SECOND YEAR LABORATORY

DIFFRACTION OF LIGHT BY SLITS

Warning: Do not look directly along the laser beam or at a direct reflection: laser light can cause permanent impairment of vision.

1 Aims

To study, quantitatively, and understand theoretically the intensity distribution of laser light diffracted through single and multiple slits.

2 Objectives

1. To measure the intensity profile of the beam as function of distance from the laser.
2. To measure the angular distribution of light diffracted from a single slit and compare this with the theoretical prediction and thus determine the width of the slit (given the wavelength).
3. To repeat this with single slits of different width, double slits, and multiple slits.

3 Apparatus

Coherent light from a low power diode laser is used to illuminate photographically-produced slits. A photodiode with a small sensitive area is used in conjunction with a linear operational amplifier to measure the intensity of the diffraction patterns. The photodiode can be moved through the interference fringes using a motorised screw thread mechanism at the rate of about 1mm per turn of the motor. The output voltage of the amplifier is measured by a computer running data logger software. Data on the photodiode and amplifier circuit are given at the end of this script.

4 Suggested Experiments

4.1 Alignment

Careful alignment at the beginning of the experiment will improve the quality of your results and save you time. Use the two apertures to align the laser beam to be normal on the detector so that you don't need to re-align every time you change the position of the detector. Think about how best to do this. Consult your demonstrator if you think you need advice.

4.2 Data Acquisition

Make sure that your detector and the amplifier are connected to the computer. Information and guidance about the data logger software can be found near the apparatus.

4.3 Calibration

Use the motor control box to adjust the horizontal position of detector; the height of the detector can be adjusted manually. Make sure that the laser beam hits the detector exactly at the centre. Check carefully and minimise any effects due to stray light. You might discover the beam saturates the detector; to avoid this saturation use the provided filter to attenuate the laser light. Make sure you make a note of the filter you use.

Calibrate the speed of the detector by measuring the time required to move a certain distance. Repeat this experiment for many distances to minimize the errors. The best scan speed has been found to be when the scale on the control box is adjusted to 1.5 for a slow scan and about 2 for a fast scan. Find the speed of the motion at the above values or any other values you are going to use in the experiment.

4.4 Direct Measurement of the Slits

Look at the slits under the travelling microscope. Sketch the layout of the slide and measure the width of the slits and their separation for any combination you think you are going to use in the following experiment.

4.5 The Single Slit

With the single slit in place, scan the intensity of the diffraction pattern over several fringes.

Note: Check every time and before starting the full scan that

1. The intensity pattern is horizontal and the detector detects all the points when scanning through. You might need to adjust the angle of the slits' slide if the intensity pattern is slightly angled.
2. The intensity of the brightest area of the pattern is not saturating the detector otherwise you might need to replace the filter between the detector and the slits.

Measure the width of the strongest fringe x (the distance between two minima) and use it with the known value of wavelength λ (shown on the label of the laser) to deduce the slit width from the equation $a = \frac{2\lambda z}{x}$, where z is the distance between the detector and the slit.

Compare your value with the previous value you measured using the microscope.

Theoretically the intensity of light diffracted at angle θ from a slit of width a is

$$I(\theta) = I(0°)\,\mathrm{sinc}^2\left(\frac{\phi}{2}\right)$$

where $\phi = \frac{2\pi}{\lambda} a \sin\theta$.

For derivation and discussion of these formulae consult the reading list or the first year laser experiment laboratory script.

Compare your measurements of the intensity of the diffraction pattern, graphically, with the expected sinc^2 function. Repeat the same work using a single slit with a different width.

4.6 The Double Slit

Use the double slits and scan across the whole intensity pattern.

The expected intensity distribution in this case is

$$I(\theta) = I(0°)\cos^2\left(\frac{\phi_d}{2}\right)\mathrm{sinc}^2\left(\frac{\phi_a}{2}\right)$$

where $\phi_a = \frac{2\pi}{\lambda} a \sin\theta$ and $\phi_d = \frac{2\pi}{\lambda} d \sin\theta$.

Here the $\cos^2$ term represents the interference pattern of a pair of infinitesimally narrow slits separated by a distance *d*, and the sinc^2 term represents a modulation of the fringe intensities due to diffraction from each slit of width *a*.

