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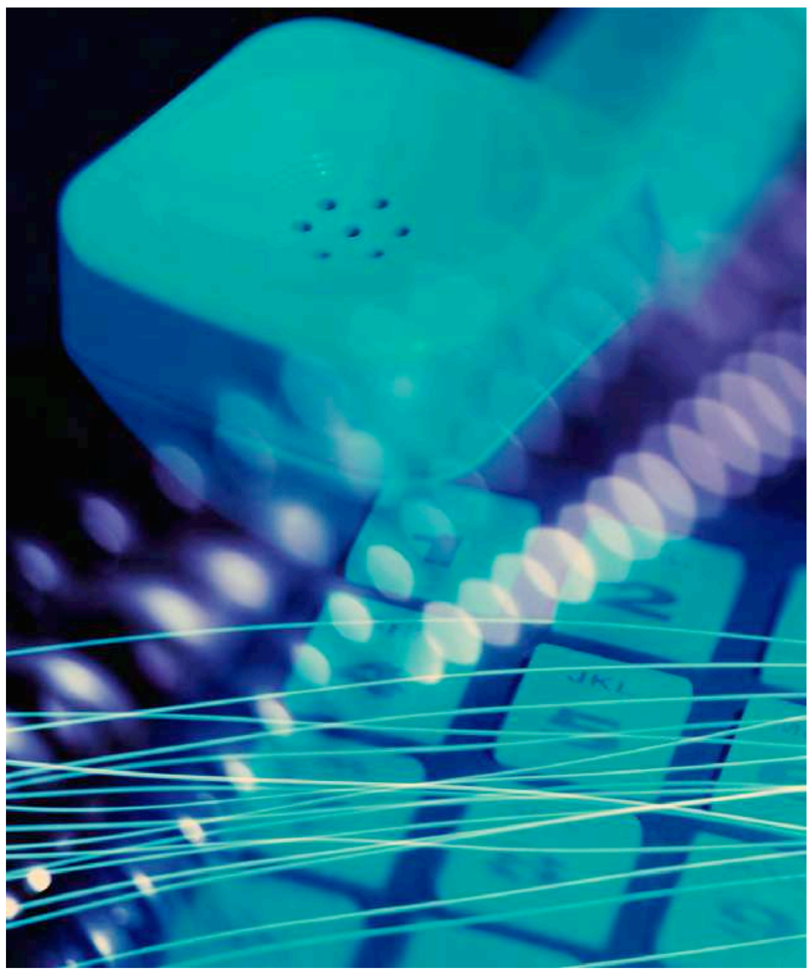
Advanced Communications and Networking Module



Industrial Fiber Optics

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IF 120265 Student's Manual Revision A

Printed in the United States of America

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Before You Begin . . .

The Industrial Fiber Optics IF-527 Fiber Optic Communications and Networking Module is a 10-day curriculum on advanced topics of fiber optics. It is designed for science, physics, industrial technology, secondary education, and vocational classrooms at grade level 11-and above. This module is a complete curriculum – no additional reading material is required except to complete homework assignments, for which a library and Internet access are adequate.

As you complete this module you may be surprised at the composition of fiber optic technology. In fact, you may have learned some of the material in other classes or modules. It is a combination of electronic, laser and optical technology and is currently in an evolving as opposed to a revolutionary stage. Optical fibers are a spin-off from the field of classical optical study. Fiber optic transmitter and receiver circuits are made from the semiconductor devices used in electronics technology. Light emitting diodes (LEDs) and laser diodes are also made from semiconductors, but laser diode operation falls in the category of physics that also describes gas and liquid lasers. The curriculum in this manual will cover how these components are used in communications and networking applications.

Everyone who samples or completes these activities will see how fiber optics is used in everyday applications to better appreciate this new and exciting technology. Please take the time to browse through this manual carefully. It contains a wealth of information when used with the reference materials, vocabulary, advanced courses, etc.

