

Non-Interference Pattern Evolving to Interference Pattern; Non-Diffraction Pattern Evolving to Diffraction Pattern; Two Non-Diffraction Patterns Evolving to Interference-Pattern-Embedded-in-Diffraction Patterns--- Wave-Wave Interference to Photon-Photon Interaction

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Abstract We experimentally show novel phenomena: (1) in the same double slit or cross double slit experiment, within macroscopic distances from diaphragm, the patterns are non-interference and gradually evolve to the interference patterns near/on the screen; (2) in the same single slit or cross single slit experiment, within macroscopic distances from diaphragm, the patterns are non-diffraction and gradually evolve to the diffraction patterns near/on the screen; (3) in the same non-parallel-two-slits experiment, within macroscopic distances from diaphragm, the patterns are non-diffraction and gradually evolve to the diffraction-interference-hybrid patterns; (4) the diffraction-interference-hybrid patterns depend on the angle between two slits. Those novel phenomena: (1) challenge the conventional light wave interpretations of the physical optics, the electromagnetic wave and the quantum probability waves, namely, those interpretations are incomplete; (2) challenging Bohr's complementarity principle and the wave-particle duality; (3) suggest that it is the photon-photon interaction, instead of the wave-wave interference, that produces the phenomena. To interpret consistently above phenomena is the challenge and demands new theory.

Keywords: double slit, cross-double slit, single slit, cross single slit, pattern evolution, interference pattern, non-interference pattern, diffraction pattern, non-diffraction pattern, interference-embedded-in-diffraction hybrid pattern

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1. Introduction

Let us briefly review the history of exploring the nature of the light.

*Light as Particles (1): Descartes

In 1637, R. Descartes stated that light was made of a large number of small discrete particles known as corpuscles. These corpuscles were elastic, rigid and weightless, and traveled in a straight line with a finite speed [1]. This understand of the light is really astonishing.

*Light as Waves (1): Huygens

In 1678, Huygens postulated that the light was made of waves [2]. Huygens' principle explains interference and diffraction of the light.

*Light as Particles (2): Newton

In 1704, Newton developed Descartes' corpuscular

theories to particle theory of the light [3]

*Light as Waves (2): Young, Fresnel, Arago

In 1801, Young [4] performed the double-slit experiment, which is considered to demonstrate that light could behave as waves. Arago observed the Poisson predicted spot [5]. Young's and Arago's experiments revived the Huygens' wave theory. The standard optical interpretation of the double slit experiments is that, *before and after passing through the double slit, the light propagates as waves and interferes after passing through the double slit.*

*Light as Wave (3): Maxwell

In 1865, Maxwell suggested that the light is EM waves [6].

*Light as Particle/quanta (3): Planck, Einstein

In 1886-1902, Hertz, Hallwachs and Lenard studied the photoelectric effect experimentally [7-9]. In 1900, Max Planck introduced the concept of quanta, which suggests that the energy carried by the EM waves could only be

released in discrete quanta [10]. In 1905, Albert Einstein, while working in Patent Office, which inspired him to think “new”, explained the photoelectric effect based on the hypothesis of light quanta [11]. This was a key step in developing quantum theory. To some extent, Descartes and Newton's corpuscular theory revived.

* Light as Wave and Particle (1): Wave-Particle Duality: Bohr

In 1927, Niels Bohr postulated that light has wave and particle complementary properties, which cannot both be observed or measured simultaneously [12].

*Mystery of Nature of Light: Einstein, Feynman

Until 1951, Einstein was still puzzled. He wrote to M. Besso: "All these 50 years of conscious brooding have brought me no nearer to the answer to the question: What are light quanta?" [13]. In 1956, Feynman stated that this wave-particle dual behavior contains the basic mystery of quantum mechanics [14].

* Light as Wave and Particle (2): Light as Photons and as Quantum Probability Waves: Glauber

Since 1963, Quantum optics started to establish [15], which studies the quantum interactions of light with matter.

In this article we experimentally study the nature of the light and show for the first time that, in the classical wave experiments, the non-wave patterns near the diaphragm evolve to the wave patterns near/on the screen, referred as Photowave phenomena. Namely, the light is photons, and it is the trajectories of photons that distribute as waves. Also, we show for the first time the hybrid pattern in two non-parallel slits experiments.

We suggest that the phenomena are attribute to photon-photon interaction, instead of wave-wave interferences.

2. Non-interference Pattern Evolving to Interference Pattern: Photon Chamber

We introduce four Zones and corresponding patterns: Particle pattern in Zone-1, Transition pattern in Zone-2, Interference pattern or Diffraction pattern in Zone-3.

2.1. Four Zones

Let us divide the space between the light source and screen into four Zones (Figure 2.1) [16]:

- (1) **Zone-0**: between the source and the double slit, in which the pattern is non-wave;
- (2) **Zone-1**: near the diaphragm, e.g., the double slit, in which the pattern is *non-interference*, referred the pattern as the **Particle pattern**;
- (3) **Zone-3**: near the screen, in which the patterns are **Interference patterns or Diffraction patterns**;
- (4) **Zone-2**: transition Zone, between Zone-1 and Zone-3, in which Particle pattern evolves to Interference pattern or Diffraction pattern, referred the patterns as the **Transition patterns** that are also the non-interference or non-diffraction.

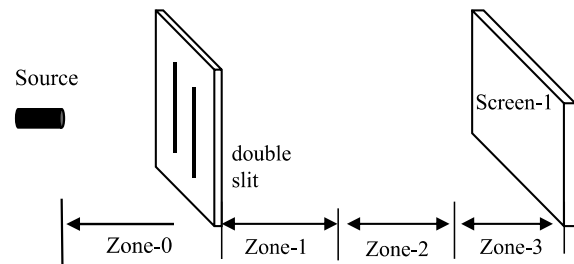


Figure 2.1. Four Zones

Note: there is no clearcut boundary between two adjacent Zones. The size of a Zone depends on the parameter of the double slit/cross double slit/single slit/cross single slit, such as the space between two slits of a double slit.

2.2. Definitions: Particle Patten, Transition Patten and Interference Pattern

Now let us define three kinds of patterns [16-19].

(1) Particle patten: in Zone-1 (Figure 2.2)

Top view (left) and cross section view (right).

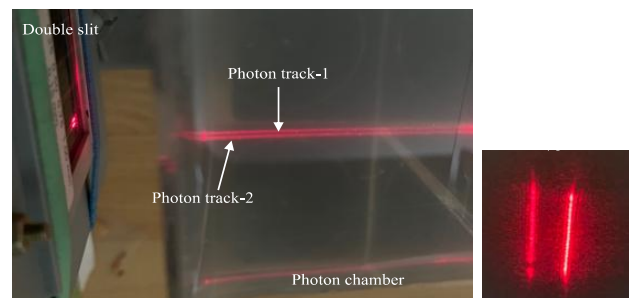


Figure 2.2. Zone-1: Photon Tracks and Particle patterns

When classical particles going through a double slit, they form the pattern that has exactly the same shape as photon track-1 and photon track-2 of Figure 2.2. Thus, we define the pattern of two photon tracks as “Particle pattern” (non-interference pattern) that indicates that the light is particles in Zone-1.

(2) Transition patten in Zone-2 (Figure 2.3):

Cross section view.

Transition patterns are the patterns that are between Particle patterns in Zone-1 and Interference patterns in Zone-3. When Particle patterns gradually transit to the Interference patterns, they are neither Particle patterns nor wave patterns and thus, we call them “Transition pattern”.



Figure 2.3. Transition pattern in Zone-2

Placing a lens in Zone-2, we have Transition pattern e.g., that of Figure 2.3. Transition pattern indicates that the light behaves not as wave in Zone-2.

(3) **Interference pattern** in Zone-3 (Figure 2.4):
Cross section view

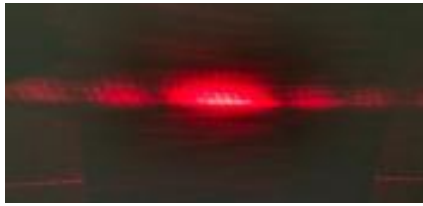


Figure 2.4. Interference pattern in Zone-3

Note: Patterns in one Zone gradually evolve to the patterns in adjacent Zone.

2.3. Photon chamber

The photon chamber consists of a transparent container filled with the mixture of water and fine powder. The photon chamber [17], functioning as a photon-detector for visualizing the photons passing through the chamber, can be applied in the double slit, the cross double slit, 1D-grating, 2D-grating, single slit and cross single slit experiments to exam whether the light beam behave as particles (photons) in those experiments. To study the double slit experiments with the photon chamber, we introduced a definition and a hypothesis (Figure 2.5).

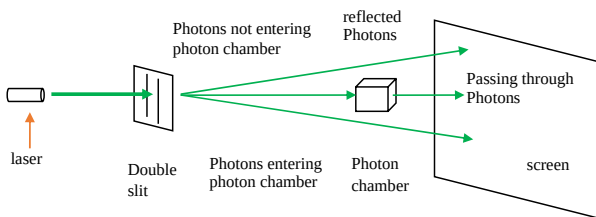


Figure 2.5. Experiments with photons chamber

***) Definition:** Group of light.

The all of the light passing through the double slit is defined as “Full Group”. The light landing on the same fringe-X is defined as the group-x. For example, the light forming the fringe $m = 0$ is defined as the group-0; the light forming the fringe $m = -1$ is defined as the group-(-1). The Full Group contains the light of all group-x and the light reflected by Photon chamber.

***) Hypothesis:** Photons in Full Group have samenature (Figure 2.5).

The light of Full Group contains the part-1 light and the part-2 light. The part-2 contains the light directly landing on the screen without passing through the photon chamber. The part-1 light enter the photon chamber, in which, the part of the light is reflected by the particles of the powder, while the remaining light passes through the photon chamber and forms the interference pattern on the screen.

The tracks of these reflected light are visible, which indicating that, before landing on the screen/detector, the light behaves as particles, photons.

Hypothesis states that all light, the part-1 light and the part-2 light, have the same nature; the reflected light and the passing through light of the part-1 light have the same nature.

The light reflected by the powder in the photon chamber and the remaining light passing through the photon chamber and forming the interference fringes on the screen, have the same nature. Namely, since the reflected light showing the particle nature, thus the remaining light of the part-1 landing on the screen and forming the fringes have the same particle nature. Thus, the part-2 of the light, as the part-1 of the light, have the same particle nature.

The photon chamber can be utilized to study the mystery of the double slit experiments, the nature of light in the classical wave experiments, wave-particle duality and complementarity principle.

In those experiments we observed both the particle nature and the wave-like distribution of the photons simultaneously in the same experiment. The experimental results are visually observable without ambiguity.

Now let us apply the photon chamber in the double slit experiments.

2.4. Experiments with Photon Chamber

2.4.1. Photon Chamber in Zone-0

Experiment-2.1: Light is particles.

Experimental setup: Figure 2.6(a) shows the schematic of the experiment. Figure 2.6(b) shows the observation.

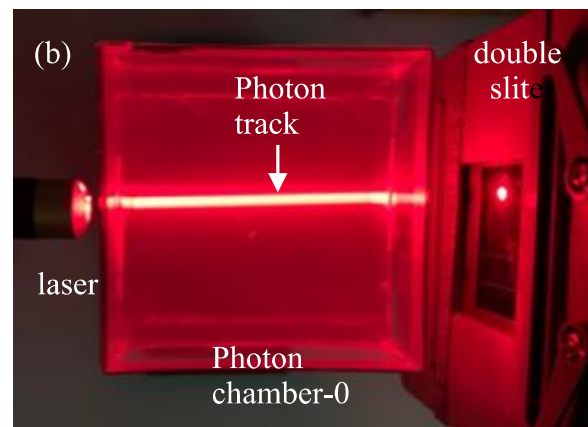
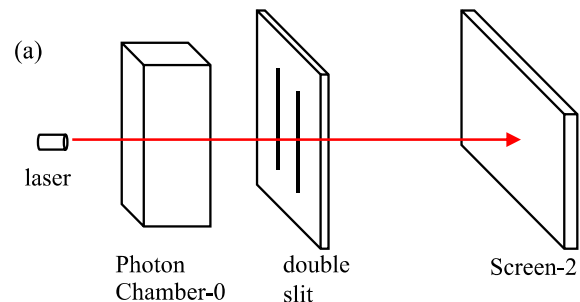


Figure 2.6. Experimental setup and observation

Observation (Figure 2.6(b)): the photon track shows up in the photon chamber-0, which indicates that the light in Zone-0, i.e., before passing through the double slit, is particles, photons.

This observation disagrees with the standard optical interpretation of the double slit experiment.

2.4.2. Photon Chamber in Zone-1: Light is Particles

Experiment-2.2: show that the light in Zone-1 is particles *after* passing through the double slit.

Experimental setup: Figure 2.7 shows the schematic of the experiment.

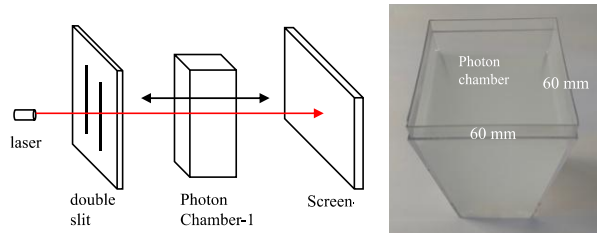


Figure 2.7. Experimental setup: photon chamber in Zone-1

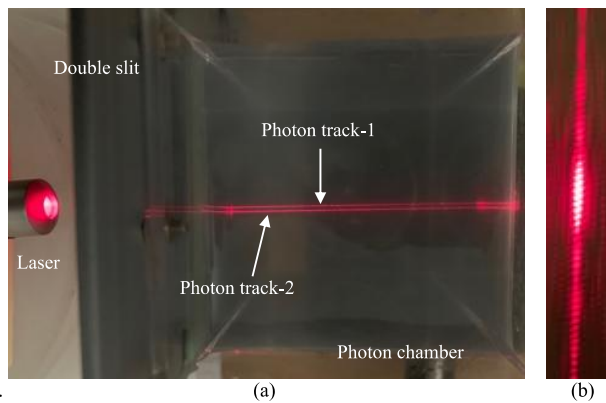


Figure 2.8. Photon Tracks: Photon Chamber in Zone-1

Observation (Figure 2.8): We observed Particle pattern, the photon track-1 and photon track-2, in the photon chamber of 60x60mm, which indicates that from the double slit to 60 mm, the light is photons, propagating along the straight-line trajectories, and the trajectories do not distribute as waves.

Two photon tracks represent two primary maximum fringes that are the non-interference patterns. While on the screen, we observe the standard interference pattern simultaneously (Figure 2.8b).

Therefore, the existing theories cannot describe the behavior of the light as photons in Zone-1.

Compare: Experiment-2.2 (Figure 2.9) with the standard interpretation of the double slit experiment (Figure 2.10).

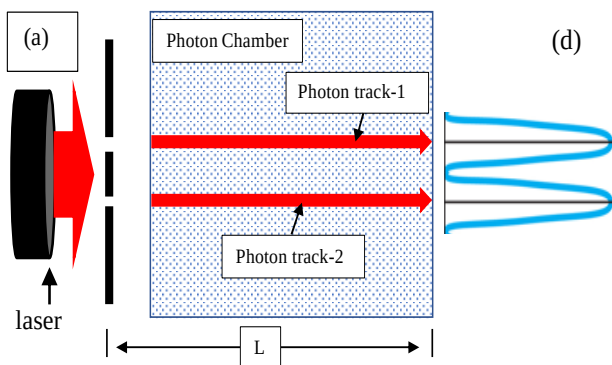


Figure 2.9. Particle pattern of two maximum intensities of double slit

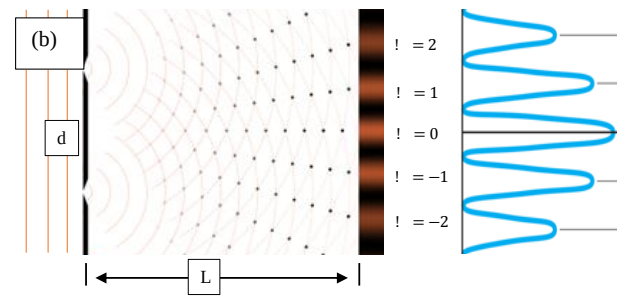


Figure 2.10. Classical interpretation of interference pattern of double slit experiment with one maximum intensity

Conclusion: The experiments show, for the first time, that, up to certain macroscopic distance from the double slit: (1) Particle patterns showing that the light is photons propagating along the straight-line trajectories (Figure 2.8a); (2) the photons' trajectories *do not distribute as waves*; (3) the wave interpretations are incomplete, namely the existing theories are not suitable for describing Particle patterns in the double slit experiment.

