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Non-Parallel-Curve-Double Slit Experiments--- Butterfly-shape Interference Pattern and Optical-Butterfly-Effect

Hui Peng*

James Peng Lab, Fremont, CA, USA
*Corresponding author: davidpeng1749@gmail.com

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Abstract Feynman (1956) called the double slit experiment "[…] it contains the only mystery. We cannot make the mystery go away by 'explaining' how it works". The photons are described by probability wave functions. The wave functions collapse to photons when measuring. However, the collapse of the wave function leads to the inconsistent/incomplete of the quantum mechanics (Penrose, 2022). In this article, we show that, the light is photons, not waves. And it is photons that produce the non-wave pattern and wave patterns in the same experiment. We refer to the phenomenon as "PhotoWave Phenomenon". We experimentally show for the first-time the novel phenomenon that is new mystery, non-parallel-curve-double slit produces Butterfly-shape interference patterns. We show the sensitive dependence of patterns on the structures of apparatus of slits: changes in the structure of the slits result in profound differences in pattern. We refer to it as "Optical-Butterfly-effect". The PhotoWave phenomena support Penrose's statement. Advances in optical experiments, i.e., PhotoWave phenomena, demand a complete theory. The experiments provide the comprehensive phenomena for further developing theoretical model to study the nature of the light and the light wave theories.

Keywords: *pattern evolution, non-parallel-curve-double slit, Butterfly-shape interference patterns, PhotoWave phenomena, Optical-Butterfly-effect*

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1. Introduction

Historically, the study of the nature of the light reached basically two concepts: wave and particle.

(1). Light is waves only: In 1690, C. Huygens established the wave theory of the light [1].

(2). Light is particles only: In 1704, Newton established the corpuscles theory [2].

(3). Light is waves only: In 1801, Young's double slit experiment [3,4] revived Huygens' wave theory.

(4). Light is Photons: In 1905, Einstein quantized the light as photons to interpret "Photoelectric effect" [5].

(5). Wave-Particle duality: In 1927, Bohr proposed the complementarity principle [6].

Until 1950s, the wave-particle duality still puzzled Einstein. In 1951, he wrote "All these 50 years of conscious brooding have brought me no nearer to the answer to the question: What are light quanta?" [7].

(6). Mystery of double slit: In 1956, Feynman called the double slit experiment "a phenomenon […], it contains the only mystery. We cannot make the mystery go away by 'explaining' how it works" [8].

(7). Light is Probability waves: a photon is described by a probability wave function which collapses to photon on detector [9].

(8). Penrose's Statement: In 2022, R. Penrose in an interview stated: "this is not something that people normally even recognize as a problem … which is known as the collapse of the wave function. Now you see current quantum mechanics strictly speaking is an inconsistent theory" [10].

In this article, we show (1) a novel phenomenon which is new mystery; (2) the nature and characteristics of the patterns of the non-parallel-curve double slit are angle-dependence. The novel experiment shows that the light is Photons not only in Photoelectric effect, but in the classical wave experiments. *It is Photons that produce wave patterns near/on the detector*. We referred to it as *"PhotoWave Phenomena"* [11,12]. Thus, no need to introduce both the wave-particle duality and the collapse of wave functions to interpret photons landing on the detector.

PhotoWave phenomena support Penrose's statement.

We introduce the term of "Optical-Butterfly-Effect" to describe the apparatus-dependence of Photo-Wave phenomena.

PhotoWave phenomena challenge the wave nature of the light. It is a challenge to consistently interpretate the PhotoWave phenomena and the Optical-Butterfly-Effect.

We provide novel experiments / PhotoWave phenomenon for further theoretical development.

2. Postulates

2.1. Postulates

The standard description of the double-slit experiment is: the light is waves, before and after passing through the double-slit. We show experimentally: the light is photons, before and after passing through the apparatuses of the slits [13,14,15,16].

Considering above two contradictory statements, we propose:

Postulate-1 on apparatus of slits: the apparatus of slits, e.g., a slide of a double slit or a slide of non-parallel-curve-double slit, does not change the nature of the light passing through it.