This manual is an integral part of the IF-527 Fiber Optic Communications and Networking Module. It will guide instructors and students through 10 separate activities, each of which has reading assignments with background knowledge and theory, lab exercises that use or apply fiber optics, and worksheets containing questions and homework assignments. At the rear of the manual is an operational and reference guide for the equipment

The Metric System is the primary unit of measure used throughout this product because it was used in the development of fiber optic technology. For those who prefer the English measurement system of inches, feet, etc., it has been listed behind metric terms (in parenthesis) for most cases. The English dimensions may not always be an exact conversion.

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 or any new products that we have to offer 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 learning.

Table of Contents

TEACHER'S MANUAL ONLY

Section Guide

INTRODUCTION & INVENTORY
ACTIVITY #1:

Objectives:

- ◊ Evaluate your current knowledge of fiber optics technology
- ◊ Review safety rules
- ◊ Inventory—familiarize you with all the components in this Fiber Optic Communications and Networking Module
- ◊ Inspect the tip of a polished optical fiber under high magnification
- ◊ See light transmitted through an optical fiber
- ◊ Learn the proper technique to clean the tips of optical fibers in connectors
- ◊ Review the history and fundamentals of fiber optics

Equipment you will need to complete this activity:

- ➢ 2 Fiber Optic Reference Guides
- ➢ All the components that are part of this module. Refer to the parts list listed in Table 1 or the detailed description of the components beginning on page 10.

To complete this activity you must:

1. Complete the Prequiz on pages 2 through 4.
2. Read the safety instructions on page 5
2. Read the section marked "Forward" in "*Fiber Optic Reference Guide*."
3. Complete **Fiber Exercise I**.
4. Answer all Questions on **Worksheet #1**.
5. Complete **Homework Assignment #1**.

Homework Assignment #1:

Read Chapters 1 and 2 in the "*Fiber Optic Reference Guide*." Also review Table A-1 in Appendix A of "*Fiber Optic Reference Guide*." Table A-1 is a table of commonly used prefixes in the scientific community. If you are slightly rusty with your Metric System you might want to review A-2 in the "*Fiber Optic Reference Guide*." Metric dimensions are used almost exclusively in fiber optics.

Pretest STUDENT: ______________________________

1. Kevlar® is material that is added to optical fiber to increase its strength.
   a) True
   b) False

2. The life expectancy of a fiber optic cable after installation is:
   a) 1 to 5 years
   b) 5 to 10 years
   c) 10 to 20 years
   d) 20 to 40 years
   e) 40 to 80 years
   f) None of the above

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
   e) None of the above

6. The first operating window for fiber optics was:
   a) 1550 nm
   b) 660 nm
   c) 1300 nm
   d) 850 mm
   e) None of the above

7. What procedures are steps of installing a fiber connector?
   a) Polishing
   b) Cleaning
   c) Cleaving
   d) Stripping jacket
   e) All of the above
   f) None of the above

8. Connectors and splices add light loss to a system or link.
   a) True
   b) False

9. What are the two types of fiber optic splices?
   a) Optical
   b) Fusion
   c) Mechanical
   d) Radical
   e) A and B
   f) B and C

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. Fiber optic couplers connect one fiber to another.
    a) True
    b) False

13. WDM allows for multiple totally independent data streams to be transmitted over a single optical fiber.
    a) True
    b) False

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

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

16. A dB is the ratio of two numbers to each other.
    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. Fiber optic components are: (Complete the sentence that makes it the most accurate.)
    a) Increasing in cost every year
    b) Staying about the same in cost
    c) Decreasing in cost every year

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 is not guided in an optical fiber.
    a) True
    b) False

SAFETY

The Industrial Fiber Optics equipment included 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 components whose outputs 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 LAB 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.

LAB EXERCISE #1

The first lab exercise in this course requires students to inventory and identify all items furnished with this fiber optic training module and required for the remaining nine activities. This inventory process will introduce you to the terminology used in the manual, and, speeds completion of the following two activities. Following this you will conduct some basic exploratory experiments to further familiarize yourself with equipment and procedures.

Experiment A: Inventory

1. Choose a flat, level table approximately 90 × 180 cm (3 × 6 feet) in size as your work area for this activity.

2. At your work area, assemble all materials your instructor provides for you.

3. Locate the item that looks like part of a soldering iron. This is a 25-watt heating element that will be part of the Hot Knife assembly you will use to cut plastic optical fiber.

