The Fresnel Biprism

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1 Abstract

In this experiment the wavelength of *Sodium Light* was measured using the so called *Fresnel Biprism* method. This has several advantages over the traditional *Young's Slits* method. The wavelength of the sodium light was found to be $6.1 \times 10^{-7} \pm 1.6 \times 10^{-7}$m, which is within experimental error of the accepted value of 5.9×10^{-7}.

2 Introduction & Theory

2.1 Young's Slits Experiment

When two coherent light sources of equal amplitude meet they set up an interference pattern consisting of a succession of bright and dark fringes. This is known as constructive and destructive interference respectively.

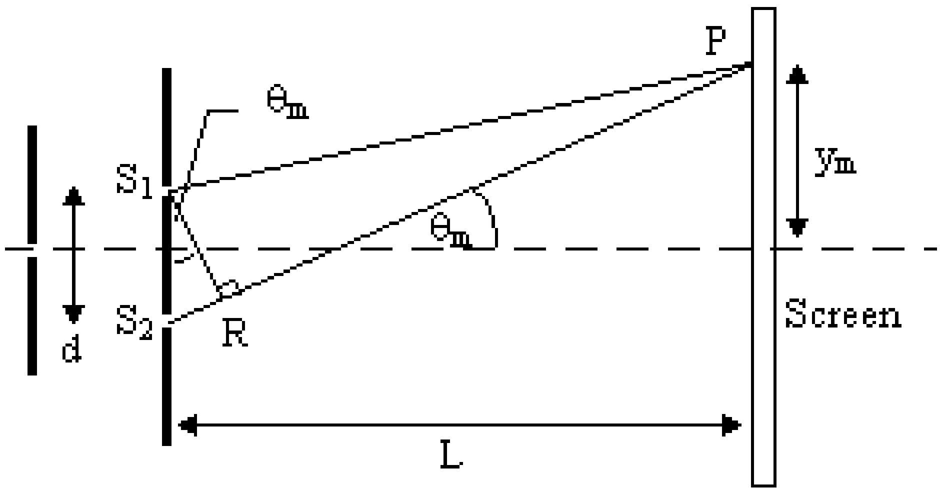

Figure 1: The Young's Slits Experiment

In Young's Slits experiment, a single source is split in two, to make two coherent sources. By diffraction the two sources interfere with each other and the resultant image as described above can be projected onto a screen. The distance between two successive fringes is given by

$$S = y_{m+1} + y_m \tag{1}$$

The wavelength λ of the light used can then be found by using the formula

$$S = \frac{\lambda L}{d} \tag{2}$$

2.2 The Fresnel Birpism

A Fresnel Biprism is a variation on the Young's Slits experiment. The Fresnel biprism consists of two thin prisms joint at their bases to form an isosceles triangle. A single wavefront impinges on both prisms; the left portion of the wavefront is refracted right while the right segment is refracted left. In the region of superposition, interference occurs as here two *virtual sources* exist.

