Laboratory 10: Interference of Light

A characteristic of waves is the ability of a single wave to split into two or more waves and for these to subsequently interfere with each other. In such processes it is possible for interfering waves to reinforce or to cancel each other out, resulting in interference and diffraction patterns. Producing such interference or diffraction patterns for a physical system is a strong indicator that the system is properly described in terms of waves. The aim of this laboratory is to investigate the production of such patterns using light.

1 Double slit interference: qualitative

a) Set up the PASCO Multiple Slit Set disk and shine the laser on the double slit for which the slit width is $a = 0.04\,\text{mm}$ and the slit spacing is $d = 0.125\,\text{mm}$. Observe and sketch the pattern, identifying the central bright spot.

b) Identify a dark spot next to the central bright spot. Explain why there is a dark spot at this location despite the fact that light travels to this area from both slits. By how many wavelengths does the distance from the further slit to this point on the screen differ from that from the closer slit? Explain your answer.

c) The disk also contains double slits with width $a = 0.04\,\text{mm}$ and slit spacing is $d = 0.25\,\text{mm}$ and $d = 0.50\,\text{mm}$. Observe the patterns produced by these. As the separation between the slits increases, does the separation between adjacent bright spots on the screen increase, decrease or stay constant?

d) Sketch the interference patterns produced by 3, 4, and 5 slits. Note that the fine details in each display a striking pattern.

e) Sketch the diffraction pattern produced when the laser light is incident on the circular aperture with diameter 0.4 mm on the Single Slit Set disk. Repeat this for the circular aperture with diameter 0.2 mm, keeping the screen the same distance from the disk. Comment on the difference between the two observed patterns. For which aperture is the central maximum of the pattern widest?

f) Sketch the diffraction pattern produced when the laser light is incident on the square aperture.

2 Determining wavelength via interference

A diffraction grating produces, from light incident upon it, a pattern of distinct bright spots separated by dark areas as illustrated in Fig. 1. The individual bright spots can be labeled with integers $m = 0, \pm 1, \pm 2, \ldots$. The wave theory of light predicts that the angle, θ_m, at which the bright spot labeled m appears is given by

$$d \sin \theta_m = m\lambda \qquad (1)$$

where d is the spacing between adjacent slits in the grating and λ is the wavelength of the light.

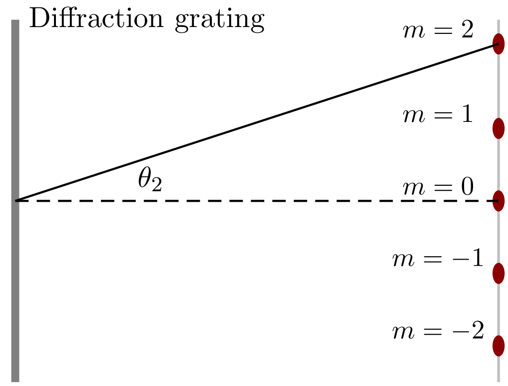

Figure 1: Diffraction pattern produced by a grating

a) Set up the laser, diffraction grating and a screen so that a diffraction pattern, containing several bright dots, is visible.

b) Provide and carry out a procedure using this diffraction pattern for determining the wavelength of the laser light. Your procedure should be such that it yields several measurements of the same wavelength. Use these to find a average value for the wavelength of the laser.

3 Double slit interference: quantitative.

Light that passes through a double slit produces a pattern of bright and dark spots as illustrated in Fig. 2. Denote the distance between adjacent intensity minima (dark spots) by Δy. The wave theory again predicts that bright spots locations are given by Eq. (1). If the screen distance L and slit separation d satisfy $L \gg d$, then this implies that, to a good approximation, the separation between adjacent dark spots is

$$\Delta y = \frac{\lambda L}{d}. \tag{2}$$

The aim of this experiment is to investigate double slit diffraction patterns and to verify Eq. (2).

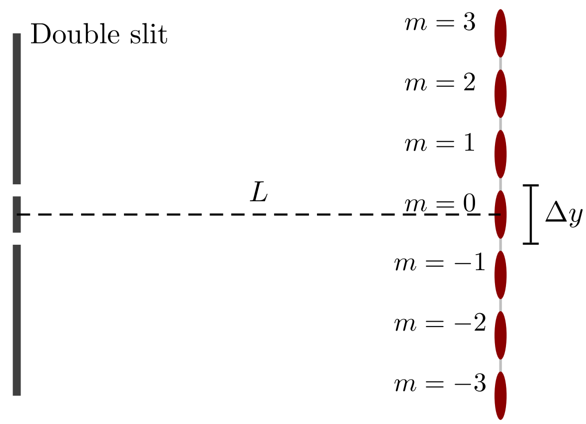

Figure 2: Double slit interference.

a) Set up the PASCO Multiple Slit Set disk and measure L.

b) Select the double slit for which the slit width is $a = 0.04\,\text{mm}$ and the separation is $d = 0.25\,\text{mm}$ and sketch the diffraction pattern as accurately as possible. Determine the separation between adjacent dark spots by measuring the distance spanned by multiple bright spots (try for at least 10). Repeat this for the double slits for which $a = 0.04\,\text{mm}$ and $d = 0.50\,\text{mm}$ and $a = 0.04\,\text{mm}$ and $d = 0.125\,\text{mm}$ (one of these exists in the "multiple slits" section of the disk).

c) For each case, calculate Δy and determine the percent difference between this and the measured separation between dark fringes. Does Eq. (2) predict correctly?