OPTICAL SOCIETY
ROCHESTER SECTION

<u>Experiments with a Laser Pointer and The *Optics Suitcase*</u>

Supplement to be used with the theme packets from *Optics Suitcase* and other materials supplied.

Support provided by APS / OSAF / SPIE and Tessera Technologies, Inc.

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Supplement Supplies

- quantity 12 ea., 650 nm (red) laser diode pointer w/ warning label
- quantity 1 ea., plastic sheet-diffractive optical element (DOE) mounted on wood frame
- quantity 11 ea., plastic sheet-DOE mounted on fold-out, white paper frame
- quantity 12 ea., white "screen": medium card stock-semi-smooth finish, paper 8.5" by 11"
- quantity 12 ea., glass bottle w/ screw cap
- quantity 12 ea., plastic, disposable, transfer pipet

Warnings Regarding Laser Pointers

Fig. 1

These are class IIIa lasers with output power <5 mW [ref: http://en.wikipedia.org/wiki/Laser_safety#Class_IIIa]. "The US Food and Drug Administration has advised that laser pointers are not toys and <u>should not be used by minors except under the direct supervision of an adult…</u>….. a brief 0.25-second exposure to a <5 mW laser such as found in red laser pointers does not pose a threat to eye health. On the other hand there is a potential for injury if a person deliberately stares into a beam of a class IIIa laser for few seconds or more at close range. Even if injury occurs, most people will fully recover their vision. "

Introduction

This supplement provides ideas and materials for simple experiments that may be done with the laser pointer and the *Optics Suitcase* during calendar year 2010, as part of LaserFEST - celebrating 50 years of Laser Innovation (www.laserfest.org). The goal is to show middle school students some of the unique attributes of the laser in comparison to other light sources. Experiments described below explore "collimation and divergence", "monochromaticity", "diffractive optical elements", "polarization", "scatter", "total internal reflection" and "heat from light". Many of these experiments utilize materials from the three theme packets in the *Optics Suitcase* [see Educational Outreach Section at http://osarochester.org/]. Some of the ideas for these experiments come from resources cited at the end of the supplement.

Advanced Preparation

Read over the entire supplement and estimate how many of the seven experiments will fit into the time allotted. Assemble and prepare all supplies ahead of time. If you choose to break up these experiments over several days, remember that the *Optics Suitcase* theme packets are necessary for many of them. Since theme packets are meant to be taken home by the students, you may need to hold onto these until all experiments are completed. **The laser pointers should be collected at the end of each presentation; they are not meant to be given away.**

To Begin

One laser pointer is intended to be used by a group of 2 to 3 students. **You, the presenter, should be the judge of how much direct supervision is required to carry out the experiments described below, based on the ages of those in your audience.**

First, go over laser safety issues: [http://web.princeton.edu/sites/ehs/LabPage/laserpointersafety.htm]

1) "Never look directly into the laser beam."
2) "Never point a laser beam at a person, even someone far away, in a car, for example."
3) "Do not aim the laser at a reflective surface like a mirror."

Per directions on the white box, pull the white tab out of the back of the pointer if it is still inserted. Examine the pointer with the students. **Note the warning labels**. A laser pointer is not a toy. "Laser pointers have become consumer novelty products and promoted as toys," says Jerome Dennis, a consumer safety officer for the FDA's Center for Devices and Radiological Health (CDRH). "They're hazardous as toys and shouldn't be used frivolously."

-[http://www.fda.gov/Radiation-EmittingProducts/RadiationSafety/AlertsandNotices/ucm153548.htm]

This laser pointer has two "on" buttons, located between the warning labels (see Fig. 1). The silver button operates a white light-emitting-diode (LED). It is not a laser. When this button is pressed, two bright, white light beams are emitted from the device. The "red" button activates the "red" diode laser, and the laser beam exits from the case from the side opposite the key ring (see red arrow in Fig. 1). [Note: Power cell replacement is discussed at the end of the supplement.] Although each experiment is given a number, they may be done in any order, and some may be omitted if time is a problem. One exception: experiments #4 and #5 should be done together.

