A Compact Disk Transmission Spectroscope

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The traditional way for students to view spectral lines arising from electron transitions between discrete atomic levels has been to provide each student with a small mounted acetate replica grating. These gratings are often low quality and spectra are difficult to see, especially toward the back of a large classroom (~200 students). Some students even find it difficult to position the gratings correctly to see the spectrum at all. One solution is to show spectra with a multimedia video projector. This has the benefit that everyone sees practically the same thing. The drawback is that students see a television picture and immediately think there is a trick involved.

This paper describes an inexpensive option that has recently become available and allows the (preferred) direct viewing of the spectra. As every physics teacher who has looked carefully at a compact disk knows, an ordinary CD makes a rather good reflection grating.[1] The design and construction details for such a simple reflective CD spectrograph have been described elsewhere.[2] However, such a reflection grating spectroscope is somewhat more complicated to make than one using a transmission grating, and so a similar device that instead employs a good-quality, inexpensive transmission grating would be very useful.

The advent of CD-Recordable disks (CD-Rs) has unexpectedly presented this possibility. When CD-Rs are purchased on a spindle, 30, 50, or 100 at a time, there is often an uncoated "protective" disk included. It has the data spiral already imprinted in the plastic, but no dye or coating applied. These blank disks are very good transmission gratings, albeit with circular rather than linear "ruling."

If the blank CD is cut radially (a fine-toothed saw works well), it can easily provide about 15 individual gratings. Should the ridges become filled with oil from fingerprints, they can be cleaned by rinsing with isopropyl alcohol, although one should avoid wiping off the disk.

For the body of the spectroscope itself, a cardboard paper towel tube may be used. (A toilet paper tube may work for students but is too short for older eyes.) An opaque cover into which a narrow slit has been cut is placed over one end. Construction paper or aluminum foil are possible cover materials. The slit should have very straight edges and be about 0.5 mm wide for a paper towel roll of length 30 cm. The grating is placed over the other end of the tube and positioned so that the grooves are parallel to the slit. Hot glue works well for fastening it in place. Inserting a piece of cardboard or a few business cards as a spacer while gluing will help. The grooves on the CD are, of course, nearly circular (they actually constitute a single spiral). Because the apparent length of the slit is small, you probably won't notice that the spectral lines are curved unless a shorter tube is used.

A standard CD has 20,625 turns of the spiral (total length of 5.8 km!), with each line spaced by 1.6 μm.[3] This provides a grating with 625 lines/mm or about 16,000 lines/in. The resolving power, R, is[4]

$$R = \frac{\lambda}{\Delta\lambda} = \frac{\lambda}{\lambda_2 - \lambda_1} = mN = 20{,}625, \qquad (1)$$

where m is the diffraction order and N is the total number of lines. The angular resolution is given by[5]

$$\Delta\theta = \frac{m}{D}\,\Delta\lambda = \frac{2.4 \times 10^{-11}\text{m}}{1.6 \times 10^{-6}\text{m}} = 1.5 \times 10^{-5}\ \text{rad} = 0.16\ \text{arc min}, \quad (2)$$

using the first-order diffraction and the grating constant of 1.6 μm.

This is about six times better than the angular resolution of the eye.[6] When one is viewing a line spectrum, the apparent width of each line cannot be less than the apparent width of the slit, which for the given dimensions is about 0.0017 rad. Substituting this value into Eq. (2), the resolution of the spectroscope is found to be about 2.6 nm. Since the sodium D-lines are about 0.6 nm apart, this instrument should not be able to separate these two lines, and in a test with a sodium lamp, it in fact could not. However, the quality and availability of these CD gratings makes them an excellent choice for simple viewing of many continuous and discrete spectral sources.

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References

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3. See http://www.disctronics.co.uk/technology/cdbasics.
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