Example: when the light is photons before passing through the apparatus, then the light is photons after passing the apparatus until landing on the detector.

Thus, the concept of the collapse of wave functions is no longer needed, which support Penrose's statement.

Postulate-1 indicates that each fringe of the interference pattern on a detector is formed independently and partially. We have experimentally confirmed this indication [13,14,15,16].

We experimentally show "PhotonWave Phenomenon" and "Optical-Butterfly-Effect" in the article.

To interpret theoretically the "PhotonWave Phenomenon" and "Optical-Butterfly-effect" is a challenge.

Postulate-2 on convex lens

To study the details of the pattern evolution, we utilize the convex lens by placing the lens at different positions between the apparatus of slits and detector, so the light patterns arriving at the input surface of the lens are different.

To utilize the convex lens to study the evolution of patterns, we propose Postulate-2 of Lens.

Postulate-2:

Postulate-2.1: the convex lens enlarges the input image that arrives at the input surface;

Postulate-2.2: The convex lens breaks/stops the evolution of the patterns;

Postulate-2.3: The convex lens does not change the nature of the input pattern.

Experiments in this article confirm Postulate-2.

2.2. Experimental Setup

Figure 2.1. Experimental setup without lens

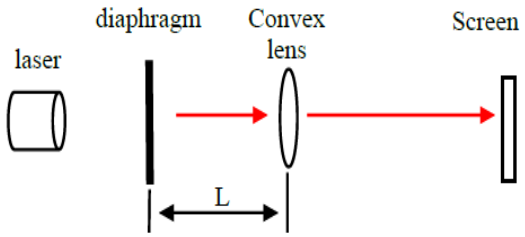


Figure 2.2. Experimental setup with lens

Experimental setup (Figure 2.1): Figure 2.1 shows Experimental setup without lens. Figure 2.2 shows Experimental setup with lens.

For most Experiments in this article, we utilize Experimental setup of Figure 2.1 and Figure 2.2.

3. PhotoWave Phenomena: Non-parallel-curve-double Slit

3.1. Non-parallel-curve-double Slit

Now we extend the curve-double-slit to the non-parallel-curve-double-slit (Figure 3.1) and then, study its pattern evolution (Figure 3.2), and the angle-dependence of the patterns (Table 1).

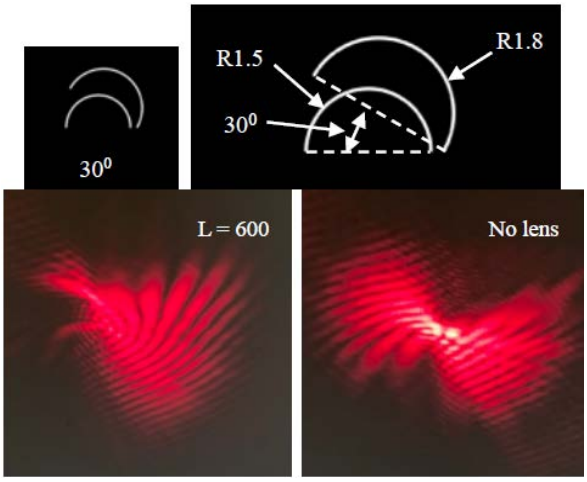


Figure 3.1. Non-parallel-curve-double slit and Butterfly-shape patterns

3.2. Pattern Evolution

Experiment-3.1 (Figure 3.2)**:** pattern evolution

Experimental setup: Figure 2.2.

Figure 3.2 shows the pattern evolution of the non-parallel-curve-double slit.

Observation (Figure 3.2):

Figures at L = 10-100 mm shows Pre-particle patterns; at L = 200 mm, showing Particle pattern, the image of the non-parallel-curved-double slit; at L = 500 mm, showing Resting-Butterfly-shape interference pattern; at L = 700 mm, showing Transition patterns; at L = 1300 mm, showing Flying-Butterfly-shape interference patterns.

Note: (1) the Pre-particle patterns, Particle pattern and Transition patterns are non-wave patterns and thus indicate that the light is photons; (2) the patterns gradually evolve, so there is no clear cut between patterns at different positions.