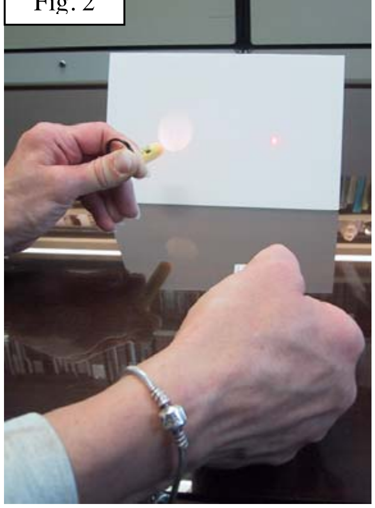
Experiment #1: Collimation and Divergence

Materials required for each group of students:

- one flashlight from the Rainbow Peephole theme packet
- one "screen"- white card stock, folded in half
- one laser pointer

Take the flashlight from the Rainbow Peephole theme packet. Erect a folded piece of white paper as a "screen" (see Fig. 2), and shine both the flashlight and the laser pointer onto it. Move both light sources closer and further away from the screen. The laser beam is naturally collimated. This means that the size of the beam expands in size (e.g., diverges) very slowly with distance. As a consequence of collimation, laser beams may be directed to distant targets with high accuracy. This can be good (laser communications, laser ranging - distance to the moon), or bad (laser beam sent into the cockpit of a commercial jet to

Fig. 2



temporarily blind the pilot). With care, the laser beam may be directed toward the ceiling or to a distant wall within the classroom where it will remain visible.

<u>Experiment #2: Monochromaticity</u>

Fig. 3

Materials required for each group of students:

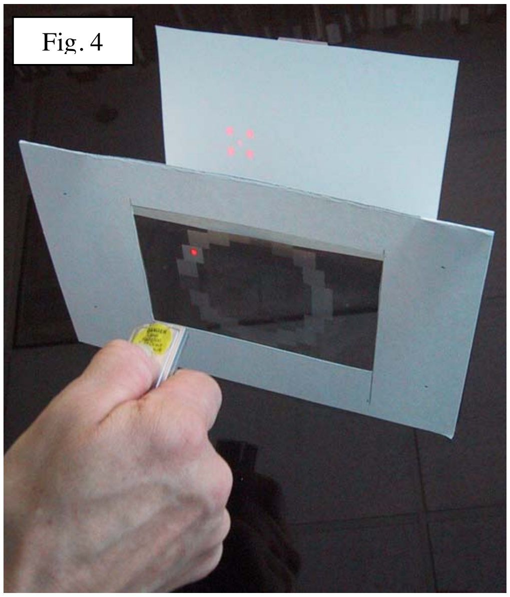
- one flashlight from the Rainbow Peephole theme packet
- one Rainbow Peephole from the Rainbow Peephole theme packet
- one "screen"- white card stock, folded in half
- one laser pointer

Take the <u>flashlight</u> and shine it through the Rainbow Peephole and into the eye, duplicating the experiment done as part of the *Optics Suitcase* presentation. The Rainbow Peephole is called a diffractive optical element (DOE -more in Experiment #3 below). The complex arrangement of bumps on the plastic film of the Rainbow Peephole (see atomic force microscope image on the packet) diffracts, or redistributes, the white light from the flashlight according to color. The light from the flashlight consists of a spectrum of colors. It is polychromatic.

Now, direct the laser beam through the Rainbow Peephole and onto the white "screen" (see Fig. 3). This laser is a monochromatic light source. It has only one color - red. Monochromaticity means only one color, and it is a property of lasers. The monochromatic property of lasers is advantageous for the treatment of skin cancers, for eye surgery, for fiber-optic relay of information in telecommunications, and for chemical research (initiation of color-specific chemical reactions).

