Laser Speckle

Say what you see

Introduction

The advance of science depends upon accurate observations and honest reporting. This activity purposely creates a situation in which each observer will make one of two opposite observations depending on whether they are nearsighted or farsighted. They will then be faced with a decision whether to report what they see even if they are the only ones who see it, or whether to go along with the group. This models the behavior of scientists in the real world.

Material

A laser, any visible light laser will work even the cheapest.
a frosted light bulb

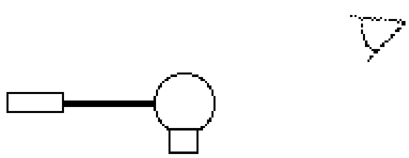
Optional:
a converging lens, such as a magnifying glass, or a microscope objective
and a white screen, e.g. cardboard

If you choose to project the speckles for the class you will need a 1 milliwatt or stronger laser.

Assembly

Mount the light bulb in a holder such as a lamp. Do not turn it on. Do not try to hold the bulb in a hand, small motions of the bulb will destroy the effect.

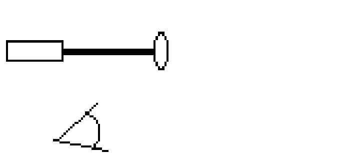
Shine the laser into the lamp from the side opposite the viewers. Make sure the laser is firmly mounted.(See magnetic optical bench) Keep the viewers 2 meters (6 feet) or more away at first.



Warning, the viewing eye should not be in line with the laser beam!

or

Shine the laser through the lens onto the screen to produce a disk of light. Stronger lenses and greater distance from the lens to the screen will produce larger, dimmer disks. A 10 cm diameter disk (fist size) is sufficient for individual viewing, a larger disk will be needed for classroom observing, experiment to find a correct size.



To Do and Notice

Look at the disk of light and notice that it is made up of many tiny bright red spots and black spots. This is called laser speckle.

Caution the observers that they are not looking for large splotches of laser light created by dirt on the optics but rather for very tiny dots of light or dark.

Ask each observer to move their head to the side, e.g. toward the right.

Ask the observers to notice which way the speckles move.

How many see the speckles moving the same way they move?

How many see them moving opposite?

How many don't see any speckles moving?

Many students will report seeing the speckles move opposite to their motion.

Some will report seeing them move the same way.

A few will report either that the speckles don't move or that they cannot see the speckles.

Start a discussion on why some students disagree with the majority opinion and whether the majority opinion should be considered "right."

Try the following experiments.

Compare the answers using your right eye and your left eye. Some people will get different answers from one eye to the next. (If one eye is nearsighted and one eye farsighted.)

Move your head up and down and compare the results with right-left motion. If you have astigmatism you may get different answers for the same eye. You may be nearsighted right-left and far-sighted up-down.

Have people with glasses remove their glasses. They will see the speckles as sharp points even without correcting lenses. The speckles may move opposite directions for them with and without their glasses.

Observe the speckles far from the screen and close to the screen. You may get opposite results as a function of distance.

Have people with excellent vision look through reading glasses to see what other people see.

What's Going On?

The waves of light from the laser are coherent before they scatter from the rough screen, that is, they are all in phase, the crests of one light wave line up with the crests of all the others. After scattering from the screen the crests no longer line up, the scattered waves interfere constructively to make bright points and destructively to make dark points. We say that the speckles are caused by interference of the laser light scattered from the rough surface of the screen. The speckles will be sharply in focus no matter where the viewer has focused his or her eyes.

Nearsighted people will see the speckles move opposite their head motion, farsighted people will see them move the same way. People with excellent eyesight will see no motion at all.(These people may have trouble seeing the speckles.)

Nearsightedness, myopia, may be different from eye to eye, it may change with distance to the object viewed, and it may be complicated by astigmatism.

The faster the dots move, the worse your vision is.

So What?

This is a very sensitive eye test. People with excellent vision may test as slightly nearsighted or farsighted on any given day or time of day. The answer may change from one time of day to another as the inter ocular pressure changes, changing the shape of the eye.

It is important to report what you see even if you are the only dissenting voice in a group. An important scientific discovery may depend on your honest report of your observations.

More Science

Persons with good vision will focus their eyes so that the wall is imaged on their retina. The speckle dots will also be imaged on the retina at the same point. So the dots appear at the same distance as the wall. When these people move their heads the dots move with the wall. Using the wall as a frame of reference the dots move with the wall and so do not move relative to the wall.

When a nearsighted person looks at the light bulb or the surface of the wall covered by speckles the speckles mislead their automatic focusing ability and they tend to focus their eyes so that a region closer to them than the wall is in focus on their retina. The wall itself will be focused slightly behind the retina. When they move their heads side to side, viewing the wall as a reference plane, the dots seem to move opposite the direction of motion of the wall. To see this, you can focus on an object like your finger held in front of the screen and notice the motion of the speckles.

A farsighted person will focus on a plane slightly behind the wall. The wall will thus be in focus slightly in front of the retina. Again using the wall as a frame of reference the dots will move relative to the wall when the viewer moves his or her eye side to side. In this case the dots move in the same direction as the head moves.

Etc.

"X-ray vision"

When the laser shines into the frosted bulb a sharp shadow of the filament may be seen if you rotate the bulb. This is because the laser beam has a small cross section and scatters when it hits the first side of the bulb spreading from a point, casting a shadow of the interior of the bulb on the opposite frosted side. A point of light, such as the bare bulb of a minimag light, held near the bulb has the same effect.

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