Teacher's Preparatory Guide

Lesson 3: The Bending Radius of an Optical Fiber

Purpose: This lab is designed to help students assess one of the limitations of an optical fiber.

Level: Middle school or high school

Time required: One 45-minute class period

Materials for each group of 2 students:
- plastic canvas 3 in. square
- continuity tester
- twisty ties
- various unjacketed 0.5 m long optical fibers (diameters of 0.25mm, 0.50 mm, 2 mm)
- 4 m unjacketed optical fiber with a diameter of 2 mm
- Morse code sheet (provided in this lab)
- laser pointer

Safety Information: If *glass* optical fibers are brought into the classroom, clean up broken glass fibers carefully for the glass splinters are difficult to see and can easily become attached to clothing and hands. If using glass optical fibers, you may consider having the students wear safety glasses in case of breakage. Using only *plastic* optical fibers would significantly reduce any safety hazards.

Teacher Background: Optical fibers are able to contain and guide light because of the index of refraction of their cores. A core with a high index of refraction allows light to be easily internally reflected as it travels down the fiber, thus allowing the fiber to be looped or curved. A simple test to see the limit of bending that a fiber can withstand is to measure the bending radius of a particular fiber. A fiber is looped and a light source is applied down the core. The loop is then slowly tightened until approximately half the original power is detected at the end of the fiber. The radius of the loop is called the *bending radius*.

An unjacketed fiber can undergo a simpler test. The fiber is looped, a source of light is applied and the loop is slowly tightened. Instead of measuring power, one can observe the amount of light escaping the fiber as the loop is tightened. This will be evident by the increasing glow of the looped fiber as the loop radius gets smaller. This glow is evidence of light escaping the fiber—the curvature is so great that the fiber can no longer contain the light.

A fiber with a smaller bending radius is beneficial for it can have a smaller footprint and it can get around tight corners. Bending radii are also established for optical waveguides such as those used on computer chips. Though bending radii for optical fibers may be on the order of millimeters, the bending radii for the semiconductor equivalent of the optical fiber – the waveguide – can be on the order of microns. The footprint sizes of all components need to

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shrink to micron and nanometer sizes to accommodate the push for more complex devices. This is an active area of research in nanoscale science and engineering.

Teaching Strategies Students will need to work in groups of two. The fibers are small and delicate and require the students to work closely with one another. For Part II of the lab, half the pairs of students could line one wall, while the other half lines an opposing wall. Then the pairs of students could be "connected" with 4 m long optical fibers that cross over each other in the middle of the room. This makes it difficult for students to trace the fiber and to know to which other pair of students they are connected. Or, one set of pairs of students could be around a corner or out in the hallway, although this may be difficult to do with a large class.

Instructional Procedure

Time	Activity	Goal
5 min	*Demonstration:* Large unjacketed optical fiber.	Review total internal reflection and index of refraction.
35 min	*Optical Fiber Limbo Lab.* Students follow directions given on *Student Worksheets.*	Characterize different sizes of optical fibers by their bending radii. Send messages using Morse code and light via optical fiber.
5 min	Clean up	Clean work space before next class.

Directions for the activity:

Procedure: Optical Fiber Demonstration

Present the unjacketed 2 mm optical fiber to the class. Dim the lights, and demonstrate the optical fiber's ability to bend and still guide light. The continuity checker can be used for this purpose. Ask the class to explain how the optical fiber guides light using the vocabulary learned in the past laboratory lessons (i.e., *Lesson 1: Refraction Tank; Lesson 2: Gelatin Waveguides*). Then ask the class to brainstorm some factors that may limit the fiber's ability to contain and guide information in the form of light.

Guided Dialog Before beginning the lab, review the meaning of these terms:

- **Index of refraction** *A measure of how much the speed of light is reduced in a medium when compared to the speed of light in vacuum.*
- **Total internal reflection** *A beam of light that is reflected at the interface of two mediums back into the original one.*

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Name:________________________________Date:_______________Class:________________

Student Worksheet

Optical Fiber Limbo: Guided Activity

Safety

Optical fibers may break if bent too much. Clean up all broken fibers carefully for the splinters are difficult to see and can easily become attached to clothing and hands.

Introduction

You will be testing the bending limits of various optical fibers, and then using an optical fiber to send a message.

