Spectra of Three Light Sources with a CD

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Recent articles[1,2] have described how a compact disc (CD) can be used to give diffraction patterns with laser light, allowing measurement of wavelength. In this note we suggest using the CD together with another recently developed artifact that students will increasingly see at home and in schools—the compact fluorescent light bulb. We outline a series of activities from qualitative "home experiments" to quantitative measurements best made in the school laboratory. In addition to allowing students to observe and measure various spectra, these activities should help them relate the physics they learn at school to everyday effects.

Enchanting effects such as those shown on the cover are best observed if the CD is held near to the light source. Useful light sources include fluorescent tubes, incandescent filament lamps, and compact fluorescent light bulbs. The effects seen are easiest to interpret if the fluorescent tube is used without a diffuser, and if the tungsten filament lamp has a clear glass envelope and preferably a long straight filament. It is also worth looking at the effects produced by street lamps (sodium, mercury). Given some suggestions about what to look for, students should be able to distinguish between the continuous spectrum given by the incandescent lamp and the bands or lines in the spectrum of the compact fluorescent lamp, for example.

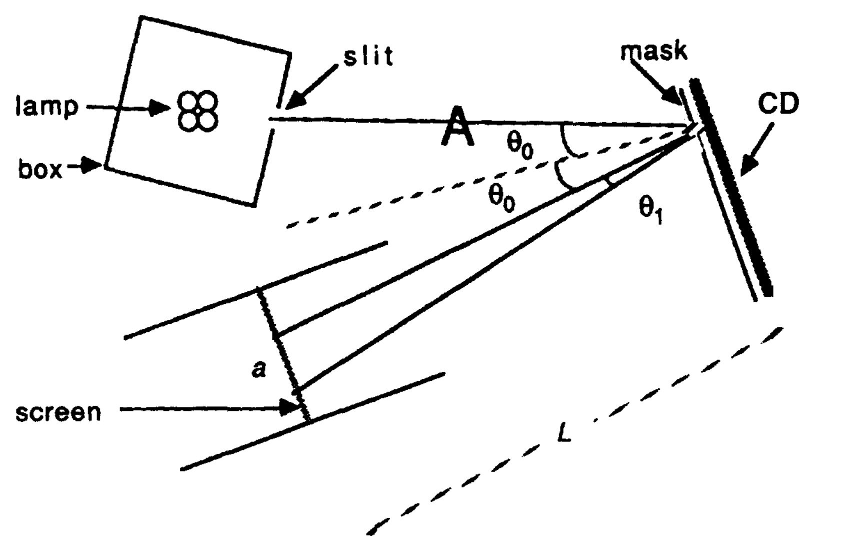

Fig. 1. Arrangement for observing spectra formed by CD and for measuring wavelengths.

Setup Considerations

The lamp used to produce the cover photo was an Osram Dulux EL 20 W. It consists of three double tubes each about 1 cm in diameter and 9 cm long. We placed a box over the lamp, with a slit about 2 mm wide to provide a narrow light source.

Using only part of the CD makes the spectrum easier to interpret and measure. We masked most of the disc with black tape, leaving a rectangular slit, perhaps 1 cm wide near the edge. The area of the CD in use is thus restricted to a series of more nearly parallel rulings, and the light source should be aligned with them. However, using only part of the CD reduces light intensity and it is then essential to work in a darkened room.

It helps to view the spectrum on a translucent screen from which stray light is excluded by a shoe box or pair of telescoping tubes, as shown in Fig. 1. The distance from the CD to the screen is about 10 cm; the lamp is about 50 cm from the CD. Intensity is greatly increased if a converging lens is added to the system at A, and the position of the screen is adjusted to produce focused images of the slit on the screen. (We use a lens of 7.5 cm diameter with 15 cm focal length.) This arrangement clearly shows strong red and green, weaker yellow and blue, and also violet. The same arrangement can be used to show the very different spectrum produced by sodium and mercury vapor lamps. Measurements of the distance between a line and the zero-order (central) image (at angle θ_0) and of the distance from CD to screen (a and L respectively in Fig. 1), allow θ_1 in the grating formula $\lambda = d \sin\theta$, and, hence, wavelength λ to be calculated. (The grating formula in this case is only approximated since incidence of light on the CD is not exactly normal.) Taking the grating spacing d to be 1600 μm, as specified by the CD manufacturers, the lens-less and focused image arrangements gave values of 0.577 and 0.584 μm, respectively, for λ_{Na}, with an estimated uncertainty of about 3%. The published value for the mean wavelength of the sodium doublet is 0.5893 μm.

If a transmission grating is available, it is well worthwhile to compare the spectra it gives with the effects described above. (The grating spacing of a 600 lines/mm grating is 1.67 μm, very close to that of the CD.)

Interpretation of Spectra

The spectrum of the compact fluorescent bulb is clearly very different from that of a fluorescent tube or an incandescent tungsten bulb. The compact fluorescent lamp spectrum contains some lines due to mercury, but also many other lines. However, it is not the continuous spectrum given by the filament lamp. The presence of much red in the compact fluorescent lamp's output explains the warmer color of the light, compared with that of a fluorescent tube. Whether these other lines are due to gases within the tube or its phosphor coating could be a subject for further research.

Economic and "Green" Issues

As an extension of the work described here, students could be invited to discuss the economics of the compact fluorescent lamp.[3] For example, the Osram Dulux EL 20 W is said to produce the same luminous flux as a 100-W incandescent lamp, for a 20-W input. The manufacturers claim a rated life of 8000 hours, compared with 1000 for the incandescent. The price in Italy is about Lit 34,000 ($28), compared with about Lit 1100 ($0.90) for an incandescent. Would installing these lamps at my home be a good investment? If I did, how much less energy would I use per year? Is this a significant proportion of my total consumption?

References

1. Christian Noldeke, *Phys. Teach.* **28**, 484 (1990).
2. James E. Kettler, *Am. J. Phys.* **59**, 367 (1991).
3. Laurent Hodges, *Phys. Teach.* **30**, 90 (1992).