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ANALYSIS OF LIGHT DIFFRACTION INTERFERENCE PATTERNS IN YOUNG'S DOUBLE SLIT EXPERIMENT

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Abstract-Young's double-slit experiment is a classic and fundamental demonstration in physics that strongly supports the wave nature of light through the phenomenon of interference. The study aims to deeply analyze the formation of diffraction and interference patterns of light that arise due to the path differences between two coherent light sources. The experiment uses a simple yet effective setup involving a monochromatic light source, two narrow slits placed close together, and a screen placed at a certain distance to capture the resulting interference pattern. Several variables are analyzed in the study, including the wavelength of the light used,the distance between two gaps and the distance from one gap to anotherThe experimental results confirm the occurrence of constructive and destructive interference, resulting in the formation of stripes moving from bright to dark in the layer. These stripes arise due to the phase difference between overlapping light waves, and their spacing and clarity are affected by the physical parameters of the setup. The analysis shows that the spacing between the stripes increases with longer wavelengths and decreases with wider slit spacing. In addition, the cohesion of the light source plays an important role in producing a clear and stable interference pattern. This experiment not only serves as a concrete verification of the theoretical wave principle in physics, but also has broader implications in modern optical technologies such as diffraction gratings, holography, and quantum mechanics. This experiment is also relevant for educational purposes because it provides an experiential learning opportunity for students to understand the behavior of light and wave interactions. Therefore, this study is expected to be a useful reference in supporting the teaching and learning of wave optics, especially in demonstrating the dual nature of light and its applications in real-world phenomena.

Keywords:*Interference, double slit experiment, wave properties of light*

I Introduction

When light waves pass through a small slit or around an obstacle, it is called diffraction of light. Light that interacts with an object whose size is comparable to its wavelength, the light waves will spread out and form a distinctive pattern. This phenomenon shows that light does not only travel in a straight line, but also has wave properties. Diffraction can be observed in various situations, such as when light passes through a double slit, a single slit, or when light passes through the edge of an object.(Hasanah, 2022)

Understanding of the wave nature of light was further strengthened through Thomas Young's double-slit experiment which demonstrated the phenomenon of interference, a characteristic feature of waves.(Ananthaswamy, 2023). In later developments, similar experiments were used in the context of quantum mechanics to demonstrate wave-particle dualism, as discussed in(Griffiths & Schroeter, 2018)

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Interference of light diffraction in Young's double slit can be analyzed through several parameters, including the width of the slit, the distance between the slits, and the wavelength of the light used. This study aims to analyze the interference pattern produced and understand the relationship between the factors that affect the pattern. Knowledge of light interference is not only important in the context of basic physics, but also has broad applications in optical technology, including in the development of devices such as lasers, microscopes, and optical sensors.(Abdullah, 2017).

In the world of education and research, understanding light diffraction and interference plays an important role as a basis for technologies such as spectroscopy, holography, and optical communication. However, although this concept is taught at the high school and college levels, students' understanding of this abstract physics phenomenon is still relatively low, especially in connecting it to its application in real life.(Mahombar, 2024)

In addition, this research also contributes to the development of a more relevant and contextual science education curriculum. By integrating the double-slit experiment into learning, students not only learn about wave theory, but can also see the real application of the concept in modern technology. It is hoped that this will increase students' interest and understanding of physics and encourage them to study other fields such as technology and science.(Biswal Biswajit Behera, 2023)

Previous research has shown that an inquiry-based experimental approach can help improve students' scientific literacy in understanding wave phenomena.(Maharani, 2024). Therefore, through a simple experiment designed to demonstrate how the wavelength of light, the distance between the slits, and the interference pattern formed on the screen interact with each other, this study aims to thoroughly study the interference phenomenon caused by the diffraction of light at a double slit.

This study aims to determine the nature of the interference pattern produced from the double-slit experiment, as well as all the elements that influence it. This study is based on previous literature research. It is expected that this study will provide additional references for teaching the concept of waves, especially about the material of diffraction and interference of light.

II Formulation of the problem

1. How is the diffraction interference pattern of light formed in Young's double slit experiment?
2. What factors affect the intensity and spacing of bright bands in an interference pattern?

III Research purposes

1. Analyzing the formation of light diffraction interference patterns in Young's double slit experiment.
2. Identify factors that influence the distribution of intensity and position of light and dark bands.