4. Determine if the heating element has a knife tip attached. If not, locate a clear plastic bottle that contains a knurled brass collar and a threaded chuck about 7.5 mm (.3 inches) in diameter and 32 mm (1.25 inches) long. Remove the collar, chuck and Exacto® knife blade from their enclosure.

5. Slide the threaded end of the slotted brass chuck through the large opening of the knurled cinch nut. Push the chuck through the cinch nut until the thread comes out the small opening in the cinch nut.

6. Thread the brass chuck/cinch nut assembly into the threaded end of the heating element until it lightly bottoms. Use your fingers to turn the slotted end of the brass chuck for this purpose. Do not tighten any further at this time

7. Insert the square (non-cutting) end of the Exacto® knife blade into the slot in the chuck. Make certain the square end of the blade slides past the large opening in the knurled cinch nut. CAUTION: DO NOT TOUCH OR PRESS THE CUTTING END OF THE BLADE WITH YOUR FINGERS OR INJURY MAY RESULT. GRASP THE BLADE ONLY ON THE FLAT PORTIONS.

8. Tighten the cinch nut so that the chuck firmly clamps the Exacto® knife. Finger-tighten only — you must allow some room for thermal expansion when the heating element is powered.

9. Identify the remaining components 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 3, notify your instructor.

10. Identify the 1 amp Power Adapters for the video transceivers. Do not try and power the video receivers with the 500 mA Power Adapter. It may not reliably operate.

11. The inspection microscope that you identified above is a specially designed tool for examining the ends of optical fibers. Please read the following paragraphs and familiarize yourself with its operation to save steps in the next activities.

Fiber inspection microscope - A specialized tool for viewing the tip or termination of fiber optic connectors. One end of the microscope has a clear plastic hood with an adapter into which an ST® fiber connector tip is inserted. A swiveling light bulb illuminates the fiber end. The other end of the microscope has the eyepiece through which the fiber is viewed. (ST is a registered trademark of AT&T).

On one narrow side of the microscope there may be a sliding adjustment (ZOOM) that moves the eyepiece. This varies the magnification of the microscope. On the opposite side is a slide switch that turns the light bulb on and off. A focus wheel in the center of the microscope has an exposed edge on two sides. Turning this wheel will adjust the focus of the microscope.

There may also be a small sliding adjustment on one face of the microscope (near the end with the clear plastic hood) that sets the angle of the light bulb.

Locate an ST style connector from the parts kit. The connector body has a knurled locking ring with bayonet-style slots. This is attached to a metal cylinder which has a large-diameter hole on one end and a small one on the other. The cylinder end with the small hole is the fiber ferrule.

12. Insert the ferrule tip (see Figure 1 for identification) into the adapter on the microscope until the ferrule body is completely seated. Turn on the microscope light and adjust the angle of the light bulb so the ferrule tip is illuminated.

13. While looking through the eyepiece adjust the focus wheel until the ferrule tip comes into focus. Make certain you apply light pressure to the ST connector to keep the ferrule seated in the microscope adapter. Try different ZOOM settings if your inspection scope has that feature.

14. When done, turn off the microscope light.

Photo 1. Fiber optic technician testing a prototype fiber optic component.

Experiment B: Fiber Tip Cleaning

It is important to keep fiber optic tips, or ferrules, clean. Before inserting them into any LED or photodetector receptacle, always inspect each end for cleanliness To learn the proper steps in cleaning a fiber connector end, go to page 96 of the *Fiber Optic Reference Guide* and read the entire section titled "Care of Fiber Optic Connectors."

1. Remove the dust cap from a 1-meter fiber cable and clean the fiber end using the procedure that you just read.

2. Throughout the rest of this manual it is expected that you will inspect the fiber ferrules before inserting them into any receptacle and clean as required with Kimwipes® and alcohol.

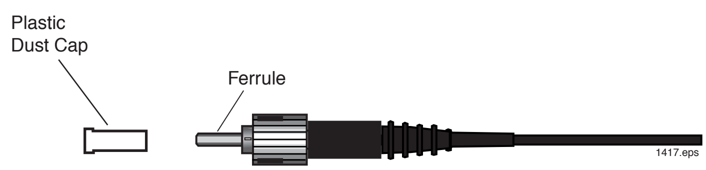

Figure 1. Identification of the dust cap and the ferrule of an ST fiber connector.