3.3. Angle-dependence of Patterns

The non-parallel-curve-double-slit of different angles (Figure 3.3) produce the different Butterfly-shape interference patterns (Table 1)

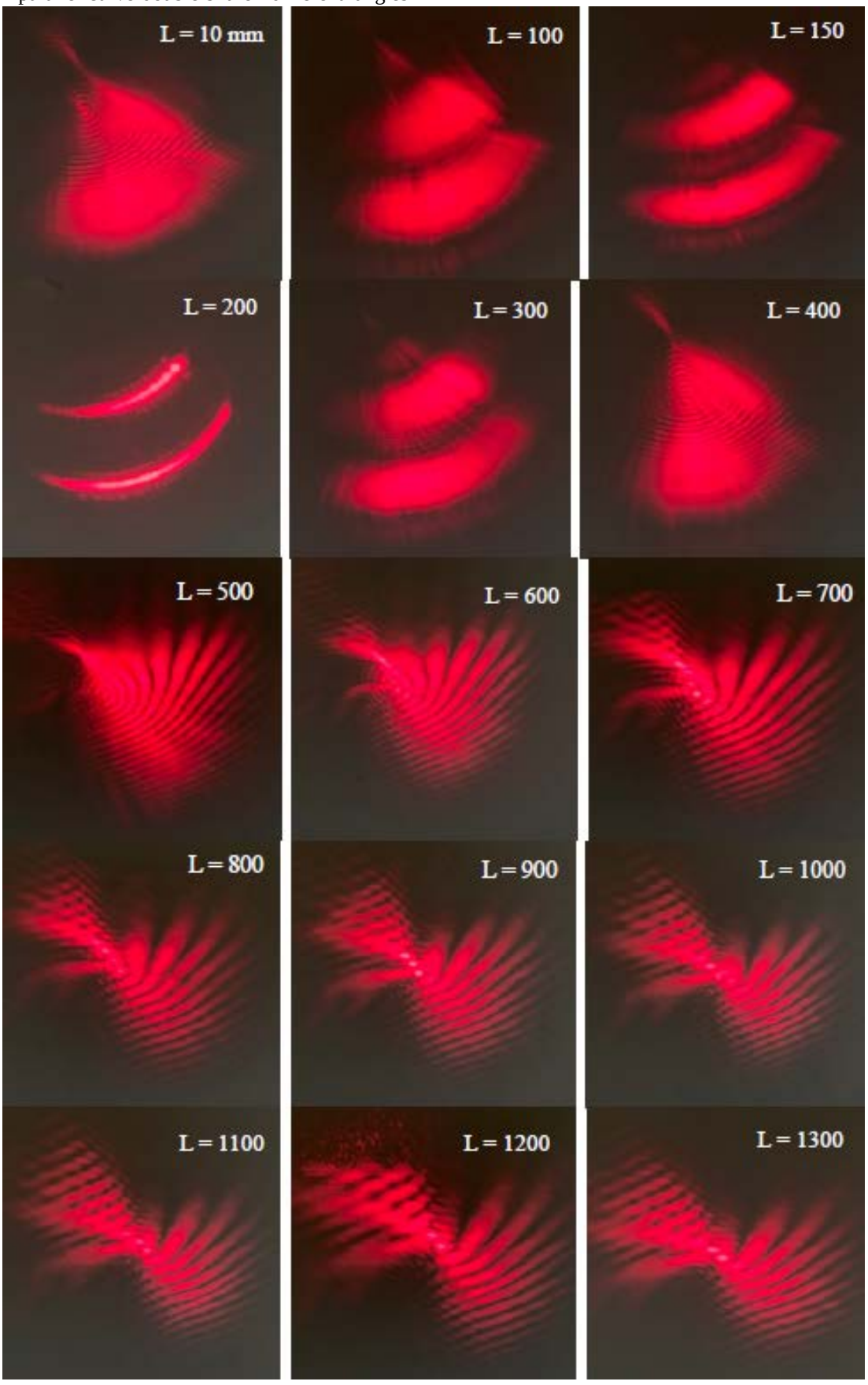


Figure 3.2. Pattern evolution

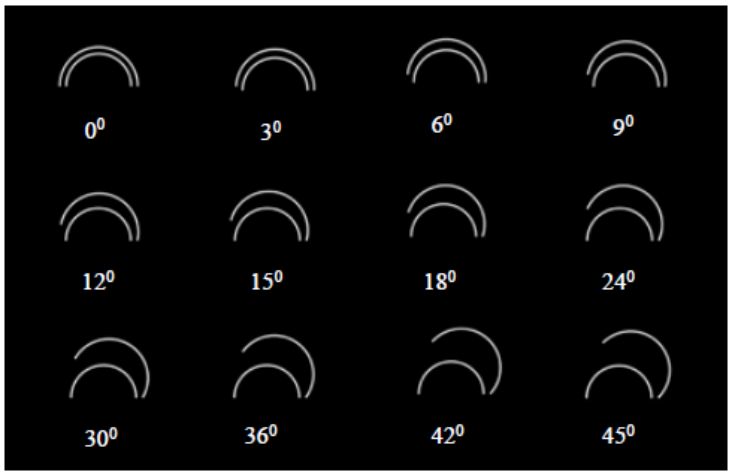


Figure 3.3. Non-parallel curved double slit of different angles

Table 1. Patterns of Non-parallel-curve-double slit of different angles

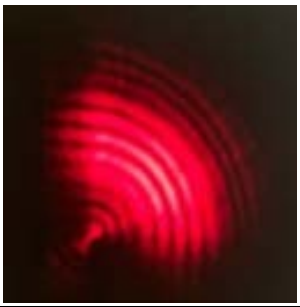