IV Research methods

The purpose of this literature study is to study the interference phenomenon due to light diffraction in Young's double slit experiment. To do so, this study analyzes various relevant scientific articles. This methodology follows a descriptive qualitative approach commonly used in literature reviews.(Ridwan, 2015)

IV.1 Types of research

This research is qualitative and uses a literature study approach; it analyzes and synthesizes previous research findings to gain a better understanding of light interference patterns.(Yuliani, 2018)

IV.2 Data Collection Techniques

To obtain data, use Google Scholar, ScienceDirect, ResearchGate, and the Directory of Open Access Journals. Selected articles must meet the following criteria:

1. Published between 2015 and 2025

2. Relevant to the topic of interference and diffraction of light, especially the double slit experiment.
3. Include experimental data, simulations, or quantitative/theoretical analysis.

According toRasimin, (2018), the selection of sources must pay attention to validity, actuality, and relevance to the research problem.

IV.3 Data Collection Techniques

The identified patterns, experimental parameters (wavelength, slit distance, and distance to the screen), and reported interference pattern results were used to analyze the obtained articles.(Qomaruddin & Sa'diyah, 2024). The results from various sources are then compared and synthesized to find the relationship between findings and contributions to the understanding of the topic.(Fadli, 2021)

V Results and Discussion

In the 1600s and 1700s, scientist Christiaan Huygens challenged Newton's particle theory of light with the idea that light could travel through the ether. Thomas Young tried to determine what happens when light passes through two closely spaced slits, known as the Young double slit, and discovered that light acts as a wave. (Febriansyah, 2024).

In terms of optical waves, double slits are one of the interesting physics phenomena to discuss again. It is interesting that light traveling through two slits with a certain distance will experience interference because waves with the same frequency collide. Constructive and destructive interference are two types that can occur. Furthermore, patterns will be created on the dark and bright screens.(Gureyev et al., 2024)

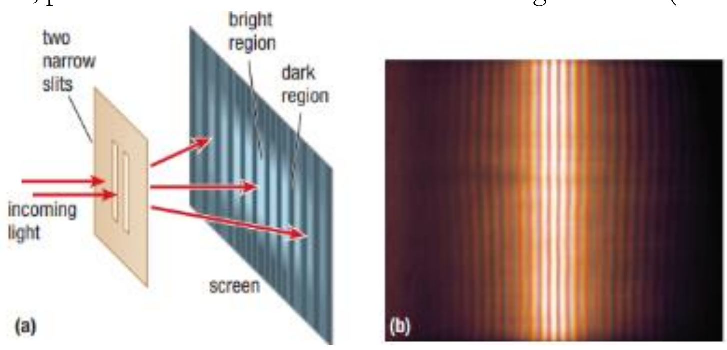

Figure 1(a) Animation of Young's double slit experiment. (b) white light passing through a small slit.

Double light sources in a dark room are produced because the light beam falls on a slit.(Wada et al., 2023).A secondary source passed through a double slit produces two new (tertiary) wave sources from each slit with a constant phase difference. The secondary sources are the same, so it can ensure that the phase difference remains constant. If the two tertiary sources from the double slit are overlapped, then the waves will be in phase and at certain points will be in phase and at other areas not.(Young's Double Slit Experiment | Physics, n.d.)

When the waves are in the same phase, their intensity will reinforce each other (constructive), conversely when they are out of phase, they will cancel each other out (dedestructive). This will cause alternating light and dark patterns on the screen. According to(Ploss et al., 2017), this pattern is known as interference fringes. Since interference patterns would not occur if sunlight were considered to consist of particles, Young's double-slit experiment demonstrated the wave nature of light. At the same time, this experiment also supported the wave theory.(Ivin Thomas, 2019).

