Teacher's Preparatory Guide

Lesson 2: Gelatin Waveguides

Purpose: This lab is designed to help students understand how a waveguide conducts light and the problems and issues involved with designing small scale waveguides.

Level: Middle school or high school

Time required: Two sequential 45-minute class periods or one 90-minute block period

Materials for each group of 2 students:
- laser pointer
- 3 cm X 4 cm piece of gelatin (unflavored)
- graph or grid paper so that angles can be easily read
- protractor
- 1/2 teaspoon granular sugar
- plastic knife
- 100 grit sandpaper, 1 in. square
- foil baking pan, 8 in. × 5 in.

Materials for demonstration
- optical path demonstrator

Material sources are found in the resource section.

Safety Information Never allow a laser beam to shine in a person's eye—it will harm a person's retina and can cause permanent blindness. A safety contract can be produced and signed by the students and/or parents prior to this lab to ensure the seriousness of the warning if required by school safety procedures.

Advanced Preparation:

1. PREPARE GELATIN

The gelatin should be made in a more concentrated form than the recipe on the package. Instead of using one packet per cup of water, mix in two packets per cup of water. This makes the gelatin firm and easy to handle. Refrigerate overnight, and keep cool until it's time to use the gelatin, or it will melt. For Part I of the lab, cut the gelatin into 3 cm × 4 cm pieces for the students to characterize. For Part II of the lab, use foil baking pans and cut 10 cm × 10 cm squares (minimum) for each student group. One baking pan should be enough for one class of 18 groups.

2. DIM LIGHTS BEFORE LAB

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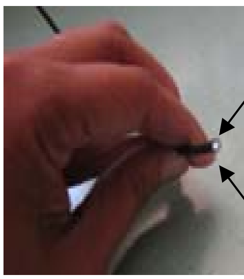
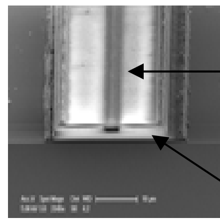
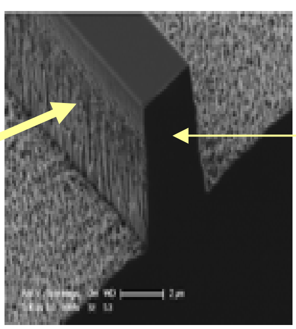
Teacher Background An optical waveguide is a material that is able to confine and guide light. The most efficient optical waveguide presently is the glass optical fiber. Originally used as a tool to look into difficult places such as in construction or during surgeries, the optical fiber has now become the standard in the communication field. Information is transferred faster and in greater quantities using the optical fiber rather than the traditional electrical cables.

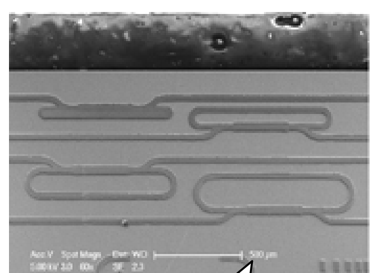
As computer chips shrink in size, research is also being devoted to reducing the size of the optical fiber so that it can be manufactured right on the computer chip itself. These micro-optical waveguides do not look like the familiar optical fiber strand but serve the same function. The optical cores that conduct the light are in the order of nanometers in size.





The concepts covered in this lab closely mirror the actual design parameters of the optical waveguides. Even the term *footprint* is used! The footprint of a structure is the area that the structure occupies on a semiconductor chip. As demand for smaller and more complex electronic components increases, it is crucial that each component has a very small footprint so that more components can fit within a certain area. Loss of light is a primary concern when designing waveguides. At a microscopic level, roughness and imperfections of sidewalls attained during the fabrication process can be catastrophic to a waveguide. Also with space being an issue on smaller computer chips, the size or footprint of the waveguide is being pushed to a very small scale—more recently on the order of microns! (SEM photos courtesy of D. John from UCSB CNSI Nanofabrication lab)





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Direction for the Activity:

Teaching Strategies: Students should work in groups of 2 with plenty of table space.

