WE ARE ON

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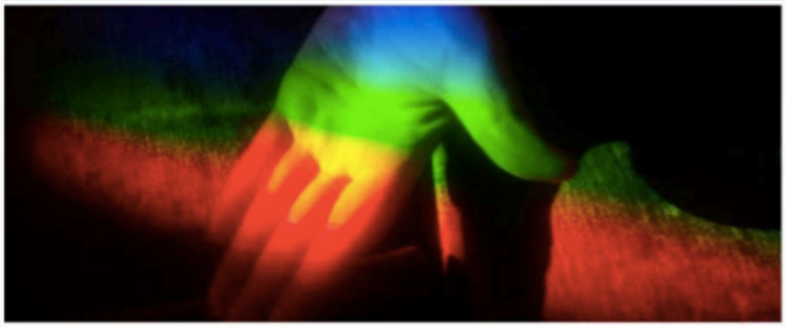

**OPTICS MAGIC**
with Judy & Nancy

#OpticsAtHome
#SeeTheLight

LET'S WONDER

# LASERS AND FLASHLIGHTS

HOW DO LASERS WORK AND WHAT MAKES LASER LIGHT DIFFERENT FROM THE LIGHT FROM A FLASHLIGHT

**MATERIALS**

Activity 1

- Laser pointer
- Flashlight with a single bulb (incandescent)
- Meter stick

Activity 2

- Laser pointer
- Flashlight
- Recordable CD or purchased diffraction grating

Activity 3

- Laser pointer
- Flashlight
- Piece of waxed paper

**WHERE TO FIND MATERIALS**

Inexpensive low power laser pointers are easy to find in dollar stores and on the web. Actually, the flashlight may be more difficult to find. You need one (especially for the spectrum) with a single bulb so the spectra from all the bulbs don't overlap. If all you can find is a multi-bulb flashlight, you can still observe the spectrum by looking at the light reflected from the CD but this is not advisable with the laser.

To observe the spectrum of the laser and flashlight you can use an old CD, stripped of its label (see below). If you want diffraction gratings for a large group try Rainbow Symphony Store www.rainbowsymphonystore.com.

**PARENT AND TEACHER NOTES:**
In this activity, children will observe three properties of laser light and learn how a laser works. They will be working with low power red laser pointers. The notes and activities of this lesson will explain how a laser makes light and how laser light is different from ordinary light.

If working with a group, it's a good idea to have rules for laser safety written where all children can see them. In general, the beam should be kept low, on the desk or table below face level. Legal laser pointers (< 5 mW in the U.S.) are generally safe but intentional misuse such as staring into the beam can lead to injury. Be careful of lasers purchased on the internet at sites with "awesome" or "wicked" in their names. Some of these are well above the safe level for casual use.

**THE WORD "LASER"** is an acronym for "*Light Amplification by Stimulated Emission of Radiation*", which refers to the way light is produced inside the laser. Acronyms are usually considered to be pronounceable words made of letters (such as NATO or RADAR), but some sources include "initialisms" as acronyms, such as LOL or FBI. Other common acronyms: NASA, NOAA, RADAR, NATO, UNICEF, POTUS, WHO, ZIP (code), OPEC, ASAP, and SCUBA.

**HOW A LASER MAKES LIGHT** The PowerPoint slides we use are available on the web at www.pblprojects.org/teaching-and-learning-optics-with-inexpensive-materials (follow the Dumpster Optics link to What is a Laser?) These explain on an elementary level how a laser works (loosely based on a delightful laser show animation by Sean "LaserGuy" Kearney). It is assumed that students know what an electron is (and that they don't really have smiley faces!). The other "player" in this explanation is the photon, a "particle" or short burst of light waves. Light has both wave and particle properties, and often we use the particle nature of light when explaining how light interacts with matter and the wave nature when we are describing how light propagates through space.

There are dozens of different kind of lasers but in general each has three components: a *medium,* a source of *energy,* and a *resonator* or *amplifying cavity*. The medium is the part that has atoms (or molecules) that can be excited by the source of energy. For example, metal ions in a glass rod can be excited by shining light of the right wavelength of light on the material. Semiconductor materials are excited by electricity. Neon in a helium-neon laser is excited by high voltage.

Energized atoms usually give off the extra energy quickly in the form of light (or heat). An ordinary light source like a light bulb produces a range of wavelengths with each photon emitted at random times and heading off in random directions. In a laser, the process of giving off energy is controlled so only a very narrow range of wavelengths is produced. *Stimulated emission*, the SE in LASER, means an atom produces light only when other light of the correct wavelength is present. All light produced this way is identical in wavelength and the waves are "in step" with each other, traveling in the same direction.

The laser medium is chosen so it has atoms that stay energized for a while, long enough for stimulated emission to occur. The first photons produced start the chain reaction of stimulated emission. To keep the process going (and amplify the light, or make it brighter) the medium is placed between two mirrors. With each round trip through the medium more and more light is created by stimulated emission. One of the mirrors is "leaky", that is, it lets some of the light escape to form the laser beam (Slide 11). In this way, light of a single color (*monochromatic)* is produced, traveling in the same direction in a tight beam. (Light not propagating along the beam axis is lost through the sides of the medium.) The activities will reveal more characteristics of laser light.