<u>Experiment #3: Diffractive Optical Element</u>

Fig. 4



Materials required for each group of students:

- one "screen"- white card stock, folded in half
- one DOE mounted on a white paper frame
- one laser pointer

Set up the DOE and place the "screen" behind it (see Fig. 4). Direct the laser beam through the DOE.

How many distinct patterns can be observed? (ans: 17 to 21, depending on how closely one looks (don't forget to shine the laser through the central region of the plastic foil). DOEs are called pattern generators for laser light. They transform a single laser beam into various simple or complex patterns. They redistribute the energy in the laser beam. The type of pattern is determined by the micron-scale profile embossed onto each square in the DOE. Other DOEs find applications in imaging systems as thin lenses or lens arrays. A form of DOE called a "*hologram*" may be used as an anti-theft device. Find the hologram on your parent's credit card.

<u>Experiment #4: Polarization</u>

Materials required for each group of students:

- one linear polarizer from the Magic Stripes theme packet
- one "screen"- white card stock, folded in half
- one laser pointer
- white correction fluid or a permanent marker pen

Fig. 5a

This experiment is a follow-up activity to the lesson on polarization and color from white light in the Optics Suitcase.

Observe room light or sunlight reflected from any shiny surface while holding up one of the linear polarizer squares. You must be looking at an angle of observation that is ~30° to 40° up from horizontal (e.g., the table top, see Fig. 5a). Rotate the polarizer. "Glare" is light that has become linearly polarized in a horizontal direction after reflection from a shiny surface. The angle is called the "polarizing angle", or "Brewster's angle", after Scottish physicist David Brewster (1781-1868). With this simple experiment you may mark the linear polarizer to indicate the horizontal polarization direction of light that is "passed" by the polarizer. [Because the Magic Stripes polarizer may not be marked to indicate the polarization "pass" direction, you may need to scrape off the white line and re-apply it with white correction fluid or a permanent marker pen (see Fig. 5a).] Polarizing sunglasses are manufactured with a vertical polarization "pass" direction, to block glare reflected of the highway (See Fig. 5a).

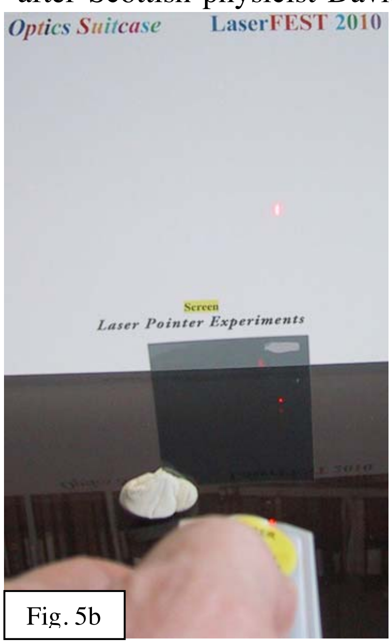


Fig. 5b

Now, erect the white screen. Shine the laser pointer on the screen and insert the marked polarizer in the beam. Rotate the polarizer to maximize the amount of laser light hitting the screen. Unlike the light from other light sources (direct sunlight, the flashlight), most laser radiation is polarized. The output beam from this laser pointer is "mostly" linearly polarized parallel to its broad, flat surface (see Fig. 5b). Show that it is not completely polarized.

<u>Experiment #5: Scatter, Polarization and Total Internal Reflection</u>

Materials required for each group of students:

- one flashlight from the Rainbow Peephole theme packet
- one (correctly marked) linear polarizer from the Magic Stripes theme packet
- one "screen"- white card stock, folded in half
- one laser pointer
- one disposable, plastic transfer pipet
- one 20 ml glass bottle with screw cap [you will need to provide some low fat or nonfat milk]

Before carrying out this experiment, the presenter should fill each bottle with about 10-15 ml of tap water to the mark on the side.