Instructional Procedure:

Time	Activity	Goal
Day 1		
7 min	*Demonstration:* Optical path demonstrator (see next page). Students will discuss, share and write answer to question in their notebooks.	Review and reinforce use of vocabulary to explain phenomenon. Vocabulary to be used: *index of refraction, total internal reflection.*
30 min	*Gelatin lab: Part I.* Students will follow directions given on *Student Worksheets* for Part I: Design Your Own Optical Waveguide.	Students will characterize and experiment with their small sample of gelatin. They will record effects of roughness due to sandpaper, sugar crystals and grooves caused by a plastic knife. Students will end the period by planning and designing their own waveguides.
Day 2		
5 min	Review goal of the period.	Remind students of goals and tasks to accomplish in the period.
25 min	*Gelatin lab: Part II.* Students will follow directions given on *Student Worksheets* for Part II: Making and Testing Your Optical Waveguide. When the students have completed their design, the teacher will check their design and confirm that the criteria have been met.	Students must create a gelatin waveguide that turns a beam of light 180° in the smallest surface area possible.
10 min	Students share results by touring the classroom. Each table group will present their design in 30 seconds or less.	Sharing results helps students see different methods of approaching the same problem and promotes articulation of science concepts.
5 min	Clean up.	Create a clean working space for next class.

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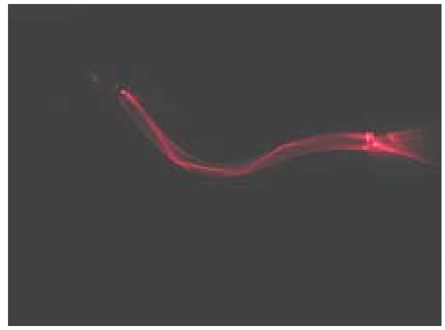
Procedure: Optical Path Demonstrator Demonstration

Hold up the optical path demonstrator, dim the lights and shine a laser pointer through one end of the optical path. Ask the students to explain using vocabulary terms *index of refraction* and *total internal reflection*. *The index of refraction of the plastic material (Lucite) is much greater than that of air so that total internal reflection is achieved easily and the light beam stays within the curved path with little loss of light.*

Optical Path Demonstrator: The lights will need to be dimmed to see the total internal reflection occurring throughout the curved bar of Lucite.

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.*
- **Angle of incidence** *The angle between the incident light beam and the normal.*
- **Angle of refraction** *The angle between the refracted light beam and the normal.*
- **Optical waveguide** *A material that is used to confine and guide light.*

Activity Recommendation: Hand out the laser pointers at the last possible moment and pick them up as soon as the students are finished with their characterization.

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Name:________________________________Date:_______________Class:________________

Student Worksheet

Gelatin Waveguides: Guided Inquiry

Safety
Never shine a laser into anyone's eyes. It can cause permanent blindness.

Introduction

Now that you understand how light can be contained and guided, you will be describing and designing your own optical gelatin waveguide that will bend a ray of light 180°! Gelatin is a colloid that scatters light.

Part I: Design Your Own Optical Waveguide

Materials

- gelatin square
- laser pointer
- graph paper
- protractor
- plastic knife
- 1/2 teaspoon of sugar
- 1 in. square of sandpaper

Question:
What factors affect how well light can be contained and guided in a material?

Make a Prediction

*Example prediction: Factors that affect total internal reflection of light within the material will determine how well light is contained and guided.*____

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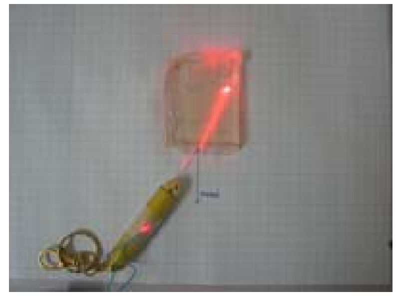
Procedure

1. Place your piece of gelatin on your graph paper.
2. Shine your laser beam through the piece of gelatin parallel to the graph paper. Use the graph paper and protractor to measure angles of incidence and refraction as the beam enters the gelatin from air. See picture to the right.



3. Use the sandpaper to roughen one side of the gelatin piece to examine the effect of roughness on the total internal reflection of the laser beam.
4. Sprinkle a few crystals of sugar on the roughened site and observe the effect of large particles on the total internal reflection of the laser beam.
5. Use the plastic knife to create vertical grooves along the side of the gelatin and observe the effect of the grooves on the total internal reflection of the laser beam.

