



Deeper Mysteries of Double Slit Experiments --- 1D and 2D Non-Interference and Interference Patterns

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Abstract: The normal double slit experiments (we refer to it as *Straight-Parallel-double-slit*) are basic experiments and Feynman's mystery in the optics/quantum mechanics. In this article, we show the following new mysteries: the characteristics of the interference patterns of the optical slit experiments depend on whether the slits are straight-lines or curve-lines and whether two slits are parallel or non-parallel; and independent on whether there are missing segments at the intersection of, for example, cross-double-slit. We ignore the effects of both the width of the slits and the distance between two slits and then, show the following: there is no variable in *Straight-Parallel-double-slit*; *Straight-Non-Parallel-double-slit* has one variable, the angle between two slits; *Curve-Parallel-double-slit* has one variable, the curvature of the slits; *Curve-Non-Parallel-double-slit* has two variables, the angle and curvature, and the curvatures of two slits may be either the same or different. The characteristics of patterns depend on those variables. The complete and consistent interpretation is a challenge. The above experiments show deeper mysteries and would motivate further study of optics.

Keywords: double-slit, non-parallel-double-slit, curve-double-slit, curve-non-parallel-double-slit, curve single slit, interference pattern, hybrid interference pattern, point-symmetry interference pattern, butterfly-shape interference pattern, optics-butterfly-effect.

INTRODUCTION

The straight single slit (the standard single slit) and straight parallel double slit (the standard double slit) experiments are basic experiments in the optics and physics, and are foundation of the wave-particle duality and quantum theory. In those experiments, the slit of the single slit is straight lines, and the slits of the double-slit is straight lines and parallel to each other. Feynman referred to the double slit experiment as the mystery of the optics/quantum mechanics. To study the mystery further, in this article, we present the experiments of the Curve-single-slit, Cross-Curve-single-slit, single-ring, Straight-Non-Parallel-double slit, Curve-Parallel-double slit, Curve-Non-Parallel-double slit, and double-ring. We show the following: the characteristics of the interference patterns of the above optics slit experiments depend on both whether the slits are straight-lines or curve-lines and whether slits are parallel or non-parallel; and independent on whether there are missing segments at the intersection of, for example, cross-double-slit. The Straight-Parallel-double-slit has no variable (in this article, we assume that the wavelength, the width of the slits, and the distance between the two slits are constant); the Straight-Non-Parallel-double-slit has one variable, the angle between two slits; the Curve-Parallel-double-slit has one variable, the curvature; the Curve-Non-Parallel-double-slit has two variables, the angle and curvature. Those new experiments show that the slight differences in the slits produce the significant

differences in the patterns and the pattern evolutions. We refer to the phenomena as the Optics-Butterfly-phenomena.

REGULAR AND IRREGULAR SLIT EXPERIMENTS

Experimental Setup

All of experiments in this article utilize the same Experimental setup (Figure 1):

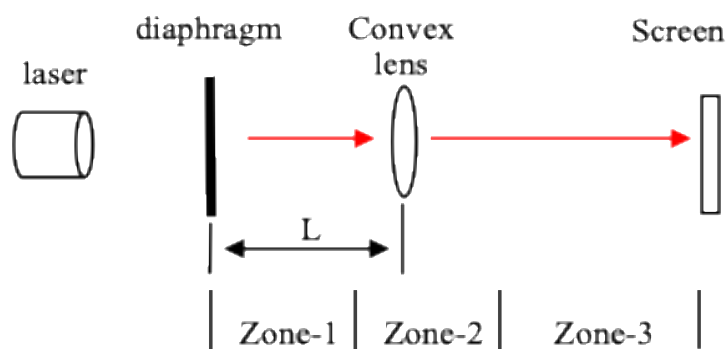


Figure 1: Experimental setup: lens placed at different positions between diaphragm and Screen.

Note: (1) The diaphragm represents the slits of different configuration, such as double slit, single slit, curve double slit, curve single slit, etc. (2) The lens does not change the input pattern, namely, the output pattern is the same as the input pattern. (3) A lens can be placed in Zone-1 (observe Particle pattern on Screen), Zone-2 (observe Transition pattern on Screen), and Zone-3 (observe Interference pattern on Screen), respectively,

Straight-Single-Slit vs. Curve-Single-Slit

The straight-single-slit has no variable. The Curve-single-slit has one variable, i.e., the radian (rad) (Figure 2).



Figure 2: Curve-single-slit with different radians.

