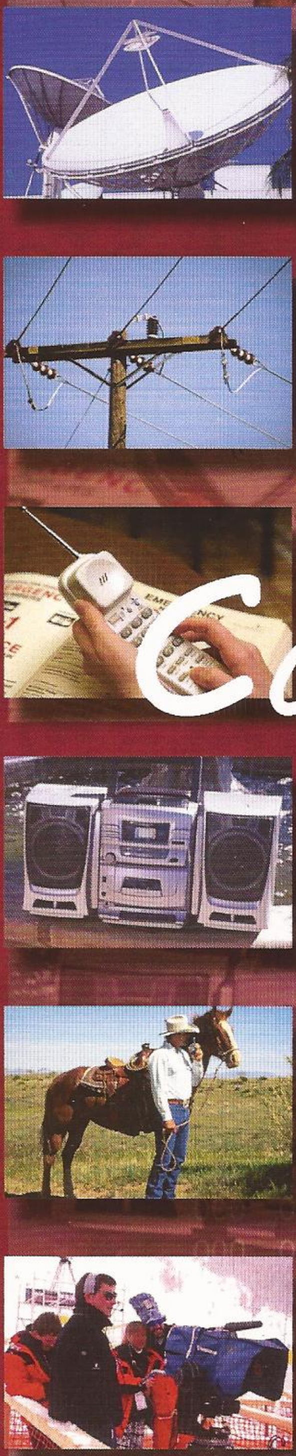
Integrated Mathematics, Science, and Technology

iMaST



COMMUNICATION PATHWAYS

Cycle #2

Technology Section

Lasers

Student Edition

2 Lasers

Introduction

Quick! What comes to mind when you hear the word laser? *Star Wars*? High tech? How about compact disc players, grocery store bar code scanners, welders, pollution detectors, or construction tools?

A laser is an optical tool designed to produce light with special qualities. The word laser comes from Light Amplification by Stimulated Emission of Radiation. Lasers send very strong bursts of light energy. They can be used to measure, cut, and weld material. They can be used to perform very delicate eye surgery. Up until the laser's development, we could only transmit power by using mechanical devices, fluids, or electrical wire. Now, researchers and technologists are proving that lasers can transmit their power directly through the atmosphere. Some lasers can be as hot as the sun. Others can be cool enough to touch. We can control their heat. Lasers can also be used to transmit messages over long distances. In other words, lasers can be a tool for communication.

In this learning cycle, you will learn more about this beam of light. In the *Applying the Idea* section, you will use your knowledge of the laser to improve a very old invention by a famous inventor!

New and revolutionary uses for lasers are being found every day in construction, manufacturing, communication, and medicine. Perhaps, as a result of this learning cycle, you will be inspired to develop a new use that no one has yet discovered.

Objectives

Upon completion of this learning cycle, you will:

- Compare laser light to ordinary light.
- Describe the various applications of lasers, particularly in communication.
- Encode and decode a message using an **analog** device.

analog

to modulate a signal by changing its strength (intensity)

Safety Alert

Before you begin these activities, make sure you read, discuss, and understand the following rules for Laser Safety.

- All lasers produce *very* intense light beams. Treat them with respect.
- Permanent eye damage is a result of looking directly at a laser.
- Close window blinds when working with lasers in the classroom to protect passers-by.
- Be very careful when shining the laser beam on highly reflective surfaces. Stray beams of reflected light can be as dangerous as the beam itself.
- Turn off and unplug the laser when moving it from place to place.
- Never leave an operating laser unattended.
- Never point a laser at anyone's face, no matter how far away they are.
- Try to perform all your laser activities/experiments at floor level to avoid accidental contact with anyone's eyes. Always keep your experiment set-ups below waist level.

All lasers have three basic parts:

1. A power source that could be in the form of light, like a strobe light or high voltage electricity. Solid lasers are usually powered by pulsing light that turns the laser on and off very rapidly. This helps prevent the laser from over-heating.

2. An **active medium** that is the actual material that makes the laser beam. The active medium will either be a solid, like a ruby; a liquid, which is a colored dye put into a glass tube; or gas, like helium-neon (He-Ne).