Materials

- continuity tester
- assorted optical fibers
- ruler
- canvas square
- twisty ties
- laser pointer

Question

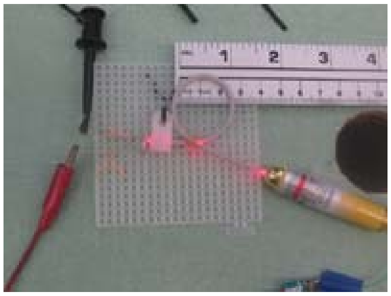
How does bending an optical fiber affect its ability to contain and guide light?

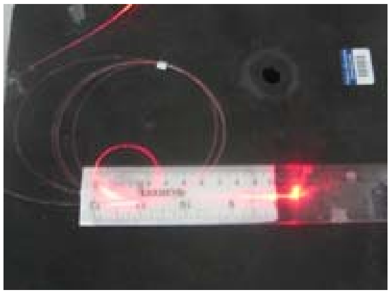
Make a Prediction

*The optical fiber will not be able to contain light if bent too much.*____

Procedure: Part I

1. Loop an optical fiber onto a canvas square as shown in the diagram to the right. Tie down the loop with twisty ties as the photo indicates.
2. Place one end of the fiber into the continuity tester and check that the light is being guided through the fiber by looking for light at the other end of the fiber.
3. Place a ruler under the loop such that the diameter of the loop can be easily measured.
4. Slowly pull the free end of the fiber so that the loop tightens. Stop when the loop begins to glow (indicating that light is escaping the fiber at that point).





5. Measure the diameter of the loop in centimeters and record the diameter and corresponding radius.

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Record Your Observations

Data Table: Bending radii of various optical fibers

Optical Fiber	Diameter of Loop (cm)	Bending Radius (cm)
A	*4*	*2*
B	*3.75*	*1.875*
C	*3.1*	*1.55*

Analyze the Results

1. Which type of optical fiber will give the smallest footprint? Why?

   Example answer: Fiber C. The optical fiber with the smallest bending radius will give the smallest footprint because it can be looped in the smallest area.

2. Does the diameter of the optical fiber affect its bending radius? Why or why not?

   The diameter does not matter as much as the difference in index of refraction between the core of the fiber and the cladding. However larger cores may be more difficult to bend because of their rigid structure.

Procedure: Part II

1. Using the Morse code sheet (see the last page of this lab), translate a short phrase into Morse code to be sent through a 4 m long unjacketed optical fiber. Your teacher will pair you with another lab group to trade messages.

Original Message:

Science Rules

Message in Morse Code:

••• -.-. .. . -. -.-. .   .-. ..- .-.. . •••

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2. Write the message you received from the other group on the first line, then translate it on the second line:

____-.-. --- --- .-..____

____*COOL*____

Record Your Observations

1. Was the receiving team able to properly decode your message? *Example answer: Yes*________
2. What were some problems encountered? *Example answer: Couldn't tell the letters apart.*____

____

____

Draw Conclusions

1. In this activity, your group was directly linked to a receiving group by an optical fiber. However, it is not practical to provide 15 optical fibers to link your group to each of the rest of the lab groups. Propose a method to link all the groups in the class with the least number of optical fibers. *All the lines need to lead into and out of a central station. At this center station, the messages are routed to the appropriate place.*______________________________

____

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2. Often in communication lines, different messages need to be sent through an optical fiber at the same exact moment; however, the messages would then be jumbled together. Propose a method to solve this problem. *One message could be delayed by a looping fiber, while the other message was sent.*____

