

Revisiting the double-slit experiment of light: from wave theory to pulse theory

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Abstract: The double-slit interference experiment has long been regarded as a cornerstone of the wave theory of light. However, optical interference patterns are absent in everyday life, prompting many scientists to question the validity of the experiment under specific conditions. Until now, no experiments have definitively challenged this theory. Here, we revisit double-slit experiment through experimental validation. Results show that light and dark fringes are not caused by light wave interference, but rather by diffraction from vertical walls of the slits. This discovery challenges the conventional wave interference theory and presents a new perspective on the pulse nature of light, where overlapping spectra enhance energy without cancellation. This research offers novel insights into the nature of light and introduces new perspectives for optical research.

1. Introduction

The wave nature of light has been a cornerstone of classical physics since Thomas Young's double-slit interference experiment in 1804 [1]. Young used sunlight as a light source and observed interference fringes through two slits, making this experiment a classic demonstration of the wave nature of light. With the advent of modern light sources such as lasers, researchers have replicated this experiment, taking advantage of the high intensity, monochromaticity, and coherence of lasers to improve the repeatability of the double-slit experiment [2, 3, 4]. The successful replication of the experiment is closely related to the availability of powerful lasers in modern optics.

The basic understanding of the double-slit experiment in traditional wave theory is well documented in many classical and modern optics texts. For example, Hecht's *A Comprehensive Exploration of Optics* explains that interference patterns are caused by phase differences and are independent of the physical properties of the slits, such as thickness or material [5]. Similarly, Griffith emphasized in his quantum mechanics textbook that interference patterns are controlled by the phase difference of the wave functions and are not affected by the screen or slit material [6]. Feynman emphasized in his *Feynman Lectures on Physics* that phase relationships, rather than the structural properties of the instrument, determine interference patterns [7]. Born and Wolff reinforced this view in their authoritative analysis of modern optics, emphasizing that interference fringes arise entirely from phase differences [8]. Furthermore, Feynman and Hibbs demonstrated the independence of interference effects from the physical properties of the experimental setup using the path integral method [9].

However, advances in optical experiments and technology have raised new questions for this traditional theory. The classical theory of wave interference has difficulty explaining some observed behaviors of light. For example, in common devices such as color displays, vacuum fluorescent screens, and movie projectors, coherence does not produce the interference patterns predicted by traditional theory. Such discrepancies suggest that drawing broad theoretical

conclusions from specific experimental conditions can be misleading, as these conclusions may apply only to specific cases rather than representing universal scientific laws. Rather than simplifying our understanding of optical phenomena, such explanations increase complexity.

Recognizing the need for a broader study of optical phenomena, we revisit classic double-slit experiment of Thomas Young with experimental validation. Our goal is to reassess the fundamental properties of light and propose a new theory of pulses that provides a more complete understanding of its behavior.