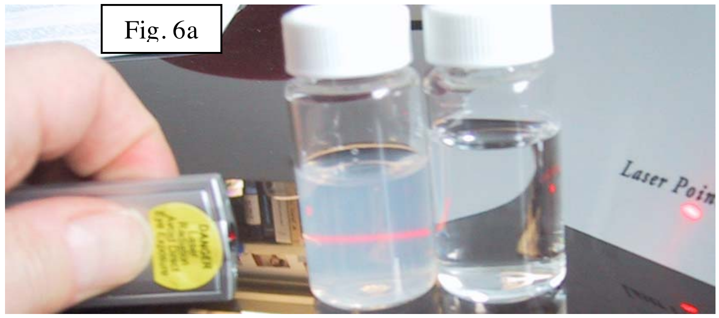


Fig. 6a

Erect the "screen" and use it as a backdrop for this experiment. Direct the laser through the bottle of water. It is not possible to see the laser beam inside the water, because the water is transparent. Using the disposable, plastic transfer pipet, add 5 drops of nonfat or no fat milk to the bottle, seal and <u>gently</u> agitate (you do not want to create bubbles). The liquid is now cloudy. Shine the laser through the bottle. The milk in the water scatters the light sideways, making the beam easily visible (see Fig. 6a). Hold the flashlight up to the side of the bottle and note the difference in divergence for this incandescent light source compared to the laser light source.

The following experiments with polarized light assume that both the Optics Suitcase Magic Patch experiment and Experiment #4 (above) were completed earlier.

Hold the laser between thumb and index finger as shown (see Fig. 6b). The laser light is now vertically polarized. Observe how the intensity of the sideways scattered laser light is diminished as a linear polarizer (from the Magic Stripes theme packet) is rotated from vertical to horizontal (see Fig. 6c). The sideways scattered light is vertically polarized. Repeat this experiment with the flashlight. The light from the flashlight is unpolarized (how can you show this?), but the sideways scattered light is still vertically polarized. Polarized lasers are needed for satellite communications; polarized lasers are used in CD readers.

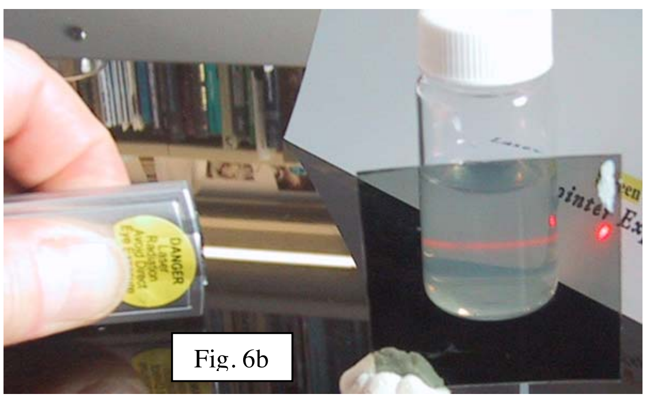


Fig. 6b

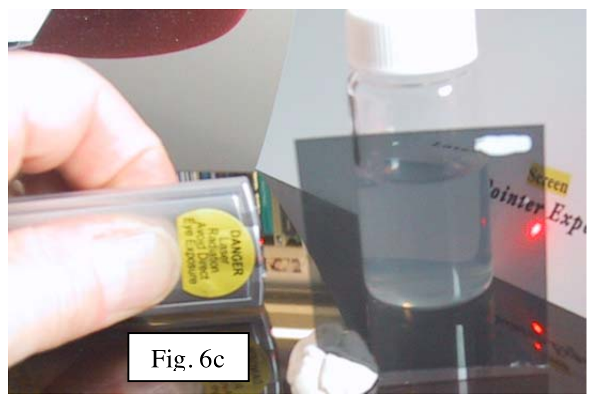


Fig. 6c

Now, tip the bottle on its side and shine the laser beam in from the end of the bottle. Vary the direction into the end of the bottle from perpendicular (see Fig. 6d) to oblique (see Fig. 6e). When the angle of the laser beam at the water/air interface inside the bottle exceeds a critical angle, the beam is totally internally reflected within the water. Fishermen may take advantage of this phenomenon to sneak up close to the edge of a brook, staying invisible to the fish. Pretend to be a fish in a swimming pool where the water's surface is smooth. What can you see? The critical angle is a key to the sparkle of cut diamonds.

