Determine the Wavelength of Laser by Means of a Double-Slit and a Single-Slit

Suni Yao

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1 Background

Young's double-slit experiment illustrates light's wave characteristics. Coherent light, like that emitted by a laser, passing through two close slits, forms an interference pattern on a screen. This pattern shows bright and dark fringes due to wave interference. Light's wavelength can be determined using the equation

$$\lambda = \frac{xd}{L}.$$

In single-slit diffraction, light through a narrow slit creates a pattern with a central bright fringe and alternating dark and bright fringes. Dark fringe positions follow the equation

$$b \sin\theta = n\lambda.$$

The experiment aims to calculate the He-Ne laser's wavelength using both methods. Results will be compared with the laser's known wavelength to gauge method accuracy. Conducting this experiment provides practical insight into diffraction and interference, reinforcing light's wave nature and improving understanding of experimental physics techniques in light property measurement.

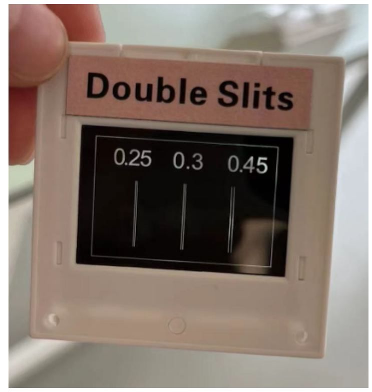
2 Aim

The aim of the experiment is:

- To calculate the wavelength of helium-neon laser by means of Young's double-slit experiment;
- To calculate the wavelength of same helium-neon laser by means of single-slit;
- Compare above results with the given wavelength of helium-neon laser on the apparatus.

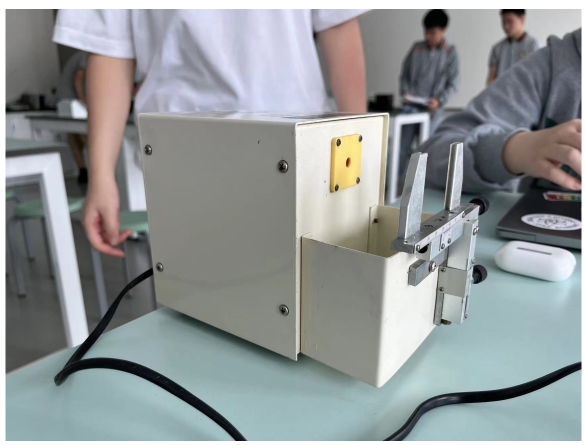
3 Apparatus

(a) Single-Slit



(b) Double-Slit

- A helium-neon laser
- A double-slit and a single-slit
- meter rule and the bench.



Safety Caution: Never let the beam straightly get into your eyes AND make sure the beam WILL NOT shoot straightly into other people's eyes as well

4 Procedure

1. Change the width of the single slit
2. Record the separation between the maxima for 3 times and take the average
3. Similarly, change the width of the double slit and record the separation between maxima.

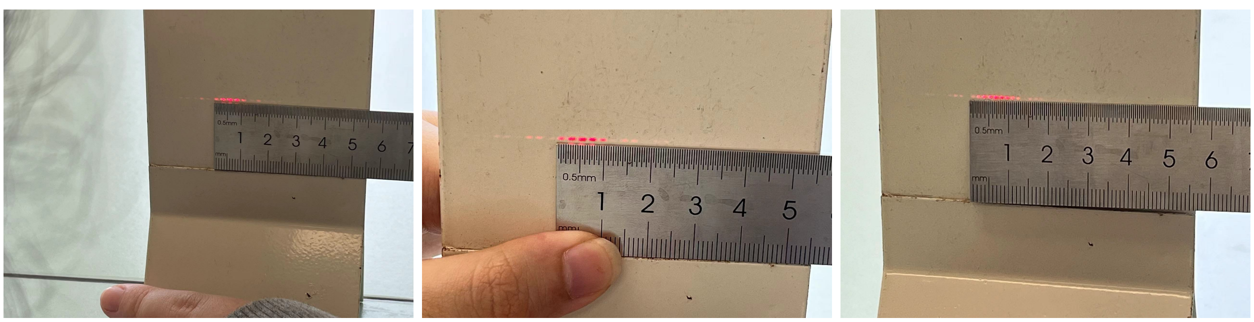
The independent variable is the width of the slit (single/double) and the dependent variable is the separation between the maxima. The light source (wavelength) is the controlled variable.

(c) 0.1 (d) 0.2

Figure 1: Single slits diffraction.

Slit Width (mm)	Separation of 1st Maxima (mm)
0.1	11
0.2	5

Table 1: Single slit raw data, including slit width and separation of the 1st maxima.



(a) 0.25 (b) 0.3 (c) 0.45

Figure 2: Double slits diffraction.

Slit Separation (mm)	Separation between maxima
0.25	2
0.3	1.5
0.45	1

Table 2: Double slits raw data, including slit width and separation of the maxima, when the distance to the light source is 104.1cm.

5 Data Collection

6 Data Processing

Therefore, we can calculate the wavelength of the laser light using $\lambda = \frac{xd}{l}$ where width of the slit os d, the width of the central maximum of the interference pattern is $2x$ in single and x in double slit, and the distance from the slit to the screen is l:

$$\begin{aligned}
\lambda_1 &= \frac{0.2 \times 2.5}{1041} = 4.803 \times 10^{-7}\text{m}, \\
\lambda_2 &= \frac{0.1 \times 5.5}{1041} = 5.283 \times 10^{-7}\text{m}, \\
\lambda_3 &= \frac{2 \times 0.25}{1041} = 4.803 \times 10^{-7}\text{m}, \\
\lambda_4 &= \frac{1.5 \times 0.3}{1041} = 4.323 \times 10^{-7}\text{m}, \\
\lambda_5 &= \frac{0.45 \times 1}{1041} = 4.323 \times 10^{-7}\text{m}.
\end{aligned}$$

So we can calculate λ as the average of $\lambda_{1,2,3,4,5}$ and the error of λ, $\Delta\lambda$.

$$\begin{aligned}
\lambda &= \frac{\sum_{i=1,2,3,4,5} \lambda_i}{5} \\
&= \frac{4.803 + 5.283 + 4.803 + 4.323 + 4.323}{5} \times 10^{-7} \\
&= 4.707 \times 10^{-7}\text{m}.
\end{aligned}$$

The error of λ is

$$\Delta\lambda = \frac{5.283 - 4.323}{2} = 0.48 \times 10^{-7} \approx 0.5 \times 10^{-7}\text{m}.$$

Thus, the wavelength of the laser source is $(4.7 \pm 0.5) \times 10^{-7}$m.

7 Conclusion and Evaluation

The experiment aimed to ascertain the wavelength of a He-Ne laser through both single-slit and double-slit diffraction approaches. The average wavelength recorded was $\lambda = \boxed{4.7 \times 10^{-7}\text{m}}$ with an error of $\boxed{\pm 0.5 \times 10^{-7}\text{m}}$.

The uniformity of outcomes across varying slit widths and separations validates the efficacy of the experimental arrangement. Enhancements could involve utilizing more accurate instruments to measure slit dimensions and fringe separations, alongside ensuring a more stable and precisely aligned setup to minimize systematic errors.

In summary, the experiment effectively offered a practical comprehension of optical measurement techniques.