2. Results and discussion

2.1 Reproduction of the double-slit experiment under different conditions

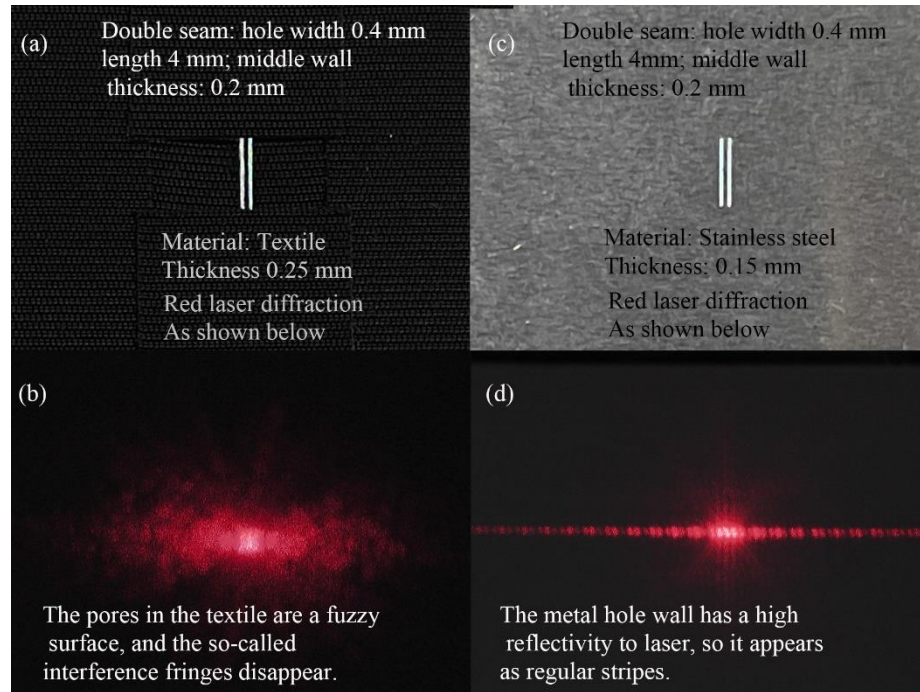


Fig. 1. Double-Slit Experiment: (a) Double slits constructed from black textile and (b) their resulting light fringe pattern, (c) Double slits made from stainless steel and (d) the corresponding light fringe pattern.

We conducted the double-slit experiment using two materials with different reflection intensities, each punched with laser-cut slits. As depicted in Fig. 1a, one set of double slits was created from black textile with a thickness of 0.25 mm. This material is characterized by its fluffy texture, high light absorption, and low light reflectivity. The parameters for these double slits are as follows: slit width of 0.4 mm, length of 4 mm, and middle wall thickness of 0.2 mm.

In contrast, as shown in Fig. 1c, the other set of double slits was made from stainless steel, a material with a smooth surface and strong light reflection. These slits were cut into a 0.15 mm thick sheet, with the same parameters: slit width of 0.4 mm, length of 4 mm, and middle wall thickness of 0.2 mm.

The images of light spots produced by the laser passing through the double slits made from the two different materials are shown in Fig. 1b and 1c. The results from the double-slit experiment using black textiles are presented in Fig. 1b. In this case, the light spots are blurred, forming a cloud-like light patch with no interference fringes. In contrast, the results from the double-slit

experiment using stainless steel, shown in Fig. 1d, successfully reproduce diffraction patterns, commonly referred to as “interference fringes”.

A comparison of the experimental results in Fig. 1c and 1d demonstrates that the material of the double-slit significantly influences the shape of the formed light spots. The double slits made of black textiles, which have strong light absorption properties, do not produce light and dark stripes. Conversely, the stainless steel double slits, with their smooth and highly reflective surfaces, effectively reproduce “interference fringes”. These observations suggest that the formation of light spots is related to the reflective properties of materials. To further investigate this phenomenon, we conducted additional experiments using a single slit.

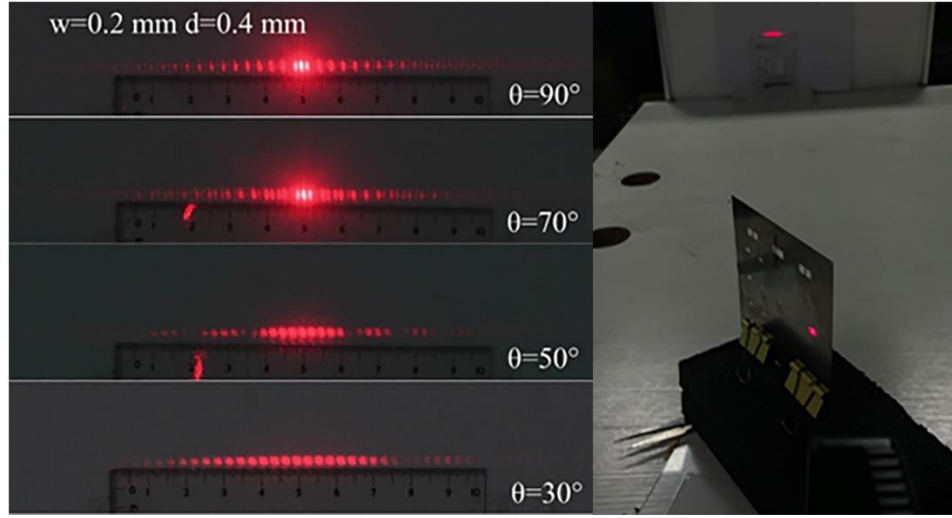


Fig. 2. Effect of double-slit inclination on fringe patterns

This experiment investigates the effect of the inclination angle (θ) of a double-slit plate on the observed fringe patterns (Fig. 2). The plate, fabricated from stainless steel, features a slit width of $w = 0.2$ mm and a separation of $d = 0.4$ mm. When the inclination angle decreases from 90° (normal incidence) to 30° , the fringe system undergoes a noticeable expansion. Specifically, the fringe spacing increases, indicating that variations in the angle modify the incidence path and projection geometry of the double-slit. These changes result in a broader distribution of the fringe pattern on the screen.