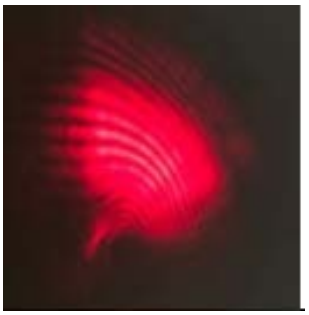
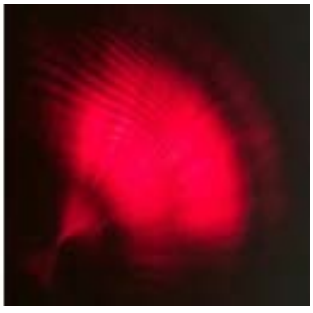
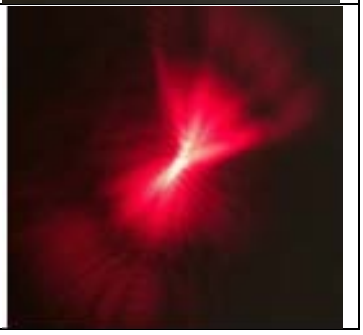
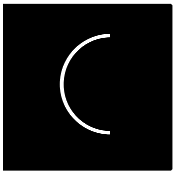
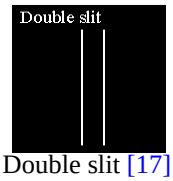
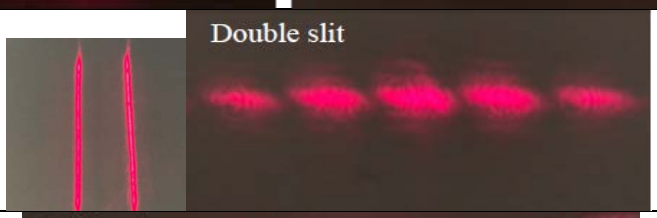
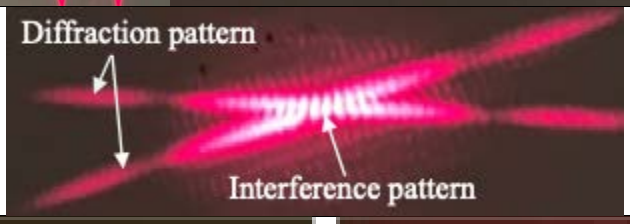
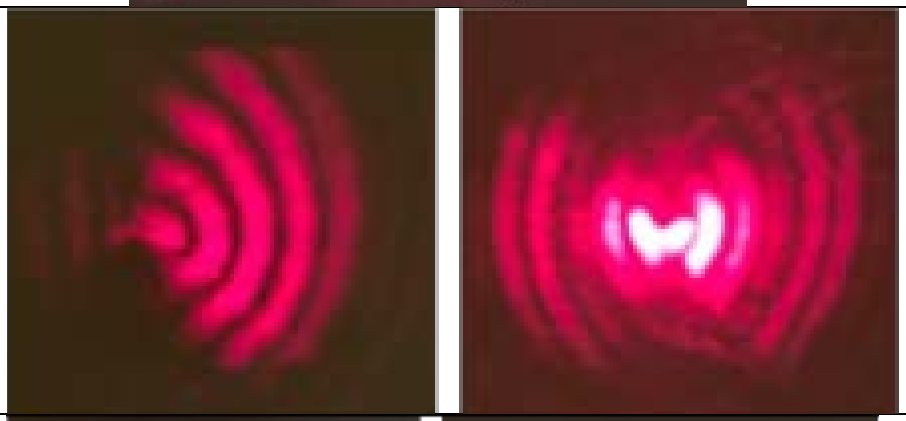
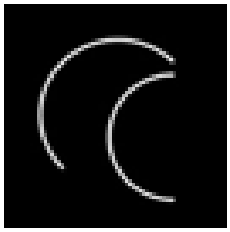
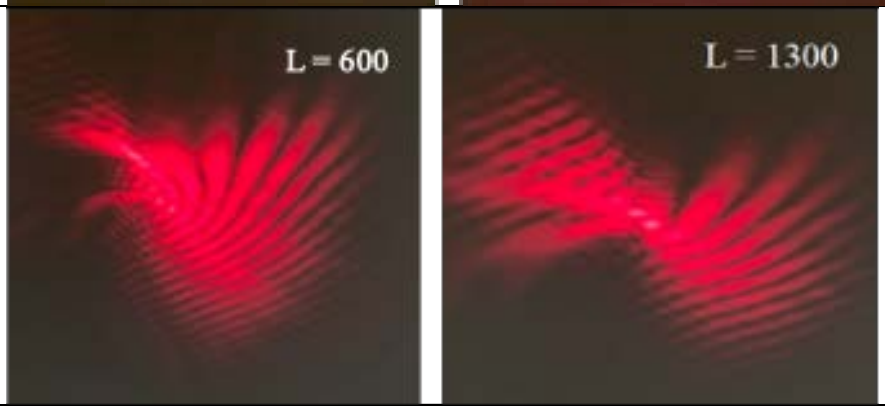
	L=200mm	L=500mm	L=1300mm
0^0			
9^0			
18^0			
45^0			