3. Remember to replace the protective dust caps on the fiber ferrules after completing an experiment or procedure.

Experiment C: Basic light transmission through an optical fiber

1. Remove the dust caps from the connectors on both ends of the 1-meter fiber cable.

2. Grasp the 1-meter fiber cable near one end with your thumb and forefinger. Point it toward a light source and different colored objects while observing the other end of the fiber. Note the changes in brightness in the end you're viewing as you move the other end around or cover its tip with a finger.

3. Holding the fiber tip about .5 mm (.020 inches) from this page, move it left to right across the heading of this section.

4. Answer Questions 5 and 6 on **Worksheet #1**.

Experiment D: ST® Fiber Connections

The standard fiber optic connector used in this module is called an ST. Throughout this module you will be asked to connect various fiber optic cables with ST connections to various devices. Rather than repeat detailed steps each and every time we will walk you through the instructions here once. Learn and use this installation/connection procedure through the rest of the module. To install an ST connector, refer to Figure 2 and complete the following steps.

1. Remove the dust cap from one of the transceiver's LEDs. Align the key on the connector body with the slot on the ST receptacle, then gently push in.

2. Rotate and push the knurled locking ring until the slots engage the bayonet ears on the ST® receptacle

3. Continue twisting against the spring tension until the knurled ring snaps and locks over the bayonet ears.

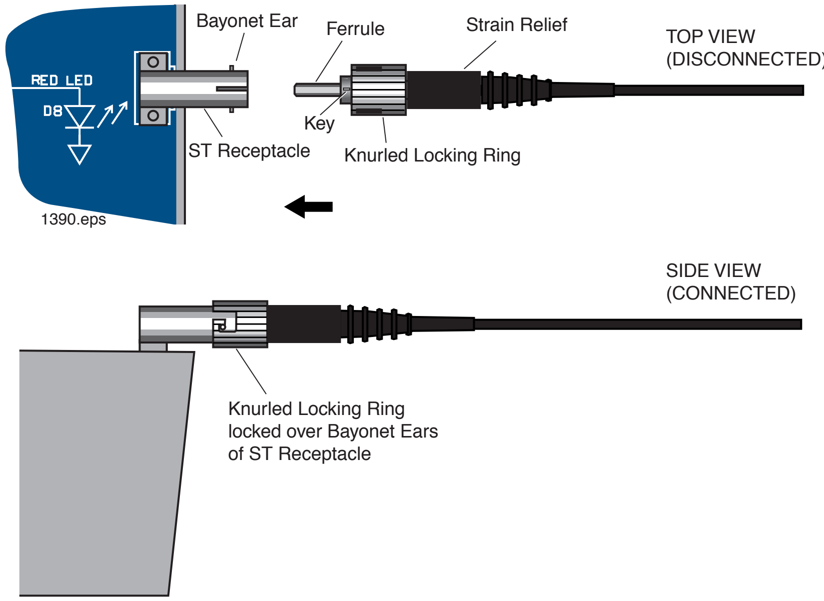

Figure 2. Installing an ST fiber connector onto a receptacle.

Procedure E: Zeroing the Fiber Optic Test Set

Throughout this manual you will be using the Fiber Optic Test Set. Each time you use it you will need to zero this instrument. This procedure is found on page 17 of its operating manual.

1. Locate the Fiber Optic Test Set manual and read the zeroing procedure. Follow and repeat the procedure until you are comfortable with the process. If you cannot locate this manual in the module materials, go to the Industrial Fiber Optics Web site and download a copy.

2. When finished, return all materials to their proper storage containers and locations.

# # #

Table 1. Inventory Sheet for Lab Activity 1.