As the inclination angle decreases, the brightness of the fringes diminishes significantly. At 90° (normal incidence), the fringes appear brightest, but their intensity declines as the angle approaches 30° . This reduction in brightness can be attributed to cumulative reflection losses along the increasingly inclined light paths, resulting in gradual light attenuation as described by the intensity decay formula, where I_n is the light intensity after n reflections, I_0 is the initial intensity, and R is the reflection coefficient (with $0 < R < 1$).

$$I_n = I_0 R^n$$

Additionally, the fringe density shifts, and new bright and dark fringes emerge with decreasing angles. At smaller angles, such as 30° , the pattern becomes more dispersed. This phenomenon arises from changes in the overlap of light paths and virtual image positions caused by the plate's inclination. The resulting "mirror-mirroring" effect produces new fringes through dynamic virtual image overlaps.

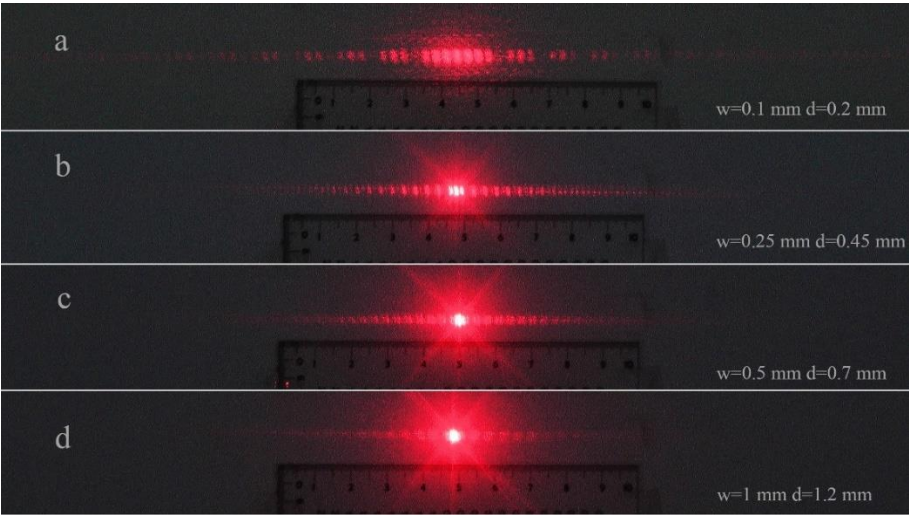


Fig. 3. Relationship between double slit width and stripes (stainless steel material)

This experiment further investigated the effect of the double slit width on the observed fringe pattern (Fig. 3). The image depicts a double slit structure made of stainless steel, with each slit having a width of w and a center-to-center spacing of d , as labeled. When the laser passes through the slits, it produces different diffraction patterns on the screen. These patterns consist of a bright central region and alternating light and dark fringes.

As the slit width becomes narrower, the diffraction effect increases, resulting in denser and more distinct fringes. Conversely, wider slits produce fewer visible fringes, with the central region exhibiting stronger intensity. The clarity and uniformity of the observed pattern is primarily attributed to the smooth and reflective properties of the stainless steel material, which improves the precision of the light interaction.

Table 1. Influence of physical parameters on diffraction patterns in double-slit experiments

Physical Parameter	Material Surface Properties	Slit Width (w)
Experimental Observations	Smooth surface (e.g., stainless steel): Produces regular and clear fringes.	Wide slit ($w > 0.5$ mm): Dominated by direct light; minimal fringes. Narrow slit ($w < 0.5$ mm): Produces enhanced fringes with higher density.
	Rough surface (e.g., textile): Results in blurry or absent fringes.	Independent of the gap width, no regular stripes can be produced.
Physical Mechanism	Smooth surfaces enhance light reflection, amplifying mirror effects.	Narrow slits increase reflection paths, intensifying diffraction effects.
	Rough surfaces scatter light, reducing fringe visibility.	Wider slits limit diffraction, with stronger central intensity.

