Scattering: Detecting the Microscopic

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Our everyday view of the world relies on the reflection of light from the objects around us. This reflection is called backscatter, especially when applied to tiny objects scattering light back to an observer when the light source is behind him or her. Very tiny objects, approximately the size of the wavelength of the illuminating source, also send light forward in the same direction, more efficiently than they backscatter light. This light travels in approximately the same direction as it came from the source. This effect, called forward scattering, is used by scientists when studying interstellar dust clouds, planetary atmospheres, and ring systems. Measurements of scattering help to determine the sizes of particles in those environments.

Materials

- Red laser pointer (be careful in setting up the experiment to make sure the laser will not project its beam into anyone's eyes)
- Two large binder clips
- Two clear, plastic or glass water bottles or cups (walls should be vertical), 50-100 mm in diameter (bottled water or soft drink bottles are good as long as they have some non-corrugated surface)
- Tap water
- Milk, non-dairy creamer, or equivalent (1/20 tsp - a "pinch" per 12 oz. of water; adjust as necessary)
- Eye dropper
- Lazy Susan turntable marked with regular angular intervals (30 or 45 degrees) through 360 degrees
- Masking, duct, or electrical tape
- Vernier light sensor, interface, and computer+monitor

Procedure

For convenience, use the binder clips as legs to stand the laser, with one also holding the laser's switch in the "on" position.

Adhere a piece of tape to one side of each sample container at the height of the laser beam that will pass through it. The tape is to prevent the laser beam from being projected past the bottle wall across the room into viewers' eyes.

Fill one container with water. Fill the second container with a highly dilute solution of milk, thoroughly mixed so the water is just slightly whitened. (Find the right proportions by experimentation in advance.)

Place the water container on the turntable concentric with the turntable axis of rotation. Place the laser on the turntable, oriented so that it passes through the sample container. The beam should project through the container onto the small piece of opaque tape on the far side (as seen by the laser) of the container. Place the light sensor at a convenient place on the table aimed to receive light coming from the sample container.

Darken the room, if possible. Project the laser beam through the container of plain water onto the tape on the container. The beam should pass straight through and be invisible or nearly so as you rotate the assembly through 360 degrees. Use stepwise movements at fixed intervals of angle as the sensor collects data. Figure 1 illustrates results.

Next, project the beam through the dilute milk solution. Laser light scattering from tiny particles of milk will delineate the laser beam. While the sensor again collects data, observe the brightness of the beam in the mixture as the turntable is rotated. The intensity of the beam is stronger or weaker according to the scattering properties of the milk particles (primarily their size) as the assembly is turned in front of the sensor and fixed observers in the room. Note how the beam brightens before the laser beam is in direct line with eyes or the sensor – this is forward scattering. Figures 2 and 3 illustrate this result.

Try other materials that will remain suspended in liquid for useful amounts of time. Flour, corn meal, corn starch, silt from a local stream bed, glitter, salt, and sugar will provide varying results. Try transparent carbonated beverages, including their foams, and cigarette smoke trapped in a jar.

Because scattering is a phenomenon dependent on both the wavelength of the wave being scattered and on the size of the scatterer, much can be learned by working in well-separated parts of the electromagnetic spectrum. Even a green laser will display different behavior. Where light waves tell us about the sizes of small particles, radio waves can tell us about the sizes of objects ranging in size from golf balls to houses, in Saturn's rings for example.

A lower "tech", but more detailed discussion of this activity may be found at http://eis.jpl.nasa.gov/cassini_epo/education/pdfs/Scattering.pdf .