2.4.3 Photon Chamber in Zone-3: Interference Pattern

Experiment-2.3 (Figure 2.11): Light is particle in Zone-3.

Experimental setup: Figure 2.11 shows the schematic of the experiment. The photon chamber may be placed at any position in Zone-3.

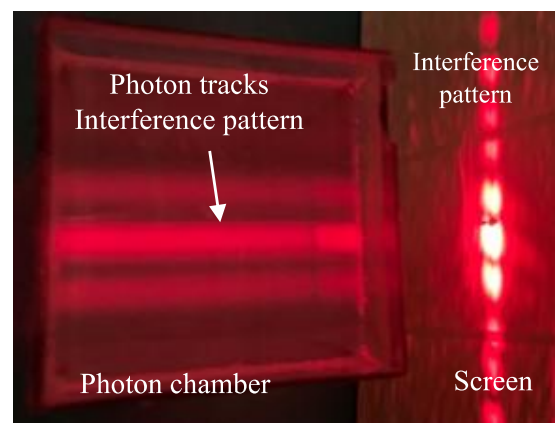
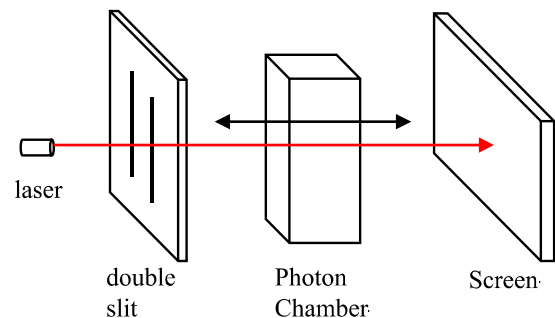


Figure 2.11. Photon Tracks: Photon Chamber in Zone-3

Observation (Figure 2.11): Photon tracks show that the light is particles in Zone-3, *after passing through double slit*. Photon chamber shows the top view of the photon tracks, the photon trajectories, distributing as Interference pattern.

Conclusion: The light beam is photons, not waves. And it is the photons' trajectories that distribute as Interference pattern, which is a challenge to explain.

2.4.4. Photon Chamber in Zone-2: Transition pattern

Experiment-2.4 (Figure 2.12): Light behaves as particle.

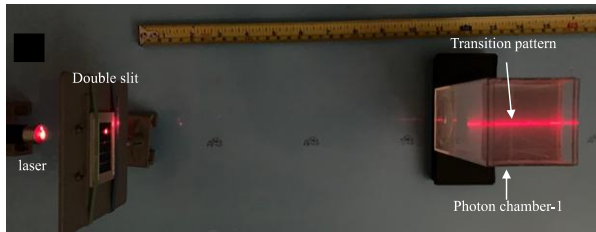


Figure 2.12. light behaving as particles in Zone-2

Observation: Figure 2.12 shows the top view of photon track, referred as the *Transition pattern* in photon chamber-1 placed in Zone-2.

Conclusion: the light behaving as particles in Zone-2, after passing through double slit. The photon chamber may be placed at any position in Zone-2.

2.4.5. Photon Chamber in Zone-1, Zone-2, Zone-3

Experiment-2.5 (Figure 2.13 and Figure 2.14):

Experimental setup (Figure 2.13). Photon chamber-1, Photon chamber-2 and Photon chamber-3, the dimensions of three photon chambers are 50x50 mm, are placed in Zone-1, Zone-2 and Zone-3 respectively.

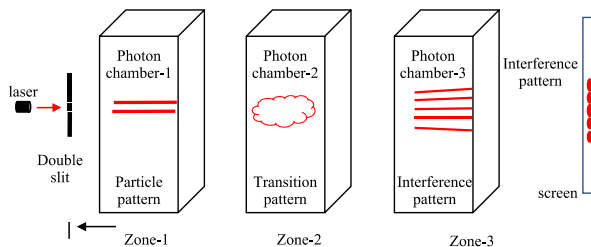


Figure 2.13. Schematic of Experimental setup

Observation (Figure 2.14): Particle pattern, Transition pattern and Interference pattern show in Photon chamber-1, Photon chamber-2 and Photon chamber-3 respectively. The interference pattern also shows on the screen.

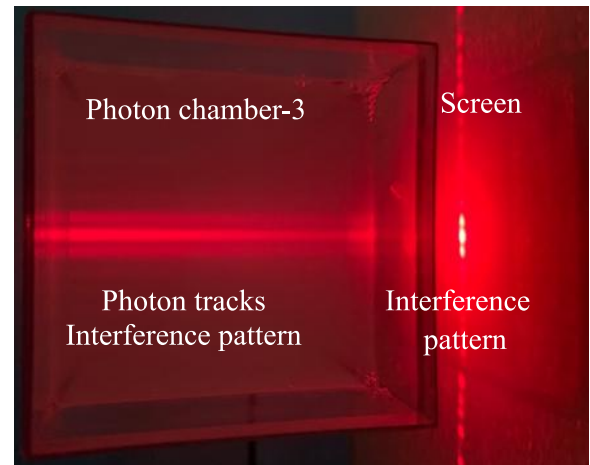
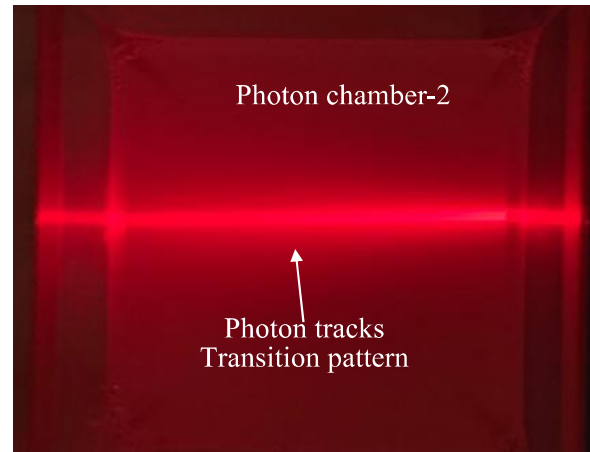
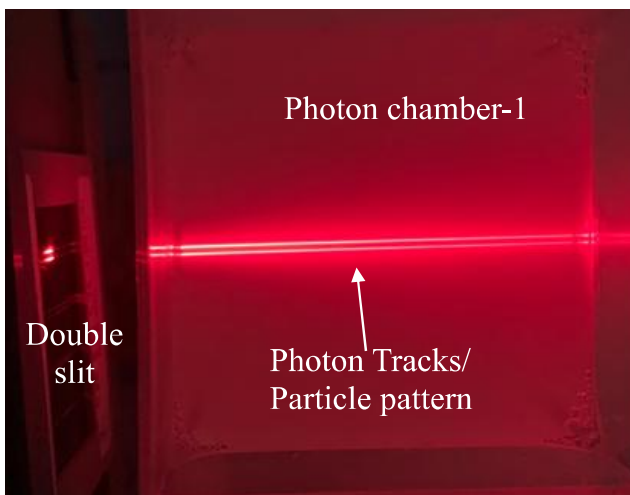


Figure 2.14. Particle pattern, Transition pattern and Interference pattern

Conclusion: (1) Particle pattern in Zone-1, evolves to Transition pattern in Zone-2, to Interference pattern in Zone-3; (2) the light is photons in three Zones, i.e., between the double slit and the screen; (3) the photon trajectories in Zone-3 distribute as wave; (4) the light as photons land on the screen with wave pattern.

The phenomena of Experiment-2.1 to experiment-2.5 are consistent. With the photon chamber, the double slit experiments show the coexistence of the particle nature and the wave distribution of the photons in the same experiments simultaneously. The existing theories cannot interpret the phenomena consistently and completely.

A consistent theory should be able to interpret the phenomena completely.

2.5. Summary

In Section 2 we propose Photon chamber to detect the traces of the light beam in the known as wave experiments, namely to visualize the passage of light beam. The experiments show that the light beam is photons moving through Photon chamber. It is the trajectory of the photons that distributes waves. The phenomena reject the conventional viewpoint of the light in wave experiment

According to the wave-particle duality, the light may be described as either particles (as photons in photoelectric effect) or waves (as optical waves, the EM waves and probability waves in all wave experiments). Bohr's complementarity principle (the One of the milestones of

quantum mechanics) states that a single quantum can exhibit a particle-like or a wave-like behavior, but never be both at the same time. These are mutually exclusive and complementary aspects of the quantum system.

However, the Photon chamber experiments show that light is particles, while distribute as wave, simultaneously in the same wave experiment and thus, challenge the wave-particle duality and the complementarity principle.

With the photon chamber, “these rather ancient experiments continue to surprise. Something more to ponder” (Ian Miller). “The double slit experiments have much to offer” (Vivien Pinner).

To study the detail of the pattern evolution, Photon chamber is not sufficient. We will use the convex lens to continuously study the pattern evolution in Section 3.

3. Non-Interference Patterns Evolving to Interference Patterns: Convex Lens

To study the evolution of the patterns between different Zones, we utilized the convex lens for the first time to study the pattern evolution by the cross-section views of the patterns [20].

3.1. Postulations of Convex Lens Utilized in Wave Experiments

In standard Textbook, the geometric optical theory of the convex lens is directly applied to the wave experiments. In the classical wave experiments, the diaphragm and screen stay at the same location. The light coming out the slits produces the certain pattern on the screen. But we have shown that the pattern changes with the distance from the diaphragm (Section 2), i.e., the pattern evolves.

Based on above consideration, for utilizing a convex lens to study the evolution of patterns, we propose new Postulates of convex lens [20].

Postulates:

First Postulate: the convex lens enlarges the input image that arrives at the input surface (Figure 3.1).

Second Postulate: The convex lens does not change the nature and characteristics of the input pattern.

Third Postulate: The convex lens breaks/stops the evolution of the patterns when the light entering the input surface.

Example-1 Testing First Postulate (Figure 3.1): For a regular object, the shape of the image of the object does not change. Thus, the input image that arrives at the input surface of the convex lens is the same image of the object. The image of an object is not the distance dependent.

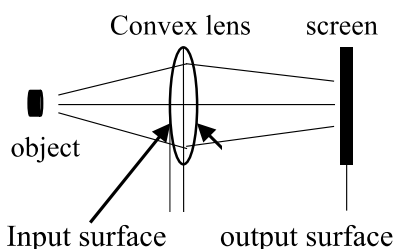


Figure 3.1. Convex lens enlarges object: “input surface”

Example-2 Testing First Postulate (Figure 3.2a):

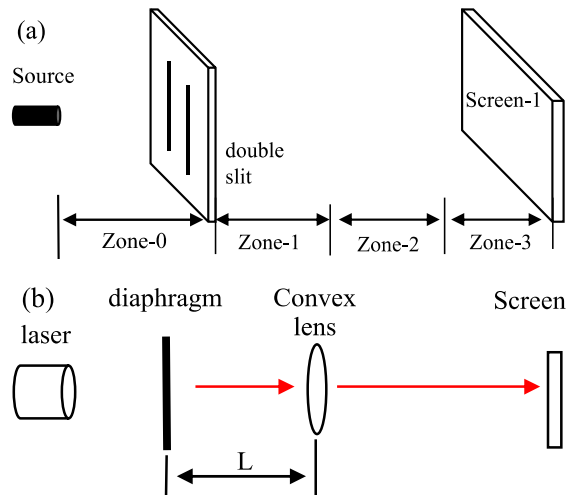


Figure 3.2. Convex lens in double slit experiment: “input surface”

For the wave experiments, as shown in Section 2, the nature and shape of patterns depend on the distance between the double slit and the screen (Figure 3.2a).

To study the evolution of the patterns of the wave experiments, the lens moves between the diaphragm and the screen (Figure 3.2b). Thus, the input image that arrives at the input surface of the convex lens is the pattern that is distance-dependent and thus, the shapes of the input images are different, even in the same experiment.

Examples testing Second Postulate: After passing through a lens, the pattern keeps the same nature: e.g.,

- (a) if the input patten is Particle pattern, the output pattern is still Particle pattern, and vice versa;
- (b) if the input patten is Transition pattern, the output pattern is still Transition pattern, and vice versa;
- (c) if the input patten is Interference pattern, the output pattern is still Interference pattern, and vice versa.

Example testing Third Postulate: as a consequence of Second Postulate, the input image and the output image of the convex lens are the same, and the output image keep the same nature and characteristics of the pattern as that of the input image; namely the evolution is stopped.

Note: the boundaries between Zone-1 and Zone-2, and between Zone-2 and Zone-3 are not clear cut. Patterns in one Zone gradually transform to the patterns in next Zone.

Experiments in Section-3 and Section-4 utilizing the convex lens are based on three Postulates and confirm them.

3.2. Non-Interference Pattern Evolving to Interference Pattern

Figure 3.2b also shows Experimental setup, which is for all of experiments in Section 3.2 and Section 3.3.

3.2.1. Double Slit Experiment

We have shown the different patterns in different Zones in the standard double slit experiment by the photon chamber in Section 2. Now let us show the evolution by utilizing convex lens.

Experiment-3.1 (Figure 3.3 to Figure 3.5)

Experimental setup: To take a clear picture, we insert a lens to enlarge the image (Figure 3.2 and Figure 3.4).



Figure 3.3. Double slit and interference pattern: no lens



Figure 3.4. Experiment: $L = 100$ mm

Placing the lens at different distance L (in “mm”) from the diaphragm, we observe the cross-section view of the pattern evolution of double slit experiment (Figure 3.5).

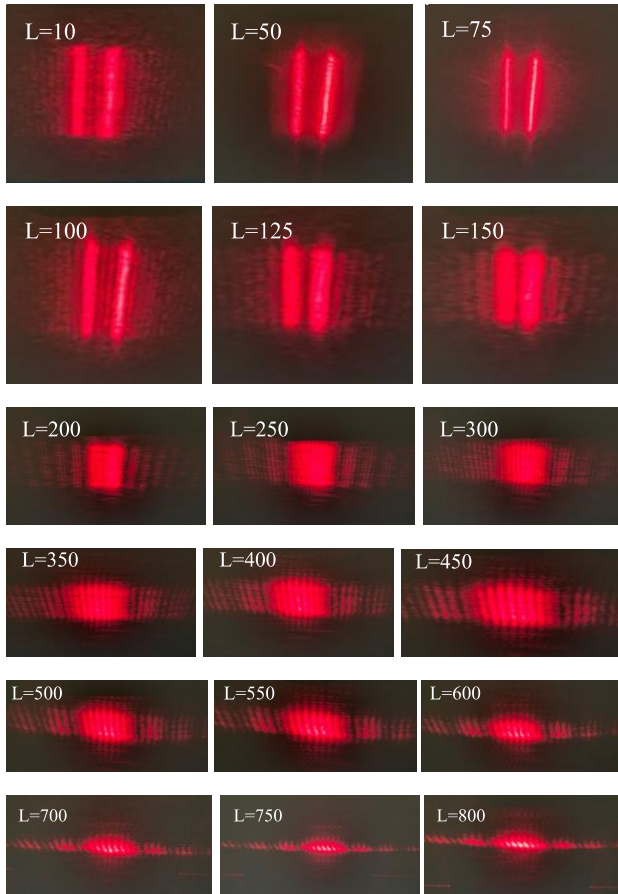


Figure 3.5. Pattern evolution of double slit experiment

Observation (Figure 3.5): at $L = 10 - 100$ mm, the patterns are Particle patterns, which are the non-interference patterns. When $L = 50 - 75$ mm, the Particle patterns are the typical image of double-slit. When $L = 150 - 450$ mm, we referred the patterns as Transition patterns. When $L \geq 600$ mm, the patterns are the interference patterns.

Note: The **vertical** Particle patterns gradually evolve to the **orthogonal** interference patterns.

Discussion: Particle pattern evolving to **orthogonal** Interference pattern (Figure 3.6)

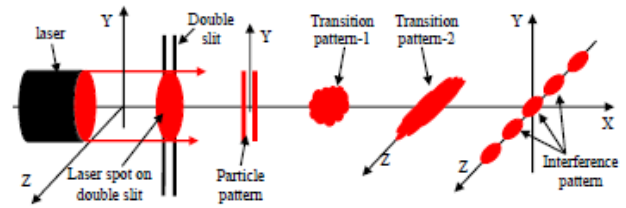


Figure 3.6. Vertical Particle patterns evolving to orthogonal interference pattern

- 1) The double slit is in Y-Z plane and along Y axis
- 2) Particle pattern is in Y-Z plane and along Y axis, which has the same length in Y direction as that of the laser spot on the double slit
- 3) Transition pattern-1 is in Y-Z plane, which has the similar dimensions in both Y and Z directions.
- 4) Transition pattern-2 is in Y-Z plane: in Y direction, the dimension of Transition pattern-2 shrinking, while in Z direction, the dimension of Transition pattern-2 expanding
- 5) Interference pattern is in Z-direction.