3. A feedback mechanism consisting of two mirrors at each end of the tube. One of the mirrors reflects 100% of the light. The second mirror is called the output coupler. It lets the light escape when it is strong enough. The beam gains strength by bouncing back and forth between the two mirrors.

active medium

the material that is excited by the power supply or another laser to produce the laser beam

monochromatic

of only one color

beam divergence

the way a light beam spreads out as it travels away from its source

Exploring I

Laser light has 3 very distinct characteristics that make it different from ordinary light. The following activities will help you see the differences.

Laser light is monochromatic

1. Using the spectrum glasses you received from the teacher, look at the lights in your room. Look at the fluorescent lights and the incandescent lights. What do you see? Record your observations in your journal.

2. Turn on the laser while being careful not to point it toward anyone. Place a piece of paper about 30 cm away from the laser so that the laser will strike it. You may need to tape it to a piece of wood or to the wall so it stands vertical. This is called a beam stop. Using the spectrum glasses, look at the point where the laser beam strikes the paper. What do you see? Record your observations in your journal. Turn off the laser.

Laser light has a low angle of divergence

3. Turn on a standard flashlight and aim the beam at a beam stop placed 24 cm away. What do you notice about the diameter of the illuminated spot on the beam stop? Measure the diameter. Compare this to the diameter of the lens on the flashlight. Record your findings in your journal.

4. Move the beam stop to a distance of 1 meter from the flashlight. Measure the diameter of the illuminated spot. Compare this to the diameter measured at 24 cm. Record your observations in your journal.

5. Move the beam stop to a distance of 3 meters from the flashlight. Does the beam still strike the beam stop? Record your observations.

6. Place the beam stop 24 cm from the laser. Measure the diameter of the beam where it strikes the beam stop. Record your observation.

7. Move the beam stop to a distance of 1 meter from the laser. What is the diameter of the beam? Again move the beam stop to a distance of 3 meters from the laser.

   What is the diameter of the beam at this distance? Record your observations for each distance in your journal. Experiment with greater distances. Is there much change in the diameter of the beam?

Laser light is coherent

coherent
to stick together

8. Place a clear 2-liter bottle of water into the path of the laser beam so that the beam shines into the side of the bottle. Notice how some of the light is scattered in the bottle. Notice how the light appears to be made up of many dark and light spots that seem to dance like glitter dropped into the beam. This phenomenon is known as speckle and is the result of a very complex interference pattern created with **coherent** light waves. Speckle is visible whenever something

interferes with the laser beam. Your teacher will tell you more about the difference.

Compare and Contrast: White light vs. Laser Light

Power	White Light	Laser Light
5 Watt	Serves as a night light in the hall	Carves wooden ornaments
60 Watt	Illuminates a small room	Can cut diamonds and steel

Getting the Idea I

1. How many different wavelengths (colors) are there in white light? How many are there in laser light?
2. Describe the difference in the way the two types of light diverge (scatter) as the beam of each gets further from the source.
3. Have you ever seen an actual laser being used for anything? How was it being used? As a class, discuss some of the ways you have seen lasers being used.

Exploring II

Because laser light is monochromatic and coherent, it has some unique behavioral characteristics. You already saw in the activity above that a laser light beam would stay focused even as it travels away from the source. In the following activity, you will see other examples of how different laser light is.

refraction
a change in the direction of light rays as they cross the boundary (interface) between two materials/mediums

Reflection, Absorption, Refraction

When a light ray strikes a surface, some of the ray bounces back. This bouncing is called reflection. You notice it very clearly in a highly reflective material like a mirror. Almost all the ray bounces back and you see a reflection of your face. Some surfaces do not reflect much of the light ray. Instead, they absorb, or soak up the ray. Dull, dark surfaces tend to absorb light. Some surfaces neither reflect nor absorb light rays well. When light rays strike a transparent surface, they pass through it. Some materials, like clear glass, are highly transparent while others, like stained glass, are less transparent. As light rays pass through a transparent material, particularly at any angle other than 90°, they bend. Observe a drinking straw in a glass of clear water. This bending is called refraction.

