

Non-Interference pattern Evolving to Interference Pattern --- New Phenomena/Mystery of Classical Wave Experiments

Hui Peng*

James Peng's Lab, Fremont, CA, USA

*Corresponding author: davidpeng1749@yahoo.com

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Abstract Young's double slit experiments revived the wave theory of light. The standard interpretation is that the light behaves as waves before and after passing through the double slit, and the superposition of waves produces the interference pattern. Feynman called the double slit experiment the only mystery in quantum mechanics. In this article, we experimentally show the novel universal phenomena: (1) within macro-distance from the diaphragm, the light rays behave as photons and produce non-interference patterns; while near the screen, the photons produce interference patterns; (2) The non-interference patterns evolve to the interference patterns gradually in the same classical wave experiment; (3) the light is photons before and after passing through the double slit; (4) The convex lens stops the further evolution. The experiments: (1) challenge the wave theories of the light; (2) violate both Bohr's complementarity principle and wave particle duality; (3) provide profound phenomena for developing optics and for studying the nature of light; (4) suggest that a complete theory should be able to consistently interpret all phenomena, including the non-interference pattern, the interference pattern, and the evolution from the non-interference to the interference pattern in the wave experiment; (5) show a new mystery that photons, as particles, distribute as waves.

Keywords: double slit, cross double slit, grating, interference pattern, non-interference pattern, evolution of pattern, superposition of waves, wave particle duality

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1. Introduction

Historically, the study of the nature of light reached two concepts: wave and particle. In 1690, Huygens established the wave theory of light [1]. In 1704, Newton established particle theory [2], which states that light is made up of small discrete particles that travel in a straight line with a finite velocity. In 1801, Young's double slit experiment [3] and the Arago-spot experiment [4] revived Huygens' wave theory. In 1905, Einstein's Photoelectric theory [5] revived, in some sense, particle theory. In 1960s, the coherent waves explain interference phenomena [6].

In this article, we report the novel phenomena of the wave experiments, which lead to new understanding and new mystery, and provide fundamental evidence for developing a complete theory of light.

2. Experiments with Photon Chamber: Light Behaves as Particles in Wave Experiments

2.1. Four Zones

In Section 2, we show that, in the classical wave experiments, such as the double slit experiment and 1D-grating experiments, within certain macro-distance from the diaphragms (Zone-1), the patterns are the non-interference (referred as the "Particle patterns"); near the screen (Zone-3), the patterns are interference; between Zone-1 and Zone-3 (i.e., Zone-2), the patterns are the non-interference patterns (referred as the "Transition patterns").

Let us define "Four Zones" first (Figure 1).

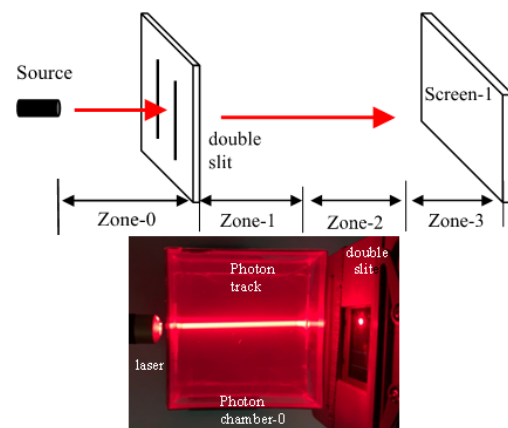


Figure 1. Four Zones

Zone-0: between the source and the diaphragm, in which the pattern is the image of the source, not waves;

Zone-1: near the diaphragm, in which the patterns are non-interference, referred as **Particle pattern**;

Zone-3: near the screen, in which the patterns are orthogonal **Interference patterns**.

Zone-2: between Zone-1 and Zone-2, in which Particle pattern evolves gradually to orthogonal interference pattern, referred as **Transition patterns** that are the non-interference.

The photon chamber-0 shows that the light is particles, photons, before passing through the diaphragm of the double slit (the bottom of Figure 1).

Note that the boundaries between Zone-1 and Zone-2, and between Zone-2 and Zone-3 are not clear cut.

2.2. Photon Chamber: Showing Top View of Patterns

For studying the nature of the light in the double slit experiments, we propose the photon chamber functioning as a photon-detector for visualizing the photons passing through the chamber [7]. The photon chamber consists of a transparent container filled with the mixture of water and fine powder that reflects photons.

