
    a) True
    b) False

14. The "two personalities" of light can be represented either as electromagnetic waves or particles/photons.
    a) True
    b) False

15. Light is a small part of the electromagnetic spectrum.
    a) True
    b) False

16. The shorter the wavelength of light, the higher its frequency.
    a) True
    b) False

17. One of the most important optical measurements of any optical material is its refractive index.
    a) True
    b) False

18. The speed of light in a vacuum is approximately $3 \times 10^8$ meter per second.
    a) True
    b) False

19. Circle the two most common materials of which optical fibers are made:
    a) Plastic
    b) Sodium chloride
    c) Gallium aluminum phosphide
    d) Glass
    e) Flint
    f) Hair
    g) Diamond

20. The principle called total internal reflection explains why light cannot be guided in an optical fiber.
    a) True
    b) False

# SAFETY

The Industrial Fiber Optics equipment that goes with this curriculum contains UL-certified power adapters and LEDs (light emitting diodes) that produce low-power incoherent radiation for maximum safety.  The LEDs are broadband red 660 nanometer devices which can not be focused to a fine spot like a laser.  Since some fiber optic equipment can contain lasers, please review our laser safety suggestions for future thought. Remember, just because you can not see the beam does not mean it is not dangerous.

## RULES OF LASER SAFETY

- Lasers produce a very intense beam of light.  Treat them with respect.  Most educational lasers have an output of less than 3 milliwatts, and will not harm the skin.
- Never look into the laser aperture while the laser is turned on!  **PERMANENT EYE DAMAGE COULD RESULT.**
- Never stare into the oncoming beam.  Never use magnifiers (such as binoculars or telescopes) to look at the beam as it travels or when it strikes a surface.
- Never point a laser at anyone's eyes or face, no matter how far away they are.
- When using a laser in the classroom or laboratory, always use a beam stop, or project the beam to areas which people won't enter or pass through.
- Never leave a laser unattended while it is turned on—and always unplug it when it's not actually being used.
- Remove all shiny objects from the area in which you will be working.  This includes rings, watches, metal bands, tools, and glass.  Reflections from the beam can be nearly as intense as the beam itself.
- Never disassemble or try to adjust the laser's internal components.  Electric shock could result.

# LASER CLASSIFICATIONS

All manufacturers of lasers used in the United States, must conform to regulations administered by the Center for Devices and Radiological Health (CDRH), a branch of the U.S. Department of Health and Human Services.

The CDRH categorizes lasers into the following classes:

| Class | Description |
|---|---|
| I | A laser or laser system which does not present a hazard to skin or eyes for any wavelength or exposure time. Exposure varies with wavelength. For ultraviolet light, (.2 to .4 μm ), exposure is less than from .8 nW to .8 μW. Visible light exposure varies from .4 μW to 200 μW and for near-infrared light, the exposure is < 200 μw. Consult CDRH regulations for specific information. |
| II | Any visible laser with an output less than 1 mW of power. Warning label requirements: yellow caution label stating maximum output of 1 mW. Generally used as classroom lab lasers, supermarket scanners and laser pointers. |
| IIIa | Any visible laser with an output over 1 mW of power with a maximum output of 5 mW of power. Warning label requirements: red danger label stating maximum output of 5 mW. Also used as classroom lab lasers, in holography, laser pointers, leveling instruments, measuring devices and alignment equipment. |
| IIIb | Any laser with an output over 5 mW of power with a maximum output of 500 mW of power and all invisible lasers with an output up to 400 mW. Warning label requirements: red danger label stating maximum output. These lasers also require a key switch for operation and a 3.5-second delay when the laser is turned on. Used in many of the same applications as the Class IIIa when more power is required. |
| IV | Any laser with an output over 500 mW of power. Warning label requirements: red danger label stating maximum output. These lasers are primarily used in industrial applications such as tooling, machining, cutting and welding. Most medical laser applications also require these high-powered lasers. |

# PARTS LIST:

Industrial Fiber Optics' Fiber Optic Demonstration System contains the following components:

- 2 Lab Modules
- 2 120-VAC-to-12-VDC 500 mA power adapters with cords
- 2 1-meter 2.2 mm outside diameter, 1000 μm core optical fiber with ST connector on one end. (Sensor Fibers)
- 1 1-meter 2.2 mm outside diameter, 1000 μm core optical fiber with ST connector on both ends.
- 1 3-meter 2.2 mm outside diameter, 1000 μm core optical fiber with black jacket and ST connectors on both ends.
- 1 10-meter 2.2 mm outside diameter, 1000 μm core optical fiber with black jacket and ST connector on both ends.
- 1 1-meter 3.2 mm outside diameter, 62.5/125 μm glass core optical fiber with orange jacket and ST connectors on both ends.
- 1 3-meter 3.2 mm outside diameter, 62.5/125 μm glass core optical fiber with gray jacket and ST connectors on both ends.
- 1 3-meter 3.2 mm outside diameter, 62.5/125 μm glass core optical fiber with orange jacket and ST connectors on both ends.
- 1 10-meter 62.5/125 μm glass core duplex optical fiber with orange jacket and ST connectors on all 4 ends.
- 1 Infrared Detection Card
- 4 Orange banana-to-yellow banana plug 18 gauge wire test leads (with blue wire insulation)
- 2 Brown banana-to-brown banana plug 18 gauge wire test leads (with blue wire insulation)
- 1 Audio Interface 22 gauge wire test lead (black 3.5 mm male jack on one end, and a smaller black male jack and an orange banana plug on the other.)
- 1 Audio Interface 22 gauge wire test lead (with a black 3.5 mm male jack on one end, and a smaller black male jack and a brown banana plug on the other.)
- 1 Package of polishing film containing two pieces of 600-grit and 3 μm polishing film 10 × 14 cm in size
- 2 Pieces of white paper 5 × 10 cm (2 × 4 inches) in size
- 2 Pieces of black paper 5 × 10 cm (2 × 4 inches) in size
- 2 Pieces of transparent plastic sheeting 5 × 10 cm (2 × 4 inches) in size
- 1 AM/FM radio with 3 AA batteries
- 1 *Laser Technology: Fiber Optics* (optional videotape)

# EQUIPMENT FAMILIARIZATION
## Lab Demonstration #1

The first Lab Demonstration in this course requires students to inventory and identify all items furnished with this fiber optic training module and required for the remaining eight Lab Demonstrations. This inventory process will introduce you to the nomenclature used in the manual and will speed completion of the following demonstrations.

### Procedure

1. Choose a flat, level table approximately 90 × 120 cm (3 × 4 feet) in size as your work area for this demonstration.
2. At your work area, assemble all materials your instructor provides for you.
3. Identify each component in **Table 1**. Write in the column marked **ACTIVITY 1**, the number of components you found. If the number that you identify does not match the numbers in Column 2, notify your instructor.
4. Reference parts list on page 7 for further description of items if required.
5. Return all materials to their proper storage containers and locations.

**#  #  #**

*Photo 1. With fiber optics being used more and more, some new home builders are installing fiber optics during construction.*

**Table 1. Inventory Sheet for Lab Demonstration 1.**

| DESCRIPTION | QUANTITY | ACTIVITY 1 |
|---|---|---|
| Lab Modules | 2 | |
| 120-VAC-to-12-VDC power adapters | 2 | |
| 1-meter Sensor Fiber with ST Connector on one end | 2 | |
| 1-meter 1000 μm core optical fiber with ST connectors on both ends | 1 | |
| 3-meter 1000 μm core optical fiber with ST connectors on both ends | 1 | |
| 10-meter 1000 μm core optical fiber with ST connectors on both ends | 1 | |
| 1-meter glass optical fiber with orange jacket | 1 | |
| 3-meter glass optical fiber with gray jacket | 1 | |
| 3-meter glass optical fiber with orange jacket | 1 | |
| 10-meter glass duplex fiber with orange jacket | 1 | |
| Orange banana-to-yellow banana wire test leads (with blue wire insulation) | 4 | |
| Brown banana-to-brown banana wire test leads (with blue wire insulation) | 2 | |
| Audio Interface wire test lead (with a black 3.5 mm male jack on one end, and a smaller black male jack and an orange banana plug on the other) | 1 | |
| Audio Interface wire test lead (with a black 3.5 mm male jack on one end, and a smaller black male jack and a brown banana plug on the other) | 1 | |
| White paper about 5 × 10 cm (2 × 4 inches) in size | 2 | |
| Black paper about 5 × 10 cm (2 × 4 inches) in size | 2 | |
| Transparent plastic sheeting about 5 × 10 cm (2 × 4 inches) in size | 2 | |
| AM/FM radio with 3 AA batteries | 1 | |
| Videotape (Optional) | 1 | |