In addition to the Feynman’s mystery of the double slit experiment, the new mysteries are:

- (1) Particle pattern (the non-interference pattern) gradually evolving to the interference pattern;
- (2) the Particle pattern along Y direction evolving to the Interference pattern along Z direction.

The challenge is to consistently interpret the new mysteries.

3.2.2. Cross double slit experiment (1)

The double slit has basically one type. The cross double slit has much more varieties than the double slit [21].

Experiment-3.2: Two double slits crossing at right angle

Figure 3.7 shows the cross double slit and its cross-interference pattern without utilizing lens.

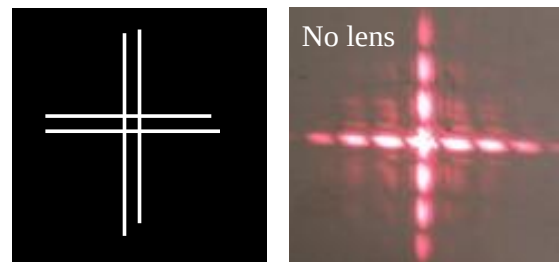
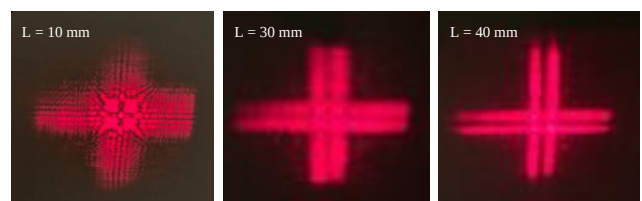


Figure 3.7. Cross double slit pattern

Placing the lens at different distance L . We observe the evolution of the patterns (Figure 3.8).



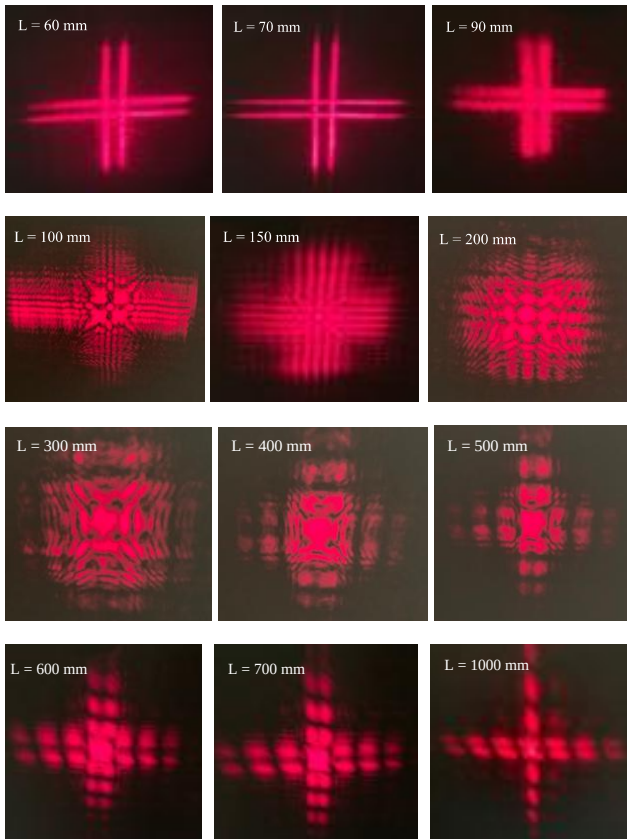


Figure 3.8. Pre-Particle pattern evolving to Interference pattern

Observation (Figure 3.8): at $L = 10$ mm, the pattern is typical Pre-Particle patterns; at $L = 70$ mm, the pattern is typical Particle pattern; at $L \geq 100$ mm, referred the patterns as Transition patterns; finally, patterns evolve to the interference pattern at $L = 1000$ mm.

Note: from $L = 10$ mm to $L = 30$ mm, the patterns are not like Particle patterns at $L = 70$ mm. We refer those patterns as Pre-Particle patterns

The double slit-AB and double slit-CD are in different orientations, so there is Pre-Particle pattern.

Discussion-1 (Figure 3.9):

Let us enlarge the intersection of double-slit-AB and double-slit-CD, as shown in Figure 3.9. The intersection has the shape of square. Four small dots, denoted as “a/c”, “b/c”, “b/d” and “a/d”, represent the four outer corners of the intersection. Except the double-slit-AB and double-slit-CD, all of other area (including the shadow square) is the opaque area. The intersection of slit-A and slit-C is denoted by a “Red square”.

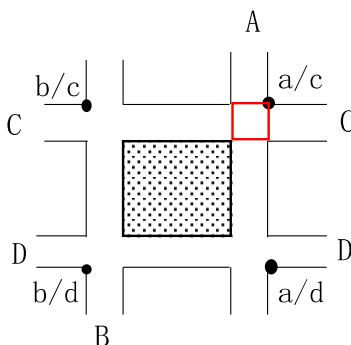


Figure 3.9. Center of Double slit-AB crossing double slit-CD

The spot of the laser beam is a circular with a diameter larger than the dimension of the intersection area. The majority of photons will land on the opaque area, while minority of photons will pass through both double-slit-AB and double-slit-CD.

According to the regular interpretation of 1D-double-slit experiment, photons passing through the slit-A (slit-B) will interfere with photons passing through the slit-B (slit-A), while photons passing through the slit-C (slit-D) will interfere with photons passing through the slit-D (slit-C).

Since emitted photons have the same optical parameters, the challenge to the standard interpretation of 1D-double-slit experiments is to explain the phenomena:

- (1) photons passing through the slit-A (slit-B) interfere with both photons passing through the slit-B (slit-A), and photons passing through the slit-C and slit-D. Similarly, photons passing through the slit-C (slit-D) interfere with both photons passing through the slit-D (slit-C), and photons passing through the slit-A and slit-B.
- (2) When the photons pass through the “Red square”, there are two questions:
 - (2-1): how the photons determine whether they are passing through slit A or slit C?
 - (2-2): how the photons determine which photons they should interfere with, the photons passing through slit-B or the photons passing through slit-D?
 - (2-3): whether the photons passing through the “Red square” would interfere with each other?

If one treats photon as a “person” as in the interpretation of delayed-choice-double-slit experiment, then the challenges are to explain the following questions:

- (1) How do photons “sense” which slit they would pass through;
- (2) how do the photons passing through a slit “find” photons passing through its “paired slit” to interfere and create the interference-pattern accordingly.

Discussion-2: About the interpretation of the behavior of photons emitted one at a time:

- (1) a photon needs to play as “four photons” simultaneously passing through the slit-A, slit-B, slit-C, and slit-D respectively.
- (2) how does the photon passing through the slit-A interfere with itself passing through the paired slit-B, but not with itself passing through the slit-C or slit-D, to create an interference pattern.

According to the standard wave interpretation, in regular 1D-double-slit experiments, the interfering waves are in the same plane; on the other hand, in 2D-cross-double-slit experiment the interfering waves are in two perpendicular planes. The regular interpretation seems impossible to explain how a photon travels through both the double-slit-AB and the double-slit-CD at the same time and somehow interferes with itself accordingly.

It is a challenge to interpret how a photon “sense”:

- (1) which slit it passes through;
- (2) which photons it will interfere with, then to create the patterns accordingly.

The above discussions may be applied to all of the cross-double slit experiments.

3.2.3. Cross Double Slit Experiment (2)

Experiment-3.3: Tilt cross double slit experiment.

Figure 3.10 shows the cross double slit and its pattern without lens.

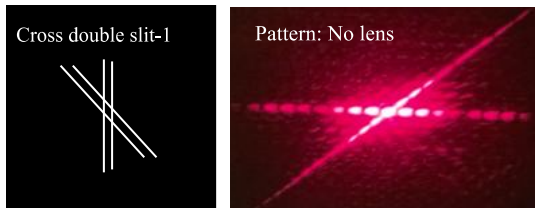


Figure 3.10. Cross double slits and its interference pattern: no lens
Figure 3.11 shows the pattern evolution with lens.

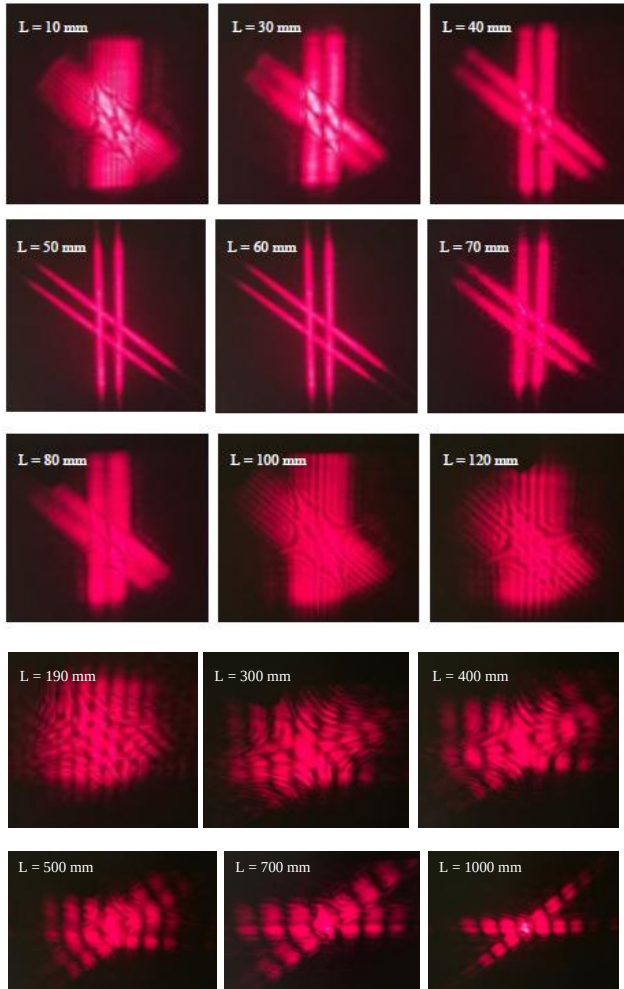


Figure 3.11. Evolution of patterns of tilt cross double slit

Observation: Figure 3.11 shows the evolution of the patterns. At $L = 10-30$ mm, showing Pre-Particle pattern; at $L = 50$ mm, is the typical image of the tilt cross double-slit, which is the non-interference patterns; at $L = 80 - 500$ mm, we referred the patterns as Transition patterns.

Pre-Particle patterns gradually evolve to the orthogonal interference patterns at $L \geq 700$ mm.

3.2.4. Cross Double Slit Experiment (3)

Experiment-3.4: Multi-Cross Double slit experiment: Figure 3.12 shows the cross double slit and its pattern.

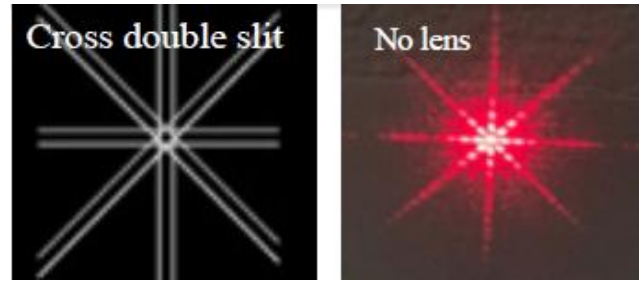


Figure 3.12. Cross double slits and pattern without lens

Figure 3.13 shows the evolution of the patterns

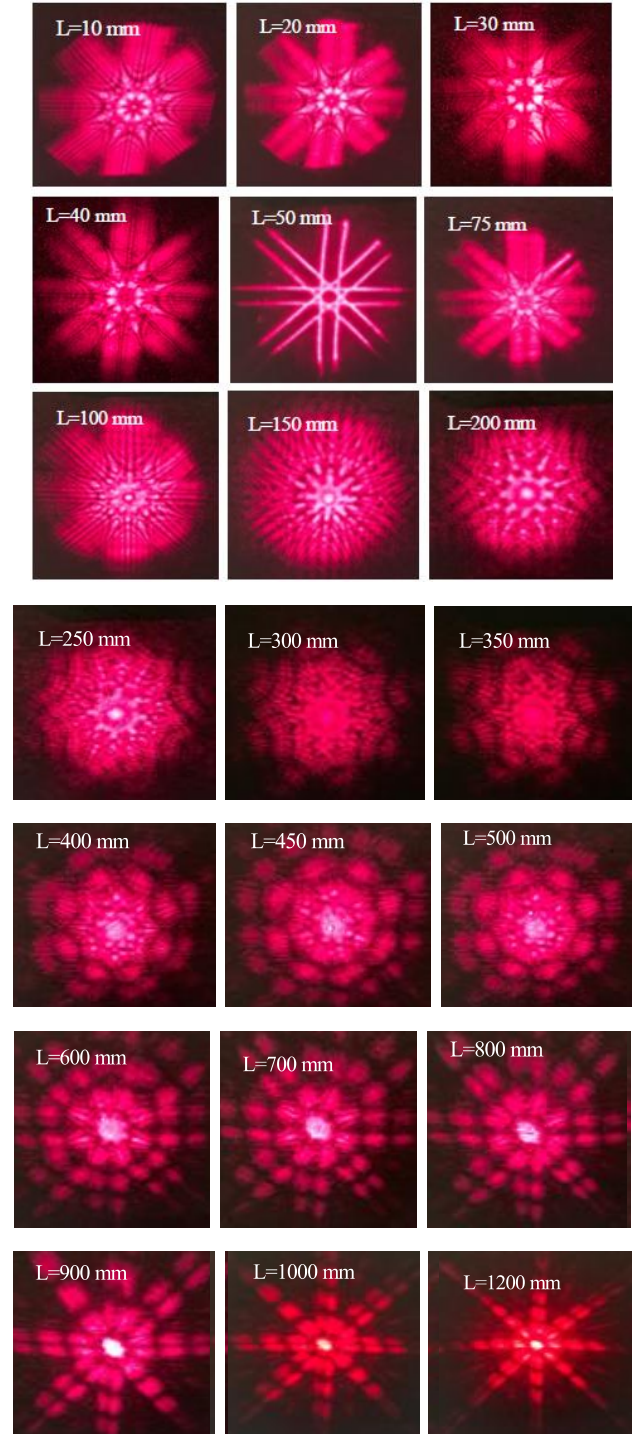


Figure 3.13. Evolution of patterns of multi cross double slit experiment

Observation: from $L = 10$ mm to $L = 40$ mm, the patterns are Pre-Particle patterns; at $L=50$ mm, the pattern is the typical particle pattern, the image of the diaphragm. The Pre-Particle patterns gradually evolve to Transition patterns and to Interference patterns at $L \geq 1200$ mm.

3.2.5. Disc Ring Experiment

Experiment-3.5: Disc-Ring experiment:

Figure 3.14 shows the Disc ring and pattern without lens.

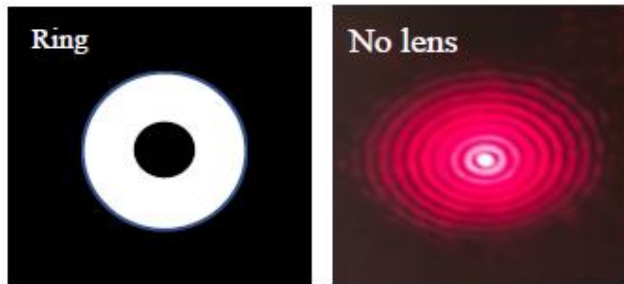


Figure 3.14. Disc ring and its pattern

Figure 3.15 shows the evolution of the patterns

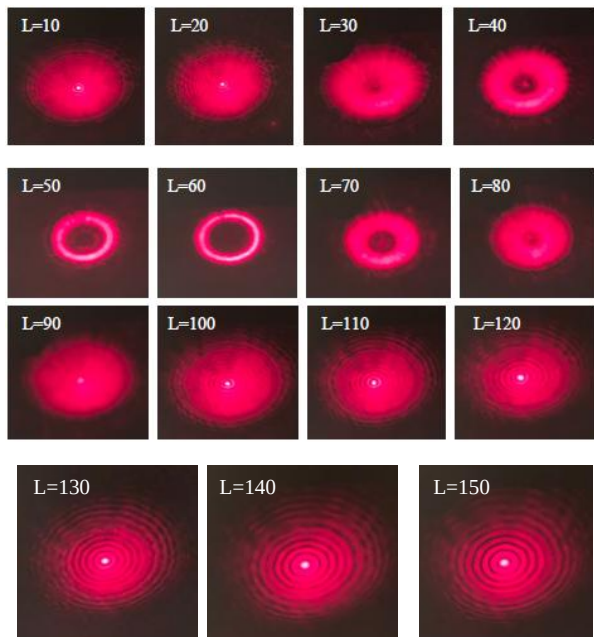


Figure 3.15. Evolution of patterns of disc ring experiment

Observation: from $L = 10$ mm to $L = 40$ mm, the patterns are Pre-Particle patterns; at $L= 60$ mm, the pattern is the typical Particle pattern that is the image of the diaphragm of the disc ring; then the pattern gradually evolves to the interference pattern at $L = 150$ mm.