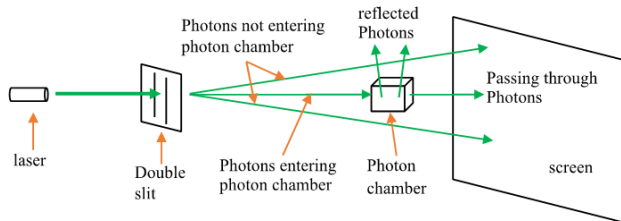


Figure 2. Photon chamber

Then we apply the photon chamber in the double slit experiments. After passing through the double slit, the partial of the light beams enter the photon chamber. In the photon chamber, the partial of light beam is reflected by the particles of the powder, while the partial of the light passes through the photon chamber and forms the interference pattern on the screen/detector (Figure 2).

We assume that the fine powder does not change the nature of the light and thus, the photon chamber does not change the nature of the light.

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

2.3. Experiments: Photon Chamber

Experiment-1: double slit experiment with photon chamber

Experimental setup: placing photon chambers in Zone-1, Zone-2 and Zone-3 respectively (Figure 3).

Observations: Figure 4(a) shows two photon tracks that corresponding to the two slits (referred the patterns as Particle patterns), but not wave pattern. Figure 4(b) shows photon tracks that show the mixture of photons' trajectories (the patterns as Transition patterns), but not wave pattern. Figure 4(c) shows photon tracks that

distribute as the interference patterns, i.e., the photons distribute as waves.

Conclusion: The photon chambers detect the tracks of the light as particles in the classical wave experiments, namely to visualize the passage of the photons of the light beam. The experiment show that the light beam is photons moving through the photon chambers, while in Zone-3, the photons distribute as waves.

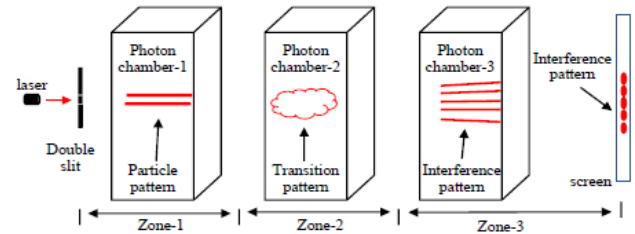


Figure 3. Experimental setup: placing photon chambers in Zone-1, Zone-2 and Zone-3

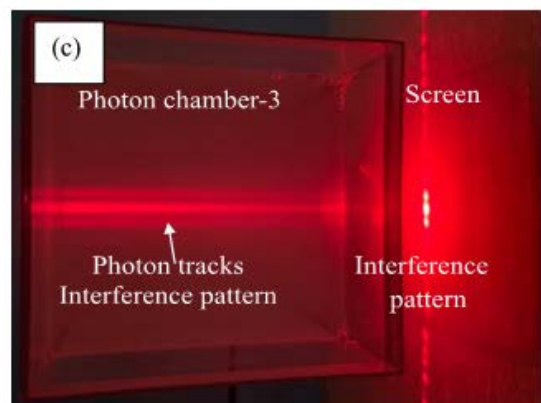
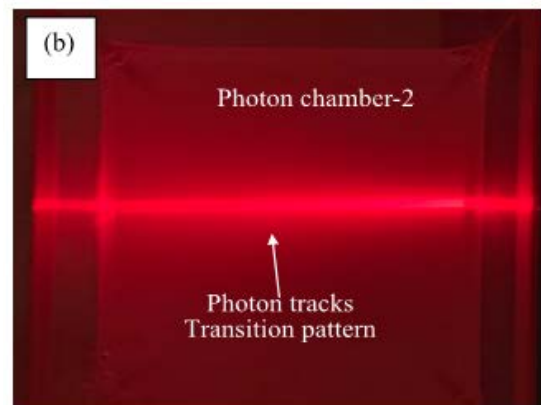
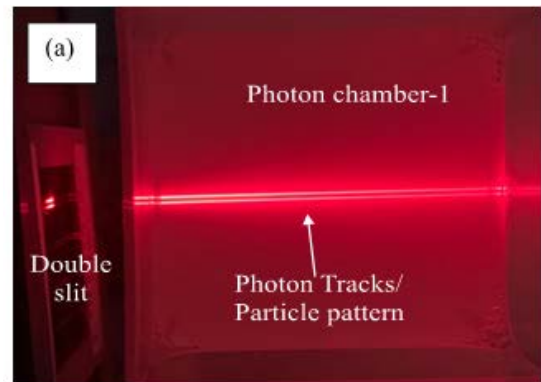


Figure 4. Photon chambers showing Photon tracks (patterns)

3. Experiments with Lens: Non-Interference Patterns Evolving to Interference Patterns

To study the evolution of the patterns, we utilize the convex lens. First, we propose Postulates.