The observed light patterns arise from a combination of diffraction, reflection, and mirror effects, influenced by the slit geometry and material properties, as illustrated in Table 1. Narrow slits enhance diffraction and enable multiple reflections within the slit walls, leading to strong, localized fringes. In contrast, wide slits diminish these effects, allowing direct light to dominate and significantly reducing fringe visibility.

Surface characteristics further shape the patterns: smooth materials, such as stainless steel, amplify mirror effects, resulting in clear and well-defined fringes. Conversely, rough surfaces, like textiles, scatter light, producing blurred or indistinct fringes. These patterns are highly sensitive to the angle of incidence but remain unaffected by polarization, underscoring the predominant role of geometric factors.

Traditional phase-based interference models fail to account for the intensity and clarity of these patterns. Instead, the results highlight the dominance of mirror effects and geometric projections. Fringe formation relies on the reflection path and the overlap of virtual images, with the tilt angle playing a critical role in determining the light projection geometry and the accumulated reflection path length. These findings align with models emphasizing pulse reflection behavior and the impact of geometric configurations.

2.2 Single-slit experiment under different conditions

We conducted single-slit experiments using the same two materials-black textiles and stainless steel-that were used in the double-slit experiment. The parameters for the single slits were set at 4×0.6 mm, as shown in Fig. 4a and 4c. The resulting images from the laser passing through these single slits are illustrated in Fig. 4b and 4d.

As observed in Fig. 4b, when light passes through a single slit made of black textile, the resulting light spots are blurred, forming a cloud-like light patch with no “interference fringes”. This result mirrors the light spot characteristics seen in the double-slit experiment. In contrast, Fig. 4c shows that when light passes through a single slit made of stainless steel, it successfully reproduces a diffraction light patch (Fig. 4d).

Comparing Fig. 1d with Fig. 4d, the light spot in Fig. 4d is more regular and orderly than that in Fig. 1d. This suggests that the light spot in Fig. 1d may be the result of two single slits overlapping. To verify this hypothesis, we designed a third set of experiments based on the principles of light reflection and diffraction. These experiments confirmed that the light spots are produced by the reflection and diffraction phenomena when the light beam passes through a smooth plane.