3.2.6. 1D Grating Experiment

Experiment-3.6: 1D grating experiment:

Figure 3.16 shows the 1D grating and its pattern



Figure 3.16. 1D grating and pattern

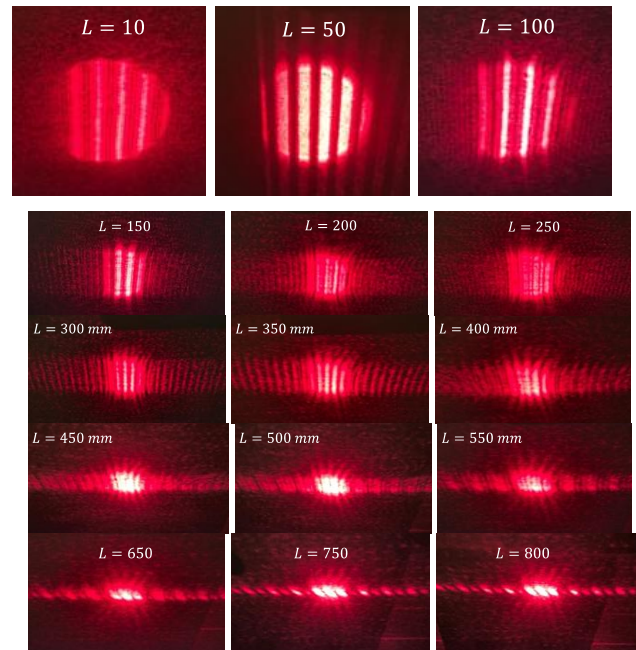


Figure 3.17. Evolution of patterns of 1D grating experiment

Observation: At $L = 50$ mm, the pattern is the typical Particle pattern, the non-interference patter. Then, when $L \geq 150$ mm, the pattern gradually evolves to the interference pattern.

Note: approximately, at $L = 10$ mm, the pattern is Particle patterns. There is no Pre-Particle pattern. Since all slits are in the same direction.

3.2.7. 2D grating experiment

Experiment-3.7: 2D grating experiment:

Figure 3.18 shows the 2D grating and pattern (no lens)

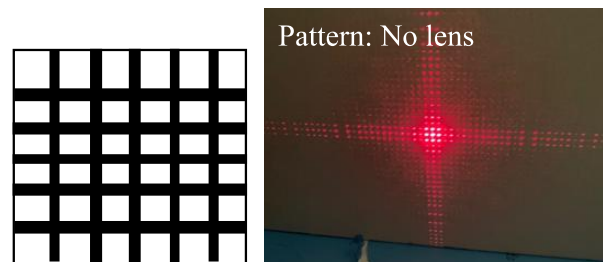
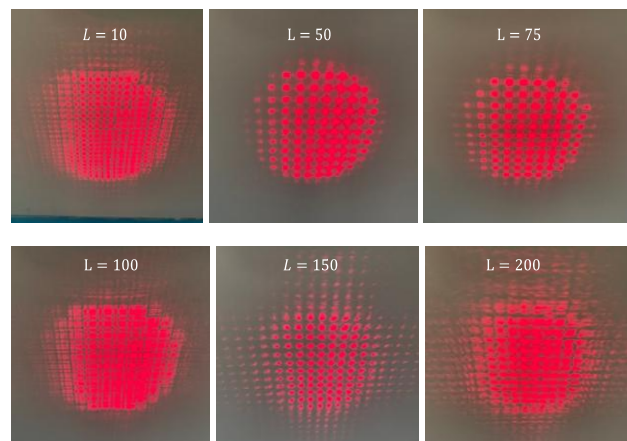


Figure 3.18. 2D grating and pattern (no lens)

Figure 3.19 shows the pattern evolution.



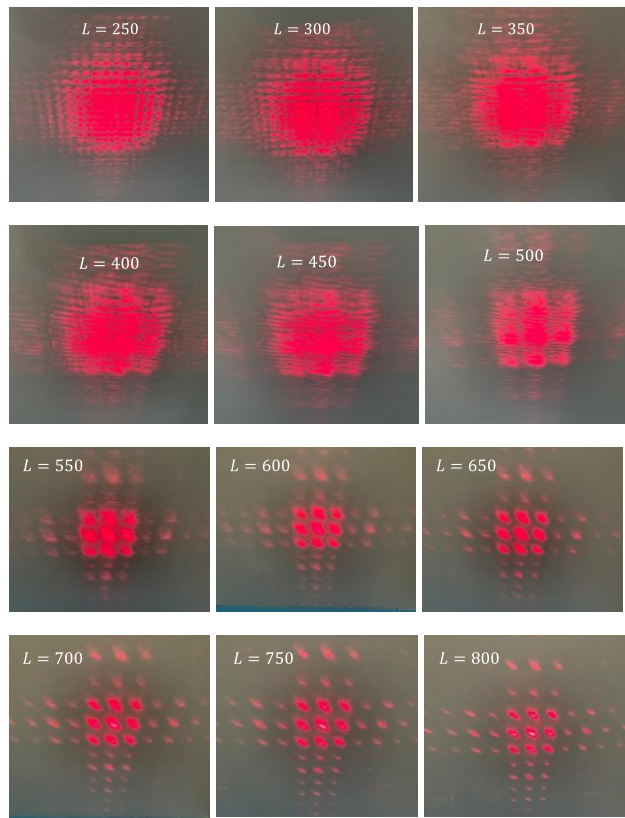


Figure 3.19. Evolution of patterns of 2D grating experiment

Observation: Figure 3.19 shows the pattern evolution. At $L = 10$ mm, the pattern is Pre-Particle patterns; at $L = 50$ mm the pattern is the typical Particle pattern; at $L = 100$ to 550 mm the patterns are the Transition pattern. At $L \geq 150$ mm, the pattern gradually evolves to the interference pattern at $L = 800$ mm.

3.3. Interaction Between Photons: Patterns Superposition

The standard interpretation of the double slit experiment is that

“After passing two slits, two light waves interfere. This interfere causes the interference pattern on the screen”.

Taking into account the fact that it is photons passing through the slits as shown in Experiments-3.1 to Experiment-3.7, we suggest that:

“After passing two or multi-slits or crossing slits, two or more beams of photons interact. It is this Photon-Photon interaction that causes the non-interference and interference patterns on the screen”.

The “wave-wave interfere” is the term in physical optics, now we suggest the “Photon-Photon interaction”, which corresponds to the “Interference” of the optical terms.

To test the “Photon-photon interaction” suggestion, see Table 3.1 and Table 3.2.

3.3.1. Test-1: Two Slits Forming A Double Slit

Let us consider the situation that two slits form a double slit,

Table 3.1. Patterns evolution of two slits forming a double slit

L: mm	Single slit-1 (SS1): pattern-1 (P1)	Single slit-2 (SS2): pattern-2 (P2)	Double slit (DS): pattern-3 (P3)	
				SS1+SS2 = DS
10				P1+P2 = P3
50				P1+P2 = P3
100				
150				P1+P2 ≠ P3
300				P1+P2 ≠ P3
450				P1+P2 ≠ P3
650				P1+P2 ≠ P3
1100/1000				P1+P2 ≠ P3

Above patterns show:

- (1) Photons pass through the single slit-1 (SS-1) produce the pattern-1 (P1); Photons pass through the single slit-2 (SS-2) produce the pattern-2 (P2); Photons pass through the double slit (DS) produce the pattern-3 (P3).
- (2) $L = 10 - 100$ mm: At the macroscopic distance “L”, $10 - 100$ mm, SS-1, SS-2 and DS produce Particle patterns P1, P2 and P3 respectively; P3 is the combination of P1 and P2.
- (3) $L = 150 - 650$ mm: we observe Transition patterns, P1, P2, and P3, respectively; P3 is NOT the combination P1 and P2. We suggest that Transition patterns P1, P2 and P3 are produced attributing to the **interactions between photons**.
- (4) $L \geq 1000/1100$ mm: we observe the Diffraction patterns, P1 and P2, and the Interference pattern P3, respectively; P3 is NOT the combination P1 and P2.
- (5) New Mystery: Particle patterns evolving to orthogonal diffraction/interference patterns.

- (6) The pattern evolution cannot be interpreted by wave theories and thus, we suggest that the patterns, P1, P2 and P3, are produced attributing to both *the interactions between photons and SS-1, SS-2 and DS respectively, and the interaction between photons, i.e., Photon-Photon interaction.*

3.3.2. Test-2: Two Double Slits Forming Cross-double Slit

Let us consider the situation that two double slits form a cross double slit,

Table 3.2. Patterns evolution of two double slits forming a cross double slit

L: mm	Double slit-1 (DS1) pattern-1 (P1)	Double slit-2 (DS2) pattern-2 (P2)	Cross Double slit (CDS) pattern-3 (P3)	
				$P1+P2 = P3$
10				$P1+P2 \neq P3$
50/70				$P1+P2 = P3$
100				$P1+P2 \neq P3$
150				$P1+P2 \neq P3$
200				$P1+P2 \neq P3$
300				$P1+P2 \neq P3$
450/400				$P1+P2 \neq P3$
650/600				$P1+P2 \neq P3$
1100/1000				$P1+P2 = P3$

We suggest that the patterns, P3 are produced attributing to both interactions between photons and DS-1, DS-2 and CDS respectively, and the interaction between photons especially for Pre-Particle pattern at $L = 10$ mm and for Transition pattern at $L = 100$ to $L=650$ mm.

3.4. Non-Interference Pattern and Interference Pattern Simultaneously Emerging on Screen

Experiment-3.8 (Figure 3.20 to 3.28): five steps

First step (Figure 3.20 to 3.21):

Experimental setup-1: Figure 3.20. Beam Splitter = BS.

The laser light propagates along three paths and produces three interference patterns at three locations, D-1, D-2 and D-3, on the screen.

Path-1: laser/diaphragm/BS-2/BS-1/D-1;

Path-2: laser/diaphragm/BS-2/mirror-2/D-2;

Path-3: laser/diaphragm/BS-2/BS-1/mirror-3/D-3.

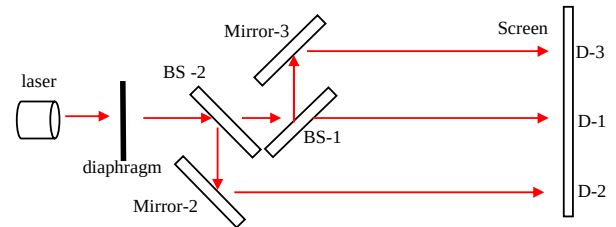


Figure 3.20. Experimental setup: first step

Observation (Figure 3.21): three standard interference patterns of the same double slit are shown at D-1, D-2 and D-3 respectively.

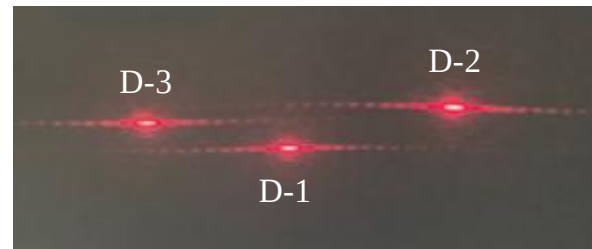


Figure 3.21. Three interference patterns

Discussion: the first step of Experiment-3.8 shows that BS-1, BS-2, Mirror-2 and Mirror-3 have no effect on the interference patterns. The first step of Experiment-3.8 can be described by wave optics.

Second step (Figure 3.22 to 3.23):

Experimental setup-2 (Figure 3.22): with three lenses, three paths are:

Path-1: laser/diaphragm/BS-2/BS-1/lens-1/D-1;

Path-2: laser/diaphragm/BS-2/mirror-2/lens-2/D-2;

Path-3: laser/diaphragm/BS-2/BS-1/mirror-3/lens-3/D-3;

Note that each Path is divided to Zone-1, Zone-2 and Zone-3 independently:

Path-1 is divided into Zone-1/Path-1, Zone-2/Path-1 and Zone-3/Path-1;

Path-2 is divided into Zone-1/Path-2, Zone-2/Path-2 and Zone-3/Path-2;

Path-3 is divided into Zone-1/Path-3, Zone-2/Path-3 and Zone-3/Path-3;

Path-3 is divided into Zone-1/Path-3, Zone-2/Path-3 and Zone-3/Path-3;

Zone-3/Path-3.

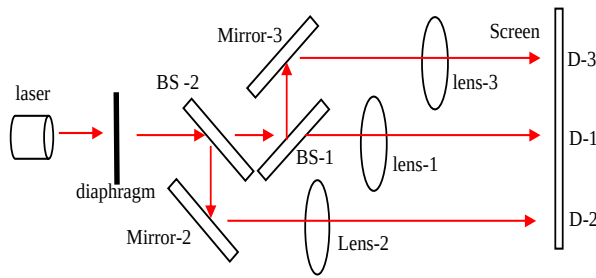


Figure 3.22. Experimental setup: second step

When lens-1 is placed in Zone-1/Path-1, Zone-2/Path-1 and Zone-3/Path-1 respectively, it will create Particle pattern, Transition pattern, and Interference pattern respectively. The same for lens-2 and lens-3. The laser light respectively propagates along three paths and produces three patterns emerging at three locations, D-1, D-2 and D-3, on the screen.

For convenience and without losing generality, we place lens-1 in Zone-1/Path-1, lens-2 in Zone-2/Path-2, and lens-3 in Zone-3/Path-3.

Observation (Figure 3.23): lens-1 create Particle pattern on D-1, the lens-2 creates Transition on D-2, while the lens-3 creates Interference pattern on D-3.

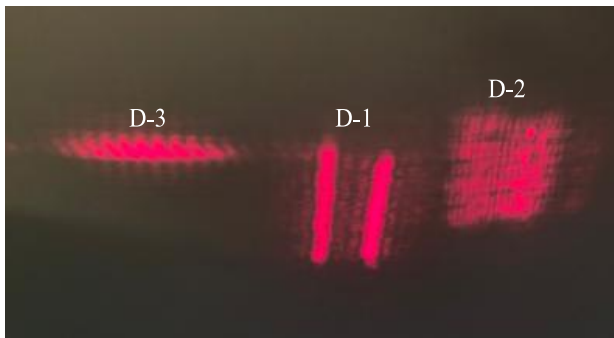


Figure 3.23. Particle pattern, Transition pattern, Interference pattern shown simultaneously

Discussion: the two non-interference patterns show the particle nature of light, while the interference pattern shows the wave distribution. Namely, the particle nature and wave distribution of the light simultaneously show on screen. It is mystery that:

- (1) the light needs to tell which path they are propagating along with;
- (2) the light needs to tell, in which Zone, lens-1, lens-2 and lens-3 are respectively placed in.
- (3) each pattern is formed independently.
- (4) Three patterns violate the existing wave theories.

Third step: (Figure 3.24 and Figure 3.25):

Experimental setup (Figure 3.24).

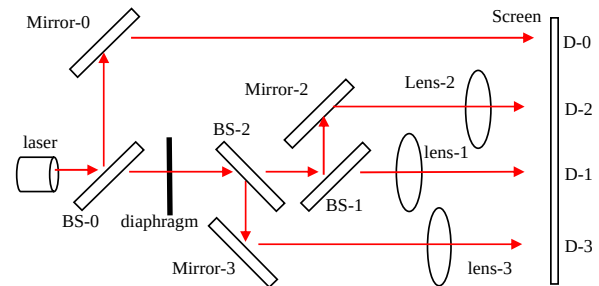


Figure 3.24. Experimental setup: third step

Based on Figure 3.22, adding BS-0 and Mirror-0 between the laser and the diaphragm. The light lands at D-0 on the screen. The Path-0 is: Path-0: laser/BS-0/mirror-0/D-0.

