CD Rainbows

P. J. Ouseph, Physics Department, University of Louisville, KY

Several papers have been published on the use of a CD as a grating for undergraduate laboratories and/or for high school and college class demonstrations.[1-7] Four years ago *The Physics Teacher* had a spectacular cover picture showing emission spectrum as viewed through a CD with no coating.[8] That picture gave the impetus to develop a system that can project the spectra of light falling on a CD on a white board or a screen. Such an arrangement would be more suitable to show diffraction spectra to a large class.

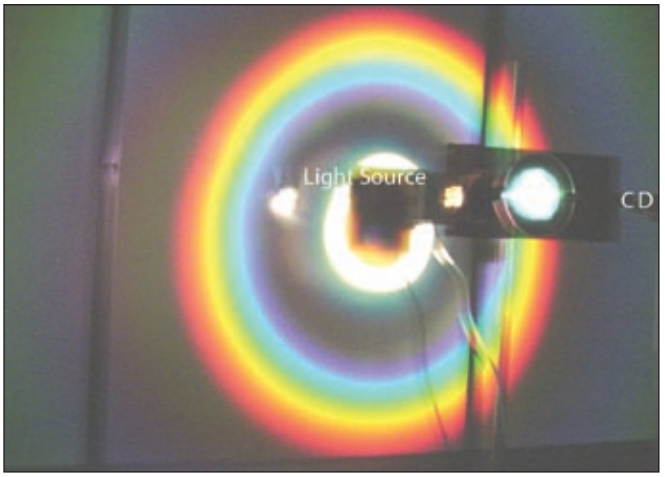

Fig. 1. Spectra of white light reflected from a standard CD.

Construction of the necessary apparatus is found to be very straightforward and simple. A standard CD, coated on one side, and a clear CD with a data spiral but with no coating, found in some CD packages, are used for this apparatus. These CDs have spirals spaced 1.6 μm apart; therefore, they make good circular gratings. A CD holder consisting of a rectangular (13 cm x 30 cm x 6 mm) black Plexiglas sheet with a central hole of 11-cm diameter was constructed. The CD is placed over the central hole with the help of two plastic screws. The black plastic holder is fixed to a plastic rod of 0.5-cm radius. A laboratory stand holds the plastic rod with a clamp. The height of the clamp can be adjusted by moving the clamp up or down, and the orientation of the plane of the CD with respect to the direction of the incident light can be easily changed by rotating the CD holder. To reduce the intensity of reflected/refracted white light falling on the board, black paper is glued to the center of the disc covering the clear central part of the disc. The key to the success of these demonstrations is the selection of an appropriate light source. We found a PASCO light source (model SF-9366) works well. In trying these light sources we observed that the focal lengths of the lenses vary from source to source. To obtain a broad light beam, we added a divergent lens to one of these light sources.

Reflection Circular Spectra

To project the spectra of white light reflected from a standard CD, the light source is placed 20 cm in front of the board, and the CD is placed in front of the light source at a distance of 5 to 10 cm. The plane of the CD and the plane of the board are parallel to each other in this configuration. Light falls on the clear side of the CD facing the board. Figure 1

 DOI: 10.1119/1.2409502

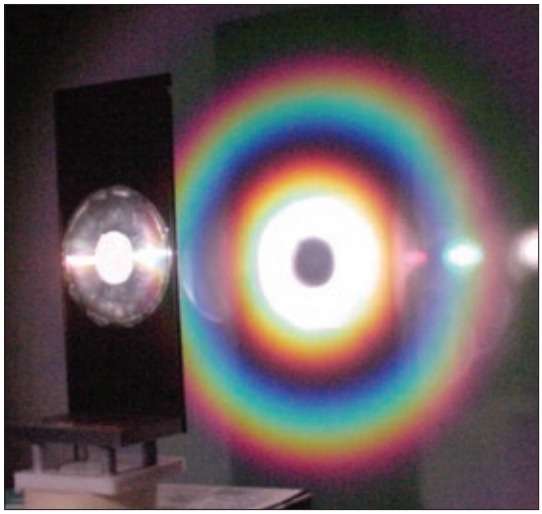

Fig. 2. Three orders of spectra produced by light falling normally on a transparent CD as seen in this figure. The light source, not seen in this figure, is in front of the CD.