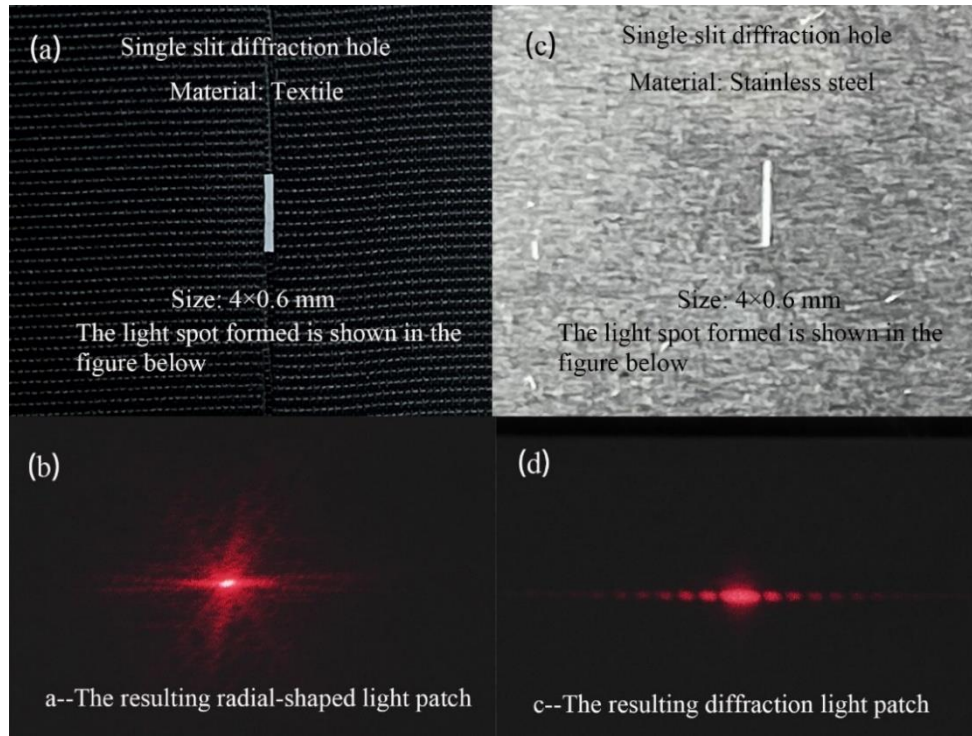


Fig. 4. Single-Slit Experiment: (a) Single slit made from black textile and (b) its resulting light fringe pattern, (c) Single slit made from stainless steel and (d) the corresponding light fringe pattern.

2.3 Light reflection and diffraction experiments

In the light reflection experiment, we used two nickel-plated metal cubes with smooth surfaces, measuring $45 \times 12 \times 4.5$ mm and $50 \times 12 \times 4.5$ mm. A high-intensity laser was directed perpendicularly onto the left and right walls of the metal cubes, respectively, as illustrated in Fig. 5a and 5b, with half of the laser beam passing through to illuminate the screen and the other half being blocked by the metal.

As shown in Fig. 5a and Fig. 5b, two light spots appeared on the screen: one circular spot created by the direct irradiation of the laser, and a horizontal linear spot projected by the light reflected off the side wall. When the two cubes were combined, forming a synthetic slit with a width of 1 mm, the laser beam produced the pattern shown in Fig. 5c. In this setup, three light spots were observed: a circular spot from the direct laser irradiation and two horizontal linear spots, each projected by the light reflected off the side walls. These observations demonstrate that the formation of the light spots is due to the reflection and diffraction of the laser beam, rather than the wave characteristics of the light itself. Theoretically, when the thickness of the double-slit material is reduced to less than λ (the wavelength of the light), the diffraction pattern is expected to disappear. However, this experiment cannot be conducted due to current material limitations.

To further explain the formation of horizontal light spots, a schematic diagram is provided in Fig. 6. This phenomenon results from the mirror-like reflections off the strongly reflective surfaces of the laser-illuminated walls. The two vertical wall planes on either side of the slit act as opposing mirrors, producing images under the intense laser light. The linear light spots observed are the result of a combined effect of mirror reflection and the properties of the laser, as depicted in Fig. 6.

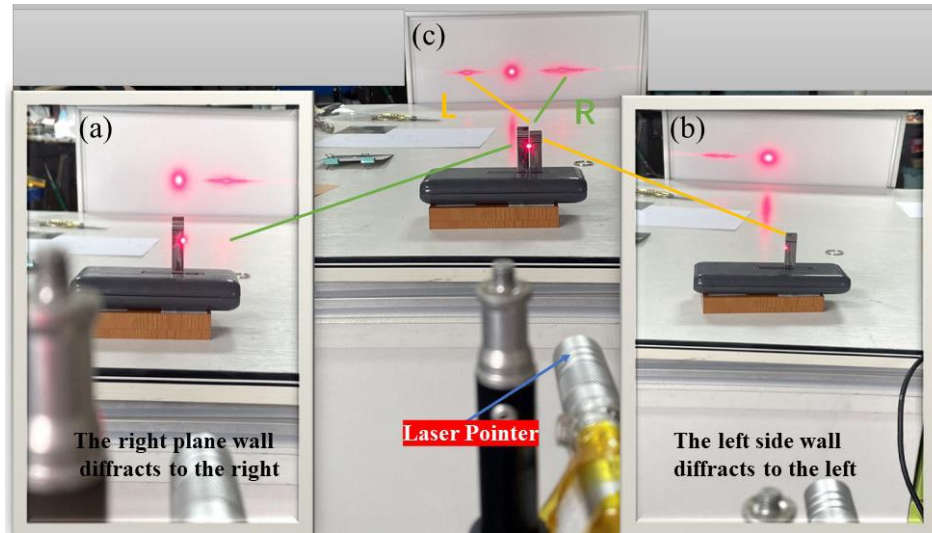


Fig. 5. Light Reflection and Diffraction Experiments: (a) Reflection experiment on the right side of a nickel-plated metal cube and the resulting light spot, (b) Reflection experiment on the left side of a nickel-plated metal cube and the corresponding light spot, (c) Single slit formed by two nickel-plated metal cubes and the resulting light fringe pattern.