Calculate the slit width and separation and compare the values with measured results. Compare your experimental graph with the equation above.

4.7 Multiple Slits

Scan the interference pattern of the multiple slits provided. Make sure the centre peak does not saturate the detector.

Investigate how

a) the intensity and

b) the width of the bright fringes

depend on the width of the single slit or number of slits.

4.8 Beam Intensity with Distance

Measure the intensity of light as a function of the distance between the detector and the laser (move the detector not the diode laser). Does the intensity of the laser go as the inverse square function of the distance? Explain your answer.

5 Reading List

1. F. G. Smith and J. H. Thomson, *Optics* (John Wiley & Sons, 1971). Chapters 9-11 give good account of single and multiple slit interference.
2. E. Hecht, *Optics* (Addison-Wesley, 1998).
3. First year laser experimental laboratory script.

You may also wish to consult the information on multiple slit interference patterns displayed on the wall of the laboratory.

Fadi Qamar, March 2005.

Revised by Dr. I. Browne, March 2005/Oct 2010, and by Dr. A. Grigorenko, Jan. 2009.

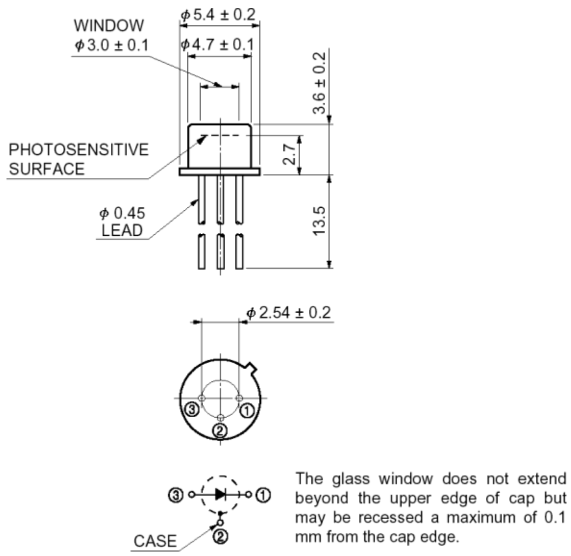

Fig. 1. Photodiode dimensions and connections. The active area is 0.2mm diameter.

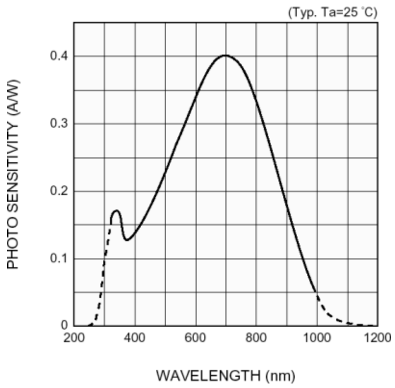

Fig. 2. Spectral response of the photodiode.

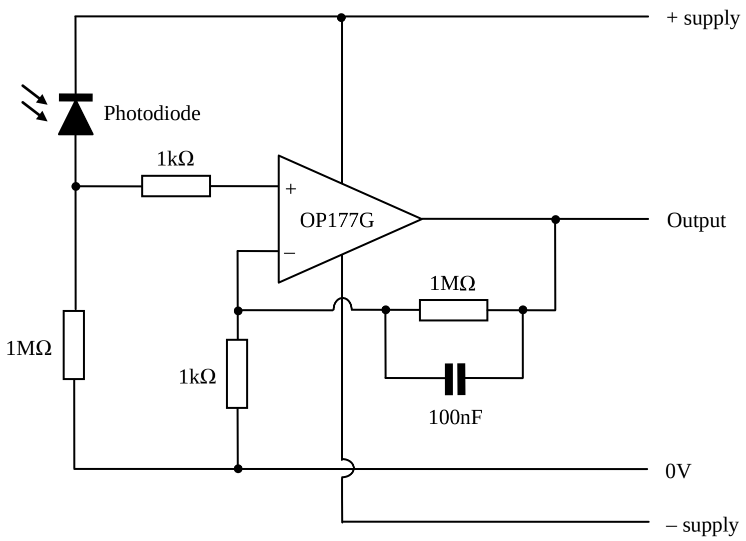

Fig. 3. Basic circuit diagram of the amplifier.