

Object: To use a two-slit interference pattern to measure the wavelength of laser light and then use the laser to determine the line spacing of a grating, and to observe a one-slit diffraction pattern and a two-dimensional diffraction pattern.

Theory: Whether light is a wave or particles was one of the great debates in the history of physics. One of the experiments that convincingly demonstrated the wave nature of light was the two-slit experiment performed by Thomas Young. Two close narrow parallel slits d apart (measured from center to center) serve as a pair of coherent light sources when illuminated by a monochromatic light source such as a laser or the light that emerges from a previous single slit. They produce a pattern of alternating light and dark bands on a screen a distance L away from the slits. A bright spot (constructive interference) is seen on the screen when the path length difference between the two slits is an integral multiple of the wavelength λ ; and a dark spot (destructive interference) is seen when the path length difference is an odd multiple of $\lambda/2$. If y is the distance on the screen away from the central maximum and we assume that $L \gg d$ and $d \gg \lambda$ (see discussion on pp. 1187-1190 and figure 37.13 in Serway) then

$$y_{\text{bright}} \approx \frac{\lambda L}{d} m \quad m = (0, \pm 1, \pm 2, \dots) \quad (1)$$

where m is called the order number, and

$$y_{\text{dark}} \approx \frac{\lambda L}{d} \left(m + \frac{1}{2} \right) \quad m = (0, \pm 1, \pm 2, \dots). \quad (2)$$

If instead of just two slits we use a grating consisting of a very large number of extremely narrow slits separated by very small distances, we can obtain an interference pattern (see section 38.4 in Serway) in which the lines corresponding to different wavelengths are distinctly spaced. (In fact, modern optical spectrometers almost always use diffraction gratings rather than prisms to obtain spectra of light with many wavelengths present.) However, in this experiment we will use the value of λ just obtained for the two-slit experiment for monochromatic light to determine the line spacing d of a diffraction grating.

For single slit of width a , we also observe a diffraction pattern of alternating light and dark spots or bands because light from one part of the slit interferes with light from another part of the slit. See section 38.2 in Serway, especially figure 38.11. However, the equation is now for dark spots:

$$y_{\text{dark}} \approx \frac{\lambda L}{a} m \quad m = (\pm 1, \pm 2, \dots). \quad (3)$$

Compare with equation 38.1 in Serway and note the appropriate approximations that must be made.

Safety Considerations: Never intentionally shine a laser in anyone's eye, and take precautions that the beam doesn't go in yours either. Please handle the slit patterns carefully as they are fragile (made from 0.005 mm electroformed nickel) and expensive.

Apparatus: Draw a detailed diagram of the equipment set-up.

Procedure:

1. In equation 1 L is easily varied (but if it is too small the approximations may not hold well), and so is d (by using different sets of slits); different values of m are also easily observed. With a Helium-Neon laser illuminating a double slit, take data for y_{bright} (you might want to average data on both sides of the center, *i.e.*, both the positive and negative values of m) for various combinations of these variables.
2. Plot y_{bright} vs. $\frac{L}{d}m$ and compare your slope to the accepted value for λ (632.8 nm for red HeNe lasers and 543 nm for green HeNe lasers).
3. Repeat for a multiple slit pattern (3 or 4 or 5 slits).
4. Replace the multiple slit with the diffraction grating and again measure y_{bright} on both sides of the central maximum.
5. Use the accepted value for λ and compute d from equation 1 and invert it to get n (the line density of the grating) and compare with the value stated on the grating.
6. Repeat procedures 1 and 2 for a two-dimensional pattern.
7. Perform a similar procedure for single-slit diffraction and for a circular aperture.

Questions:

1. For more precise measurements, the above approximations should not be used. How much do they contribute to your error? What is the more accurate version of the formula?
2. In this laboratory you observed both interference and diffraction. What is the difference between them?
3. What difference do you see in the interference pattern for green laser vs. red laser, and why?
4. In crystals, atoms are arranged in periodic structures that can be thought of as diffraction gratings with a very large line density. What type of electromagnetic radiation should be used in such experiments? Why? (Hint: see section 38.5 in Serway.) (The structure of DNA was discovered this way; you may want to read *The Double Helix*.)

Conclusions: