Compact Fluorescent Lamp Observed Through a Diffraction Grating

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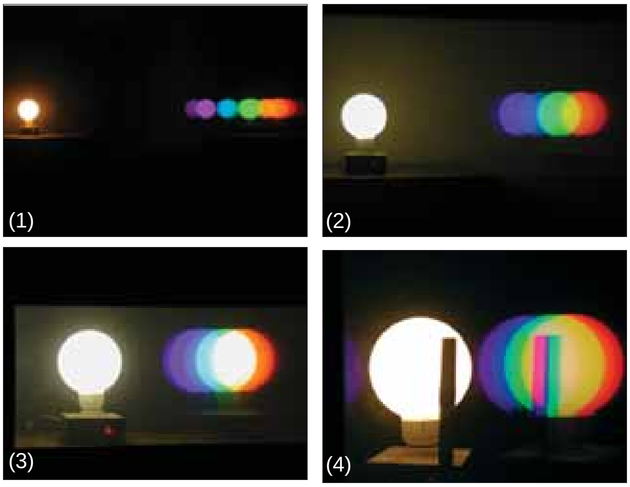
This paper describes the use of a compact fluorescent lamp and a diffraction grating to introduce some basic concepts connected with the perception of colors. If a spherical compact fluorescent lamp is observed through a diffraction grating from a distance of 3 m or more, some interesting and perhaps unexpected features (Fig. 1) may be noticed: interesting, because of the many images having the shape of disks with different brilliant colors (corresponding to the wavelengths of emission lines in the discharge spectrum of the gas mixture in the lamp). There are unexpected features because when we get closer to the lamp it is possible to see that some of the different colored images become superimposed. Colors seen in the overlapping areas are quite different from those of the original disks. The appearance of these new colors has to do with how we perceive color.

The mixing of diffracted colors shown in Fig. 2 cannot be seen when the light source has the usual shape of a thin line. Here we find, for example, in the area where the red image overlaps the green, a yellow image that can be seen even if it didn't exist before. Similarly, the superposition of green and blue gives a cyan colored area.

Moving still closer to the lamp (around 30 cm or so), it's possible to see a white area (Fig. 3) that is due to the superposition of the red, green, and blue images. All of this is in accordance with the well-known fact that the sensation of colors is not unique, i.e., any perceived color can be obtained by the superposition of other appropriate colors.

Another interesting observation may be made when a pen or other similar object is placed between the lamp and the grating. With the lamp and grating separated by about a ½ m, several colors are incident on the pen and so a number of shadows will be cast, each having a different color (Fig. 4). The color of each shadow depends on which one (or more) of the incident colors are blocked out by the pen. In an ideal situation consisting of only three incident colors, red, blue, and green having the proper relative intensities, one would expect that the overlapping area would appear white. But if the pen were to block only the green beam, for example, then the area corresponding



Figs. 1–4. Multiple colored images of a compact fluorescent lamp viewed through a diffraction grating. (2) Overlapped images showing new colors, e.g. yellow and cyan. (3) Superposition of a number of colors to produce white. (4) Colored shadows of a pen. The pen subtracts one or more colors from the mixture.

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to the shadow of the pen would appear magenta. In the same manner cyan and yellow would appear if a pen were to block out the red or blue, respectively.

Now we can try to explain some other aspects of this demonstration, for example:

1) Why do the colored images that we can see through a grating have the same geometrical shape as the lamp? That is because any extended light source may be thought of as a set of many thin, luminous slits, one beside the other. So the images seen through the grating are in the form of thin, adjacent lines, all having the same color and height. In this manner the image of any extended source can be seen to have a shape similar to that of the source. In other words, a grating does not deform images.
2) Some of the images are particularly sharp. These correspond to the most monochromatic spectral lines.
3) If the dispersion of the grating is not high enough it is possible to notice second-order spectra. In this case the superposition described above may occur more readily, because images of different orders can overlap.

Note About the Equipment

It's best to observe the lamp against a black and homogeneous background. The spherical (encapsulated) compact fluorescent lamp must have high intensity. We suggest not less than 20 W, 1160 lm, with a diameter of 12 cm. The grating must be of good quality, in order to give sharp images, and it should be as large as possible. For our photos we used holographic diffraction grating film, 1000 lines per mm, 15 cm x 30 cm (Edmund Cat. No. T30402-67). The pictures were taken using a Nikon digital camera, and we overexposed each picture in order to produce satisfactory images of the colored disks.

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