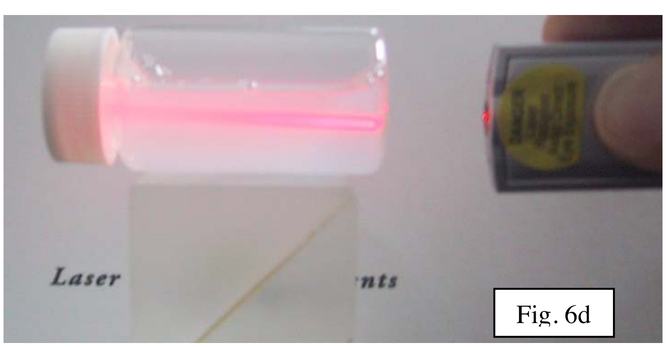


Fig. 6d

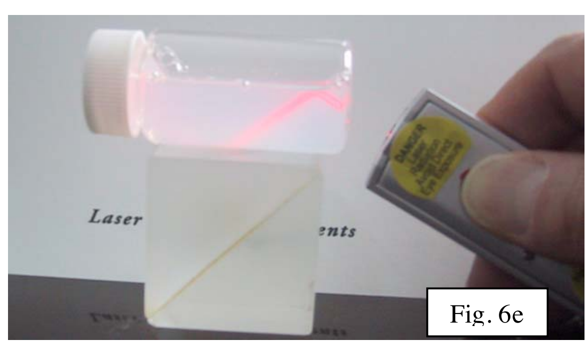


Fig. 6e

Experiment #6: Heat from Light

Materials required for each group of students:

- one flashlight from the Rainbow Peephole theme packet
- one liquid crystal mood patch from the Magic Patch theme packet
- one laser pointer

Take the magic patch and hold it between thumb and index finger so the color-changing side faces up. Turn on the flashlight and shine it onto the patch from the rear, while gradually decreasing the distance between the two. How close does the flashlight bulb have to come to the patch in order to observe a color change (see Fig. 7a)? Move the patch over the flashlight bulb. Can you always find the location of the flashlight bulb? Do the same experiment with the laser pointer (see Fig. 7b). Think about how useful lasers are for industrial cutting and welding applications, and for laser surgery.