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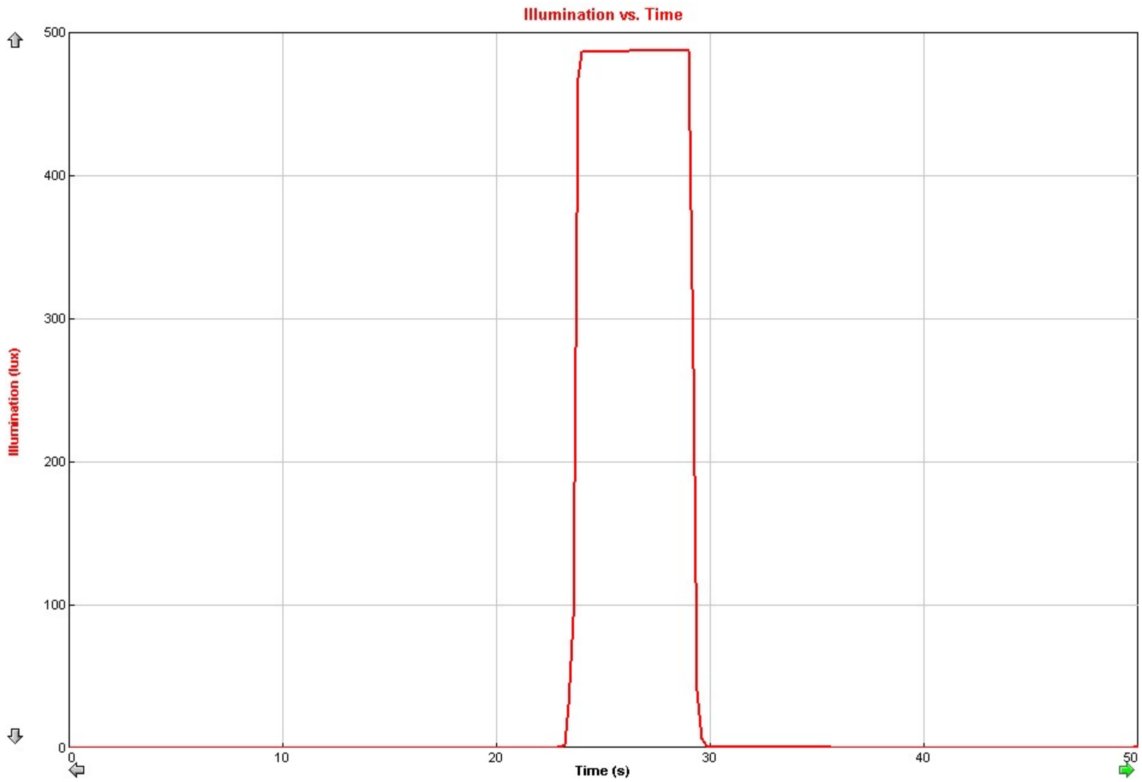

Figure 1. The laser beam was projected through clear tap water. The turntable was rotated stepwise in 45 degree increments.