Now that you are familiar with the characteristics of laser light, let's see how laser light performs in various conditions.

1. Place a beam stop about 1 meter from the laser.
2. Turn on the laser and sprinkle sawdust in the beam.
3. Why can you see the beam? What is the effect of the sawdust on the "power" of the laser beam striking the beam stop? Record your findings and theories in your journal.
4. Place a clear glass bottle in the path of the laser beam.
5. Pour water into the bottle so that the beam must pass through it. What effect did this have on the beam?
6. Remove the water from the bottle and replace it with some other liquid provided by your instructor. Record the liquid and the results in your journal.
7. What effect does a concave or convex lens have on laser light? Design and conduct an experiment to explore the use of lenses with lasers. Make a diagram of your experiments and record your observations in your journal.
8. Position a clear, 2-liter plastic bottle full of water near the edge of a table.
9. Position the laser so that the beam goes through the bottle near the bottom.
10. Poke a hole in the bottle where the laser beam comes out of the bottle so that water comes out in a small but steady stream. Be sure to set up a pan or bucket to catch the water.
11. What happens to the laser beam in the stream of water? Record your observations.

12. Aim the laser beam into one end of a Plexiglas® rod. What happens?

13. Try bending the rod at various angles. What is the result?

14. Experiment with reflecting the laser beam with mirrors. Small mirrors can be held in position with a small ball of clay.

15. Set up several mirrors to reflect the laser beam around, over, and/or under an obstacle. What are some of the applications of reflecting a laser?

Getting the Idea II

1. What effect do various materials have on laser light?

2. How do different materials affect the energy of the laser light beam? Give specific examples from your explorations.

3. The water stream and the Plexiglas® rod function as a "pipe" for light. Explain why you think this works.

4. Why is a "pipe" for light necessary?

5. List some applications for fiber optics.

Exploring III

In the *Applying the Idea* section of this learning cycle, you will be constructing a laser communication device. This requires assembling a simple electronic circuit. Electronic components are usually held together with solder. Solder is a combination of two metals, lead and tin. It has a low melting temperature and conducts electricity very well. It is usually melted with a soldering iron held against the wires or component.

There are several types of solder to be used for a variety of applications. The two main types are resin core and acid core. Acid core is used to hold metal together, like a galvanized metal bucket or the radiator in a car. Resin core is used for electronics. Do not use acid core for electronics, the acid eats the components.

It is important to practice soldering before you actually solder the components used for your project. There is nothing difficult about it; it just takes some time to gain the skill.

1. Before you begin, look at the tip of the soldering iron. It does not have to be shiny, but it should be clean. There are several ways to clean it. Ask your teacher for help.

2. Plug in the soldering iron. It takes a few minutes to warm up. Be sure the tip is not resting on the tabletop. It will melt or burn a hole.

3. While the iron is heating, strip about 1" of insulation off the ends to two wires. Twist these together.

4. The iron is hot enough when solder touched against the tip melts immediately. If the tip is clean, a little solder should stick to it. This is called "tinning the tip." A properly "tinned" tip is necessary to get proper heat transfer to the joint being soldered. If the tip will not tin, try cleaning it again.

5. Hold the soldering iron tip against one side of the twisted wires. Touch the solder against the other side. The soldering iron heats the wire; the wire melts the solder.

6. The solder should be drawn into the twisted wires. If it does not, touch some solder onto the tip to tin it again.

7. If the solder looks like a glob or bead, it has not been drawn in properly. Don't add more solder; just heat it up a bit more.

With some practice, you will become skilled enough at soldering to consistently make a proper joint quickly. Practice on several wires.

Once the wire/wire connection has been mastered, it is time to advance on to wire/component connections. This is really the same thing, except that now you must be careful not to damage the component with too much heat. Some components, such as relays and a potentiometers, can be damaged by melting the plastic case. Others, such as transistors and diodes, can be damaged internally. You may not see the damage on the outside, yet the component has been ruined on the inside. For your laser communication devise, there is very little danger of damaging the components. For the optical reader that you will be building in *Putting Light to Work,* damage to a component is much more likely.