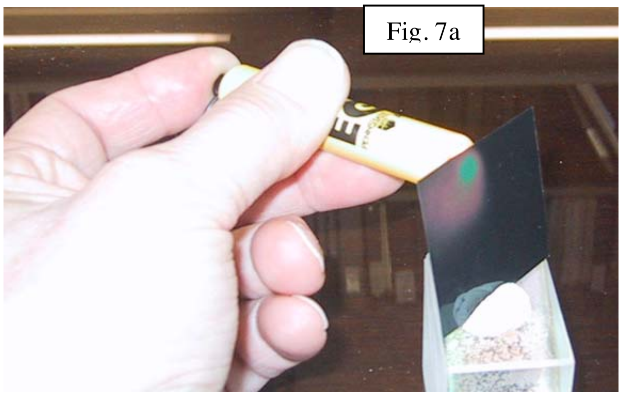


Fig. 7a

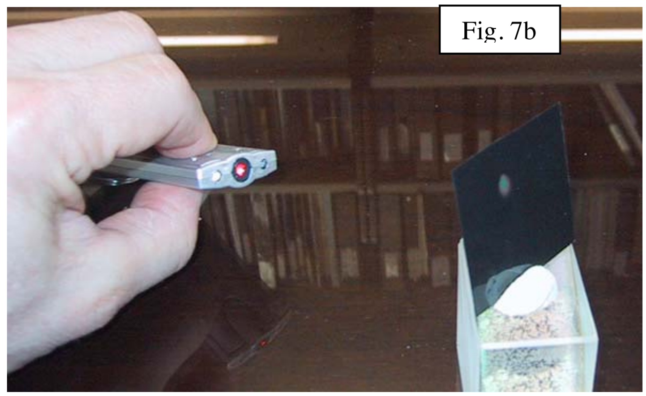


Fig. 7b

Resources

- Safety and Laser Pointers: L. Bren, "Illuminating Facts About Laser Pointers," FDA Consumer Magazine (May-June 2005) http://www.fda.gov/fdac/features/2005/305_laser.html; and "Illuminating the Hazards of Powerful Laser Products," FDA Consumer Health Information / U.S. Food and Drug Administration (June 2009) http://www.fda.gov/downloads/ForConsumers/ConsumerUpdates/UCM167564.pdf
- Brewster's angle and "glare": M. G. Raymer, **The Silicon Web**, Taylor & Francis p. 254 (2009).
- Total internal reflection: J. O'Connell, "Optics Experiments Using a Laser Pointer," *The Physics Teacher*, vol. **37**, p. 445 (Oct., 1999).
- Scatter: R. E. Benenson, "Light Polarization Experiments with a Diode Laser Pointer," *The Physics Teacher*, vol. **38**, p. 44 (Jan., 2000).

Acknowledgments

We gratefully acknowledge the OSA Foundation for the provision of 500 laser diode pointers; APS, OSA and SPIE for a LaserFEST Grant to assemble and distribute this supplement with The *Optics Suitcase*; Tessera Technologies, Inc., for the provision of 500 DOEs; and Stephanie Bloch / Bruce Smith -members of the Technical Council / Rochester Section / OSA for suggesting the use of DOEs and where to obtain them. Finally we acknowledge the Laboratory for Laser Energetics of the University of Rochester for providing logistics support for the assembly and distribution of this Laser Pointer Supplement and The *Optics Suitcase*.

Addendum - Laser Pointer Battery Replacement

The light output of the pointer will diminish with time. The two batteries that power the pointer may be replaced with fresh ones by removal of six, tiny screws. Use a small, jeweler's Phillips head screwdriver. Once disassembled, the pointer consists of 3 parts (see Fig. 8): top cover with warning labels, middle portion with buttons, and base with circuits, laser diode, and LEDs.

The two batteries are located under the metal clip at the bottom of the base. [In Fig. 8, one battery has been removed, while the other remains in place.] Remove and carefully dispose of the two **"lithium" cells, model # CR1220 3V**. Replace with two fresh cells. These should be inserted with the (+) side facing down. During re-assembly of the unit, carefully replace the key ring over the metal knob on the base.

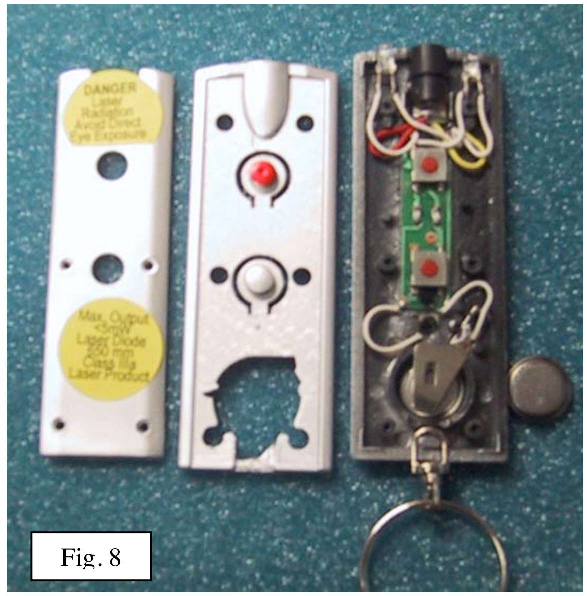


Fig. 8