# INTRODUCTION TO FIBER OPTICS
## Reading Assignment #1

Only a few years ago fiber optics was little more than a laboratory curiosity. Physicists and other scientists in research labs were the only people doing much work in this field. Generally, it was considered an optical phenomenon with few practical applications in the real world.

Scientists and technicians pursued the technology purely for the sake of learning more about its scientific facts—not knowing that they would unlock a whole new world of practical and useful fiber optic devices. In the beginning, optical fibers were used only to illuminate hard-to-reach places such as the inside of a computer disk drive, or produce novelties such as "light trees" and multi-colored flashlights.

Today the applications are numerous, and more applications are being discovered almost daily. As only one example: In the medical field, using fiber optic probes, doctors can inspect the interior of our throat, esophagus and intestines. They can do the same inside human veins and arteries, to check for cholesterol blockage or disease. By combining fiber optics with lasers, doctors can clear blocked arteries without resorting to open heart surgery.

In most industries and professions, it is possible to transmit audio and video information over great distances and at very high speeds thanks to fiber optic technology. Data signals are carried by light waves and guided through flexible, hair-thin plastic or glass optical light pipes—more commonly known as fiber optic cable. You will learn how this is done and use these principles in the activities in this manual.

From seeing commercials on TV, you probably know that many long-distance telephone companies use fiber optics to link their main telephone distribution systems in the United States. More optical fiber is being added every day—underground, in buildings and on the same “telephone poles” that have supported copper wire telephone lines for almost a hundred years. Optical fibers are even being installed on electric power distribution poles because fiber optics is immune to electromagnetic interference (EMI) from the electrical wires.

The U.S. Armed Forces use optical fiber for portable battlefield communications, due to its reduced weight, smaller size and ability to avoid electronic eavesdropping. Other military applications include transmitting conversations between the cockpits of supersonic fighter aircraft and command stations on the ground or aboard Navy ships. Optical fiber is also used as a communication link to guide missiles to their targets. The same security advantages have led businesses to extensive use of fiber optics to transmit proprietary and financial data.

As fiber optic technology continues to advance, it will affect more and more parts of your everyday life:

- Custom and continually updating paperless, environmentally clean "newspapers" available for instant display on your home TV.
- High-definition TV will become reality—the lines you can now see so clearly on the TV screen will almost disappear.
- Accredited college classes on all kinds of subjects will be available in the comfort of your own home with two way communication.
- Internet access that will dwarf today's "high" modem speeds of 33 and 56 k will become common.
- New and dramatically improved medical procedures will emerge.

We have barely scratched the surface of fiber optics' potential to improve nearly every aspect of our existence. Now, in this manual, you will venture into the historical events that slowly but surely brought fiber optics into our lives.

