Interference using a Fresnel Biprism

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1 Introduction and Theory



Figure 1: The Fresnel biprism.

When two coherent light sources meet, they interfere and produce an interference pattern. In this experiment, a plane wave from a helium neon laser is shone through a converging lens of very small focal length such that the light coming from the laser, travelling parallel to the optic axis of the lens, converges at the focus of the lens (point A) and forms a point source of light.

Light from this point source then passes through Fresnel's biprism. Fresnel's biprism is a piece of apparatus which consists of two thin prisms joined at their bases to form an isosceles triangle and refracts light from a point source so that it produces two virtual images of this source. Fresnel's biprism in this experiment forms two virtual images of the point source; A_1 and A_2 , both in the plane of the focus of the lens.

These two virtual point sources interfere and produce an interference pattern which can be seen on a screen in the form of light and dark fringes, similar to the interference pattern seen when viewing Youngs double slit experiment. The two point sources are completely coherent (ie. have the same frequency and a constant phase relationship) as they are both virtual images of the one point source. Coherence of the two sources is important in forming a clear interference pattern, as we get maxima and minima when the two interfering waves are completely in or out of phase.



Figure 2: Determining the value for a.

The distance between the two virtual sources, a, can be found using

$$a = \left(\frac{L_1}{L_2}\right)A\tag{1}$$

where L_1 is taken to be the distance between the plane of the sources and the plane of the converging lens, L_2 is taken to be the distance between the sources and the screen and A is the distance between the two imaginary sources. This method of calculation involves placing a converging lens between the biprism and the screen in order to get an image of the two sources on the screen. As a result, A can be found directly, as can L_1 and L_2 .

Finally, the calculated value of a can be used in order to verify the wavelength of light from the helium neon laser using

$$d = \frac{\lambda L}{a},\tag{2}$$

where d is the distance between any two intensity maxima or minima and L is the distance between the plane of the virtual light sources and the plane of the screen.

2 Experimental Method

Our objective in part one of this experiment was to observe and investigate the interference pattern produced as a result of passing monochromatic light of known wavelength, diverging from a point source, through a Fresnel biprism. We also aimed to vary the distance between the source and the biprism so that the resulting change in width of the interference fringes could be observed. In part two of the experiment we set out to calculate the distance *a* between the two coherent imaginary light sources created by passing light through the biprism. Finally in part 3, we aimed to use our value of *a* along with the calculated distance between the interference fringes to verify the wavelength of the monochromatic light, which in the case of the helium neon laser is accepted to be $\lambda = 632.8$ nm.

An HeNe laser was mounted at the end of an optical rail and a screen was mounted at the other end. The laser was aligned so that the beam pointed parallel to the optical rail and was incident on the screen. The spherical lens with focal length +5mm was placed 12cm in front of the laser and the height was adjusted so that the beam of the laser passed directly through the lens. The Fresnel biprism was then placed on the far side of the lens approximately 7cm away. The biprism was adjusted until the "rib" which corresponded to the centre of the prism was approximately in the centre of the beam of light. An interference pattern



Figure 3: Experimental setup.

should be observed on the screen. By moving the screen towards and away from the biprism, the effect that distance had on the size of the fringes was observed.

For the second part, the screen at the end of the optical rail was removed and the optical rail was aligned perpendicular to the wall, approximately 1m beyond the end of the optical rail. A +200mm focal length lens was placed onto the optical rail beyond the biprism and the lens was shifted backwards and forwards until two sharply defined points appeared on the wall. These points were the two coherent sources. A piece of paper was placed on the wall and the location of these two points was marked on the piece of paper. The distance A between these two points was measured using a ruler. The distance between the 200mm lens and the screen, L_2 , as well as the distance between the 200mm lens and the sources, L_1 , i.e. the location of the focal point of the 5mm mirror, was measured.

For the third part, the apparatus remained the same as in part 2 except the +200mm lens was removed. An interference pattern was observed on the wall once again and a sheet of paper was placed onto the wall. Adjacent minima in the diffraction pattern were marked on the sheet of paper. The distance L between the +5mm lens and the wall was also measured.

3 Results and Analysis

Values of $L_1 = 22.5 \pm 0.1$ cm and $L_2 = 154 \pm 1$ cm were measured on the optical rail. The distance between the two points on the screen was measured to be 4 ± 1 mm. Thus, a value of $a = 0.06 \pm 0.02$ cm was obtained.

For the final part of the experiment, values of $L = 177 \pm 0.1$ cm and $d = 2 \pm 1$ mm were measured. Using these measurements, the obtained value for a and (2), a value of 660 ± 370 nm was obtained for the HeNe laser.

4 Discussion and Conclusions

A change was observed in the width of the interference fringes when the biprism was moved along the optical bench. When the biprism was moved back, the spacing between the fringes decreased, as expected.

The first point of note is that there is very notable effect on changing the distance between the biprism and the source. When the biprism is close to the source, there is a small number of well spaced and defined fringes, whereas when the biprism is further away, there are a larger number of fringes with smaller spaces in between them. This can be explained due to the fact that when the biprism is further away, the light that enters the biprism does so at a more acute angle than when the biprism is closer. This produces a more tightly packed interference pattern and as a result, there are more fringes spaced closer together. There was some potential error in setting up the system in that the rib of the prism was meant to be at the centre of the illuminated area, this is fairly subjective as the area surrounding the rib was illuminated weakly and so it was difficult to determine where the centre of this area was. The alignment of the biprism may have caused some inaccuracies further on in the experiment.

The light rays from the biprism were focused onto the screen with a converging lens until two distinct points showing the imaginary sources could be seen on the screen. The distance between the imaginary sources was found to be $a = 0.06 \pm 0.02$ cm. There is no real way to compare this answer to a reference source as each optical system tends to be different in one way or another however this number was used in part 3 to calculate the wavelength of the laser beam. There was again some subjectivity in this measurement as it was difficult to determine where the point where the two imaginary sources were most focused. Also, there was a large error in this measurement as a millimetre measurement was taken with a ruler. In reality this measurement should have been taken with a much more accurate device like a callipers, however, given the equipment on hand, this was the best that could have been achieved.

The wavelength of the laser was calculated to be 660 ± 370 nm. The laser was a HeNe laser and has a quoted wavelength value of 632.5 nm. This means that the quoted value does lie very close to our measured value, and therefore that the distance between the imaginary sources must have been reasonably close. The incredibly large error for this value can be explained due to the fact that many of the measurements we took were very small and taken with inaccurate equipment, for example we measured 2mm with an error of 1mm, and similarly for the calculation of the distance between the two imaginary sources. These errors propagated through the calculation and caused our error to be rather gigantic. Given the measurements that needed to be taken and the tools at hand, this large error was unavoidable.

It is worth noting that in order to get the required distance between the +200mm lens and the screen, the screen could not be attached to the optical rail as the optical rail was not long enough. The screen not being attached to the optical rail added considerably errors and inaccuracies to our measurements as measuring the distance between the lens and the screen could no longer simply be read off of the rail. The measuring tape had to be used. Also, alignment between the rest of the optical system and the screen become a larger issue as it was more difficult to align the screen accurately due to the fact that the screen was no longer attached to the optical rail. Solutions to this problem would be to simply repeat the experiment with a longer optical rail or on one of the designated optical benches.

Overall, our observations of the interference patterns produced the appropriate results and the wavelength of the HeNe laser lies well within our margin of error. All of the aims of the experiment were accomplished. This experiment could be deemed a success in spite of the potential sources of error. Ideally, the experiment would be repeated with more accurate measurement equipment in order to cut down the error.