**ACTIVITY 1 – HOW IS LASER LIGHT DIFFERENT FROM A FLASHLIGHT? (DIVERGENCE)**

Be sure the lasers are pointed only at the wall and not at other people! The laser or flashlight should be held steady for measurement. Try holding them on the edge of a table or other firm surface. Be sure the light isn't blocked by the surface.

The laser spot will be bright and difficult to measure. It may be elongated rather than round. In that case, be sure to measure the same dimension (length or width) from both 1 m and 2 m. The flashlight will probably make a smudgy blob of light with some dark patches. Again, have students decide what to measure and be consistent between the two distances.

You can ask the children to decide how to determine how much a beam has spread. One method is to divide the larger diameter (more distant measurement) by the smaller diameter to see how much bigger the spot is when the light source is farther away. The laser should spread very little, the flashlight will spread quite a bit even with a focusing mirror behind the bulb. Divergence means spreading, so what is important is not how large the spot is but how much the spot size changes as the laser or flashlight is moved away from the wall. If there is space in the room, the measurement can be repeated at other distances.

The laser spot will have spread noticeably across the room but not as much as the flashlight. Because laser beams do not diverge much, they have been aimed at the moon where they strike mirrors left there by astronauts. The beams are then reflected back to Earth. Measuring the time for the laser beam to go from Earth to the moon and back allows the distance to the moon to be very accurately measured.

Distance = Speed of light x Time

**ACTIVITY 2 – HOW IS LASER LIGHT DIFFERENT FROM A FLASHLIGHT? (WAVELENGTH SPECTRUM)**

You will need a diffraction grating to separate light into its component colors. You can make one from an old recordable CD or use a purchased one.

To use a CD: Cut a recordable CD into four pieces using sturdy scissors. You need the kind of CD you can record on; the labels on commercially recorded CDs are too difficult to remove. Round the sharp edges of the pieces. Use tape to remove the metal coating by placing tape on the coating and pulling sharply upward.

It may be necessary to darken the room so the flashlight spectrum can be seen. It should be a rainbow. Be sure the entire beam goes through the CD. If the flashlight is large, it may be necessary to cover part of the beam so the spectrum is not washed out by light that goes around the CD. The laser will produce several spots but they will be red, no other colors should be seen. Students seem to focus on the number of spots, not the color. You might point out that the flashlight also makes "spots" but that they are larger and the ones on either side of the center spot are rainbows.

*Monochromatic* is an "impress your friends" word. It helps to break into its component parts: mono = one, chromatic = color. The laser is monochromatic because of the way its light is made through stimulated emission.

**ACTIVITY 3 – HOW IS LASER LIGHT DIFFERENT FROM A FLASHLIGHT? (COHERENCE)**
Coherence is a fairly complicated concept (even for college students) but children will be able to see the result of coherent light in this experiment. You will probably need to dim the lights and hold the laser fairly close to the wall (15-20 cm). When spread out by the waxed paper the laser spot will show small bright spots that appear to move as you move your head. The spots are called *laser speckle.* The flashlight spot will show little change except maybe to be smoother. There will be no speckle. There is a photograph of laser speckle in the video demonstration of the activities mentioned in the Resources below.

The monochromatic waves that make up the laser beam are orderly, they stay "in step" with each other as they travel. This property is called *coherence*. You can describe the laser as making coherent light. When coherent light reflects from the wall the waves interfere to create a mottled pattern called *laser speckle.* This will be seen on the wall as a pattern of small bright and dark spots that seem to move as the beam moves. The coherence of laser light allows lasers to be used for applications like making holograms. The flashlight beam will not show any speckle because the chaotic multicolor waves of a flashlight are not coherent.

**SUMMARY**
These are the three properties of laser light. They arise from the way laser light is produced (stimulated emission in a reflecting cavity):

- laser light travels in a tight beam and does not spread much (small *divergence*)
- laser light is made up of one color (*monochromatic*)
- the waves in a laser beam stay in step as they travel (*coherent*)

**RESOURCES**
The Dumpster Optics Power Point slides for classroom use for this lesson are here:
https://www.pblprojects.org/teaching-and-learning-optics-with-inexpensive-materials/

With a group of cooperative students you can illustrate spontaneous emission of light ("regular" light source) and stimulated emission of light (laser) with a handful of ping-pong balls. (Or you can just use balled up pieces of paper that won't fly as far.) Tell students that when they are sitting they are in the "ground state" and when energized by a photon (ping pong ball) they are to stand up.

> Spontaneous emission – (Start in the "ground state") Toss out a few ping-pong balls. Receiving students stand up (are energized) and immediately toss the ball in a random direction and sit down (back to the non energized state).
>
> Stimulated emission – (Start in the "excited state") Hand out a few balls. "Excited state" students remain standing until a ball passes by, then they toss theirs in the same direction and sit down. You begin the process by tossing a "photon" toward one of the excited students. It takes some practice but students usually enjoy the activity.

The activities for this lesson are shown in a video on the PBL Projects YouTube channel
http://bit.ly/1OmntIq