Wave Interference Experiment and Its Connection to Particle–Wave Duality

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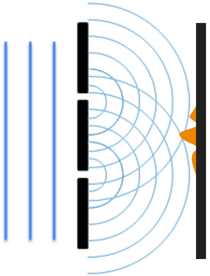
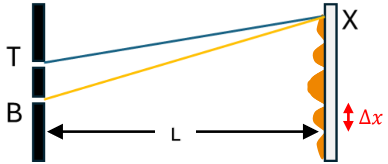
INTRODUCTION/MOTIVATION

In quantum limit, particle possess traits of waves and vice versa, also known as particle-wave duality. In order to understand this unique duality, we tried to study the characteristics of wave. Representative characteristics of wave include diffraction and interference. Double slit and single slit experiment, first performed by Thomas Young in 1801 to demonstrate the wave nature of light [1], is a perfect experiment to analyze these wave characteristics quantitatively.
Here, we demonstrated the double-/single- slit experiment and quantitatively analyzed the interference pattern to confirm the theoretical model.



THEORETICAL MODEL

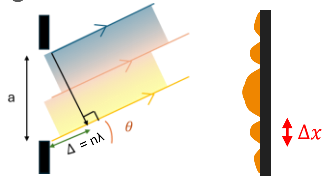
Double Slit:



nth dark fringe $x_n = \left(n + \frac{1}{2}\right)\frac{\lambda L}{d}$

At the screen, the wave traveled will interfere with one another after passing through both slits. Depending on the difference between length, the wave will result in constructively interfere (bright) or destructively interfere (dark).

Single Slit:

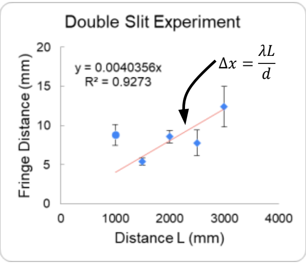


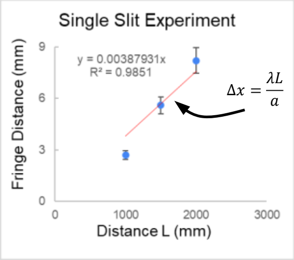
nth dark fringe $x_n = \left(n + \frac{1}{2}\right)\frac{\lambda L}{a}$

In a single slit experiment, the ray of light that enters a single slit all interfere with one another and the distance from the blue ray and yellow ray times integers in wavelengths will be destructively interfered.

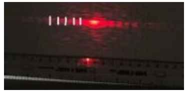
RESULTS/ANALYSIS

Δx : Fringe Distance





Fraunhofer pattern :



Extracted double slit distance :

$$d = \frac{\lambda}{s} = 162.3\ \mu m$$

Extracted single slit width :

$$a = \frac{\lambda}{s} = 172.7\ \mu m$$

Error analysis

There are several sources of error that we encountered throughout this experiment. Firstly, in order to measure the distance between the wave interference, we took a photo of the interference pattern alongside a ruler. This ruler introduced a margin of error of ±1 cm. Additionally, the distance between the light and pattern and the ruler may introduce some variability. Lastly the photos that we used to measure the interference were sometimes blurry.

OUTLOOK/DISCUSSION

By experimentally analyzing the charateristics of wave with double slit and single slit interference, interference of the particle wavefunction could be intuitively understood.
One can develop the experiment further by (1) using different parameters (wavelength, slit, etc.) (2) using single-photon source or electron beam, atom [2] to directly explore the particle-wave duality.

REFERENCE

1) *Double-slit experiment that proved the wave nature of light explored in time,* Science News, Imperial College London, Hayley Dunning (04. 2023)
2) *Double slits with single atoms*, Physics World (02.2020)

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