Get green: Fun with thin film interference

BY MICHAEL E. KNOTTS

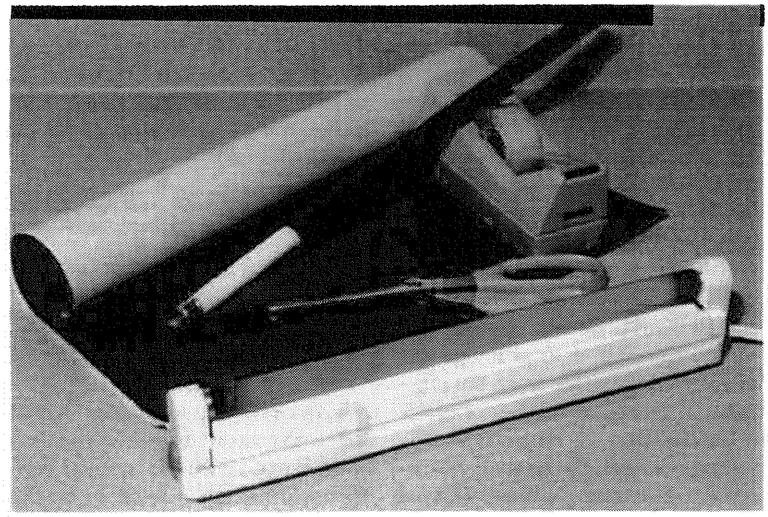

Figure 1. A simple, homemade monochromatic lamp that uses a standard fluorescent tube and a dark green plastic filter.

If you look closely at everyday objects, chances are you're likely to encounter many examples of optical thin film interference effects. Brilliant colored patterns seen in soap bubbles or reflections from oil slicks on wet pavement are familiar examples, visible in daylight. Such white light patterns are striking, but patterns with much greater contrast can be observed using a monochromatic lamp. Monochromatic lamps are sold specifically for the purpose of viewing thin film interference effects,[1] but they cost more than most casual home experimenters are willing to spend. This article describes how to make your own monochromatic lamp for less than $25 and then gives you some fun experiments you can conduct with Newton rings and other thin film effects. For those with a higher budget, an improved design is described that can be made for about $85.

Lamp making

All that is needed to make a monochromatic lamp is a fluorescent lamp and a dark green filter. Fluorescent bulbs contain a low pressure mercury vapor, which, when on, is excited by a high voltage discharge throughout the length of the tube. The discharge emits copious amounts of ultraviolet light, as well as visible wavelengths, one of which is the green mercury emission line at 546.1 nm.

Usually, the inside of the lamp is covered with phosphors that convert the uv to visible light via fluorescence. If you look at a fluorescent lamp with a spectroscope, you'll notice that the spectrum contains a broad distribution of visible wavelengths and several bright emission lines—the most visible at 546.1 nm. An adequate monochromatic lamp can be made by using a dark green filter to block the visible light, except for the bright 546.1 nm green emission line. The light escaping from the filtered fluorescent tube will be substantially dimmer than the unfiltered tube, but it will be suitable for conducting interference experiments in a dark room.

I used a Roscolux #90 (dark green) filter,[2] sold in 20" × 24" sheets for photographic and theatrical lighting applications. Such filters are available in dozens of colors and can be purchased locally ($5–6 per sheet) from large camera stores that cater to commercial photographers,

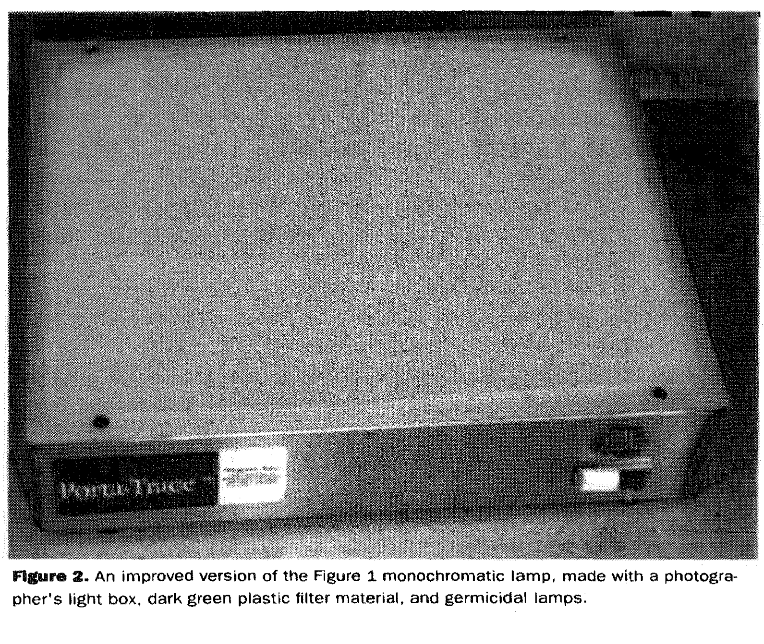

Figure 2. An improved version of the Figure 1 monochromatic lamp, made with a photographer's light box, dark green plastic filter material, and germicidal lamps.