DESCRIPTION	QUANTITY	ACTIVITY 1
Hot knife with blade attachment and stand	1	
Fiber Optic Video Transceiver Modules	3	
120-VAC-to-14-VDC 1-Amp power adapters	3	
Photonics Wall Chart	1	
Infrared Sensing Card	1	
Scale	1	
1-meter 980/1000 μm plastic core fiber cables with ST/ST connectors on both ends	2	
3-meter 980/1000 μm plastic core fiber cables with ST/ST connectors on both ends	1	
10-meter 980/1000 μm plastic core fiber cables with ST/ST connectors on both ends	2	
Isopropyl Alcohol (130 ml)	1	
Kimwipes®	1	
Microphones	2	
DC motor with mount	1	
120-VAC-to-12-VDC 500 mA power adapter	1	
Micro-Strip fiber stripper	1	
ST polishing puck	1	
Fiber optic crimp tool	1	
Professional Fiber Cutter	1	
ST® Barrel Connectors	2	
Tool box	1	
Fiber Optics Test Set	1	
1 x 2 fiber coupler or splitter	1	
2-meter length of 980/1000 μm plastic core unterminated fiber cable	1*	
ST® fiber connectors	2*	
Fiber optic splice	1*	

Sheet of 2000 grit sandpaper (gray)	1*
Sheet of 3 μm polishing film (pink)	1*
Audio patch cord with 3.5 mm mono plugs	2
Glass polishing plate	1
Fiber optic inspection microscope	1
Polishing slurry (130 ml)	1
Vial of index-matching gel	1
AM/FM radio with 3 AA batteries	2
Coaxial cables with Type F connectors	2
10 meters of coax	1
Optical Demultiplexer	1
Fiber Optic Reference Guides	2
Teacher's Curriculum Manual	1
Student Curriculum Manuals	2

ST is a registered trademark of AT&T. Kimwipes is a registered trademark of Kimberly-Clark.

* The number indicated is the minimum quantity needed to complete the activities in this manual once. There may be more than the number indicated when this product is new or recently re-supplied.

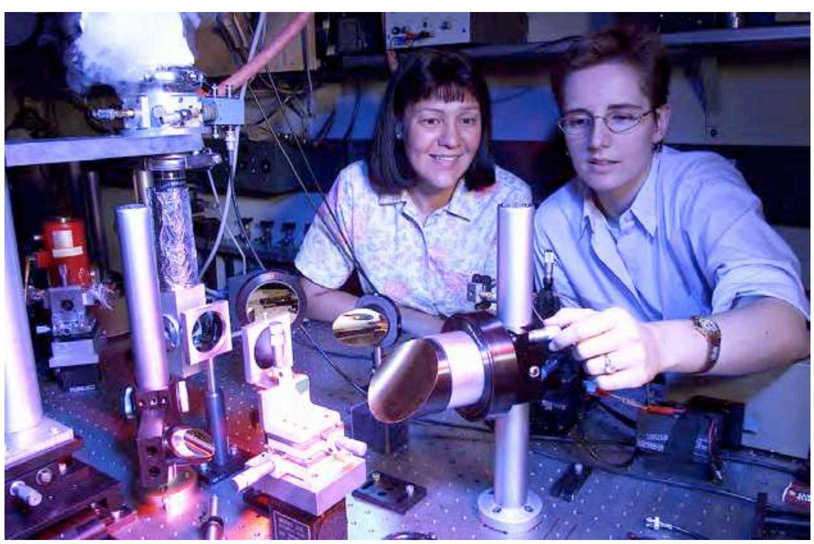

Photo 2. Students setting up equipment on an optical table for testing a prototype laser.

Worksheet #1 Student: ____________________________

1. One of the reasons fiber optics hasn't been used in more areas has been the improvement in copper cable such as twisted pair.
   a) True
   b) False

2. The symbol for refractive index is:
   a) n
   b) c
   c) **M**
   d) $\propto$
   e) None of the above

3. There are no standards in fiber optics. Every manufacturer does what it wants.
   a) True
   b) False

4. Fiber optics has extraordinary opportunities for future applications because of its immense bandwidth.
   a) True
   b) False

5. Do any colors of light seem to transmit better through the 1-meter fiber cable than others?

6. What changes do you observe in the brightness at the other end of the fiber?

OPTICAL FIBER CHARACTERISTICS
ACTIVITY #2:

Objectives:

◊ Learn about the optical fiber manufacturing process
◊ Review the principles of optical fiber operation
◊ Describe the two types of optical fiber by mode structure
◊ Understand the effects of "attenuation" and "dispersion" in optical fiber
◊ Describe the different types of absorption in optical fiber
◊ Compare performance characteristics of various optical fiber types
◊ Set up fiber optic lab equipment to send voice signals over optical fiber
◊ Demonstrate optical fiber's ability to carry different wavelengths of light
◊ Use a special imaging card to identify near-infrared radiation or light

Equipment you will need to complete this activity:

- 2 Fiber Optic Reference Guides
- 1 Photonics Wall Chart
- 2 120-VAC-to-14-VDC 1-amp power adapters
- 2 Fiber Optic Video Transceivers
- 2 Microphones
- 2 10-meter fiber cables
- 1 Infrared sensing card

To complete this activity you must:

1. Review **Homework Assignment #1** with your instructor to answer any questions that you may have from reading.
2. Read pages 15 through 28 in Chapter 3 of "*Fiber Optic Reference Guide.*"
3. Answer Questions 1 through 11 on **Worksheet #2**.
4. On the "Photonics Wall Chart" identify the four different fiber optic optical windows as described in Chapter 1 of "*Fiber Optic Reference Guide.*"
5. Find the chemical composition of one detector on the Photonics Wall Chart that is capable of detecting the third fiber optic operating window. Write this chemical composition in response to Question 12 of **Worksheet #2**.
6. Complete **Lab Exercise 2**.
7. Complete **Homework Assignment #2**.

Homework Assignment #2:

Once you begin working in industry you may often find yourself in a position where you need to locate sources for products or services. One of the most powerful resources you can use is the Internet. Several Web sites are dedicated as sources for products and services. Two such sites are *http://fiberoptic.com* and *http://photonicsnet.com*. Go to these web sites and explore. Write 50 to 100 words describing what you found on the sites.

Photo 3. A technician prepares to align and position a single-mode optical fiber with a laser. The very small dimensions of single-mode optical fiber require very precise positioning equipment.

LAB EXERCISE #2

In your first experiment you will set up a duplex (bi-directional) voice transmission project with which you and your fellow students can communicate with each other over optical fiber cables using different wavelengths of light. You will then use a special sensing card to convert infrared light (radiation) to visible light. Finally you will familiarize yourself with how to connect/switch various transceiver input jacks to three different LED outputs.

Experiment A: Voice Transmission

This experiment will show you how easy it is to make productive use of fiber optics technology or building blocks. The equipment that you assemble will transmit voices from one location to another, using light traveling through an optical fiber. You'll learn that, along with your own voice, other sounds can be carried over the optical fiber.

1. Choose two flat, level locations approximately 60 × 90 cm (2 × 3 feet) in size, separated by 6 to 7 m (20 to 23 feet). (This demonstration is most dramatic if a door or other sound barrier is located between the two fiber optic transceivers to impede the direct path of sounds produced in the two areas.)
2. Place both 10-meter fiber cables, one microphone, one power adapter, a transceiver and the infrared sensing card at Location 1. Place one microphone, a transceiver and a power adapter at Location 2.

Setup Location 1

3. Your equipment set-up should look like Figure 3 when completed. You may wish to refer to this figure as you complete the following steps.
4. Insert the 3.5 mm male plug on the end of the microphone into the AUDIO 1 jack located in the upper left portion of the Transceiver.
5. Locate the RED LED ST receptacle in the upper right portion of the Transceiver's front panel. Remove the LED's and fiber ferrules' dust caps and attach one end of a 10-meter fiber cable to the RED LED receptacle.
6. Locate the OPTICAL INPUT receptacle on the Transceiver's front panel. Remove dust caps and insert one end of the other 10-meter fiber cable into the receptacle.
7. Insert the small end of one 120-Volt Power Adapter cord into the black plastic power input jack on the Transceiver.
8. Plug the two-pronged end of the Power Adapter into a 120-volt wall outlet or extension cord.
9. Located directly to the right of the power jack is the on/off switch for the Transceiver. Push the switch tab to the left to turn the Transceiver on. At this time the green LED above the power jack and switch should light up. If not, make sure both ends of the Power Adapter are firmly plugged in.