Note: in this article, we assume that the radiuses of curves are constant. Next, we show: (1) the patterns and the pattern evolution of a straight-single-slit; and (2) the pattern evolution and the radian-dependence of the patterns of the curve-single-slits.

Experiment-1: Pattern and pattern evolution of a straight-single-slit and curve-single-slits (Table 1).

Table 1: straight single slit and curve single slits

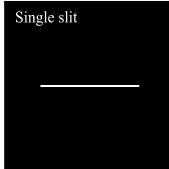
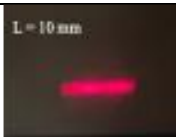
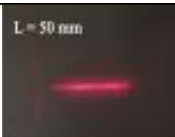
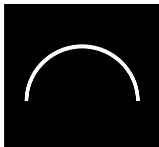


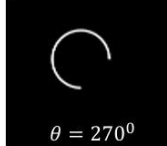
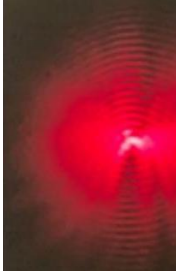
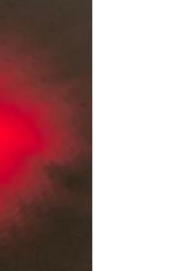


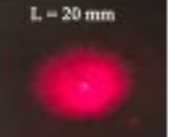
| Slit | Pattern | | | | |
|---|---|--|--|--|--|
| Straight-single-slit  |  | | | | |
| |  | | | | |
| 180° curve-single-slit  |  | | | | |
| |  | | | | |
| 270° curve-single-slit  |  | | | | |
| |  | | | | |
| 360° curve-single-slit (or Single-ring)  |  | | | | |
| |  | | | | |

Table 1 shows the patterns and the pattern evolutions of both the straight single slit and the curve single slits. The patterns are profoundly different: the pattern of a straight single slit is one dimension, while the patterns of the curve-single-slits are two dimensions. The patterns are curvature dependent.

Cross-Straight-Single-Slit vs Cross-Curve-Single-Slit

Next, let us compare a cross-straight-single-slit and a cross-curve-single-slit.

Experiment-2 (Table 2): Pattern and pattern evolution of a cross-straight-single-slit and cross-curve-single-slit.

Table 2: Cross-straight-single-slit and cross-curve-single-slit


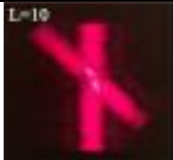










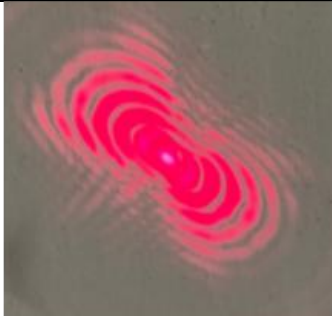


| | | | | | | | | | | |
|------------------------------|--|---|---|---|---|--|---|---|---|---|
| Cross-straight-single-slit |  | | | | |  |  |  |  |  |
| |  |  |  |  |  | | | | | |
| Cross-180°-curve-single-slit |  | | | | |  | | | | |
| 180° curve-single-slit |  | | | | |  | | | | |
| | (This is for comparison) | | | | | | | | | |

Table 2 shows the following: the pattern of the cross-curve-single-slit is a complicated interference pattern, and complicate than both the patterns of the cross-straight-single-slit, and the patterns of the curve-single-slit. Three patterns are completely different.

Straight-Parallel-Double-Slit vs. Curve-Parallel-Double-Slit

Let us consider the patterns and pattern evolutions of both Straight-parallel-double slit and Curve-Parallel-Double-Slit (Figure 3)



Figure 3: Curve-parallel-double-slits with different curvatures.

Experiment-3: Straight-parallel-double slit experiment and Curve-parallel-double-slit Experiments (Table 3)

Table 3: Comparison of Pattern and pattern-evolution of both Straight-parallel-double slit and Curve-parallel-double-slit

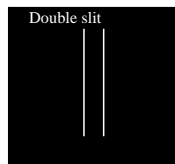
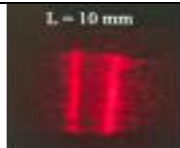
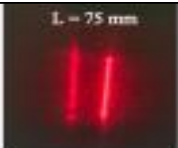
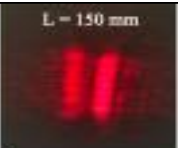