3.1. Postulates: Precise Rules of Convex Lens

In the geometrical optics, a lens does not change the image of an object, except enlarging it. In classical wave experiments, the light coming out of the slits has the certain pattern (the Particle pattern that shows the image of the slits or disc ring). However, as we have shown above that the patterns are distance-dependent. When the convex lens moves, the patterns arriving at the input surface of the lens change (Figure 5). Figure 4 shows the different patterns at the different Zones/distances.

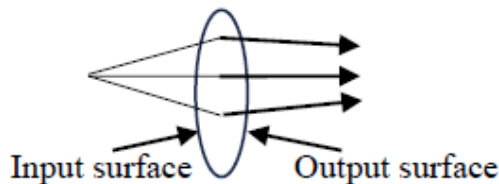


Figure 5. Convex lens

We propose the following Postulates [8].

First Postulate: the convex lens enlarges the input pattern that arrives at the input surface of the lens.

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.

Example-1 of First Postulate: 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, but enlarged. Namely the image of an object is not the distance-dependent.

Example-2 of First Postulate: For the wave experiments, the input pattern that arrives at the input surface of the convex lens is the pattern that is distance-dependent and thus, the shapes of the input patterns are different in the same experiment, and enlarged.

Example of Second Postulate: After passing through a convex lens, the pattern keeps the same nature:

- (a) if an input pattern is a Particle pattern, the output pattern is still the Particle pattern;
- (b) if an input pattern is a Transition pattern, the output pattern is still the Transition pattern;
- (c) if an input pattern is an Interference pattern, the output pattern is still the Interference pattern;
- (d) all of the output patterns are enlarged input patterns.

Example of 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.

Experiment-2 to -10 in Section 3 are based on three Postulates and confirm them. Note that 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 another zone. To study the evolutions of the patterns between different Zones, we utilize the convex lens that shows the cross-sectional view.

3.2. Evolution of Patterns of Classical Wave Experiments

3.2.1. Experimental setup

Experimental setups of Experiment-2 to -10 in Section 3.2 are the same and is shown in Figure 6.

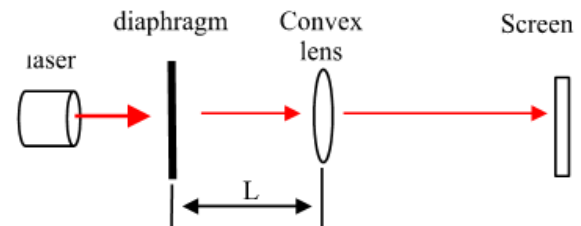


Figure 6. Experimental setup for Section 3.2

Based on Postulations, we place the lens at the different distances "L" from the diaphragm to explore the evolution of the patterns of the single slit, double slit, single slit crossing double slit, cross double slit, Arago-type disc ring, 1D grating and 2D grating.

3.2.2. Evolution of Patterns of Single Slit Experiment

Experiment-2:

Figure 7 shows the standard diaphragm and the pattern of a single slit experiment.

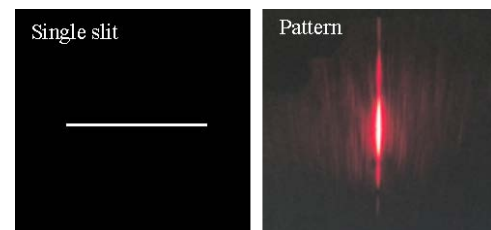


Figure 7. Standard single slit experiment

Placing the convex lens at the different distances L from the single slit. To study the evolution of the pattern, the L varies from 10 mm to 1000 mm.

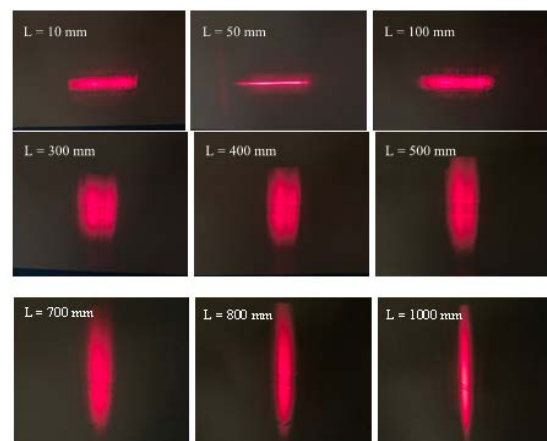


Figure 8. Evolution of pattern of single slit experiment

Observation: Figure 8 shows the cross-section views of the evolution of patterns, which show how the horizontal non-interference pattern (start from $L = 10$ mm) evolves to the orthogonal interference pattern ($L \geq 1000$ mm) of single slit experiment. The patterns are distance-dependent. The pattern at $L = 50$ mm is the typical particle pattern which shows the image of the single slit. The pattern at $L = 1000$ mm is the typical Interference / diffraction pattern.

3.2.3. Evolution of Patterns of Double Slit Experiment

Experiment-3:

Figure 9 shows the diaphragm and the interference pattern of the standard double slit experiment

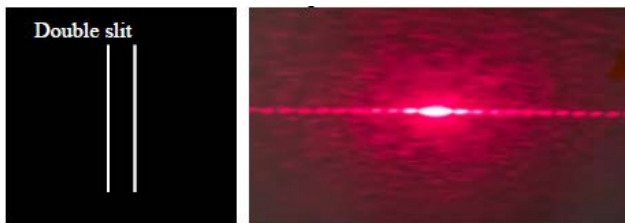


Figure 9. Standard double slit experiment

Placing the convex lens at different distances L from the double slit. To study the evolution of the pattern, the L varies from 10 mm to 1000 mm.

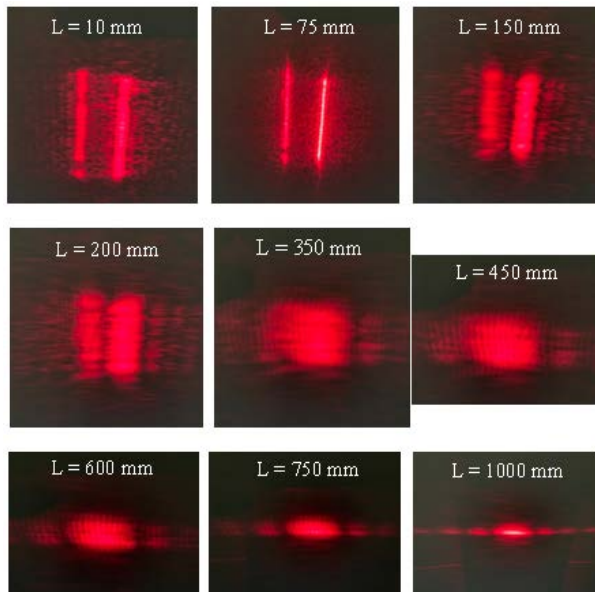


Figure 10. Evolution of pattern of double slit experiment

Observation: When $L = 75$ mm, the vertical pattern is the typical image of double-slit (Particle pattern), which is the non-interference patterns. When $L \geq 200$ mm, the patterns are Transition patterns. When $L \geq 750$ mm, the patterns are the interference patterns. The vertical Particle patterns gradually evolve to the orthogonal interference patterns.

Note: approximately, from $L = 10$ mm to $L = 150$ mm, the patterns are Particle patterns.

3.2.4. Evolution of Patterns of Single Slit Crossing Double Slit Experiment

Experiment-4:

Figure 11 shows the standard diaphragm and the pattern of the single slit crossing double slit.