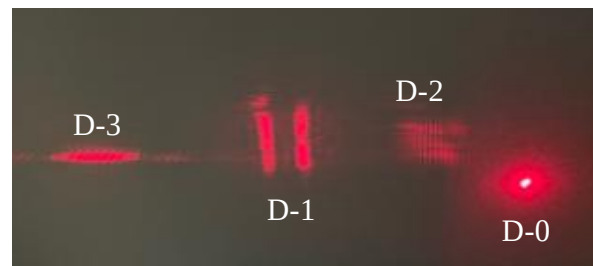


Figure 3.25. Four patterns shown simultaneously

Observation: the light respectively passes through path-0, path-1, path-2 and path-3, and produce the image of the laser on D-0, Particle pattern on D-1, Transition pattern on D-2, and Interference pattern on D-3 respectively.

Discussion: the third step of Experiment-3.8 shows: (1) the light behaves as particles before passing through the diaphragm, not as waves; (2) the two non-interference patterns show the particle nature of light, while the interference pattern shows the wave distribution; (3) each pattern is formed independently.

It is mystery: to determine its behavior,

- (1) the light needs to tell whether it will pass the diaphragm;
- (2) the light needs to tell which path it is propagating along;
- (3) the light needs to tell, in which Zone, lens-1, lens-2 and lens-3 are respectively placed in.
- (4) Three patterns violate the existing wave theories.

Fourth step: (Figure 3.26 and Figure 3.27):

Experimental setup (Figure 3.26):

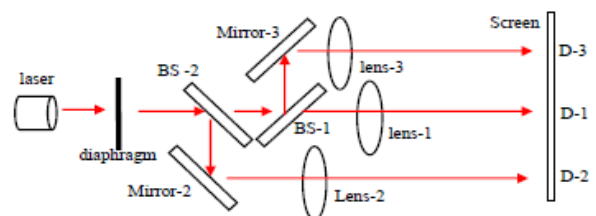


Figure 3.26. Experimental setup: fourth step

The experimental setup of Figure 3.26 produces three patterns as show in Figure 3.23. Then adding Metal tube-2 in Path-2 near the screen; placing Shield-3 in Path-3 near the screen (Figure 3.27).

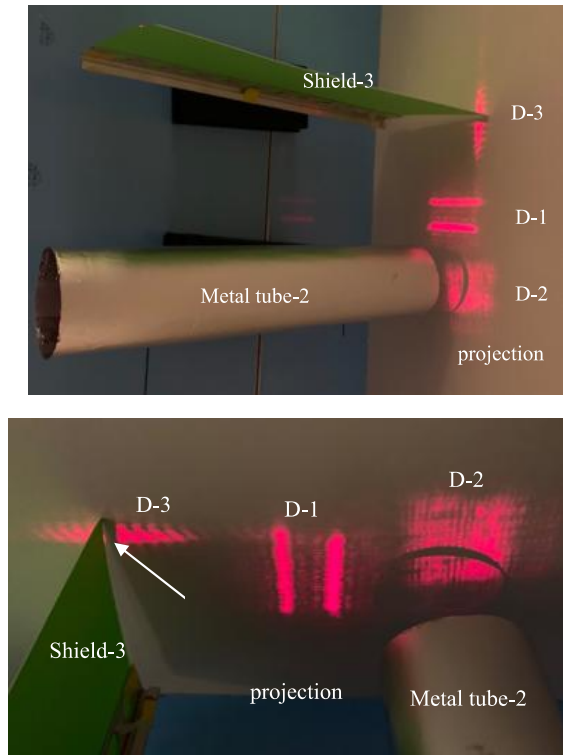


Figure 3.27. Experiment: Shield-3/Metal tube-2

Observation (Figure 3.27): Shield-3 does not affect the patterns either on D-3 or on D-1 or on D-2. The conductive Metal tube-2 does not affect the patterns on D-2. Thus the light is not EM waves.

Fifth step: (Figure 3.28): Based on Fourth step, adding Blocker-1 in Path-1.

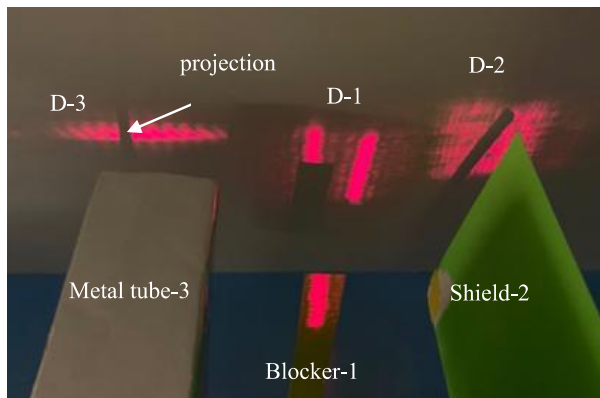


Figure 3.28. Experiment with Blocker, Shield, Metal tube

Observation: part of Particle pattern is formed on Blocker-1, the remaining is formed at D-1 on the screen.

Conclusion: Blocker-1 blocks the part of pattern on D-1, but not on D-2 and D-3.

3.5. Summery

The light is photons even in the classical wave experiments, e.g., the double slit experiment, before and after passing through the diaphragms.

The phenomena of Experiments in Section 3 cannot be described by wave theories of the light, and violate complementarity principle.

The mystery is why and how the photons distribute as waves?

We suggest a mechanism of the phenomena of Section 3, that the non-interference and the interference patterns are produced by Photon-Photon interaction.

4. Non-diffraction Pattern Evolving to Diffraction Pattern: Convex lens

The double slit has been extended to the cross double slits that have much more variations [21,22]. In Section 2 and Section 3, we show the universal phenomena that, the nature and the characteristics of the patterns depend on distance from the double slit/cross double slit, e.g., in Zone-1, Zone-2 and Zone-3, the patterns are Particle patterns, Transition patterns and Interference patterns, respectively. Namely, in the same classical experiment, the non-interference patterns evolve to the interference patterns [23,24].

In this Section, we first extend the single slit to the cross single slits that have much more variations, and then, show the phenomena of the non-diffraction patterns evolving to the diffraction patterns [25].

4.1. Single Slit to Cross-Single-Slit

First let us extend the single slit to the cross single slit [26]. Thus, we have variety of configurations of the shingle slit crossing single slit, and the single slit crossing double slit, etc., as shown in Figure 4.1.

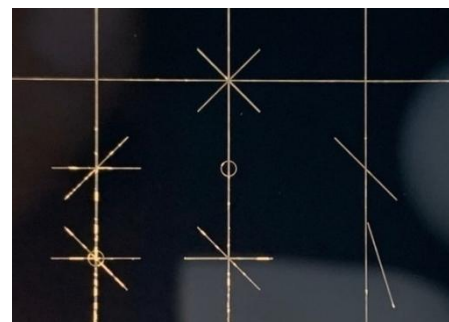


Figure 4.1. Diaphragms of single slit crossing single slit and single slit crossing double slit

4.2. Experiments

Experimental setup

We use the same experimental setup for all experiments in Section 4, with different diaphragms and placing the lens at different locations between the diaphragm and the screen (Figure 4.2).

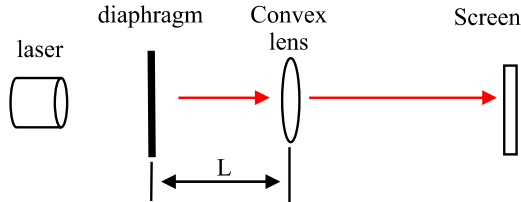


Figure 4.2. Experimental setup

Experiment-4.1: Single slit experiment

Figure 4.3 shows the standard single slit and its diffraction pattern without utilizing lens.

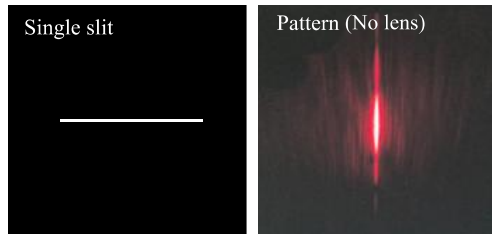


Figure 4.3. Single slit and pattern without lens

Figure 4.4 shows the patterns evolution when the lens is placed at the distant L from the single slit. The L changes from 10 mm to 1000 mm.

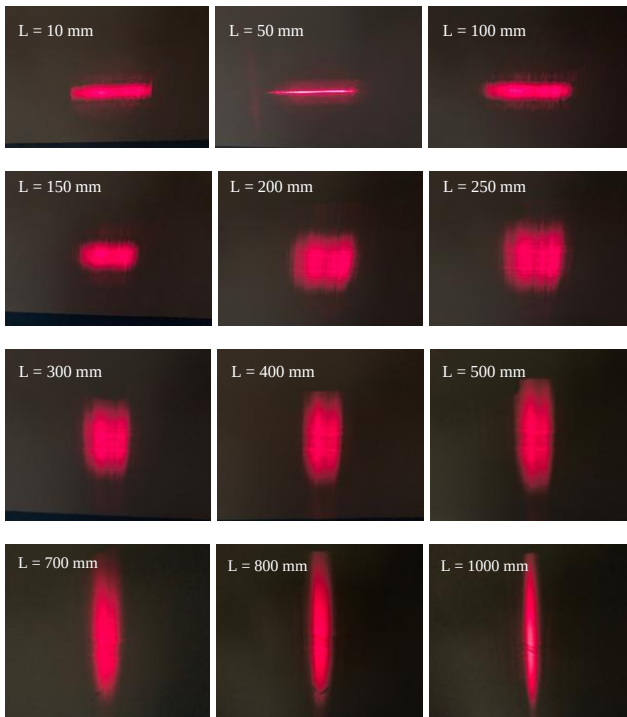


Figure 4.4. Pattern evolution of single slit experiment

Observation: We observe the evolution of the patterns. Namely, the patterns are distance-dependent. Figure 4.4 shows the cross-section views of the evolution of the patterns, which show how the **horizontal** non-diffraction

patter (start from $L = 10$ mm) evolves to the **orthogonal** diffraction pattern at ($L \geq 1000$ mm). The pattern at $L = 50$ mm is typical Particle pattern which is the image of the single slit. Between $L = 150 - 700$, we call the patterns "Transition pattern". When $L \geq 700$ mm, the patterns evolve to the typical vertical diffraction patterns

Experiment-4.2: Single slit crossing single slit (1)

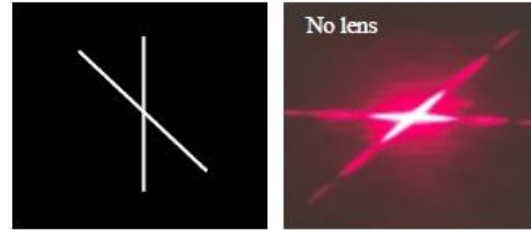


Figure 4.5. Cross single slit and pattern: no lens

Figure 4.6 shows the pattern evolution.

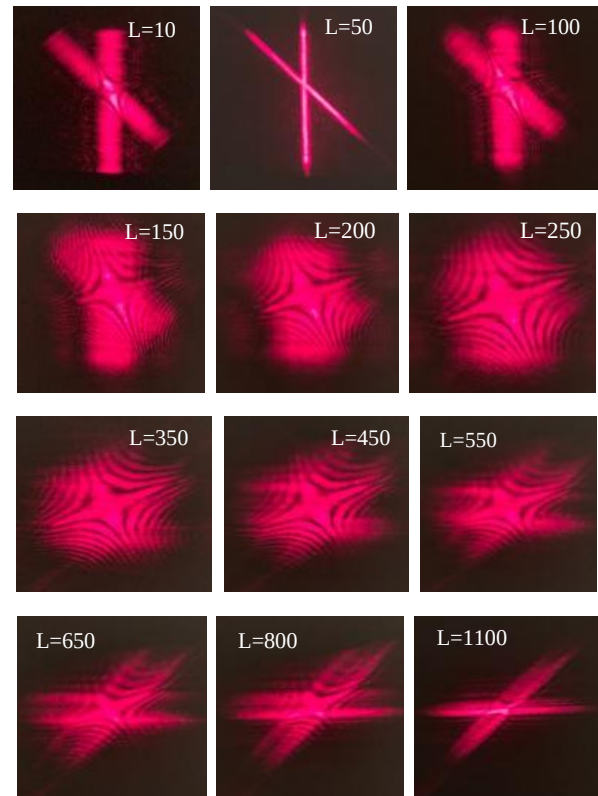


Figure 4.6. Pattern evolution of cross single slit experiment

Observation (Figure 4.6): Figure 4.6 shows the cross-section views of the evolution of the patterns, which show how the non-diffraction pater (start from $L = 10$ mm) evolves to the **orthogonal** diffraction pattern.

Experiment-4.3: Single slit crossing single slit (2)

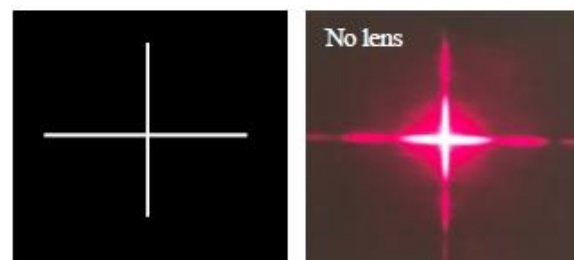


Figure 4.7. Cross single slit and pattern: no lens

Figure 4.8 shows the pattern evolution.

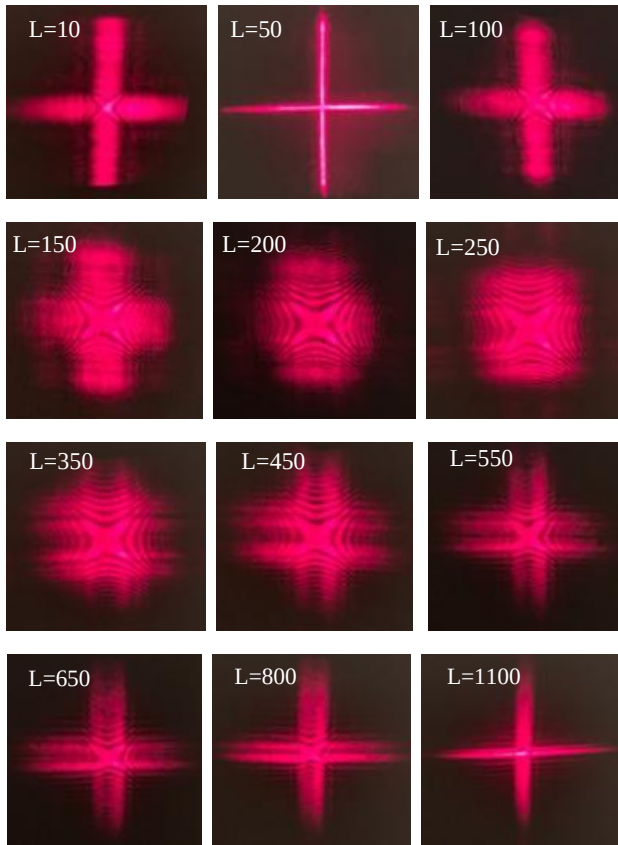


Figure 4.8. Pattern evolution of cross single slit experiment

Observation (Figure 4.8): Figure 4.8 shows the cross-section views of the evolution of the patterns, which show how the non-diffraction patten evolves to the diffraction pattern.

Experiment-4.4:

Four Single slits crossing at the same point (Figure 4.9).

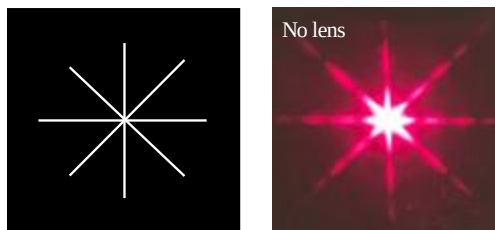


Figure 4.9. Cross single slit and pattern: no lens

Figure 4.10 shows the pattern evolution.

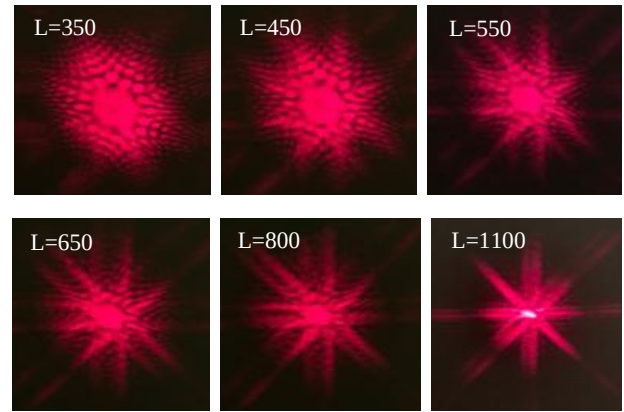
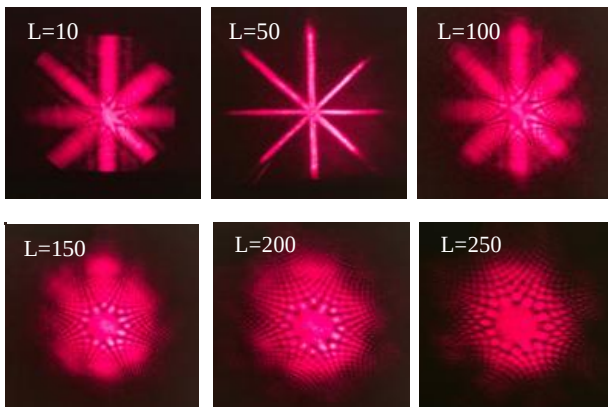


Figure 4.10. Pattern volution of cross single slit experiment

Observation: Figure 4.10 shows the cross-section views of the evolution of the patterns, which show how the non-diffraction patten evolves to the diffraction pattern.