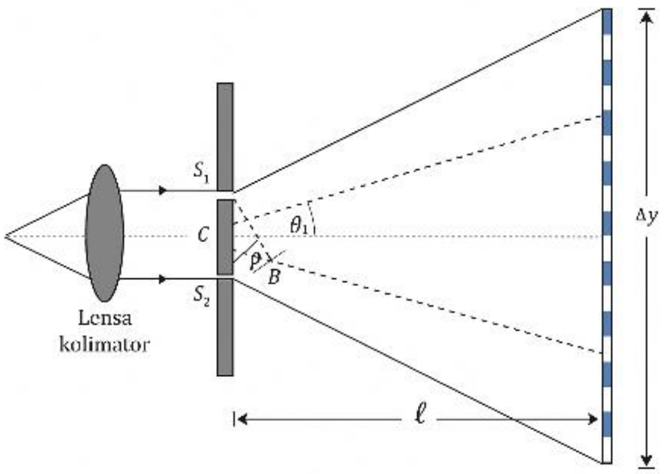

Figure 2young interference experiment

Interference patterns alternating between bright and dark lines on the screen are produced by both experiments. (Figure 2). When there is maximum interference or mutually reinforcing interference between the two light sources, bright lines will appear.(Jackson et al., 2018). In contrast, dark lines appear when there is little or no interference between the two light sources. A truly dark area will form at the location of least interference if the amplitudes of the two light sources are equal.(Permata et al., 2023). Observe the following two-slit interference degradations to determine the pattern formed from two-slit interference:

If the distance and the distance are much greater than the distance with = d, the ray and the distance can be considered parallel and the difference in their distances is ΔS = . From the triangle obtained$S_1A\ S_2BS_1\ ke\ S_2S_1\ S_2S_1A\ S_2AS_2BS_1\ S_2B$

$$s_2\text{B} = S_1\ S_2\ Sin\theta = \text{d} \sin\theta \tag{1}$$

In triangle COA, d is the distance between the next two slits,

$$Sin\theta = \frac{p}{CA} \tag{2}$$

For smaller angles, we will get

$$\tan\theta = \frac{p}{l} = sin\theta \tag{3}$$

Ifθsmall, then p/l is small or p<<<l so that the difference in the speed of light between the sources$S_1\ dan\ S_2$will satisfy the following equation.

$$\Delta\text{s} = \text{B} = \text{d}\ \text{sin} s_2\theta = \text{d}\ \tan\ \theta \frac{dp}{l} \tag{4}$$

If two waves arrive at point A in phase, maximum interference will occur. This occurs when the phases of the two waves are the same and the path difference is a multiple of a whole number of wavelengths.

$$\Delta\text{s} = \text{m}\lambda \tag{5}$$

So, the maximum interference equation becomes

$$\frac{dp}{l} = (2n-1)\ \frac{1}{2}\ \lambda \tag{6}$$

Where d is the distance between layers, p is the distance from the interference center point (O) to the bright line at A, I is the distance between layers, and m is the interference order (0, 1, 2, 3,...).

1. Formation of Interference Pattern in Young's Double Slit

The interference pattern of bright and dark lines appearing regularly on a screen is produced by Young's double-slit experiment. This pattern is the result of the interference of two coherent light waves coming from two narrow slits. When a monochromatic light beam (for example from a laser) is passed through the double slits, each slit acts as a source of new waves.(Pearson et al., 2018). If two waves from the gap:

- In phase (meeting at peak with peak and valley with valley), then constructive interference occurs → produces a bright band(Permata et al., 2023).
- Out of phase (peak meets valley), then destructive interference occurs → produces dark bands(Peng, 2021).

The difference between in-phase and out-of-phase waves can be explained in (Figure 3).

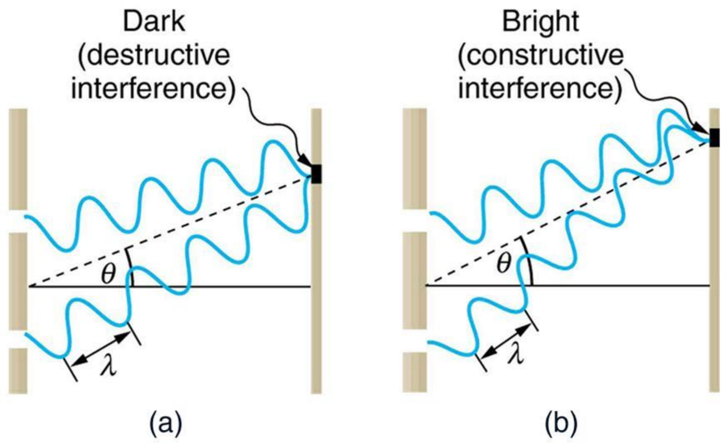

Figure 3(a) light interference and (b) dark interference

The light and dark patterns appear to form bands, or fringes, that are symmetrically distributed about the center of the pattern, or zero line. When the paths of two beams differ by one wavelength, or some other integer multiple of the wavelength, constructive interference occurs. The equation can be written as follows:

$$d \sin \theta = m \lambda \quad (8)$$

Where :

The distance d between the slits at the wavelength (λ) of light m, where i is the interference order (0,1,2,3,...), and θ is the angle of the screen positioned above the ground.Destructive interference (mutual weakening) occurs when the paths of two beams overlap by ½ the wavelength (or 3/2λ ,5/2 λ etc.)(Nor, 2007)the equation can be written:

$$d \sin \theta = (m + \frac{1}{2} \lambda) \quad (9)$$

From equations (8) and (9) it can be seen that except for the 0th order in the middle, the position of the fringes depends on the wavelength. Consequently, when white light is incident on a double slit or grating, the middle fringes are white, but the first and subsequent fringes are visible light spectrum like a rainbow, as Young found in his experiments. Anglethe small ping is purple and the largest is red(Fatihah et al., 2024).