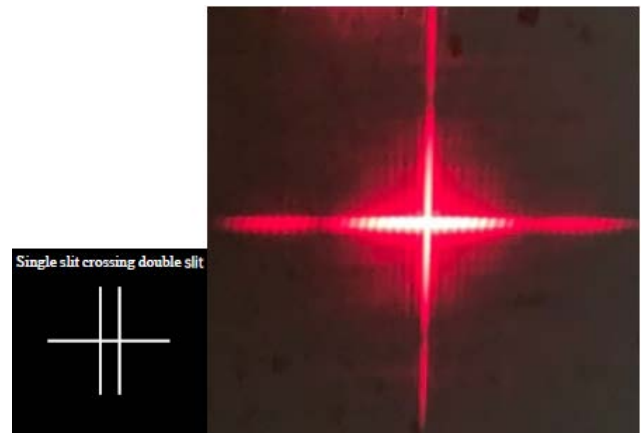


Figure 11. Standard single slit crossing double slit experiment

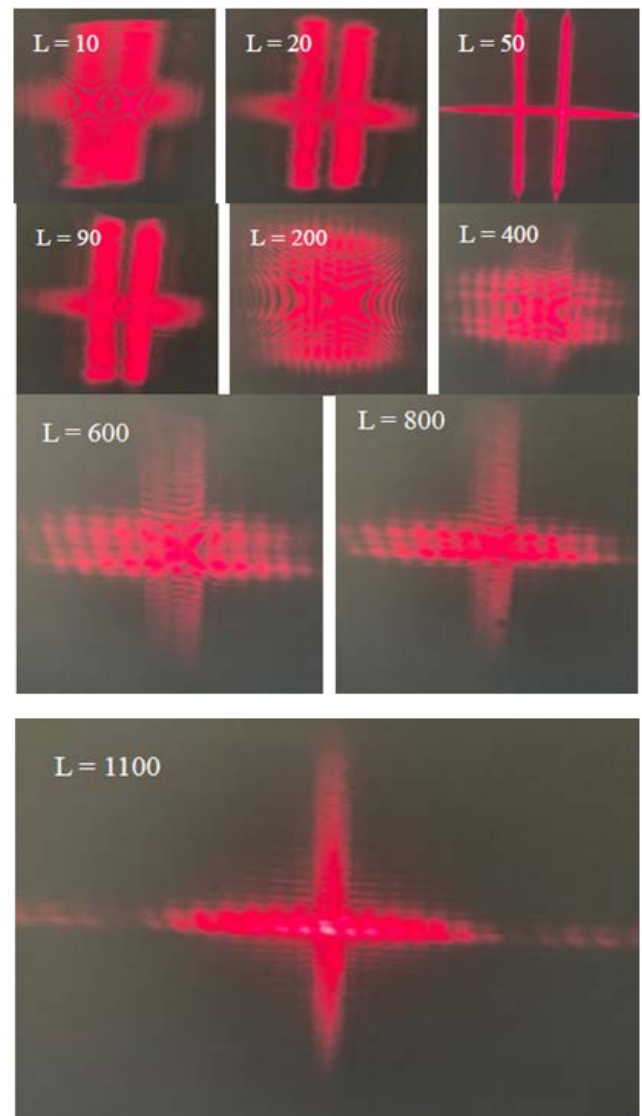


Figure 12. Evolution of pattern of single slit crossing double slit

Placing the convex lens at different distances L from the diaphragm. To study the evolution of the pattern, the L varies from 10 mm to 1100 mm.

Observation: When $L = 50$ mm, the pattern is the typical image of the single slit crossing double slit. When $L = 200$ to 800 mm, we have Transition patterns. When $L \geq 1100$ mm, the patterns are the interference patterns. The Pre-Particle patterns gradually evolve to the interference patterns.

Note: $L = 10$ mm and $L = 20$ mm show the Pre-Particle patterns, which are more complex than Particle patterns.

3.2.5. Evolution of Patterns of Orthogonal Cross Double Slit Experiment

Experiment-5:

Figure 13 shows the standard diaphragm and the pattern of an orthogonal cross double slit [9]

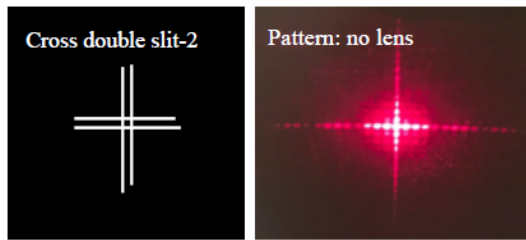


Figure 13. Standard Orthogonal cross double slit experiment

Placing the convex lens at different distances L from the diaphragm. To study the evolution of the pattern, the L varies from 10 mm to 1000 mm

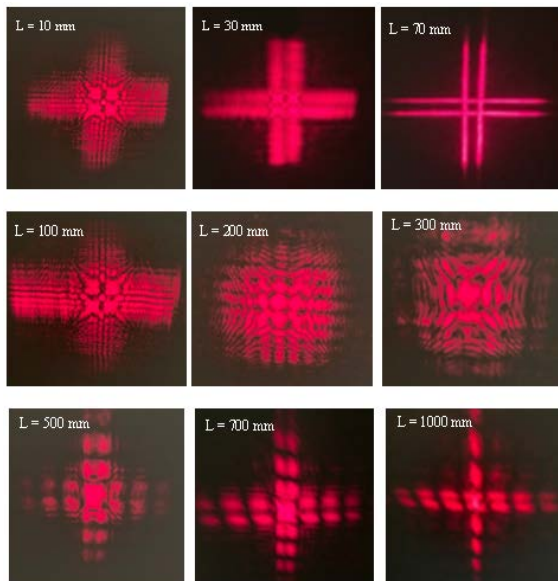


Figure 14. Evolution of pattern of Orthogonal cross double slit

Observation: When $L = 70$ mm, the pattern is the typical image of the cross double-slit. When $L = 100$ to 500 mm, we referred the patterns as Transition patterns. When $L \geq 700$ mm, the patterns are the interference patterns. The Pre-Particle patterns gradually evolve to the interference patterns.

Note: from $L = 10$ mm to $L = 30$ mm, the patterns are Pre- Particle patterns, which are more complex than Particle patterns.

3.2.6. Evolution of Patterns of Tilt Cross Double Slit

Experiment-6:

Figure 15 shows the standard diaphragm and the pattern of the tilt cross double slit.