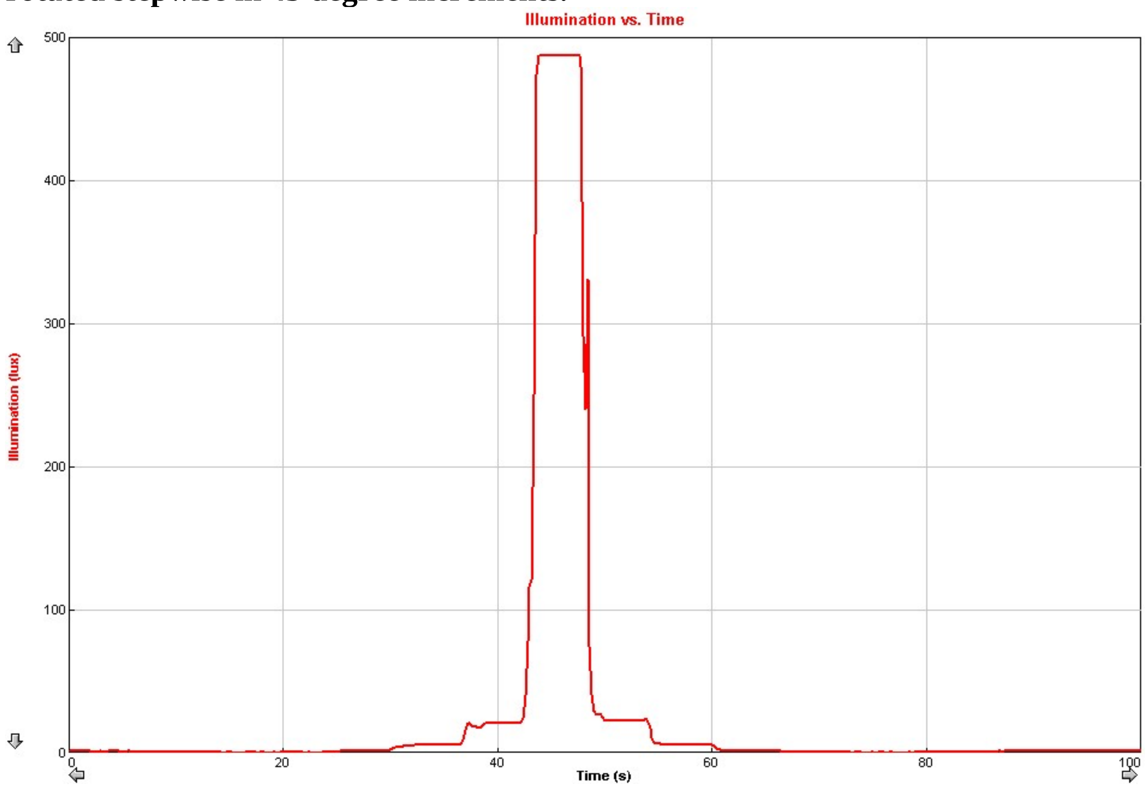

Figure 2. The laser beam was projected through water with a few drops of milk mixed in. The turntable was rotated stepwise in 45 degree increments.

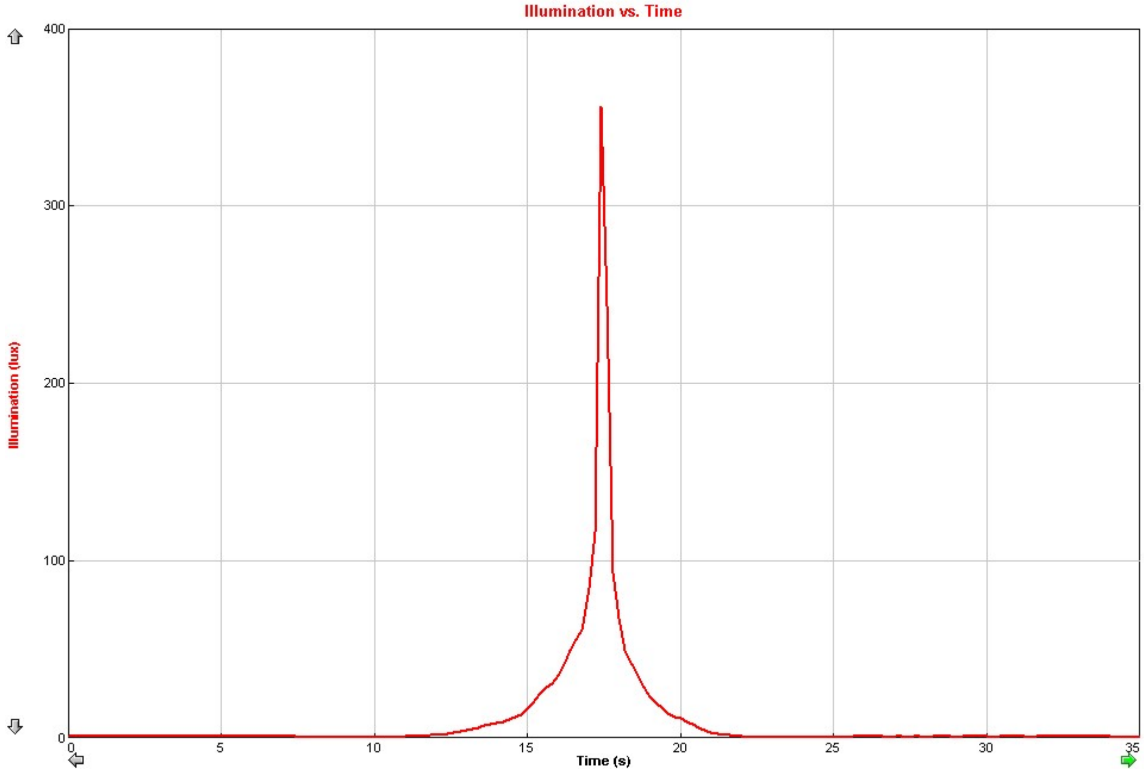

Figure 3. The laser beam was projected through water with a few drops of milk mixed in. The turntable was rotated continuously.