A Timeline of Laser Technology

1960	The first laser is a ruby laser.
1962	Two years after its invention, the laser is used to perform eye surgery.
1970	The laser is first used to cut and weld steel.
1972	The laser disk is introduced.
1974	The laser is used to count atoms in molecules.
1974	The laser is used in the development of bar code scanners.
1975	The laser printer is first developed.
1981	Optical disks, a form of laser audio recorders, is developed.
1982	The first Compact Disc (CD) is produced, Billy Joel's "52nd Street."
1984	A nuclear fusion reaction is started using concentrated laser beams.
1985	Nuclear x-ray Laser Weapons system (Star Wars) is a feasible reality.
1991	Laser is used in manufacturing to make patterns.
1992	Lasers are used to illuminate deep-sea photography.

1. Begin by fastening the wire to the component if possible. Twisting them together, looping the wire through a hole, or twisting it around a post are all options. If this is not possible, have a helper hold it in position so that they touch with as much surface area as possible.

2. Clamp a heat sink between the component and the solder joint if possible. A heat sink is a clamp or other small device that draws the heat away from the component. Your teacher will demonstrate this to you. On components with leads, a heat sink can usually be clamped on easily. On components with terminals, it may be impossible; there just is not enough room.

3. Touch the soldering iron to one side of the terminal, the solder to the other, just as when doing wire/wire joints. This time, however, do this as quickly as possible to avoid the chance of damaging the component.
   Be careful not to burn your helper.

Getting the Idea III

1. What is "tinning" and why is it important?

2. What is solder? What type is used for electronics and why?

3. How do you get the solder to be "drawn in" to the wires?

4. Describe a good solder joint and a bad solder joint.

5. What is a heat sink and why is it needed?

Other Applications of Lasers

- Missile guidance, holography, surveying and construction
- Measuring distance and density/clarity
- Pollution/poison gas detection
- Commonly used in industry to cut metal and by the military for range finding

Applying the Idea

In this activity, you will be building a device that applies modern laser technology to improve an old invention. Over 100 years ago, Alexander Graham Bell discovered that light could be used to transmit sound. He developed a device known as a photophone. It was one of the first experiments involving optical communication. At that time, Mr. Bell thought that a light beam from almost any source could be used to transmit sound. His photophone worked by reflecting focused sunlight off a mirror. The mirror was attached to a **diaphragm**. When someone talked into the photophone, the diaphragm would vibrate. You learned in previous activities that sound produces waves. Sound waves striking the diaphragm caused it to **modulate** the light reflecting off the mirror. The modulated light was then focused on a receiver containing a material sensitive to light. The sound was reproduced in an electrical receiver (earphones).

diaphragm

a thin disk that vibrates in response to sound waves to produce electric signals or that vibrates in response to electric signals to produce sound waves

modulate

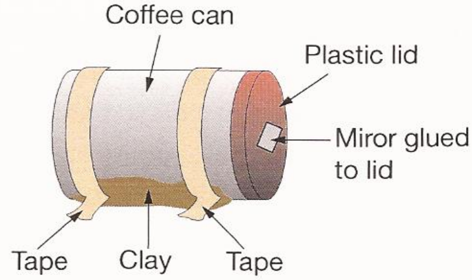
to vary the characteristics of a wave, such as the wave's frequency, amplitude, or phase

The only powerful light source Bell had available was the sun. Further experimentation in the1880s proved this communication device to be impractical. With the invention of the laser in 1960, however, communication by light is not only practical, but is actually much better than communication through wires.

Bell's photophone and the laser photophone that you are going to build operate on the same principle. The light beam is modulated. That is, the intensity, or strength, of the light striking the receiver is changed. The sound waves made Bell's mirror vibrate which made the reflected light "bounce around." Because of this "bouncing" sometimes the light striking the receiver was strong, sometimes not as strong. Bell's receiver, and yours also, was a light sensitive resistor, called a photocell. It allows a lot of electricity to flow through it when a strong light strikes the surface. When the light is not as strong, the resistance is greater so less electricity can flow through it. The speaker that Bell invented, and your headphones, convert the changes in the amount of electricity into sound. This is called an "analog" signal. "Analog" means modulation by changing the intensity. Most radios and televisions operate on analog signals.