stores that sell theatrical supplies, or by mail order.[3]

The simplest approach is to cut a piece of the plastic filter material slightly longer than the glass portion and slightly wider than the circumference of the bulb. Wrap it snugly around the tube and tape it at the seam. To ensure a strong monochromatic source, double wrap it or use two pieces of plastic. Once wrapped, place the tube into a housing. A small fixture that holds an F8T5 tube (8 W, 5/8" in diameter) does nicely, and can be purchased at a hardware store or home improvement center for less than $20 (see Fig. 1).

I purchased a small light box (sold for examining photographic negatives and transparencies) for $50 (see Fig. 2), to make an even better monochromatic light source—it's not only brighter and very monochromatic, but also diffuses evenly over a large area. I opened the lid's box and replaced the two F8T5 tubes with G8T5 germicidal lamps. Germicidal lamps can be ordered from specialty lighting suppliers[4] and should cost less than $25. I also covered the underside of the 1/4" thick diffusing plastic lid with Roscolux #90 filter material and re-assembled it.

Germicidal lamps are like standard fluorescent lamps except that they have no phosphor coating and are made of a clear glass that transmits short wavelength uv light. They can cause sunburn and, if looked at, injure eyes—*it is very important to operate them with a protective cover that absorbs ultraviolet light.* The diffusing plastic lid of my light box (and/or the green filter) does an excellent job of blocking the uv. I tested this by placing fluorescent objects in front of the lamp; no fluorescence was visible. Essentially all light escaping the box is the green 546.1 nm mercury emission line.

Discovering interference

With your monochromatic lamp at hand, go prospecting for interesting optical effects anywhere you find a thin film. "Thin" means having a thickness comparable to the wavelength of light—in this case 546.1 nm. Light reflecting off one side of the film interferes with light reflecting off the other.

If you look at a film illuminated by an extended monochromatic source (such as the ones described here), you'll most likely see dark and light bands, usually referred to as "fringes of equal thickness." Think of them as contour lines, like those on a topographic map, that trace out the fluctuating thickness of the film—in intervals of one half the wavelength divided by the index of refraction—instead of the height/depth of hills and valleys.[5]

Much fun can be had with microscope slides or, even better, cover glasses. Take a couple out of the box, carefully clean and dry them, place them on top of each other on a dark sheet of paper (to improve contrast) and then rub them together under monochromatic illumination. Fringes will be visible as a result of interference in the trapped air gap (see "After Image," page 64). If you push down with a pencil eraser, you'll see the fringes shift as you change the air gap.

Next, try rubbing a little alcohol on a fresh slide and watch the fringes shift as the fluid dries (you'll see colored fringes in white light). Mix up some detergent in water and make a film by dipping a ring or wire loop into the solution. Watch the fringes move as gravity distorts the film. Try stretching some plastic food wrap under the monochromatic lamp, and look for a myriad of wavy fringes. Pull it really tight (it may help to stretch it over a clear bowl held above a dark background). Set a clear glass bowl filled with water on a dark background. Put a single drop of light machine oil on the surface of water. Thin circular fringes will appear as the oil spreads.

The possibilities are endless—see how many interesting thin film interference effects you can find around the house. I'd love to hear of your oddest examples.

References

1. Edmund Scientific (609/573-6250) sells monochromatic lamps between $150 and $225, depending on the size.
2. Roscoe Laboratories (800/767-2669), the maker of Roscolux filters, said that the #90 filter is a polycarbonate sheet co-extruded with dye. They offered to send me a free swatch book containing samples of dozens of different filters and accompanying spectral transmittance measurements.
3. Contact suppliers such as B & H Photo Video (800/606-6969, http://www. bhphotovideo.com), or Calumet Professional Imaging (800/225-8638).
4. See the Yellow Pages, especially of a major city.
5. For more details about the physics of thin film interference, see a good optics textbook, for example, E. Hecht, *Optics, 2nd edition* (Addison-Wesley, Reading, Mass., 1989), sec. 9.41.

Michael E. Knotts, *OPN* contributing editor, is postdoctoral research fellow in the School of Physics, Georgia Tech, Atlanta, Ga.; ph281mk@prism.gatech.edu.