Record Your Observations

Material: *Gelatin*		**Effect of sandpaper**	**Effect of sugar crystals**	**Effect of grooves**
Angle of Incidence	*20°*	*Side of gelatin glows brighter showing that light is leaving the waveguide.*	*Sugar crystals on the side of the gelatin glow brightly representing points at which light is leaving the waveguide.*	*Side of gelatin glows brighter showing that light is leaving the waveguide.*
Angle of refraction	*15°*			

1. Experiment with your piece of gelatin and describe at least two more ways to positively or negatively affect the total internal reflection or light containment.
   a. *Example answer: Pieces of gelatin placed next to each other will allow light to pass through the interface between the pieces. Light can still be contained.*________________

   ____

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b. *Example answer: Corners on the gelatin will not guide the beam of light very well. Light is poorly contained.*

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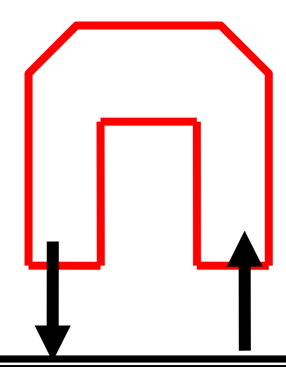
Analyze the Results

1. Small optical waveguides are beneficial for they take up less space, thereby increasing the number of waveguides that can be placed on a computer chip. What is the surface area called that an optical waveguide occupies? ____*footprint*__________________
2. Using the observations you have made, design a gelatin optical waveguide that will:
   a. turn a beam of light 180°
   b. occupy the smallest footprint possible
3. Draw your design below and describe at least two aspects of your design that you feel will allow you to meet the above criteria.

Gelatin Optical Waveguide Design



Design Features:

a. *Example answer: We will use a cake slicer with a flat blade to get smooth sides on the gelatin for better total internal reflection.*______________________

____

b. *Example answer: We will use one single piece of gelatin to keep down the number of interfaces the light will need to pass through.*______________________

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Name:________________________________Date:_______________Class:________________

Student Worksheet

Gelatin Waveguides: Guided Inquiry

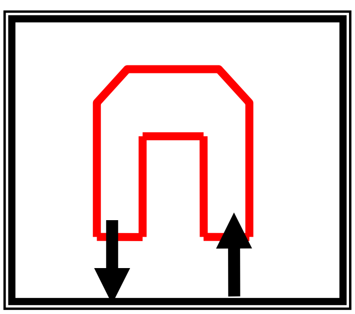
Safety
Never shine a laser into anyone's eyes. It can cause permanent blindness.

Part II: Making and Testing Your Optical Waveguide

Materials
- 4" × 5" gelatin piece
- laser pointer
- graph paper

Procedure
1. Place your piece of gelatin on your graph paper.
2. Using the design that you developed, create an optical waveguide. You may use the laser pointer to test the waveguide as you make it.
3. Demonstrate your optical waveguide to your teacher.
4. When approved, calculate your optical waveguide's footprint.

Record Your Observations
1. Sketch a diagram of your working gelatin optical waveguide.



2. Calculate the footprint of your gelatin optical waveguide.

   Total length (cm) *Example answer: 9 cm* Total width (cm) *Example answer: 6 cm*___

   Footprint *Example answer: 54 cm²*_____

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3. Review the design features that you described yesterday. Describe how well or poorly each design feature worked. If you discovered new features today, describe those as well.

Design Features:

a. *Example answer: Smoother sides helped increase total internal reflection.*

b. *Example answer: Carving from one piece of gelatin was difficult. We made lots of errors and finally had to piece together 3 sections to complete the design.*

c. *Example answer: The sides did not have to be completely curved; small angles seemed to work just as well.*

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Cleanup: Store gelatin in a closed container in the refrigerator for reuse. Have students return laser pointers to designated container.

Enhancing Understanding Cover this section *after* the activity.

The success of the gelatin waveguides are judged qualitatively in this lab. However, quantitative measurements of power loss are necessary when designing actual waveguides. You can introduce rough quantitative measurements by using a photo-detector. This device allows current to flow when exposed to light. A photo-detector attached to a multi-meter allows a student to measure changes of current when a light is passed through a waveguide. This change can then be another criteria to optimize in the lab.