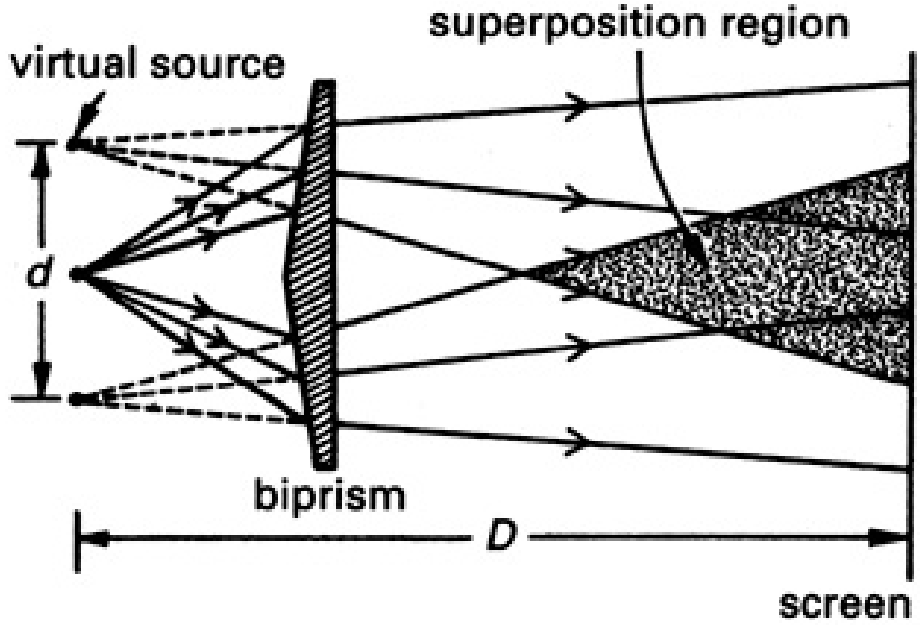

Figure 2: The Fresnel Biprism

For the Young's slits experiment, we must approximate that the slits act as point sources. This however is not the case, since the slits have finite width. This finite size of the secondary slits gives rise to unwanted diffraction effects which causes errors. The Fresnel biprism overcomes this problem of extended secondary slits by replacing them with virtual slits which are point-like.

As this experiment is analogous to Young slits, the formula above holds with the minor exception that d can not be measured directly since the two slits are purely virtual. Instead, d is determined by placing a converging lens between the biprism and the screen and forming real images of the virtual slits on the screen. From the magnification formula

$$\frac{d_1}{d} = \frac{v_1}{u_1} \text{ and } \frac{d_2}{d} = \frac{v_2}{u_2} = \frac{u_1}{v_1}$$

we find that

$$d = \sqrt{d_1 d_2} \tag{3}$$

Putting this into the Young's Slits equation gives

$$\lambda = \frac{S\sqrt{d_1 d_2}}{L} \tag{4}$$

3 Experimental Method

The sodium lamp was turned on and allowed to warm up.

The light source, the slit, the biprism and the eyepiece were set up such that they were all in line and at the same height. The slit and the biprism edge were ensured to be parallel.

The biprism was then placed 15 to 20cm from the slit, and using only ones eye, the biprism was rotated slightly until a fringe pattern could be seen through it.

This was then repeated using the eyepiece to obtain the best visibility of the fringes.

Finally, the eyepiece was moved to a distance of 1.12m from the slit, and the lens was placed between the biprism and the eyepiece. A sheet of paper was then used as a screen to check that sharp images were formed at two positions.

The lens was then removed, and S was measured. To do this, the distance across about 20 fringes was measured a range of times and an average value was calculated.

The lens was then put back in place, and d_1 and d_2 were measured.

The wavelength λ of the sodium light was then calculated using the above equation.

4 Results & Analysis

The following data was recorded

Parameter	value
L	1.12 ± 0.01m
d_1	4.0 ± 0.5mm
d_2	1.0 ± 0.5mm
S_1	5.63 ± 0.00028mm
S_2	5.572 ± 0.00033mm
S_3	5.549 ± 0.00031mm

This gives an average value for S of 0.341 ± 0.026mm, and we find $d = 2.00 \pm 0.52$mm.

Therefore we get $\lambda = 6.1 \times 10^{-7} \pm 1.6 \times 10^{-7}$m.

5 Error Analysis

We have the following errors,

$$\begin{aligned} \Delta d &= \frac{d_2 \Delta d_1 + d_1 \Delta d_2}{2d} \\ &= \pm 0.52\text{mm} \end{aligned}$$

$$\begin{aligned} \Delta S &= \frac{\Delta s}{\sqrt{3}} \\ &= \pm 0.026\text{mm} \end{aligned}$$

$$\begin{aligned} \Delta \lambda &= \lambda \left[\frac{\Delta d}{d} + \frac{\Delta S}{S} + \frac{\Delta L}{L} \right] \\ &= \pm 160\text{nm} \end{aligned}$$

However, the main source of error in this experiment is that involved with counting the number of fringes measured. This was estimated to be ± 2 fringes per measurement.

6 Conclusions

By using the Fresnel Biprism method we were able to calculate the wavelength of the sodium light was to be $6.1 \times 10^{-7} \pm 1.6 \times 10^{-7}$m, which is within experimental error of the accepted value of 5.9×10^{-7}. This method is more accurate than the Young's Slits method, however, a better method of calculating the fringe separation would yield an even more accurate result.