# # #

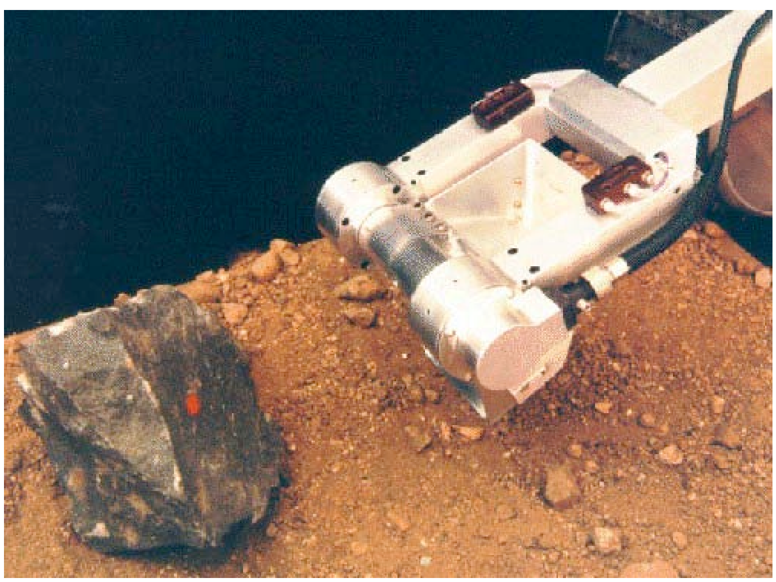

*Photo 2. Optical fiber is used to transfer light on a lunar microrover arm to an internal optical analyzer.*

## Worksheet #1 Student: ______________________________

1. The use of fiber optic materials does not decrease weight or size in aircraft.
   a) True
   b) False

2. List three applications of fiber optics:

   ______________________________

   ______________________________

   ______________________________

3. Fiber optic cabling is being installed:
   a) As replacement for copper telephone lines
   b) Underground
   c) In buildings
   d) All of the above

4. Early optical systems were dependent upon:
   a) Weather conditions
   b) Line of sight
   c) Time of day
   d) All of the above

5. Light is a form of energy.
   a) True
   b) False
   c) Sometimes
   d) Rarely

6. Light, in the fiber optics vocabulary, means electromagnetic radiation or energy in the wavelength range including infrared, visible and ultraviolet.
   a) True
   b) False

7. Wavelength of light is:
   a) $= \frac{c}{f}$
   b) $= \frac{f}{c}$
   c) $= c \cdot f$
   d) $= a \cdot b$

8. Total internal reflection is the fundamental principle that keeps light confined in an optical fiber.
   a) True
   b) False

9. Circle the two materials that are used in optical fibers.
   a) Plastic
   b) Uranium
   c) Glass
   d) Silicon
   e) Carbon

10. The two most common light sources for fiber optics are:
    a) Lasers
    b) Flares
    c) LEDs
    d) Incandescent bulbs

## NOTES

# FIBER OPTICS AT THE BEGINNING
## ACTIVITY #2:

You will begin your studies of fiber optics by delving into the history of light communications that led to modern-day fiber optics applications. You may find it interesting that optical communications started long ago. Its beginning was not in the 20th century as one might think. After learning about the history of optical communications, you will set up equipment that will allow you to transmit your own voice over optical fiber.

## Equipment Needed:

- 2 Lab Modules
- 2 120-VAC-to-12-VDC power adapters with cords
- 1 10-meter duplex optical fiber
- 2 Orange banana-to-yellow banana wire test leads (with blue wire insulation)
- 2 Brown banana-to-brown banana wire test leads (with blue wire insulation)

## *To complete this activity you must:*

1. Complete **Reading Assignment #2**.
2. Answer Questions 1 through 5 on **Worksheet #2**.
3. Complete **Lab Demonstration #2 - VOICE TRANSMISSION OVER OPTICAL FIBER**.
4. Complete **Homework Assignment #2**.

## Homework Assignment #2:

Find and read one article in a newspaper or magazine about fiber optics. This article can be about any aspect of fiber optics including technology, application, or business. List the name of the article, its author and the publication in which it appeared. Good places to look include *Time*, *Newsweek*, daily papers, and science magazines. You may also look in the reference section of this manual for other suggestions.

# WHEN DID FIBER OPTICS BEGIN?
## Reading assignment #2

Light has been used as a form of communications for thousands of years. Undoubtedly, our prehistoric ancestors used the flickering light of campfires and torches to find their way in the darkness, and to signal each other.

Native Americans used smoke signals to extend the distances over which they could communicate with each other. Light also played an important role in the American Revolution. Lanterns displayed in the belfry of the Old North Church— "*One if by land, two if by sea...*"—sent Paul Revere on his famous ride, alerting citizens that British forces were attacking. Even today, lighthouses along rugged seacoasts relay their simple message warning sailors: "Danger! Stay away! Rocks or shallow water!"