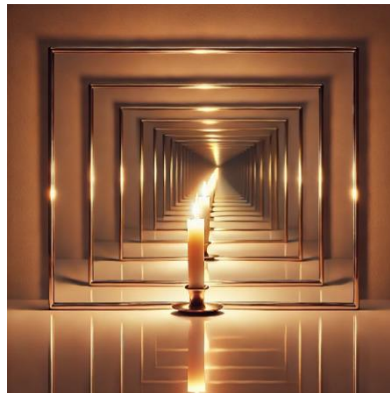


Fig. 6. Reflection of a candle in one of two opposing mirrors.

In this experiment, the observed bright and dark fringe patterns are primarily attributed to a “mirror-mirroring” effect generated by the double-slit structure. This effect occurs because each slit edge acts as a reflecting surface, producing multiple overlapping virtual images. The spacing between these virtual images, which governs the fringe spacing, is described by the mirror-mirroring formula:

$$D = \frac{d}{1 - d}$$

where d is the separation between the mirrors (or slit edges) and D is imaginary distance in the mirror. This formula determines the spacing of the fringes observed on the screen, as the virtual images overlap due to the multiple reflections between the slit edges.

2.4 Double-slit with lens experiment

At the time, the true nature of light was not well understood, leading to the long-held belief that the “observer effect” caused a measurement-induced collapse. To demonstrate that the traditional double-slit experiment does not produce interference in three-dimensional space, we

designed a comparative experiment as depicted in Fig. 7. As shown in Fig. 7a, when a laser beam passes through the double slits (made of stainless steel), it forms horizontal bright and dark fringes. We then introduced a convex lens between the double-slit plate and the screen to test for light interference using the lens's imaging principle, as illustrated in Fig. 7b.

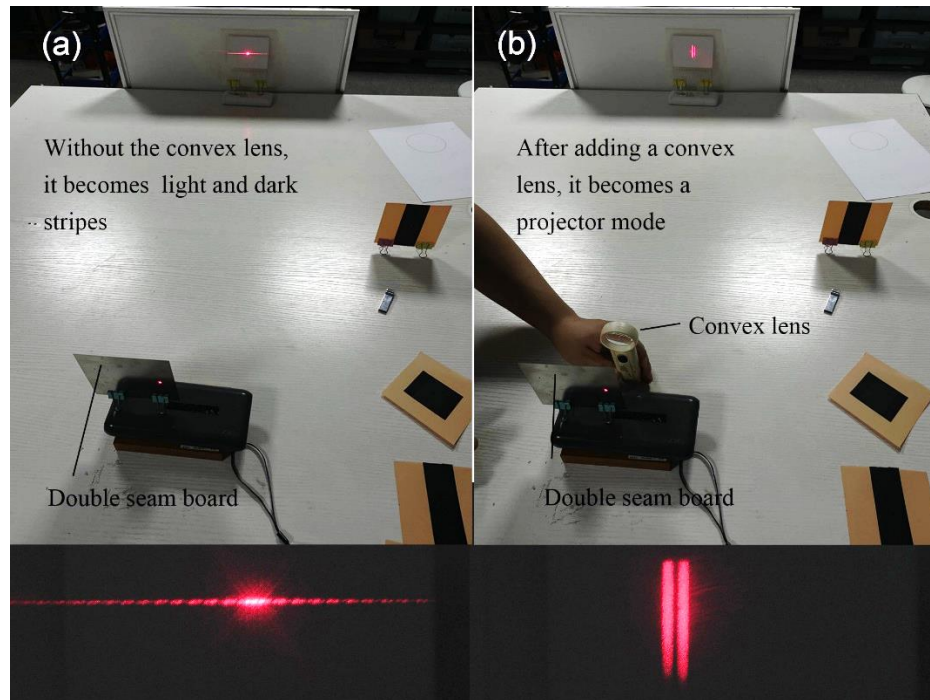


Fig. 7. Double-slit experiment: (a) without a lens, and (b) with a lens.

