INTERFERENCE AND DIFFRACTION OF LIGHT

Object: In this experiment you will see how the superposition of waves is used to explain interference and diffraction patterns.

Apparatus: Provision for subdued lighting of the laboratory (such as reflector lamps directed against walls), a 1 milliwatt He-Ne laser, optics kit consisting of: double-slit of labeled separation with metal holder and block for same, meter stick, 30 cm ruler, 15 cm plastic scale.

Precautions: DIRECT THE LASER BEAM TOWARD THE WALL AT THE END OF YOUR BENCH. NEVER LOOK INTO THE BEAM. NEVER DIRECT IT TOWARD ANOTHER PERSON'S FACE EITHER DIRECTLY OR BY REFLECTION FROM A SHINY SURFACE. This is a low power laser, but more than momentary exposure might injure the retina of one's eye.

Discussion: In this experiment we illustrate some aspects of the wave properties of light, using as a light source a 1-mW helium-neon laser. In conventional light sources, the phase of the light waves emitted by individual atoms is random (incoherent) even when the wavelength emitted is the same. By contrast, the atoms in a laser source emit waves that are in phase, or coherent. The light from our laser is also monochromatic (of one wavelength). A feature of the laser discharge tube with its internally-reflecting end windows is that the emitted beam has very small divergence (less than one-tenth degree). The narrowness of the light beam and its brightness permit doing, rather easily, some fundamental experiments.

Procedure: Set the inverted apparatus box on the end of your table furthest from the wall and place the laser on top of it and direct it toward the wall (Fig. 1). Switch on the laser and note the very bright red image-spot on the wall. Now place the double-slit in the aluminum holder (white label next to base), place the holder on the second aluminum block, and set these on the end of the inverted apparatus box (Fig. 1). Adjust the double slit position to intercept the laser beam. You should now observe on the wall a set of interference fringes, fading out away from center and then reappearing very weakly. (The room lighting must be dim to observe these features.) From the spacing, Δy, of the fringes and the distance, D, of the double-slit from the wall, we will compute the separation, d, of the two slits (see Fig.2).

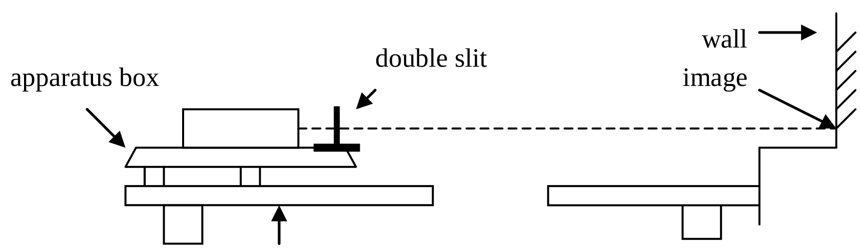

Fig. 1

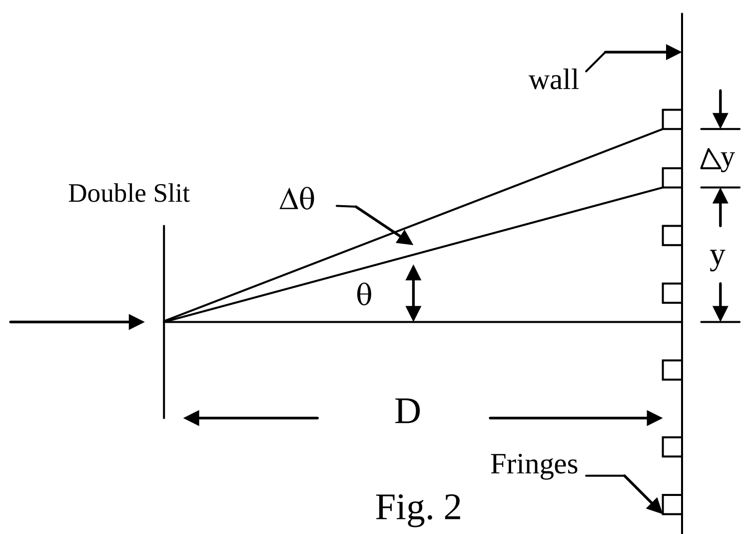

Fig. 2

The condition for a maximum intensity in the interference pattern, i.e., a bright fringe, is given by $d\sin\theta = m\lambda$, and for small θ, $\sin\theta \approx \tan\theta \approx \theta$ where θ is in radians. Therefore

$$\theta = \frac{m\lambda}{d}$$

From Fig. 2 we see that

$$\tan\theta = \theta = \frac{y}{D}$$

Combining these two equations gives

$$y_m = \frac{m\lambda D}{d}$$

For the adjacent fringe, we have

$$Y_{m+1} = \frac{(m+1)\lambda D}{d}$$

and subtracting the first from the second gives

$$\Delta y = \frac{\lambda D}{d}$$

Given <u>λ = 633 nm</u> for He-Ne laser and measuring Δy and D we can find the slit separation, d.

Measure D with the meter stick and use the white plastic scale to measure Δy. The dark fringes are narrower than the bright ones, so measure to the center of the dark fringes to obtain five fringe intervals as shown in Fig. 3.

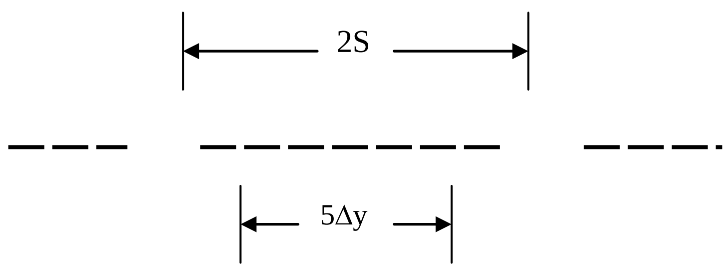

Fig. 3

Compute d in millimeters and compare your results with the value marked on the double slit.

The width of the individual slits (too narrow to measure reliably with a microscope) can be estimated by measuring the separation, on each side of center, of the minimum "fade out" points in the interference pattern. Letting this distance be 2s (see Fig. 3), the angular distance from center is given by

$$\tan\theta \approx \frac{s}{D}$$

The wave theory of double-slit diffraction gives

$$\theta = \frac{\lambda}{a}$$

where a is the width of the individual slits. Measure the distance 2s and compute a in millimeters. Finally, write your value for the ratio d/a.