10. Set the VOLUME control knob to the 12 o'clock position.

11. Press the middle momentary switch (as indicated in Figure 3) in the center of the TRANSMITTER portion of the Transceiver until the green LED labeled D6 is lit.

12. Press the momentary switch in the RECEIVER portion of the Transceiver until the LED labeled D19 is lit.

13. String both 10-meter fiber cables between the two locations.

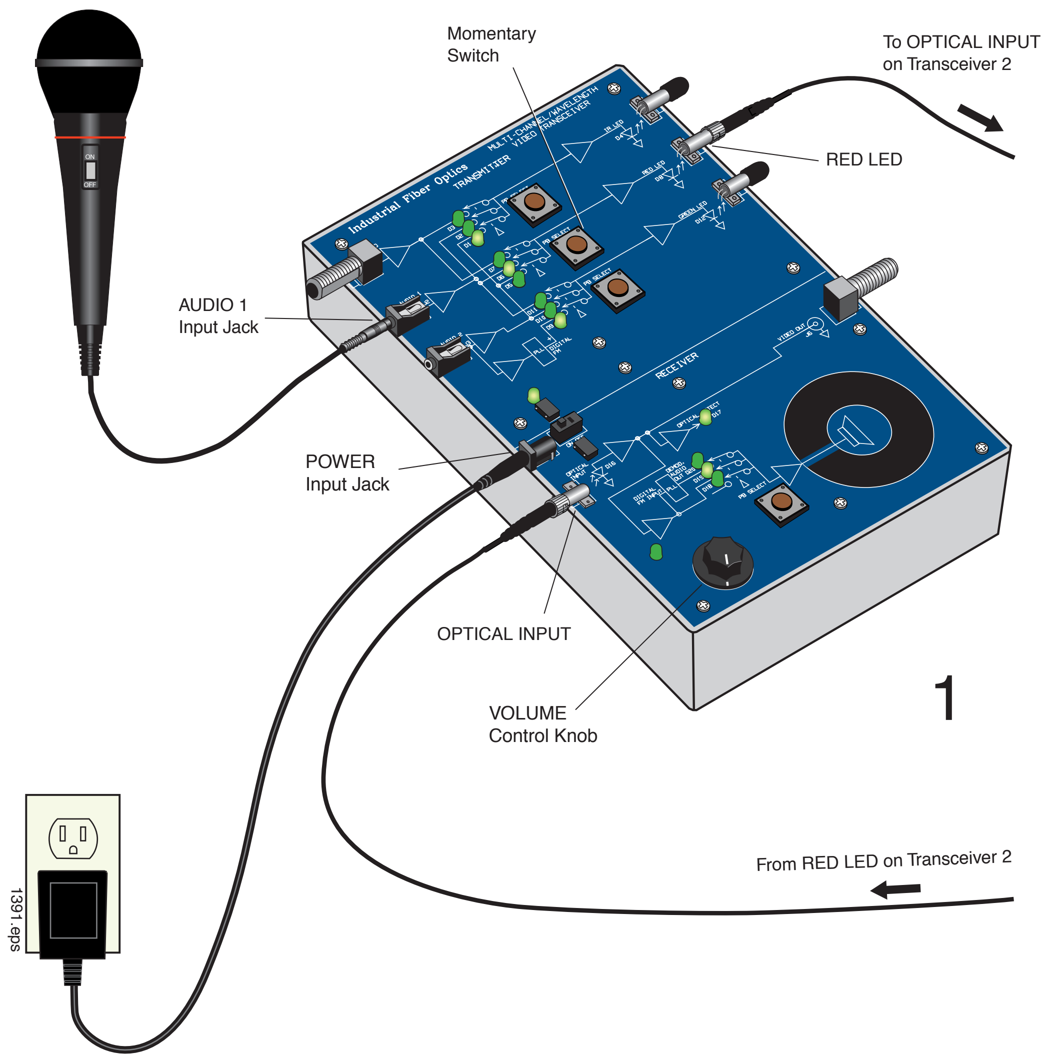

Figure 3. Equipment set-up for Location 1 to complete the Voice Transmission Experiment.

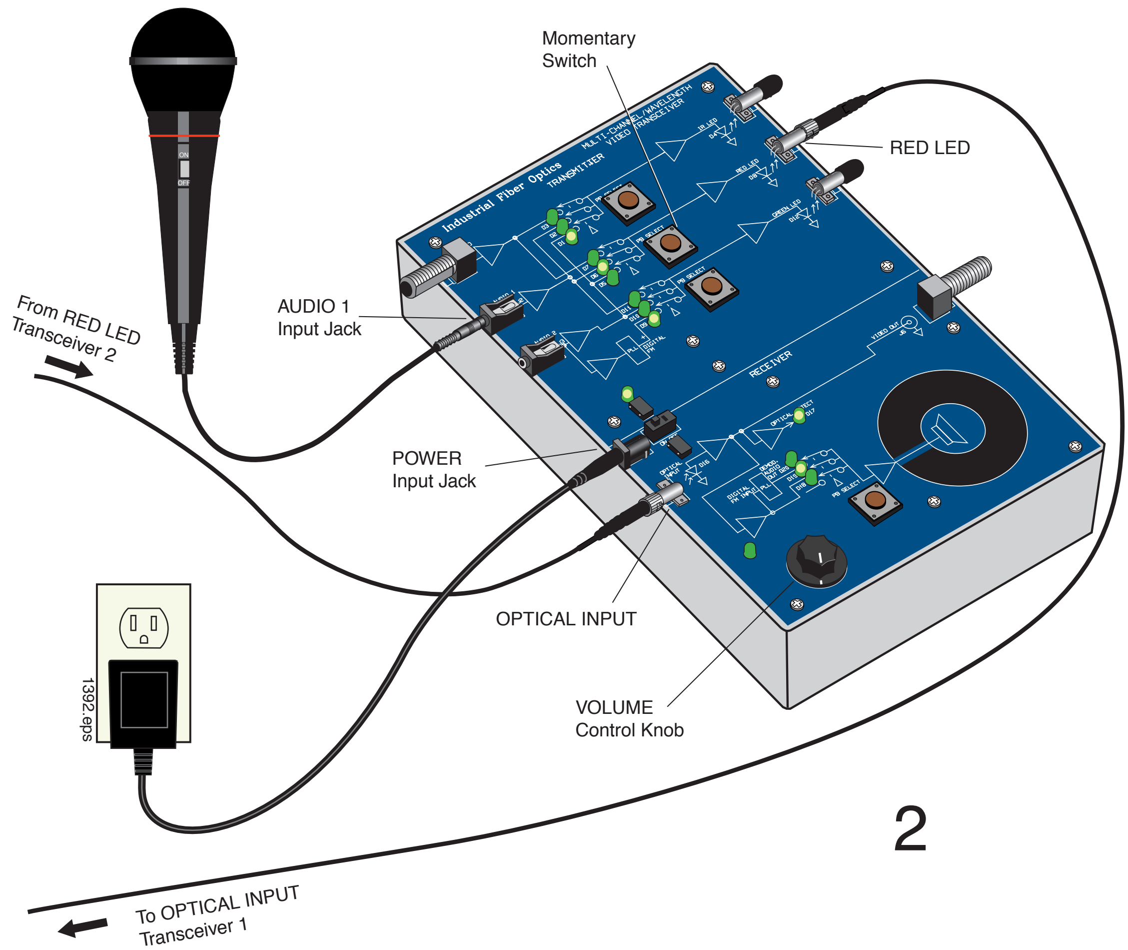

Figure 4. Equipment set-up for Location 2 to complete the Voice Transmission Experiment.

Setup Location 2

14. Your equipment set-up at this location should look like Figure 4 when completed. You may wish to reference this figure as you complete the following steps.

15. Insert the 3.5 mm plug of the microphone into the AUDIO 1 jack on the Transceiver.

16. Identify the fiber cable that is installed on the RED LED at Location 1 by the red glow being emitted from the end. Attach this fiber end to the OPTICAL INPUT receptacle at Location 2.

17. Attach the remaining fiber end to the RED LED receptacle at Location 2.

18. Insert the small end of one 120-volt power adapter cord into the power jack on the Transceiver.

19. Plug the two-pronged end of the Power Adapter into a 120-volt wall outlet or extension cord.