The experimental results revealed that, with the lens in place and by adjusting its focal length, a fringe pattern corresponding to the double slits was produced—essentially the projected image of the double slits. This outcome confirms that light does not undergo interference in three-dimensional space.

If the horizontal bright and dark fringes were indeed the result of light interference in three-dimensional space—where light waves constructively or destructively interfere, altering their phase and transforming energy—the convex lens's imaging principle would not have produced a clear projected image of the double slits. However, by introducing the lens, we successfully restored the projected image of the double slits, thereby demonstrating that light does not exhibit interference in three-dimensional space.

2.5 The discrepancy between existing theory and experimental reality

To further verify the experimental phenomenon with the traditional theory, we conducted a verification experiment using white light. We projected a white LED light source, with a diameter of 5 mm, onto a screen positioned 100 mm away. A circular plane with a diameter of 100 mm was set on the screen to calculate the distance from the edge of the light source to the center of the screen and to determine the phase difference among the red, green, and blue components of the white light.

According to traditional optical theory, if light interference occurs, there should be a measurable phase difference between the red, green, and blue light components that reach the

center of the screen from the edge. If such a phase difference exists, the light source would exhibit a color shift; if not, it would indicate a discrepancy between theoretical predictions and actual observations.

We calculated the relationship between the light path and wavelength according to traditional optical theory, comparing these calculations with experimental results. As illustrated in Fig. 8, the vertical side A equals 100 mm, the horizontal side B equals 2.5 mm, and the hypotenuse C, calculated using the Pythagorean theorem, is 100.03 mm. The phase differences for the red (760 nm), green (577 nm), and blue (450 nm) light from the edge of the light source to the center of the circular screen were then computed.

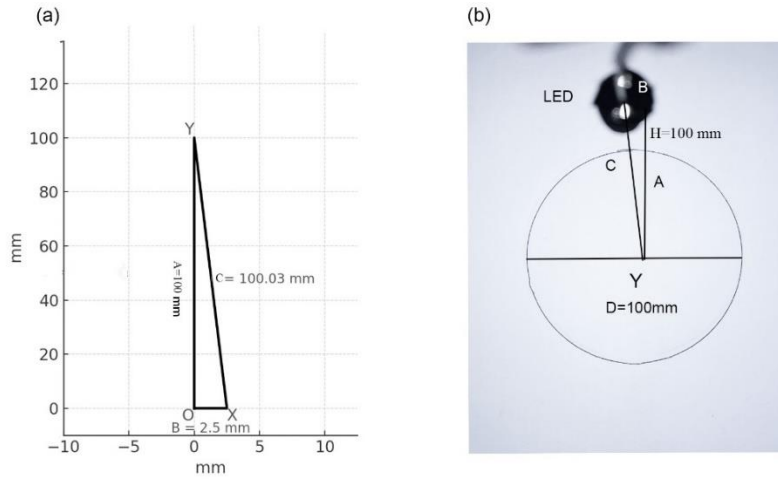


Fig. 8. (a) Triangular plane model illustrating light phase differences, and (b) experimental projection effect of an LED light source.

This experiment aimed to compare theoretical predictions with actual experimental outcomes, highlighting any discrepancies between traditional optical theory and observed phenomena. The phase difference $\Delta\phi$ is calculated using the relationship between the optical path difference and the wavelength λ . The formula is as follows: The phase difference $\Delta\phi$ is calculated based on the relationship between the optical path difference and the wavelength λ . The formula is as follows:

$$\Delta\phi = \frac{2\pi\Delta L}{\lambda}$$

$$\Delta L = 0.03 \text{ mm} = 0.03 \times 10^{-3} \text{ m}$$

The phase differences for different colors of light are calculated as follows:

Red light ($\lambda = 760 \text{ nm} = 760 \times 10^{-9} \text{ m}$):

$$\Delta\phi = \frac{2\pi \times 0.03 \times 10^{-3}}{760 \times 10^{-9}} \approx 247.4 \text{ radians}$$

Greenlight ($\lambda = 577 \text{ nm} = 577 \times 10^{-9} \text{ m}$):

$$\Delta\phi = \frac{2\pi \times 0.03 \times 10^{-3}}{577 \times 10^{-9}} \approx 327.1 \text{ radians}$$