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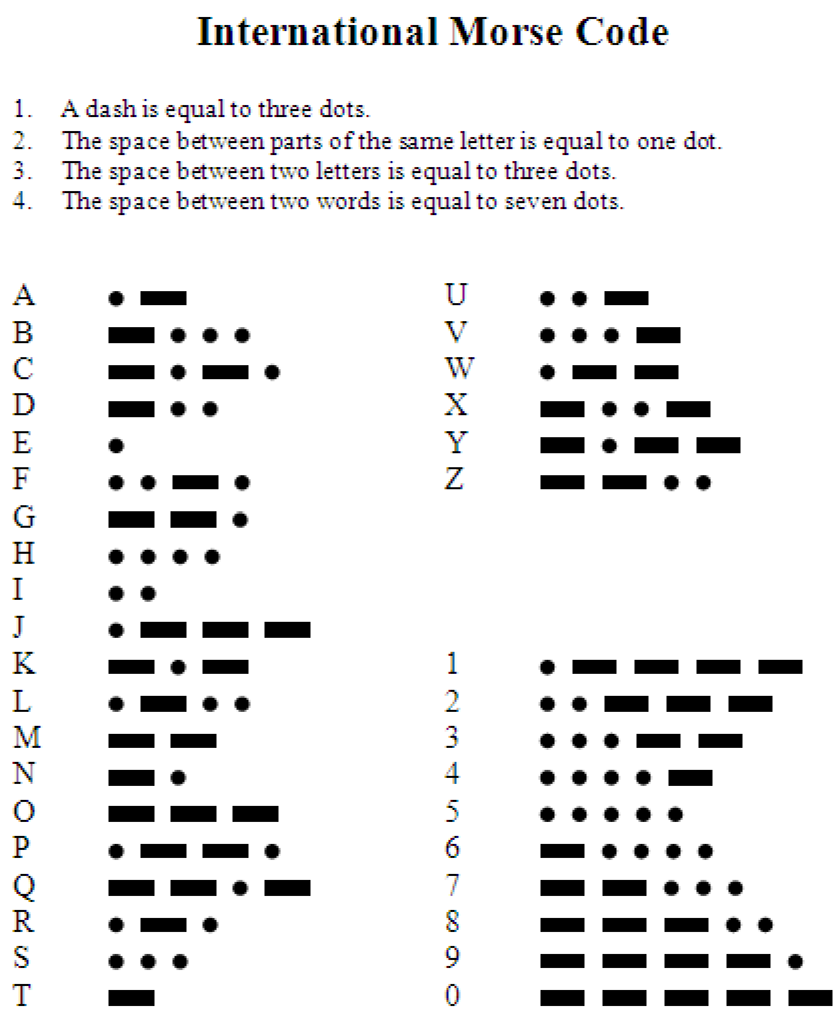

International Morse Code

1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to seven dots.

A	• —	U	• • —
B	— • • •	V	• • • —
C	— • — •	W	• — —
D	— • •	X	— • • —
E	•	Y	— • — —
F	• • — •	Z	— — • •
G	— — •		
H	• • • •		
I	• •		
J	• — — —		
K	— • —	1	• — — — —
L	• — • •	2	• • — — —
M	— —	3	• • • — —
N	— •	4	• • • • —
O	— — —	5	• • • • •
P	• — — •	6	— • • • •
Q	— — • —	7	— — • • •
R	• — •	8	— — — • •
S	• • •	9	— — — — •
T	—	0	— — — — —

This image is from Wikipedia: http://en.wikipedia.org/wiki/Morse_code August 6, 2008

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Cleanup Sweep up all broken glass shards thoroughly.

Assessment
Each student should turn in completed student worksheets, answering the questions with reasonable responses.

Resources: (resources for teachers on optical fibers and their uses)
http://www.science.org.au/nova/021/021key.htm
http://www.ece.umd.edu/~davis/optfib.html
http://www.spiritus-temporis.com/optical-fiber/uses-of-optical-fibers.html
How Fiber Optics Work http://communication.howstuffworks.com/fiber-optic-communications/fiber-optic.htm
Optical fiber http://en.wikipedia.org/wiki/Optical_fiber
Fiber Optics http://www.arcelect.com/fibercable.htm

Material sources:

The Fiber Optics Store http://www.fiberopticsstore.com	**craft store**
• Pro'sKit Fiber Light Source/continuity checker [900-168] • optical fibers	• plastic canvas squares

National Science Education Standards (Grades 5–8)
Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry

Content Standard B: Physical Science
- Transfer of Energy

National Science Education Standards (Grades 9–12)
Content Standard A: Scientific as Inquiry
- Abilities necessary to do scientific inquiry

Content Standard B: Physical Science
- Interactions of energy and matter

California Science Education Standards (Grade 7–8)
Grade 7, Content Standard 6: Physical Principles in Living Systems (Physical Sciences)
- c. Students know light travels in straight lines if the medium it travels through does not change.
- f. Students know light can be reflected, refracted, transmitted, and absorbed by matter.

Grade 7, Content Standard 7: Investigation and Experimentation
- a. Select and use appropriate tools and technology to perform tests, collect data, and display data.

Grade 8, Content Standard 9: Investigation and Experimentation

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f. Apply simple mathematic relationships to determine a missing quantity in a mathematic expression, given the two remaining terms.

California Science Education Standards (Grades 9–12)

Investigation and Experimentation, Content Standard 1

a. Select and use appropriate tools and technology to perform tests, collect data, analyze relationships, and display data.
c. Formulate explanations by using logic and evidence.

Physics, Content Standard 4: Waves

f. Students know how to identify the characteristic properties of waves: interference (beats), diffraction, refraction, Doppler effect, and polarization.

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