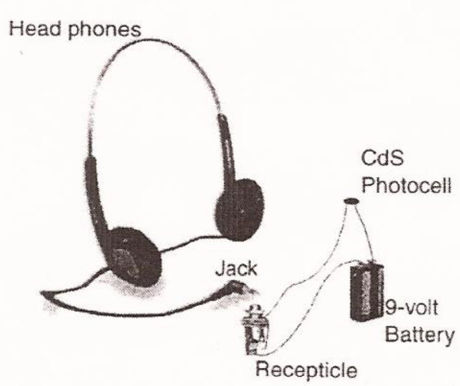
How to build the Encoder device

1. To send a message with a laser, the beam must be modulated. This is called "encoding" the message.

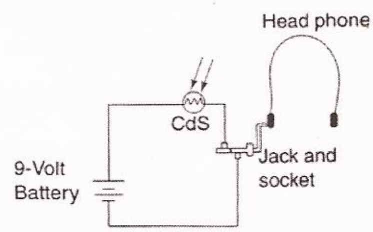


2. Cut both ends out of a coffee can. This will be the encoding device.
3. Glue a small mirror (about 1 cm square) to the outside of the plastic lid of the coffee can about 2-3 cm from the center. You can experiment with the best placement of the mirror later. Put the lid back on the coffee can.

How to build the Decoder device

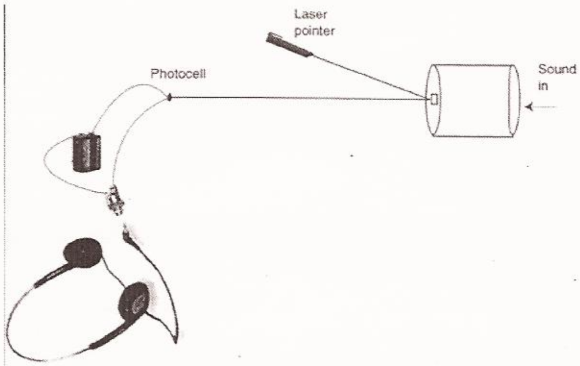


1. For the decoding device, obtain a battery, a cadmium sulfide photocell, and a headphone jack receptacle from your instructor.
2. Solder the black wire from the 9 volt battery clip to one of the leads on the cadmium sulfide photocell.



3. Solder the other lead from the photocell to one of the terminals on the headphone jack receptacle.
4. Solder the red wire from the battery clip to the other terminal on the headphone jack receptacle.

How to use your Photophone



1. To use your "new and improved" photophone, secure the encoder to a tabletop. This cannot move, not even a little! The best way to do this might be to form some clay into a saddle and tape the can down.
2. Aim a laser at the mirror. Secure the laser so it does not move either.
3. Place the photocell so that the beam strikes it. Secure the photocell to something stationary such as a block of wood, etc. A distance of 5 meters, or so, may actually work better than if you are too close.
4. One of the members of your group should talk (or sing) into the coffee can encoder. Listen on the headphones. Adjust the alignment of the laser for the best sound quality.
5. Experiment with different distances, mirror placement, and other variables to improve the sound quality of your photophone. Alexander Graham Bell devised and tested some 50 different designs for the photophone. Eventually he was able to transmit a message 213 meters (236 yards). You may be able to exceed this distance using the laser and lenses!

Expanding the Idea

- Using the library and/or the World Wide Web, find at least five applications for lasers. Do research on the types of lasers that are available today. For what is each type typically used?
    - How does each type of laser differ from one another?
    - What is the active medium that is used to produce the laser?
    - How is the power of a laser specified?

- What kinds of lasers are being used in the military? How are they being used there? What are some of the possible future uses of lasers by the military?

- Discuss the timeline of laser technology development. Choose a topic from the list or one of your own and research how lasers are being used today.