Experiment-4.5: Single slit crossing ring

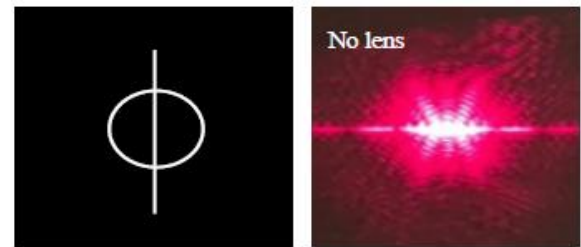


Figure 4.11. Single slit crossing ring and pattern: no lens

Figure 4.12 shows the pattern evolution.

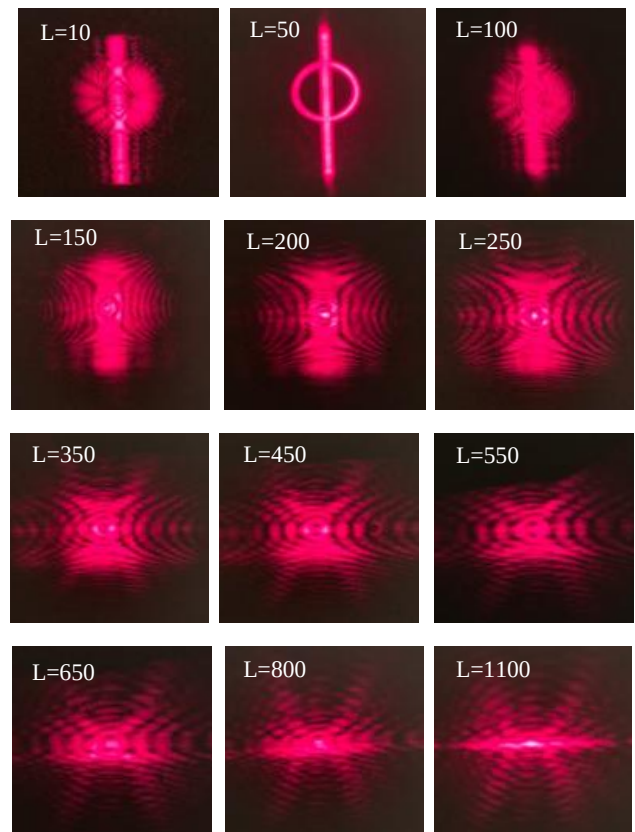


Figure 4.12. Pattern evolution of single slit cross ring experiment

Observation (Figure 4.12): Figure 4.12 shows the cross-section views of the evolution of the patterns, which show how the non-diffraction pattern evolves to the diffraction pattern.

Experiment-4.6:

Single slit crossing a double-slit (Figure 4.13).

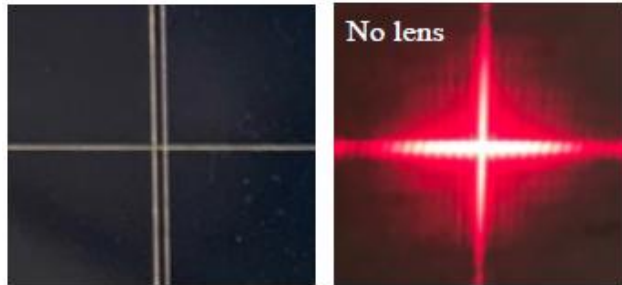


Figure 4.13. Single slit cross double slit and its diffraction crossing interference pattern: no lens

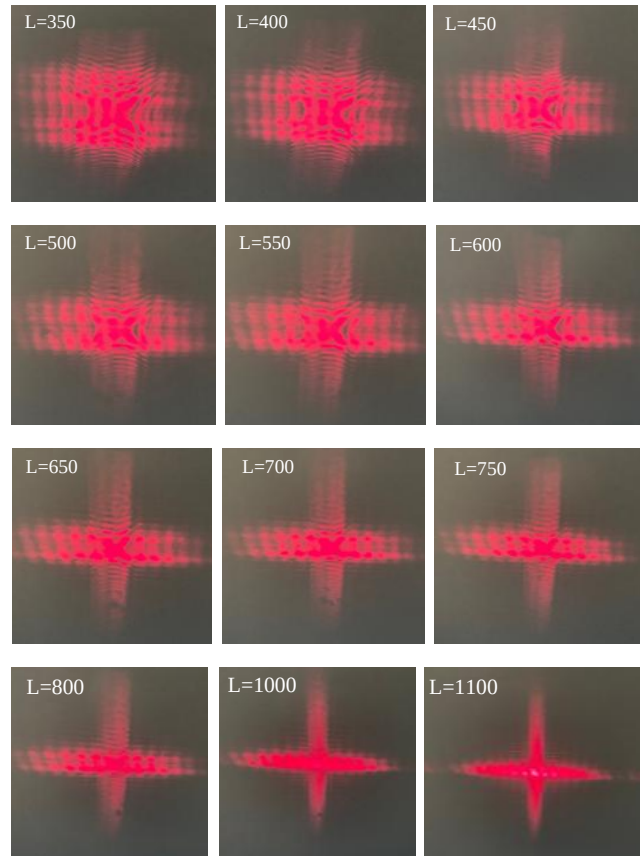
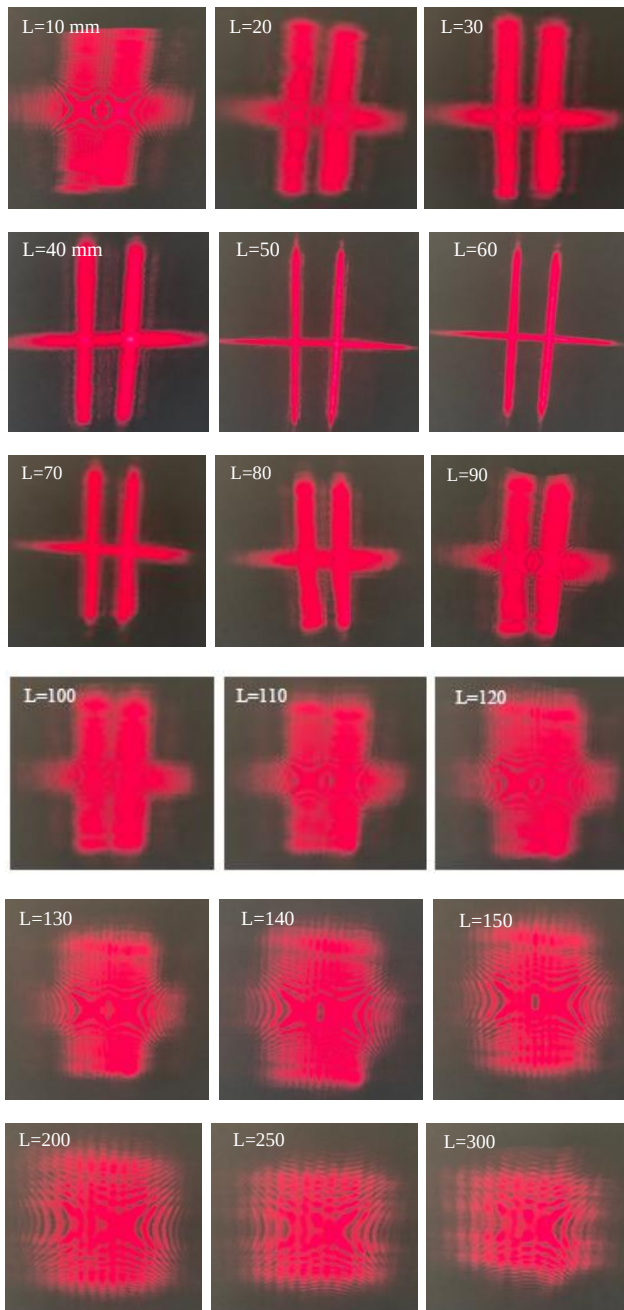


Figure 4.14. Pattern evolution

Figure 4.14 shows Pre-Particle pattern, Particle pattern, Transition Pattern and the combination of interference pattern and diffraction pattern.

Experiment-4.7:

Single slits crossing two double slit (Figure 4.15).

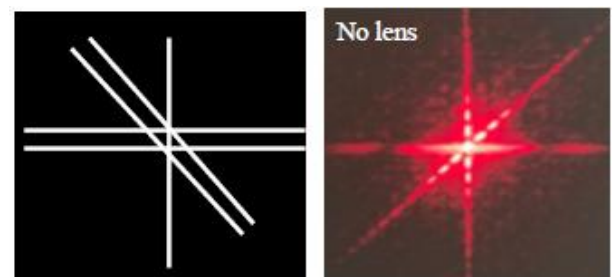
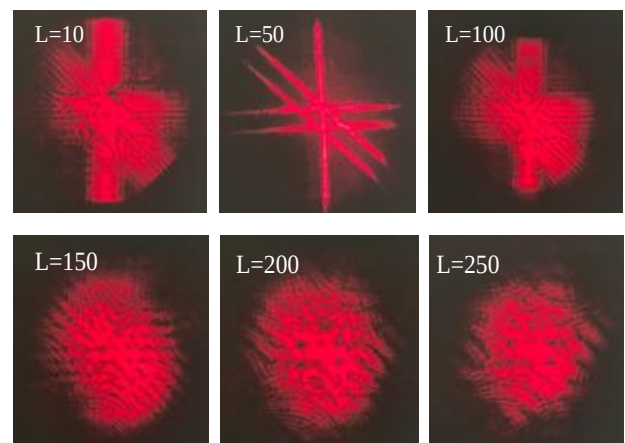


Figure 4.15. Single slit crossing two double slits and its pattern



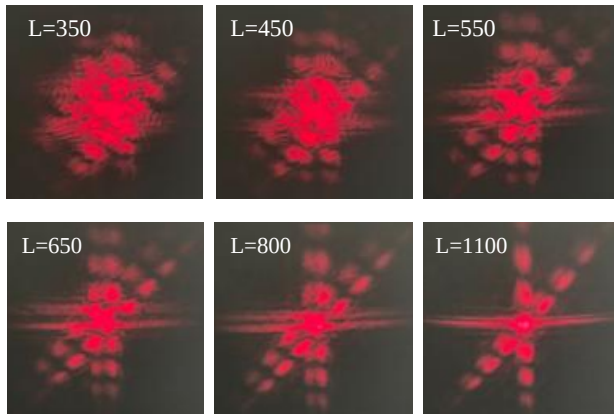


Figure 4.16. Pattern evolution of single slit crossing double slit

Observation: Figure 4.16 shows the cross-section views of the evolution of the patterns, which show how the non-diffraction pattern evolves to the diffraction pattern, and how the non-interference pattern evolve to the interference patterns simultaneously.

4.3. Summary

In this Section, we

- (1) proposed the cross single slit.
- (2) show the patterns evolution from the non-diffraction patterns to the diffraction patterns.
- (3) two evolutions taking place in the same experiments (e.g., Experiment-4.6 and Experiment-4.7): The non-diffraction patterns evolving to the diffraction patterns, while the non-interference patterns evolving to the interference patterns.

The existing wave theories can only interpret the final diffraction patterns in Zone-3, and cannot interpret the pattern evolution of the single slit/cross single slit experiments.

The consistent and complete interpretations are demanded.

The photon-photon interaction may interpret the evolution, especially the non-diffraction patterns, i.e., the Pre-Particle pattern, Particle pattern, and Transition patterns.

5. Two non-diffraction Pattern Evolving to Diffraction + Interference Pattern (hybrid pattern): Lens

5.1. Two non-parallel Slits Producing Interference-Diffraction Hybrid Pattern

5.1.1. Experiment-5.1 : Hybrid Pattern

Experimental setup (Figure 5.1):

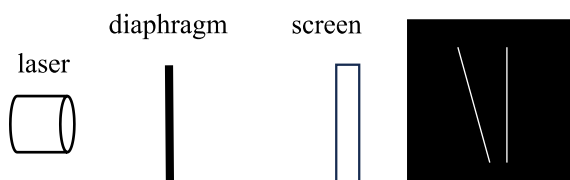


Figure 5.1. Experimental setup and diaphragm

The angle between two slits is 17.5° .

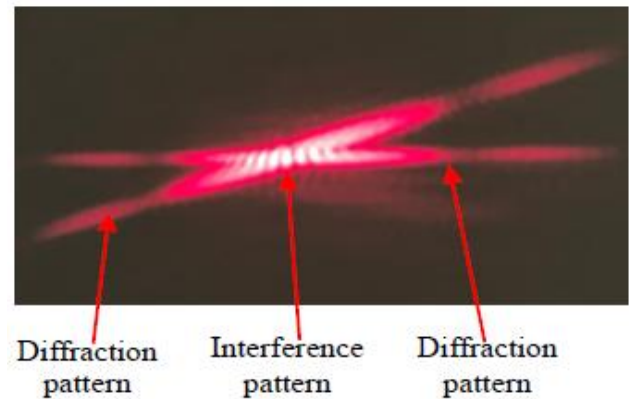


Figure 5.2. Hybrid pattern

Observation: Figure 5.2 shows for the first time that the partial interference pattern embedded in the diffraction patterns, referred as “hybrid pattern” [24].

5.1.2. Experiment: Evolution of Hybrid pattern

Experiment-5.2: pattern evolution

Experimental setup (Figure 5.3):

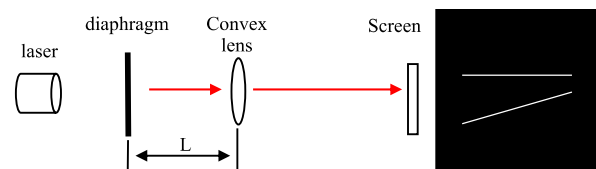
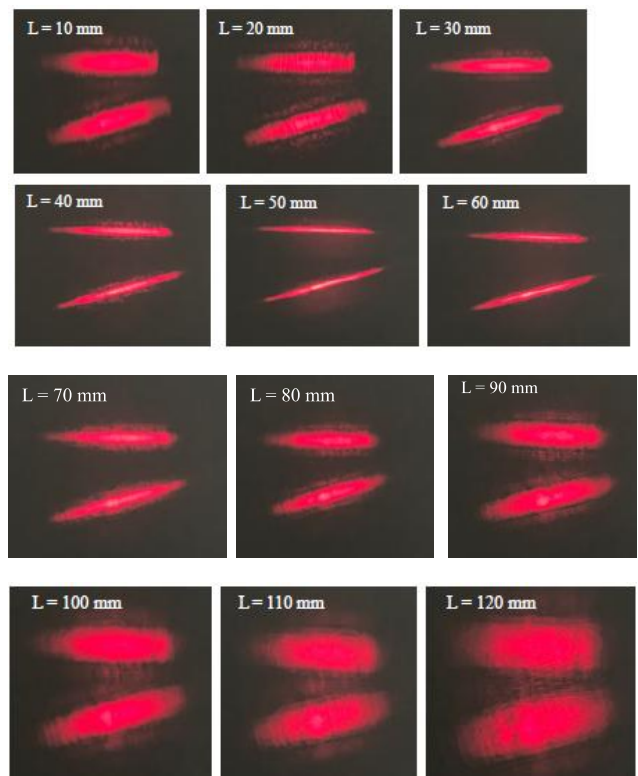


Figure 5.3. Experimental setup

Figure 5.4 shows the evolution of the Interference-Diffraction hybrid pattern.



