VL-O1: DETERMINATION OF THE WAVELENGTH OF MONOCHROMATIC LIGHT BY YOUNG'S DOUBLE SLIT EXPERIMENT

Objectives:

➢ To understand the interference phenomenon of light.

➢ To study the Young's double-slit experiment for measuring the wavelength of monochromatic light.

System requirements:

Computer (Desktop/Laptop), Operating systems: Windows, Wave-interference_en (zipped) file.

Advise:

Students are advised to follow the **procedures written in this manual very strictly** while performing the experiment. D**o not try to explore anything else in the experiment.**

Theory:

S is a monochromatic source of light of wavelength λ. S_1 and S_2 are two parallel slits separated by a distance d and are equidistance from the source S. These two slits along with main source S act as coherent sources of light and the slit width is comparable to λ. Let PR be a screen placed at a distance D from the slits. The distance from S_1 to center of the screen O is equal to the distance from S_2 to O. Therefore, waves from both slits arrive at O are in phase and a bright interference band appears there. Let the point, P, located on the screen at a distance x_n from the point O, represent the nth bright fringe.

Using geometry, one can write the path difference between waves reaching at point P from slits S_1 and S_2 as

$(S_2P - S_1P) = \frac{2x_n d}{(S_2P + S_1P)} = \frac{x_n d}{D}$.

Since x_n and d are small compared to D. So, $S_2P \cong S_1P = D$

According to the condition of constructive interference, $\frac{x_n d}{D} = n\lambda$ [where, n = 0, 1, 2 … …]

The nth order bright fringe occurs when $x_n = \frac{n\lambda D}{d}$ and the $(n+1)^{th}$ order bright fringe occurs when $x_{n+1} = \frac{(n+1)\lambda D}{d}$.
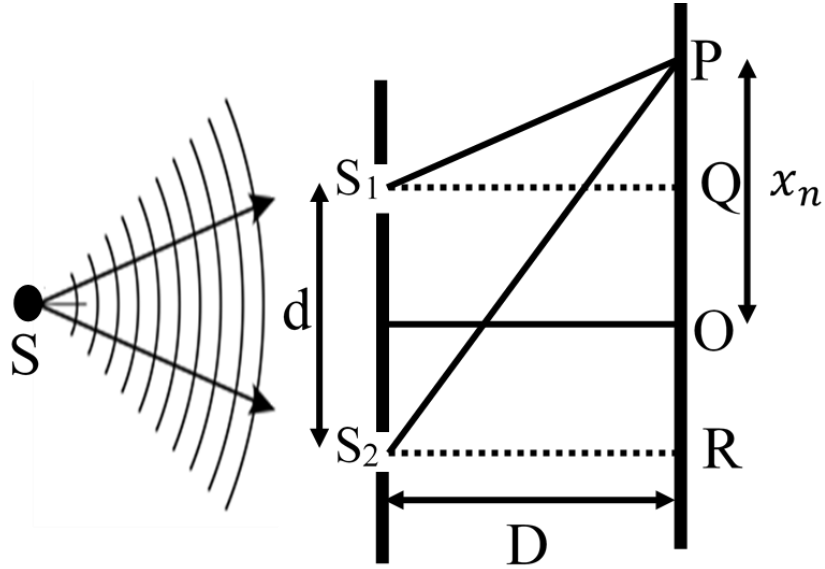
Fig. 1: Schematic diagram of the geometrical representation of Young's double slit experiment.

The fringe separation, β is given by $\quad \beta = x_{n+1} - x_n = \dfrac{\lambda D}{d}$

Hence, the wavelength is given by

$$\lambda = \frac{\beta d}{D} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots . (1)$$

Procedures:

1. Unzip "**wave-interference_en**" file. Now open the "**wave-interference _en.html**" file with your web browser say using "google chrome".
2. Double click on the "slits" option from "Wave Interference" (Fig. 2).
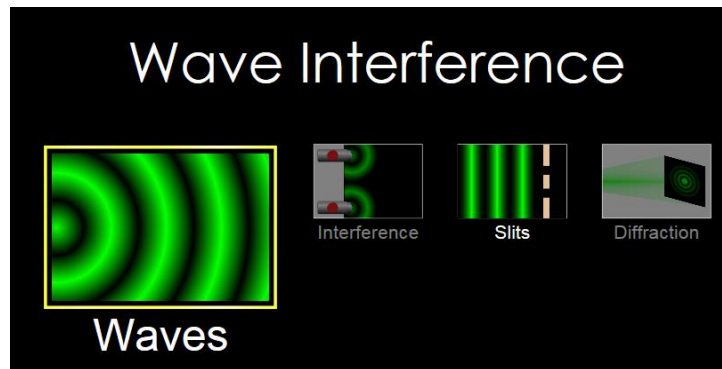

Fig. 2

3. This simulation allows you generate water, sound and light waves as indicated by the faucet, speaker and laser pointer icon on the right side of the screen. Click on the laser pointer icon (marked by 3 in the Fig. 3).

4. Then click on the "Screen" and "Intensity" options (marked by 4) for adding screen in your experimental setup and observing the distribution of intensity on the screen, respectively.

5. The default option is seen as "one slit". Click the down arrow and change the option to "Two Slits" (marked by 5).

6. Select a frequency of a color (say green) by moving the arrow on the visible color spectrum (marked by 6).

7. Press the green button on the light generator (marked by 7 in the left side) and generate interference pattern on the screen.

8. Adjust the "Slit Width" (500 nm) and "Slit Separation" (1500 nm) (marked by 8) to see at least three bright interference fringes of equal width on the screen.