Placing the convex lens at different distances L from the diaphragm. To study the evolution of the pattern, the L varies from 10 mm to 1000 mm

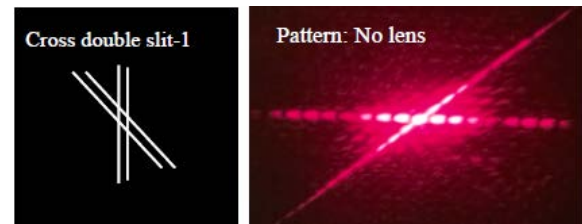


Figure 15. Standard single slit crossing double slit experiment

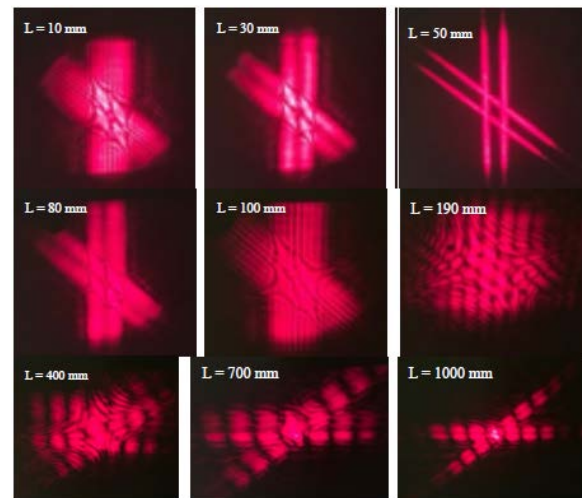


Figure 16. Evolution of pattern of tilt cross double slit

Observation: When $L = 50$ mm, the pattern is the typical image of tilt cross double-slit. When $L = 100$ to 500 mm, we referred the patterns as Transition patterns. When $L \geq 700$ mm, the patterns are the interference patterns. The Pre-Particle patterns gradually evolve to the interference patterns.

Note: from $L = 10$ mm to $L = 30$ mm, the patterns are Pre- Particle patterns, which are more complex than Particle patterns.

3.2.7. Evolution of Patterns of Multi Cross Double Slit

Experiment-7:

Figure 17 shows the standard diaphragm and the pattern of the multi cross double slit.

Placing the convex lens at different distances L from the diaphragm. To study the evolution of the pattern, the L varies from 10 mm to 1200 mm.

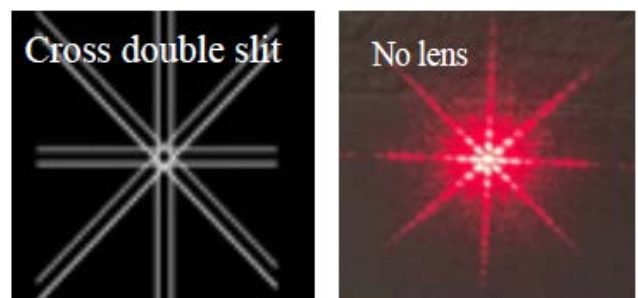


Figure 17. Standard multi cross double slit experiment

Figure 18 shows the evolution of the patterns.