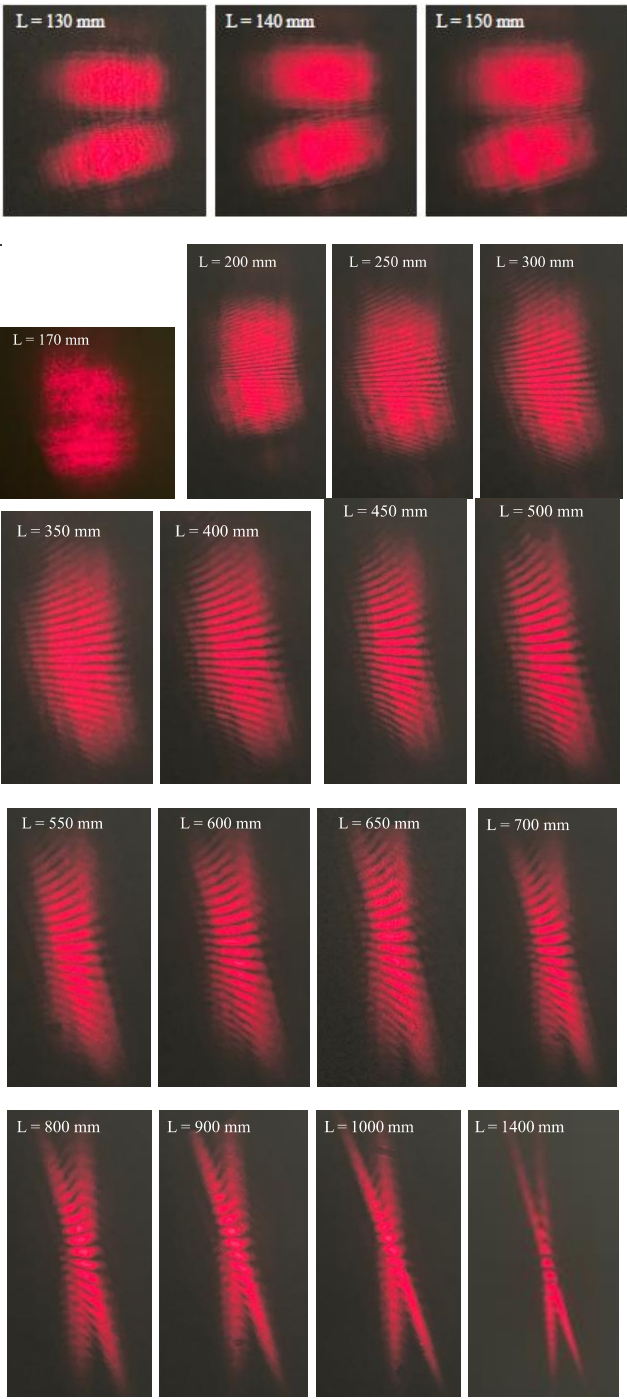


Figure 5.4. Evolution of Interference-Diffraction hybrid pattern

Observation: Figure 5.4 shows for the first time how two particle pattens (start at $L=10$ mm) evolve to the Interference-Diffraction hybrid pattern, i.e., the partial interference pattern embedded in two diffraction patterns.

5.2. Interaction Between Photons: Non-parallel-Two-Slit

A horizontal single (SS1) slit and a tilt single slit (SS2) form the non-parallel two slits (NTS). The patterns are summarized in Table 5.1.

Table 5.1. Patterns of non-parallel two slit

L: mm	Single slit-1 (SS1): pattern-1 (P1)	Single slit-2 (SS2): pattern-2 (P2)	Non-parallel two slit (NTS): pattern-3 (P3)	Remark
				SS1+SS2 = NTS
10				$P1+P2 = P3$
50				$P1+P2 = P3$
100				$P1+P2 = P3$
150				$P1+P2 \approx P3$
200				$P1+P2 \neq P3$
300				$P1+P2 \neq P3$
450				$P1+P2 \neq P3$
650				$P1+P2 \neq P3$
800				$P1+P2 \neq P3$
1100/1000				$P1+P2 \neq P3$

Observation: start from $L = 150$ mm, two separated patterns of P3 start to combine, and continuously evolve.

Conclusion: to interpret the phenomena, we suggest that the evolution of P3 shows the effect of the interactions between photons from two slits.

5.3. Interference Pattern to Hybrid Pattern to Diffraction Pattern: Parallel Double Slit to Non-Parallel-Two-Slit

The interference phenomena and the diffraction phenomena are two basic phenomena in physical optics. The standard interpretation of the double slit experiment is that before and after passing through the double slit diaphragm, the light behaves as waves, either the optical waves, or the Electromagnetic waves, or the probability waves, and the patterns are interference. The two slits are parallel.

Experiment-5.1 shows that, when the two slits are not parallel, the pattern is the hybrid pattern, i.e., the partial interference pattern is embedded in the diffraction patterns.

Next, we show the phenomena: when the angle between two slits increases from the 0° to 45° , the interference pattern becomes the partial interference + diffraction hybrid patterns and, finally, become the crossing diffraction patterns. In the two non-parallel-slits experiments, the nature and the characteristics of the patterns depend not only on the distance from the diaphragm, but also on the angle between two slits.

5.3.1. Diaphragm of Non-Parallel-Two-slits

Now, we study the non-parallel two slits. For this purpose, we utilize the diaphragm containing 16 two-slits with different angles: $0^\circ - 45^\circ$ (Figure 5.5.).

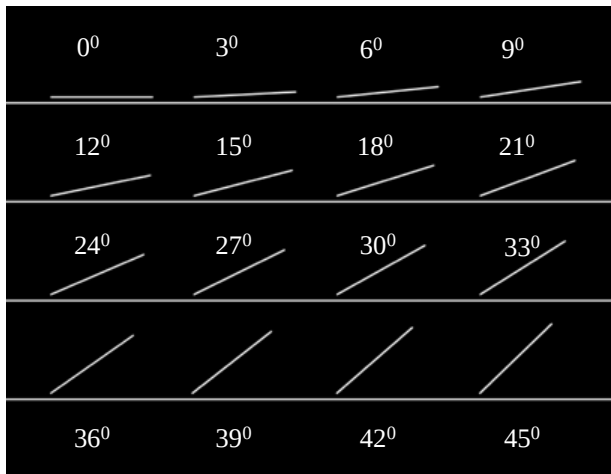


Figure 5.5. Diaphragm of parallel two-slits and non-parallel two-slits with angles: $0^\circ - 45^\circ$

The distances between the bottom-end of each tilt short slit and the horizontal long slits are all 0.3 mm [27].

5.3.2. Experiments: patterns of two-slits experiments depending on angle between two slits

Experiment setup: The same experiment setup (Figure 5.6) is for Experiment-5.3 to Experiment-5.18. We set the distance between the diaphragm and the screen 1400 mm.

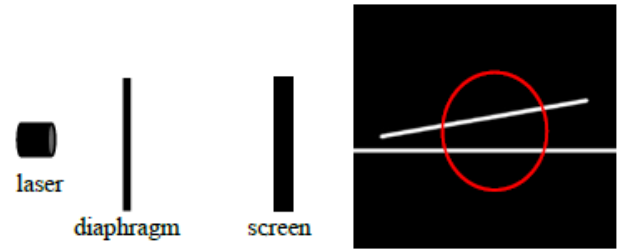


Figure 5.6. Experiment setup and non-parallel two-slits

The laser with beam-diameter 3 mm aims at the non-parallel two-slits, as shown by the red circle in Figure 5.6.

Experiment-5.3 : 0° between two slits:

Experimental setup: is shown in Figure 5.6.

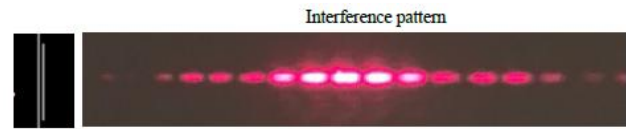


Figure 5.7. Standard double slit experiment: interference pattern

Observation: the parallel-two-slit (the normal double slit) produces the interference pattern, which can be interpreted by all three standard wave theories. Figure 5.7 clearly shows the fringes $m = \pm 6$.

Experiment-5.4: 3° between two slits:

In this experiment, the angle between two slits is 3° .

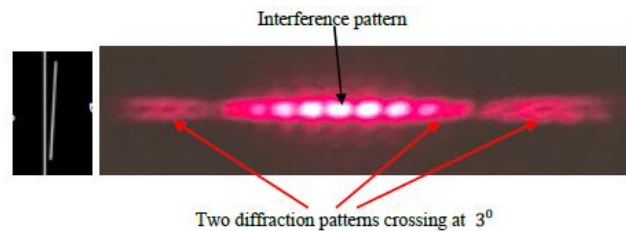


Figure 5.8. Non-parallel two-slit: hybrid pattern

Observation: we observe the hybrid pattern, i.e., the partial interference pattern embedded in the diffraction patterns. Two diffraction patterns are barely distinguishable. The partial interference pattern shows $m = \pm 3$ fringes.

The nature and characteristic of the pattern is sensitive to the angle between two slits.

It is challenge to interpret the hybrid pattern by the wave theories.

Experiment-5.5: 6° between two-slits:

In this experiment, the angle between two slits is 6° .

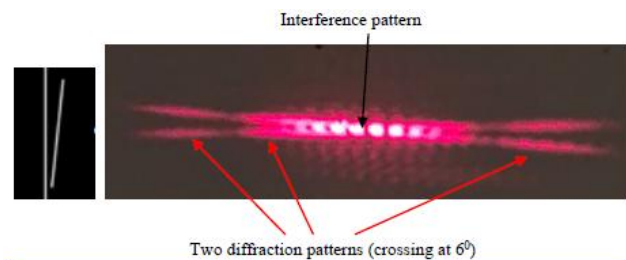


Figure 5.9. Non-parallel two-slit: hybrid pattern

Observation: we observe the hybrid pattern. The two diffraction patterns are clearly distinguishable. The partial interference pattern shows $m = \pm 3$.

Experiment-5.6: 9° between two slits:

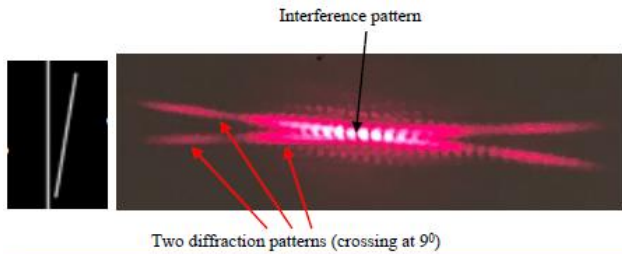


Figure 5.10. Non-parallel two-slit: hybrid pattern

Observation: we observe the hybrid pattern. The interference pattern is embedded in two diffraction patterns.

Experiment-5.7: 12° between two slits:

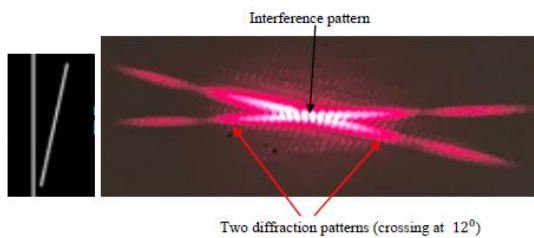


Figure 5.11. Non-parallel two-slit: hybrid pattern

Observation: we observe the hybrid pattern.

Experiment-5.8: 15° between two slits:

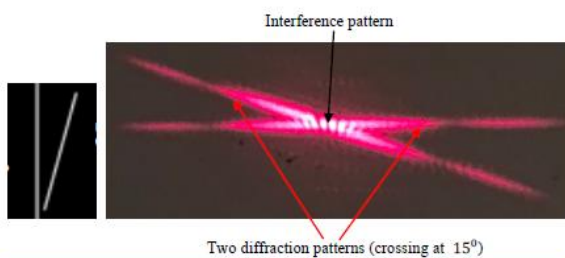


Figure 5.12. Non-parallel two-slit: hybrid pattern

Observation: we observe the hybrid pattern.

Experiment-5.9: 18° between two slits:

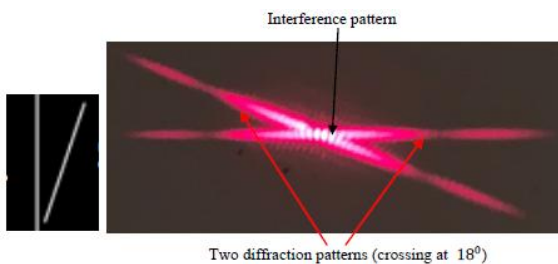


Figure 5.13. Non-parallel two-slit: hybrid pattern

Observation: we observe the hybrid pattern.

Experiment-5.10: 21° between two slits:

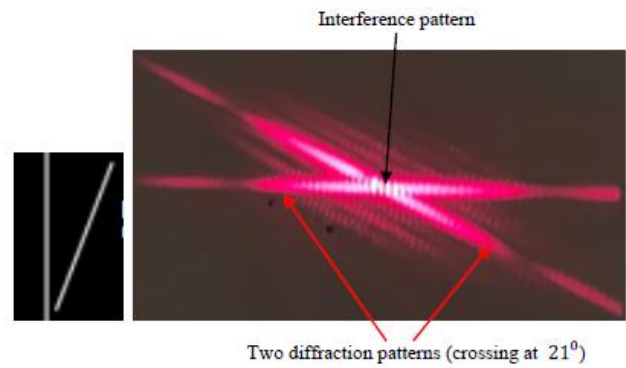


Figure 5.14. Non-parallel two-slit: hybrid pattern

Observation: we observe the hybrid pattern.

Experiment-5.11: 24° between two slits:

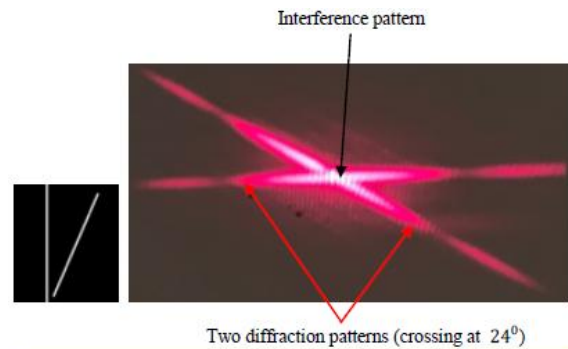


Figure 5.15. Non-parallel two-slit: hybrid pattern

Observation: we observe the hybrid pattern.

Experiment-5.12: 27° between two slits:

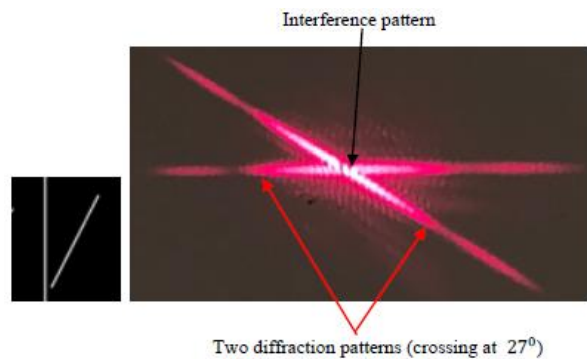


Figure 5.16. Non-parallel two-slit: hybrid pattern

Observation: we observe the hybrid pattern.