Assessment

The teacher can assess the worksheet by completeness and thoughtfulness in both the formulation and reflection of the design features. During the class period, the teacher can conduct formative assessments through questioning. The students should become comfortable with using the correct terminology to describe the task and content.

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Resources: You may wish to use these resources either as background or as a resource for students to use:

- *Using Jello to Show Refraction and Reflection:* http://www.worsleyschool.net/science/files/jello/andrefraction.html
- *Taking a Closer Look: Light and Optics:* http://www.thetrc.org/trc/fieldtrip/Journal%201/266A5C1E-CCC8-49B7-A6A8-68000EB2AE8D.html
- NNIN RET Lab Jell-O® Waveguide Lab: http://www.nanotech.ucsb.edu/NanotechNew/activities.html
- *A Mini-Guide: Working with the Gelatin* (found at the end of this teacher's guide)

Material Sources:

Sz-wholesale.com http://www.sz-wholesale.com/P/Laser-Pointer/Bullet-laser-pointer------------71703.html	• laser pointers
office store	• graph paper • protractors
grocery store	• gelatin
Arbor Scientific http://www.arborsci.com/detail.aspx?ID=418	• optical path demonstrator (product ID: P2-9620)

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

Content Standard E: Science and Technology

- Abilities of technological design

National Science Education Standards (Grades 9–12)

Content Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry

Content Standard B: Physical Science

- Interactions of energy and matter

Content Standard E: Science and Technology

- Abilities of technological design

California Science Education Standards (Grades 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.
c. Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from the scientific evidence.

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Grade 8, Content Standard 9: Science and Investigation

a. Plan and conduct a scientific investigation to test a hypothesis.
1. 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.
d. Formulate explanations by using logic and evidence.
g. Recognize the usefulness and limitations of models and theories as scientific representations of reality.

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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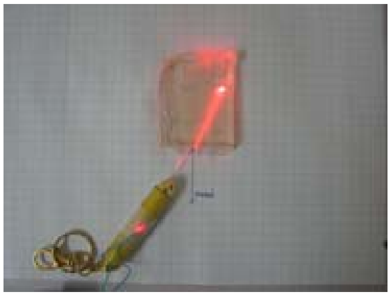
A Mini-Guide: Working with the Gelatin

These photos were created to help you visualize the lab materials and to show possible results.

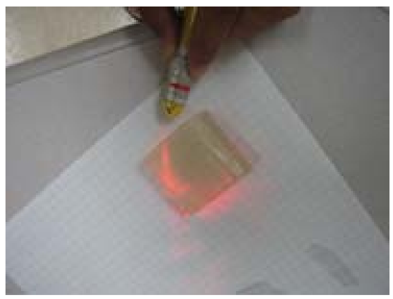


Beam of light is refracted as it enters the gelatin.

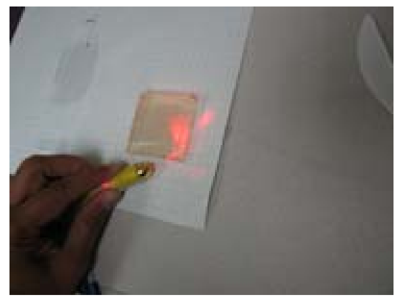
Measuring the angle of refraction.

Measuring the angle of incidence.

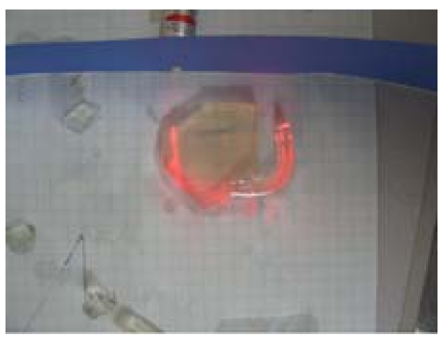
Loss of light due to grooves on the sides of the gelatin.



Loss of light due to sandpaper roughness on the sides of the gelatin.



Loss of light due to sugar crystals on the sides of the gelatin.



Gelatin waveguide turning light 180°.

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