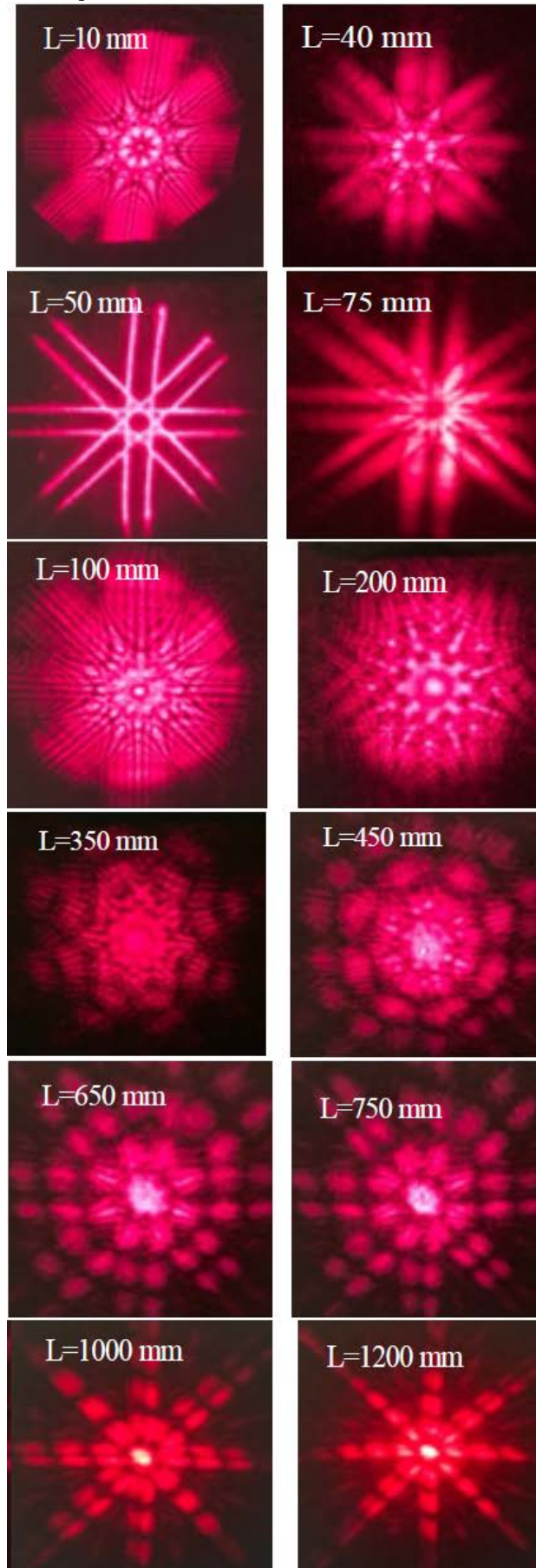


Figure 18. Evolution of patterns of multi cross double slit experiment

Observation: When $L=50$ mm, the pattern is the typical particle pattern that is the image of the diaphragm. The Pre-Particle patterns gradually evolve to Transition patterns and finally to Interference patterns at $L \geq 1000$ mm

Note: approximately, from $L = 10$ mm to $L = 40$ mm, the patterns are Pre-Particle patterns.

3.2.8. Evolution of Patterns of Disc Ring

Experiment-8:

Figure 19 shows the standard diaphragm and the pattern of the disc ring experiment.

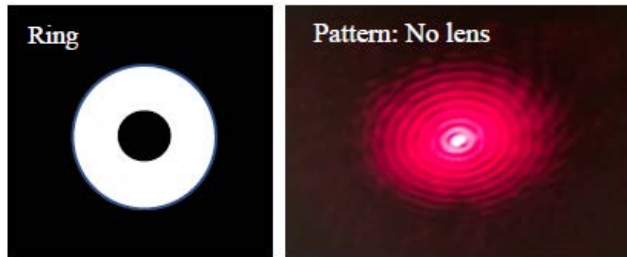


Figure 19. Standard disc ring experiment

Figure 20 shows the evolution of the patterns

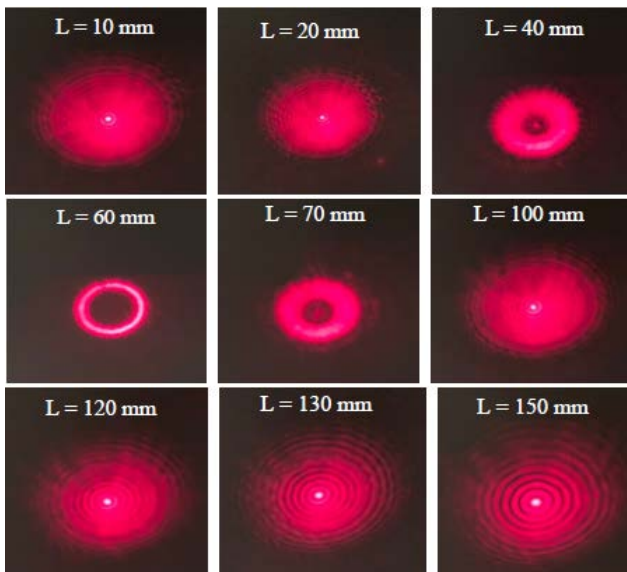


Figure 20. Evolution of patterns of disc ring experiment

Observation: When $L=60$ mm, the pattern is the typical particle pattern that is the image of the diaphragm. The Pre-Particle patterns gradually evolve to Transition patterns and finally to Interference patterns at $L \geq 130$ mm

Note: at $L = 10 - 40$ mm, the patterns are Pre-Particle patterns.

3.2.9. Evolution of patterns of 1D grating

Experiment-9:

Figure 21 shows the standard diaphragm and the interference pattern of the 1D grating.