9. Pause the simulation by clicking the paste color circular button (marked by 9 in the bottom side).

10. Drag the measuring tape tool out of the box from the upper right (marked by 10) and use it to measure the fringe separation (β) (measure the peak to nearest peak distance from the intensity graph, marked by 11, to obtain β), slit separation (d) and slit to screen distance (D). Record these values in the table.

11. Keeping the "Slit Width" fixed, increase the "Slit Separation" at 2100 and 2800 nm so that you can get 5 and 7 fringes on the screen, respectively after removing the pause (marked by 9). Repeat procedures 9 and 10.

12. Calculate the value of λ for green light by substituting the values of β, d and D in Eq. (1).

13. Click on the "Graph" option (marked by 12) and you will see an electric field graph (marked by 13) on the screen.

14. Pause the simulation by clicking the paste color circular button (marked by 9) for measuring the wavelength from the electric field graph (peak to nearest peak distance) using the measuring tape. Record this value in the table, this is measured wavelength and considered as standard value.

15. Calculate the % of error between your calculated average wavelength (**observed value**) and measured wavelength (**standard value**) in the error analysis.

16. Adjust the frequency of light for red color from the color spectrum and repeat the procedures from (8) to (15).
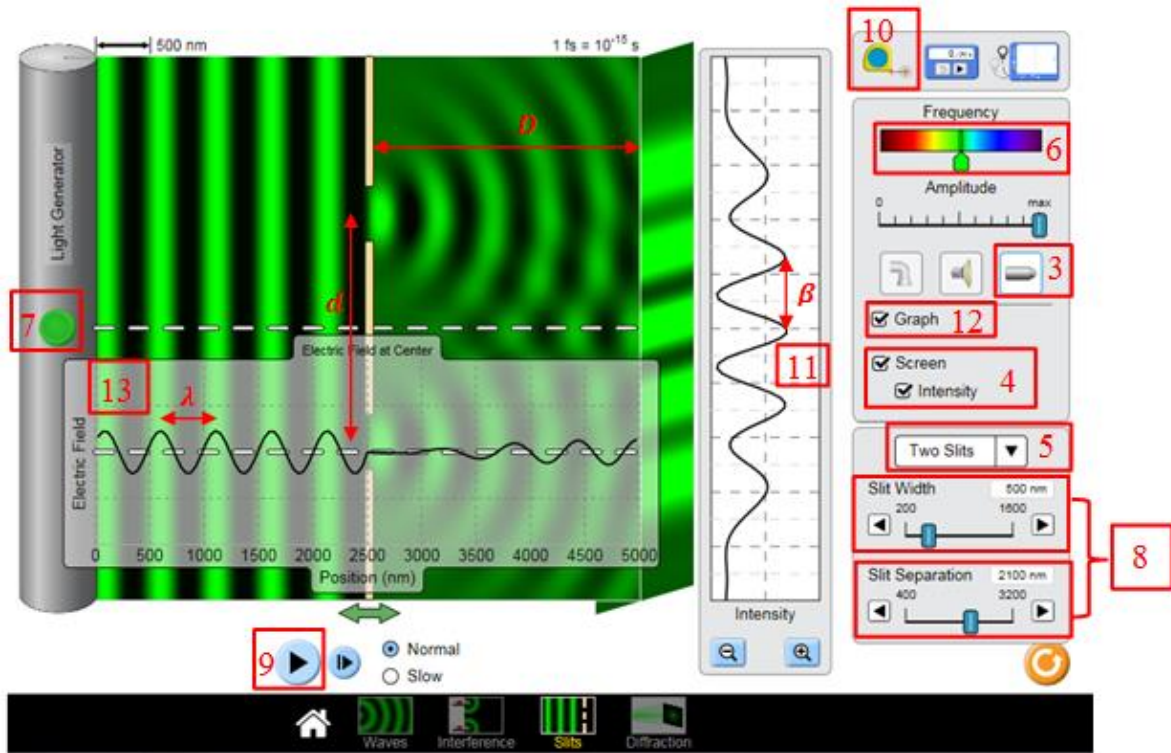

Fig. 3

Data Collections:

Table for the determination of wavelength of monochromatic visible light

Color of light	Slit separation, d (nm)		Fringe width, β (nm)		Distance of the screen, D (nm)	Calculated wavelength, λ (nm)		Average wavelength λ (nm)	Measured wavelength, λ (nm)
Green	d_1		β_1			λ_1			
	d_2		β_2			λ_2			
	d_3		β_3			λ_3			
Red	d_1		β_1			λ_1			
	d_2		β_2			λ_2			
	d_3		β_3			λ_3			
Blue	d_1		β_1			λ_1			
	d_2		β_2			λ_2			
	d_3		β_3			λ_3			

Calculations:

The wavelengths is given by, $\lambda = \frac{\beta d}{D}$

Results:

1. Wavelength of green light = ………nm
2. Wavelength of red light = ………nm
3. Wavelength of blue light = ………nm

Error Analysis:

$$\% \text{ of error} = \frac{\text{Observed value} \sim \text{standard value}}{\text{Standard value}} \times 100 \%$$

1. % of error for the wavelength of green light = ………
2. % of error for the wavelength of red light = ………
3. % of error for the wavelength of blue light = ………

Discussion:

Based on your understanding from this experiment, answer the following questions:

1) If you change the width of the slit, what do you notice? What happens when you increase the slit width significantly?
2) If you change the color of the light from red to blue, what happens to the fringe width?
3) What are the factors on which the width of the fringe depends?
4) Is there any loss of energy in the interference phenomenon? Justify your answer.
5) If you change the distance between slit and screen, what do you notice?
6) If you change the slit separation by keeping the slit width fixed, what happens to the interference patters?