2. Factors Affecting Interference Patterns

Based on theory and experimental observation results, there are several main factors that influence the shape and size of interference patterns.(Mendrofa & Harefa, 2025):

1) Distance Between Gap (d)

The spacing between the bright bands (Δy) increases with the distance between the slits. Conversely, the pattern becomes denser with increasing distance.

2) Wavelength of Light (λ)
   a) Wider interference patterns are produced by light with longer wavelengths, such as red.
   b) A denser pattern is produced by light with shorter wavelengths, such as blue.(Rifa'i, 2025).
3) Distance from Slit to Screen (L)
   The further the screen is from the gap, the wider the fringe (distance between light/dark patterns).
4) Coherence and Monochromaticity of Light
   Coherence means that light waves have a constant phase difference. Monochromatic (single-color) light such as lasers is well suited to making patterns sharper and clearer.(Chen et al., 2020).

The experimental results are also consistent with Leinonen's findings showing that the intensity and distribution of interference patterns can be modulated by using certain light polarities and metal surfaces, as in the surface plasmon technique.(Leinonen et al., 2021). This indicates that the interference phenomenon depends not only on the slit distance and wavelength, but also on the interaction of the electromagnetic field with the material through which the light passes.(Shaw et al., 2020).

3. Interference Theory Calculation

The formula used to determine the position of the m-th bright band is:

$$y_m = \frac{m\lambda L}{d} \tag{10}$$

With the caption:

According to Murray (2020) is the position of the m-th bright band from the center, M is the interference order (0, 1, 2, 3, ...), is the wavelength of light, L is the distance from the slit to the screen and d is the distance between the two slits.Y_m(Murray, 2020). According to this formula:

a) The bright bands will be located further away from the center as the order (m) increases.
b) The longer the wavelength (λ) → the position of the bright band is further away.
c) The smaller the gap distance (d) → the wider the pattern.

In the study by Tsalatsin, a simple experimental approach was used to determine the wavelength of light based on the position of the bright bands.(Tsalatsin, 2014). The measurement results proved to be accurate and in accordance with theoretical values, indicating that the double slit experiment can be used as a quantitative method to measure the wavelength of light precisely provided that the geometric measurements are carried out carefully.(Muhammad & Omama, 2020).

VI Conclusion

Young's double-slit experiment successfully demonstrated the formation of an interference pattern characterized by alternating bright and dark stripes on a screen. This pattern is formed by the coherent superposition of light waves passing through two narrow slits, where constructive interference produces bright stripes and destructive interference produces dark stripes. This experiment clearly supports the wave nature of light, contradicting previous theories that only considered light as particles, and highlights the fundamental wave nature of light. This phenomenon is influenced by several key factors such as the distance between the slits, the wavelength of the light used, and the distance between the slits and the screen. For example, a smaller slit distance results in a wider spacing of the stripes, while a longer wavelength results in a wider pattern. The use of a monochromatic, coherent light source, such as a laser, is essential to obtain sharp and clear interference stripes. Although this experiment effectively illustrates the wave behavior of light and can be used quantitatively to measure wavelength with accuracy, it has limitations in precision that are highly dependent on the experimental setup, including the accuracy of the geometric measurements and the environmental conditions. Nevertheless, the experiment remains highly relevant in classical and modern physics, as it also provides fundamental insights into quantum mechanics, where even massive particles such as electrons exhibit wave interference. This makes the double-slit experiment a powerful educational and research tool for understanding wave-particle duality and the nature of quantum phenomena. For future applications, improving the accuracy of the measurements through sophisticated instruments and exploring interference in different materials or with varying polarizations of light could deepen understanding and open up new avenues for optical and quantum technologies. Overall, the double-slit experiment remains an essential element in physics education and research due to its clear demonstration of fundamental wave properties and its wide applications in scientific investigations.

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