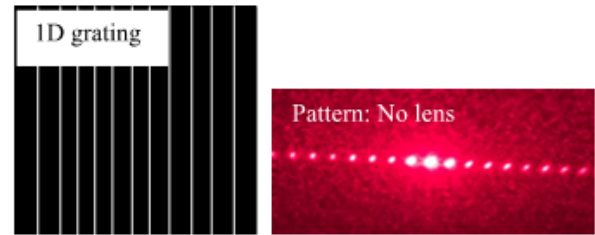


Figure 21. Standard 1D grating experiment

Figure 22 shows the evolution of the patterns

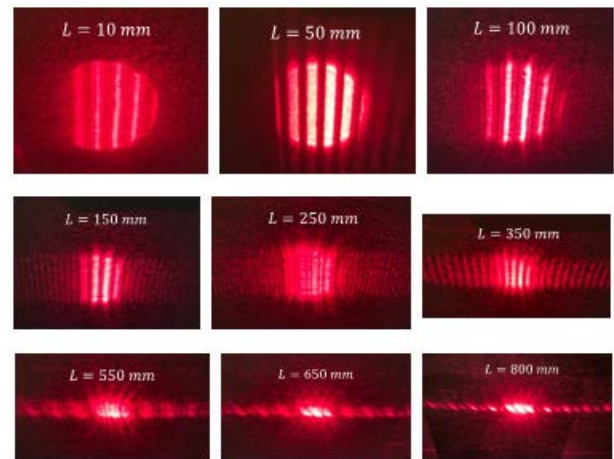


Figure 22. Evolution of patterns of 1D grating experiment

Observation: At $L = 50$ mm, the pattern is the typical Particle pattern, the non-interference pater. Then, the Particle patterns gradually evolves to the interference pattern.

Note: at $L = 10$ mm, the pattern is Particle patterns. There is no Pre-Particle pattern.

3.2.10. Evolution of Patterns of 2D Grating

Experiment-10:

Figure 23 shows the standard diaphragm and the pattern of a 2D grating.

Figure 24 shows the evolution of the patterns

Observation: Figure 24 shows the evolution of the patterns. The pattern at $L = 50$ mm is the typical Particle pattern. The Pre-Particle patterns gradually evolve to the interference patterns.

Note: at $L = 10$ mm, the pattern is Pre-Particle patterns.

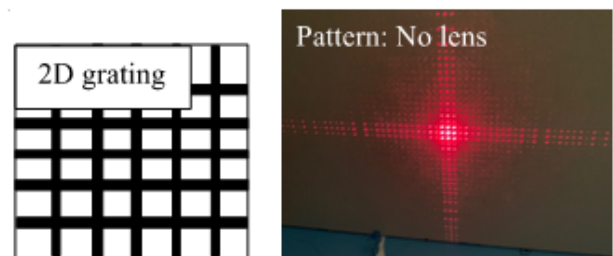


Figure 23. Standard 2D grating experiment

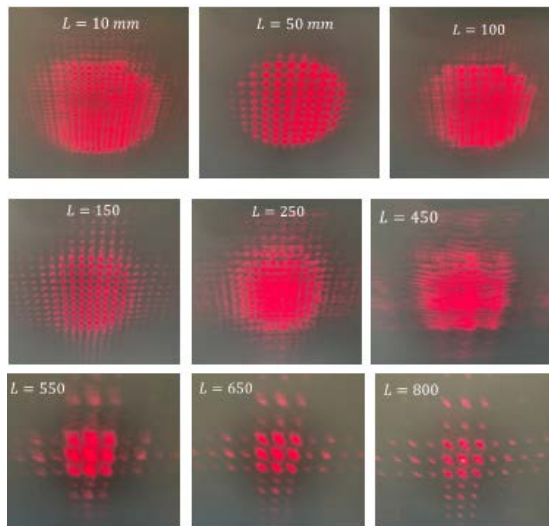


Figure 24. Evolution of patterns of 2D grating experiment

4. Summary

The phenomena of wave Experiment-1 to -10 are consistent, and show that, in the classical wave experiment, the light is photons **before and after** passing through the diaphragms. The phenomena of the non-interference patterns evolving to the interference patterns are universal for the classical wave experiments, and show new mystery.

Challenges are:

- (1) what is the mechanism of photons, as particles, distributing as waves in Zone-3; while, in Zone-1 and Zone-2, photons distribute as particle, which is natural;
- (2) to interpret consistently the evolution phenomena;

- (3) there is a phenomenon that: for a single slit, a double slit and a 1D grating, for which all slits are in the same orientation, there is no Pre-Particle pattern; however, for cross double slit and 2D grating, for which the slits are in different orientations, there are Pre-Particle patterns, which is complex to interpret.

In this article, we show the novel phenomena, new understandings and new mystery of the wave experiments for theoretically restudying the nature of the light and the concepts of both coherence and wave function collapse.

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