These early optical systems worked well for transmitting very simple messages. Longer messages, either spoken or written, had to be conveyed person-to-person, or carried by animals, ships and wagons. The saddlebag mail delivery service performed by "Pony Express" riders in the 1800s was, for a brief period, the fastest form of communication in America. Still, the distance that could be traveled in one day was limited—usually by sore feet, tired horses and days at sea when no wind filled the sails of ships.

In the 1790s Claude Chappe built an optical telegraph stretching across France from Paris to Lille, a distance of 230 kilometers. The ingenious system used a series of signalmen, lights and movable arms in high towers to relay signals by day or night. A visual message transmitted from one tower would be read by the operator of the next tower, using a telescope. The second operator would arrange his own tower's signaling arms to relay the original message on to the next tower. And so on, through tower after tower. In this manner a message traveled from beginning to end in about 15 minutes.

**Table 2. Standard units of measure.**

| UNIT | SYMBOL | MEASURE OF |
|---|---|---|
| meter | m | length |
| gram | g | mass |
| second | s | time |
| joule | J | energy |
| watt | W | power |
| hertz | Hz | frequency |
| ampere | A | current |
| degrees Kelvin | °K | temperature |
| degrees Celsius | °C | temperature |
| farad | f | capacitance |
| ohm | Ω | resistance |

In the early years of the United States, Boston communicated with a nearby island using an optical telegraph. This method of communication eventually was replaced by the electric telegraph, which was faster, could operate even in poor weather conditions, and at any time of day.

However, optical data transmission technology was due to return—and when it did, the electric telegraph seemed primitive by comparison.

In 1870, before members of the British Royal Society, John Tyndall demonstrated light being guided in an arcing stream of water. (Today this phenomenon is called "light guiding by total internal reflection." See Figure 1.) About the same time, Alexander Graham Bell demonstrated the "Photophone." Although not practical, because it used sunlight as the optical source and thus didn't work at night, it demonstrated how light could be modulated to carry an audio (voice) signal to a remote location.

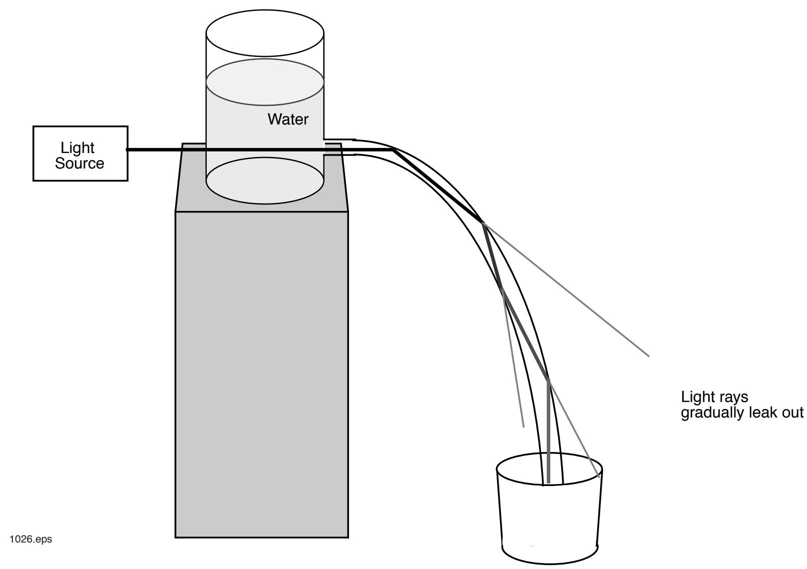


Figure 1. John Tyndall's experiment: Guiding light in a descending arc of water.

Fiber optic communications as we know it today originated in 1934 at American Telephone and Telegraph (AT&T) with research done by Norman R. French. He was granted a patent for an "optical telephone system" which carried voice signals on beams of light through a network of "light pipes." Although Mr. French didn't live to see it, his ideas were the beginning of today's fiber optic phone network.

During World War II the MASER (Microwave Amplification by the Stimulated Emission of Radiation) was developed. This concept was followed by the creation of the LASER in 1960 by Theodore H. Maiman of Hughes Research Laboratories in Malibu, California. Initially capitalized, LASER (abbreviation for Light Amplification by the Stimulated Emission of Radiation) is now a common word: laser. (It is ironic that the legal determination of patent rights to the LASER wasn't made until 1989, many years later.)