Blue light ($\lambda = 450 \text{ nm} = 450 \times 10^{-9} \text{ m}$):

$$\Delta\phi = \frac{2\pi \times 0.03 \times 10^{-3}}{450 \times 10^{-9}} \approx 418.9 \text{ radians}$$

According to traditional optical theory, when white light is reflected, slight changes in the path length introduce phase differences among red, green, and blue light. According to wave theory, these phase differences should result in color shifts or distortions. Thus, the center of the light plane in the circle shown in Fig. 8 should exhibit a color shift and darkening due to these phase differences. However, as shown in Fig. 8b, no such phenomenon is observed. Additionally, in everyday life and natural environments, light does not display a color cast, which contradicts the wave theory of light, indicating that when multiple wavelengths of light are superimposed, their energy is enhanced rather than interfering with or canceling each other.

2.6 New theory: the pulse nature of light

Our experiments have challenged the coherence theory of light and led us to propose a new theory: the pulse nature of light. According to this theory, light does not behave as a continuous wave in the traditional sense but rather propagates in the form of discrete pulses. This implies that the energy of light pulses does not cancel out through interference but instead superimposes and enhances.

Moreover, the propagation and expansion of light in three-dimensional space significantly influence its behavior. After being emitted from a point source, light spreads in all directions as spherical waves. As light propagates in three-dimensional space, its energy is distributed over an increasingly larger surface area with distance, explaining the inverse square law of light intensity (where the intensity I is inversely proportional to the square of the distance r , $I \propto 1/r^2$).

While our model primarily considers the propagation of light on a two-dimensional plane, it is crucial to recognize that light travels in three-dimensional space. This three-dimensional propagation may alter wavefront arrangements and affect interference patterns, further demonstrating that the phenomenon of coherent cancellation of light waves does not occur as traditionally thought.

2.7 The pulse theory of light: explaining light phenomena in applications

Verification in Display Technology: The pulse theory of light has been validated and supported by various real-life applications. For instance, in liquid crystal displays (LCDs) and other display devices, the light source is composed of multiple pixels that emit light pulses independently. These pulses do not cancel each other out due to "coherence"; instead, they contribute to a stable and clear image display. This demonstrates that the superposition of light pulses enhances image brightness without causing the mutual cancellation that traditional wave theory would predict.

Support from Projection Technology: In movie projection, projectors create bright and high-contrast images by superimposing multiple light sources. If light exhibited coherence in the traditional sense, the meeting of light waves would likely result in mutual cancellation, leading to uneven brightness or color distortion. However, in practice, the projected images remain clear and consistent, indicating that coherent interference does not occur. Instead, the observed phenomena align with the pulse theory of light.

Everyday Light Phenomena: In natural lighting conditions, whether from sunlight or artificial sources, light distribution is uniform and stable. If light waves were coherent, "interference fringes" would likely form where waves meet. However, such interference is not observed in reality. The pulse theory of light explains this uniform distribution, avoiding the energy loss that would result from interference.

These examples from everyday life illustrate the pulse theory's consistency with actual observations, offering a new perspective on the nature of light. This theory challenges the traditional concept of light wave coherence and suggests new directions for optics fields. Moreover, the pulse theory is consistent with how light propagates in three-dimensional space in nature, a concept that future studies could further verify and explain through three-dimensional modeling.

3. Conclusion

The “double-slit experiment” and the “observer effect” have been experimentally reevaluated, prompting a fundamental shift in understanding light behavior. This study demonstrates that the observed double-slit interference phenomenon arises from vertical wall diffraction, rather than wave interference. A simple triangular phase formula reveals that white light cannot sustain phase relationships, challenging traditional wave-based explanations. Building on this finding, we introduce the pulse wave theory of light, which posits that light superposition enhances energy rather than causing mutual cancellation. This perspective fundamentally redefines the traditional view of light wave interference, offering deeper insights into the nature of light and paving the way for innovative advancements in optics.

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Availability of data and materials

The datasets used or analysed during the current study are available from the corresponding author on reasonable request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Authors' contributions

NL, ZWL and TL proposed the idea, completed the theoretical analysis and prepared the manuscript. ZWL and TL performed the experiments. ZWL supervised the overall projects. All the authors analyzed the data and discussed the results. All the authors read and approved the final manuscript before submission.

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