Table 2. Comparison of different slits and their patterns

Slit	Patterns
 Single slit [17]	
 Curve-single slit [18]	
 Double slit [17]	
 Non-parallel-double slit [19]	
 Curve-double slit [20]	
 Non-parallel-curve-double slit [21]	

4. Discussion

We proposed and performed the non-parallel-curve-double slit experiments, which show both the non-wave patterns (such as Pre-particle patterns, Particle patterns, Transition patterns), and the Butterfly-shape interference patterns.

The coexistence of the non-wave patterns and Butterfly-shape interference patterns in the same experiment indicates that the light is photons, but wave, and it is photons that produce both the non-wave patterns and the Butterfly-shape interference patterns, we refer to it as PhotoWave experiment/phenomenon.

Not-so-indicative-differences in the structures of slits lead to the profound differences in the patterns (Table 2). Namely, Table 2 shows the sensitive dependence of patterns on the structures of the slits. We refer to the phenomenon as "*Optical-Butterfly-Effect*", which is the optical analogy of "Chaos Butterfly Effect"

It is not necessary to introduce the concept of "collapse of the wave function" in PhotoWave phenomena; which supporting Penrose's statement.

No need of wave-particle duality to explain both Photoelectric Effect and PhotoWave Phenomena. We suggest that PhotoWave Phenomena may be attribute to the interactions between photons after passing through the double slit.

It is a challenge to consistently/completely explain PhotoWave Phenomena and "Optical-Butterfly-Effect".

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