Experiment-5.13: 30° between two slits:

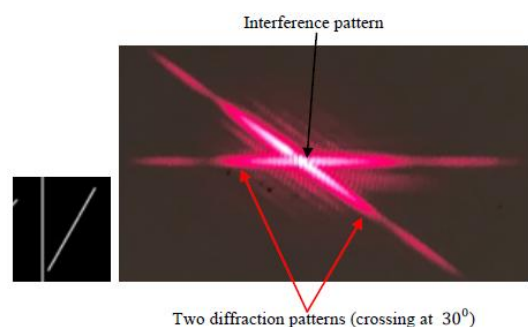


Figure 5.17. Non-parallel two-slit: hybrid pattern

Observation: we observe the hybrid pattern.
Experiment-5.14: 33° between two slits:

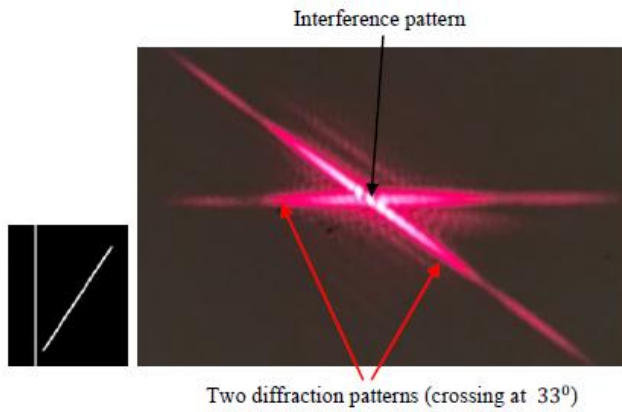


Figure 5.18. Non-parallel two-slit: hybrid pattern

Observation: we observe the hybrid pattern.
Experiment-5.15: 36° between two slits

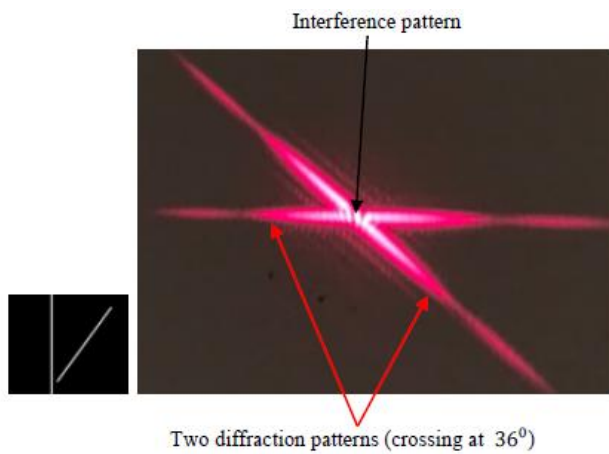


Figure 5.19. Non-parallel two-slit: hybrid pattern

Observation: we observe the hybrid pattern.
Experiment-5.16: 39° between two slits:

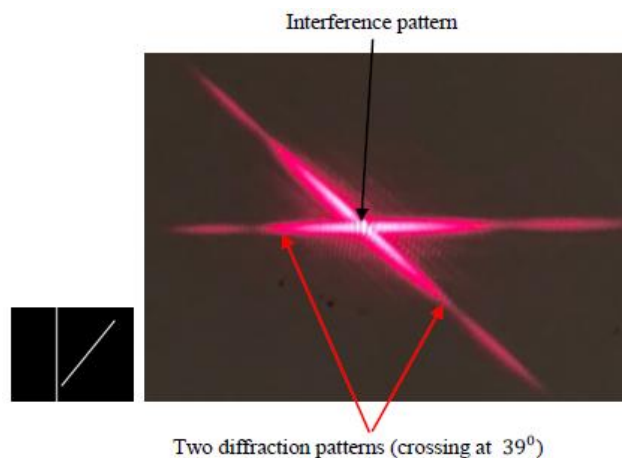


Figure 5.20. Non-parallel two-slit: hybrid pattern

Observation: we observe the hybrid pattern.
Experiment-5.17: 42° between two slits:

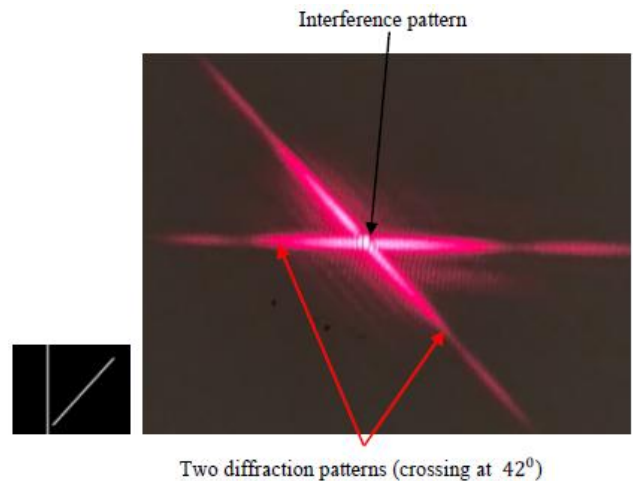


Figure 5.21. Non-parallel two-slit: hybrid pattern

Observation: we observe the hybrid pattern.
Experiment-5.18: 45° between two slits:

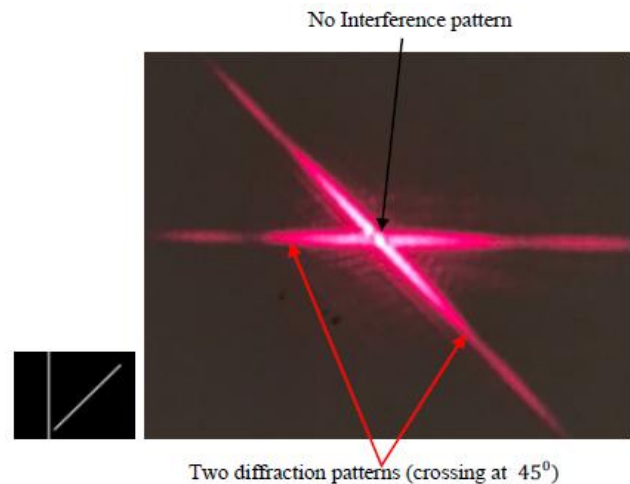


Figure 5.22. Non-parallel two-slit: hybrid pattern

Observation: there are two diffraction patterns and no partial interference pattern and thus, the pattern is not the hybrid pattern. For the angle larger than 45° , the pattern is two diffraction patterns crossing, there is no embedded interference pattern.

5.4. Summary

We show for the first time that when the angle between two slits is 0° , the pattern is the interference pattern; increase the angle between the two slits, the patterns are the hybrid pattern; at 45° , the pattern becomes the diffraction pattern.

The non-parallel two slits produce the pattern that contains two diffraction patterns and the partial interference pattern embedded in the diffraction patterns, referred as the Interference + diffraction hybrid patterns or the hybrid patterns. The hybrid patterns depend on the angle between two slits.

It is challenge for the wave theories to interpret the hybrid pattern and thus, we suggest that the hybrid pattern indicates the interaction between photons, in addition to the interaction between photons and matters.

Appendix

A1. Focal point of lens in wave experiment

Experiment-A1 (Figure A1):

We have shown the interference patterns in Zone-3. Now let us place the lens in Zone-3. Using 100x300 mm photon chamber.

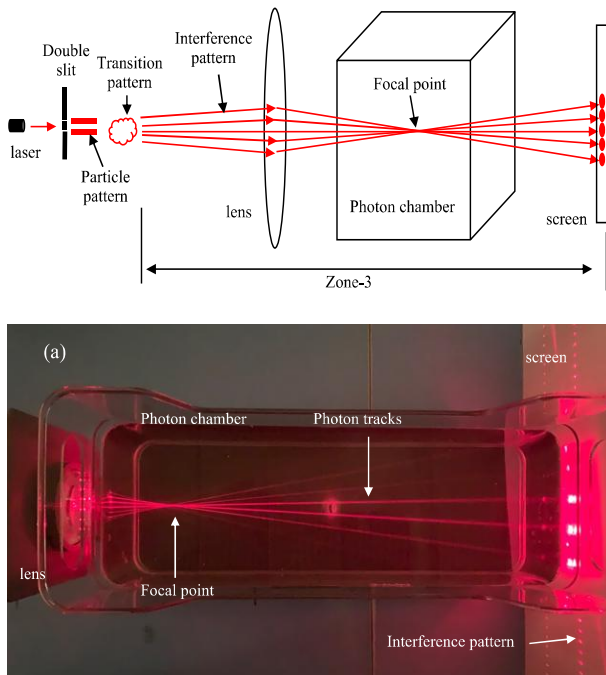


Figure A1. Light beams (Interference pattern) brought to focus by convex lens

Observation: Figure A1 shows the focal point in the photon chamber that obeys the geometrical theory of thin lens theory. The pattern at the focal point is neither non-interference pattern nor interference pattern, but is a cross point of photons trajectories [20].

A2. Double Slit Experiments: Blockers and Shields in

Zone-3: New phenomena: Fringes formed

Independently and partially

In the classical double slit experiment, we add blockers and shields to show the particle nature of the light in the classical wave experiments. To prove that the light is photons near the screen in the double slit experiments, we perform the following experiments. The conclusion of the following experiments consistent with that of this article.

Experiment-A2 (Figure A2): Double slit experiment with blocker

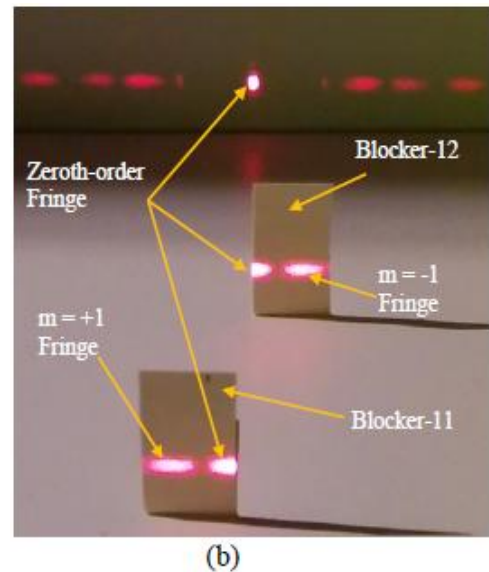
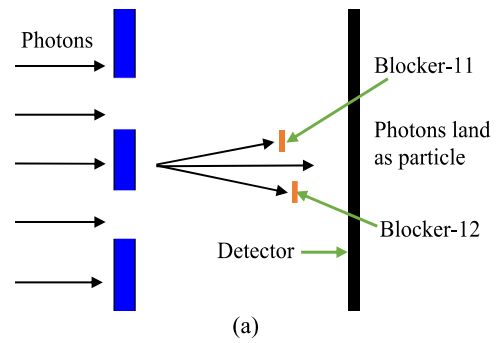
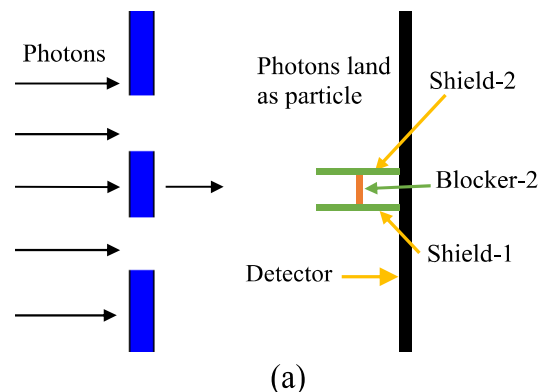


Figure A2. Double slit experiment with blockers

Observation (Figure A2b): Two blockers are arranged such that portions of the zeroth-order fringe are formed on the screen, blocker-11 and blocker-12, respectively, which indicate that the fringe can be formed partially. The existence of each blocker does not affect the fringes formed on other blockers and on the detector. Namely, fringes are formed independently.

Experiment-A3 (Figure A3): Double slit experiment with blocker and Shields

Experimental setup (Figure A3a): Figure A3(a) shows Experimental setup. Two Shields contacting the screen.



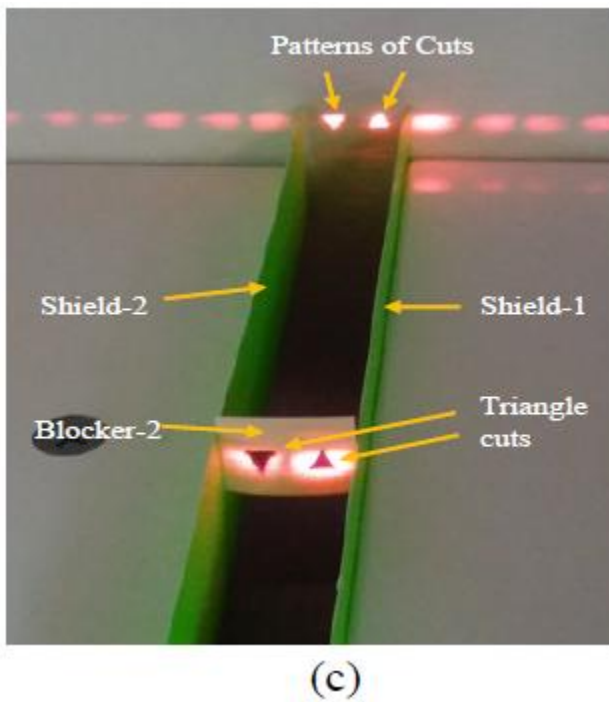
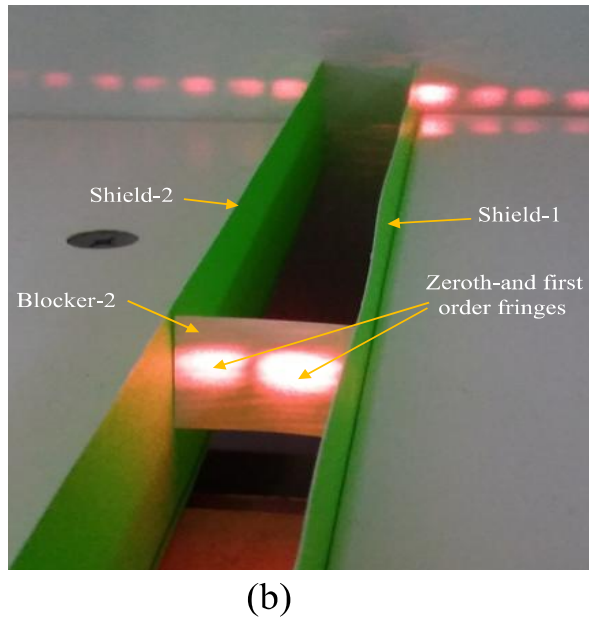


Figure A3. Double slit experiment with blockers, shields

Observation: Figure A3b shows that two fringes are formed on blocker-2, and the remaining fringes are formed on the detector. Namely, Fringes can be formed independently. Two shields have no effect on the interference pattern. This observation indicates that the light is particle/photons near the screen.

Figure A3c shows that Photons pass through two triangle-shaped cuts and form exactly the same triangle-shaped patterns on the detector, which indicates that photons move along straight lines, which indicates the particle nature of photons; the fringes are formed partially and independently.

Note that the photons are not directly from the source; they are just pass through a double slit and, according to the standard wave interpretation, they should be waves.

The conclusion is that the light is particles even in classical wave experiment, which consistent with the experiments of Section-2, -3, -4, -5.

Experiment-A4. Figure A4a shows the experimental setup.

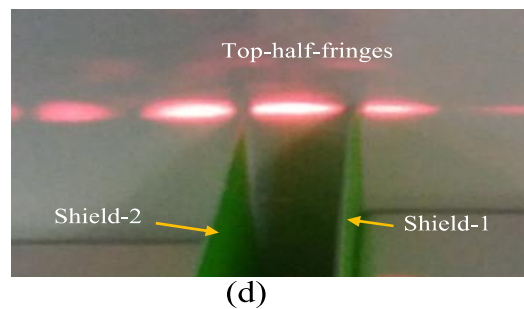
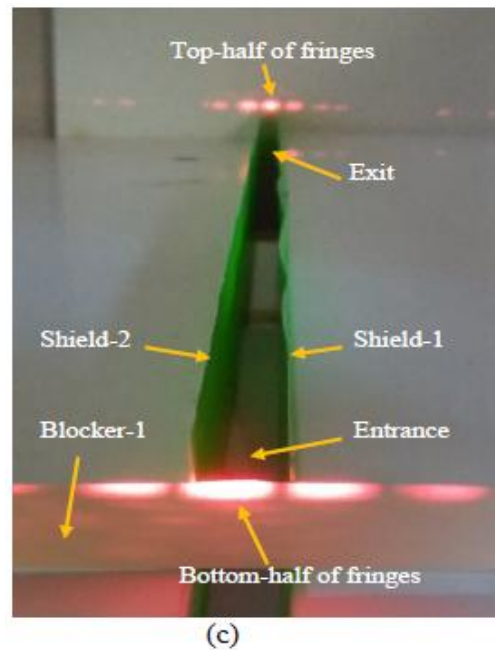
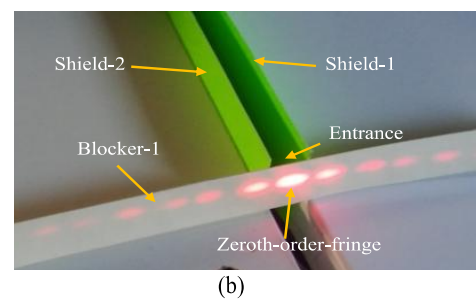
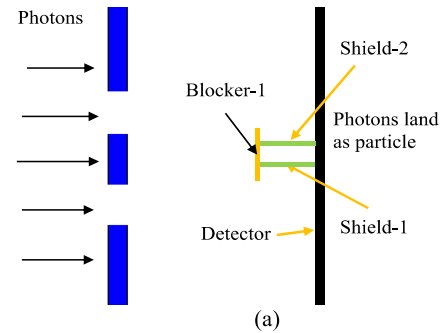


Figure A4. Double slit experiment with Blocker and Shields

Observation: Figure A4b shows that the interference pattern is formed on blocker-1 instead of the screen. Then cutting the top portion of blocker-1. Figure A4c and A4d show that the bottom half of the fringes still show on blocker-1, while the top half show on the detector. Namely each fringe can be formed partially. And shields have no effect on the interference pattern.

Discussion: Experiment-A2 to Experiment-A4 are consistent, and indicate that in the double slit experiments, the light is photons, and it is photons that distribute as wave on the screen.

The existing wave theories of physical optics cannot interpret Experiment-A1 to Experiment-A4 and thus, are incomplete, and new complete theory is demanded.

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