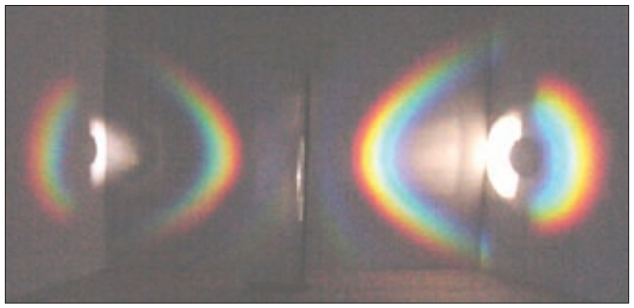

Fig. 3. Rainbow-like spectra produced by white light falling on a CD at a large angle of incidence.

shows the circular rainbow-like spectra obtained in this demonstration. The brightest spectrum has a diameter of 35 cm, and the spectra are clearly visible to students in large lecture halls of 200–300 seating.

Transmission Circular Spectra

To obtain transmission circular spectra, a transparent CD is placed about 40 cm from the board and illuminated with light from a PASCO source. As in the first demonstration, the plane of the CD and the plane of the board are parallel to each other in this configuration. The circular spectra observed are shown in Fig. 2.

Noncircular Spectra

By rotating the CD holder and thereby changing the angle of incidence of light, interesting noncircular spectra can be obtained. An example is shown in Fig. 3. For this demonstration the center of the transparent

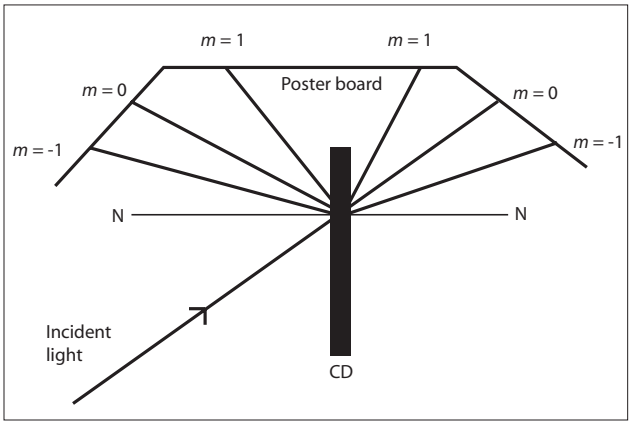

Fig. 4. Line drawing illustrates the positions of the spectra of different orders on the transmitted light (right) and reflected light (left) side.

CD is at a distance of 10 cm from the poster board, and the plane of the CD is normal to the plane of the board. Light is falling on the CD at an angle of incidence of about 60°. For this demonstration half of the front of the light source is covered so that less than half of the CD close to the board is illuminated. Rainbows can be seen on the transmitted light side as well as on the reflected side (Fig. 3). Each side shows two bright rainbows. Spectra on the transmitted side are brighter than those on the reflected side. Notice that two sections of the poster board are at an angle to the central section. Spectrum away from the CD is visible only because the poster board is bent on both sides.

Figure 4 is a line drawing that shows the directions of the reflected and transmitted light as well as the positions where spectra are seen on the poster board. The line NN is normal to the plane of the CD.

Conclusion

The demonstrations discussed here are suitable and interesting for high school and college physics classes. The spectra obtained with a standard CD with coating on one side are as interesting as the spectra obtained with a transparent CD. As can be seen in Figs. 1 and 2, light falling on the disk is broad enough to almost cover the CD. This is done mainly to increase the brightness of the projected spectra in large classrooms. Reducing the angular width, on the other hand, will improve the resolution of the spectra.

References

1. C. Noldeke, "Compact disk diffraction," *Phys. Teach.* **28**, 484–485 (Oct. 1990).

2. J. Kettler, "A compact disk as a diffraction grating," *Am. J. Phys.* **59**, 367–368 (April 1991).
3. V. Zanetti and J. Harris, "Spectra of three light sources with a CD," *Phys. Teach.* **31**, 82–83 (Feb. 1993).
4. F. Wakabayashi, K. Hamada, and K. Sone, "CD-ROM spectroscope," *J. Chem. Educ.* **75**, 1569–1570 (Dec. 1998).
5. T. Knauer, "A compact disk transition spectroscope," *Phys. Teach.* **40**, 466–467 (Nov. 2002).
6. P. Gluck, "Compact disk optics," *Phys. Teach*. **40**, 467–468 (Nov. 2002).
7. J. Tellinghuisen, "Exploring the diffraction grating using a He-Ne laser and a CD-ROM," *J. Chem. Educ.* **79**, 703 (June 2002).
8. See *The Physics Teacher* Nov. 2002 cover photo.

PACS codes: 01.50.My, 42.00.00

P.J. Ouseph *received his Ph.D. from Fordham University in 1961 and in the same year joined the University of Louisville Physics Department. He is currently involved in surface science and the study of graphene sheets. He has published more than 25 articles on undergraduate experiments and classroom demonstrations. And he has received several awards in the AAPT apparatus competitions.*
Department of Physics and Astronomy, University of Louisville, KY 40292; pjouse01@louisville.edu