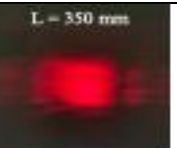

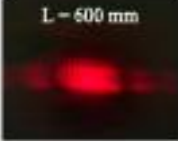

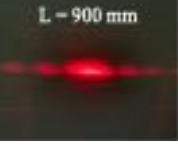

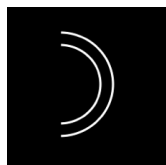
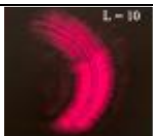
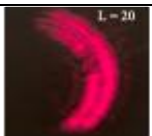
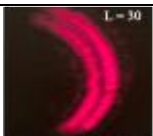
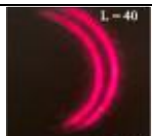

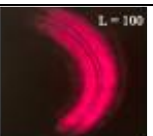



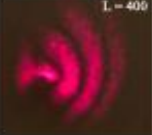
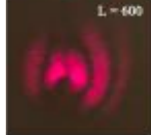

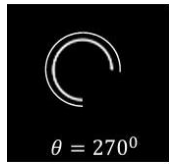
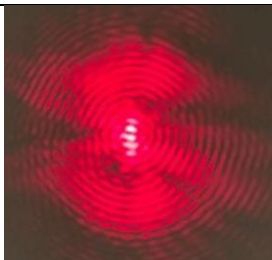


| | | | |
|---|--|---|--|
| <p>Straight-parallel-double-slit</p> <p>Double slit</p>  |           | | |
| <p>Curve-parallel-double-slit 90°</p>  |             | | |
| <p>Curve-parallel-double-slit 270°</p>  <p>$\theta = 270^\circ$</p> |  | <p>Curve-parallel- double-slit 360° (double-ring)</p>  |  |

Table 3 shows the following: the patterns and the pattern evolutions of both the straight double slit and the curve double slits. The patterns are profoundly different: the pattern of a straight double slit is one dimension, while the patterns of the curve-double-slits are two dimensions. The patterns are radian-dependent.

Cross-Straight-Parallel-Double-Slit vs Cross-Curve-Parallel-Double-Slit

Experiment-4 (Table 4): The patterns of Two straight-parallel-double-slits crossing and Two curve-parallel-double-slits crossing.

Table 4: The patterns of cross-straight-double-slits and of cross-curve-double-slits.


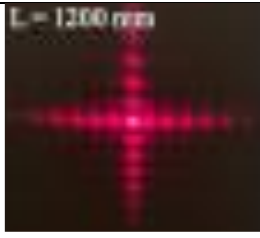


| | | | |
|--|---|--|---|
| Two straight-parallel-double-slits crossing  |  | Two curve-parallel-double-slits crossing  |  |
|--|---|--|---|

Table 4 shows that the patterns are profoundly different.

Straight-Parallel-Double-Slit vs. Straight-Non-Parallel-Double-Slit

Experiment-5 (Table 5): The patterns of non-parallel-double-slits (Figure 4) are angle-dependent.

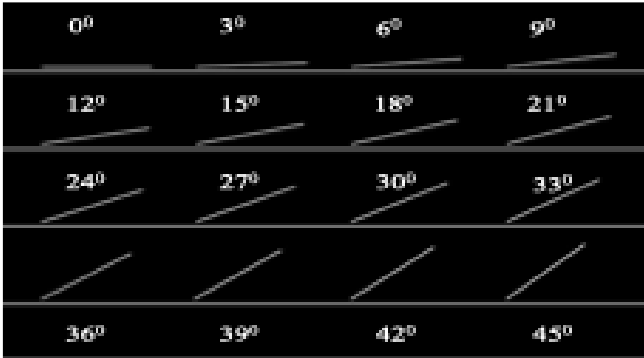


Figure 4: No-parallel-double-slits with different angles

For clear comparison, we still show the straight-parallel-double slit first in Table 5.

Table 5: Comparison of patterns of non-parallel-double-slits comparing with parallel-double-slit.

| | | | | | |
|---|--|--|--|--|--|
| <div>Straight-parallel-double-slit</div> <div>Double slit</div> | | | | | |
| | | | | | |
| <div>Straight-non-parallel-double-slit (2024-01)</div> | | | | | |
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Table 5 shows the patterns and the pattern evolutions of both the straight-parallel-double slit and the straight-non-parallel-double slit. The patterns are profoundly different: the pattern of a straight double slit is one dimension, while the patterns of the straight-non-parallel-double slit are two dimensions, referred to it as Hybrid-interference-pattern, which is angle dependent.

Straight-Parallel-Double-Slit vs. Curve-Non-Parallel-Double-Slit

Experiment-6 (Table 6): The patterns of the curve-non-parallel-double-slits are angle-dependent.

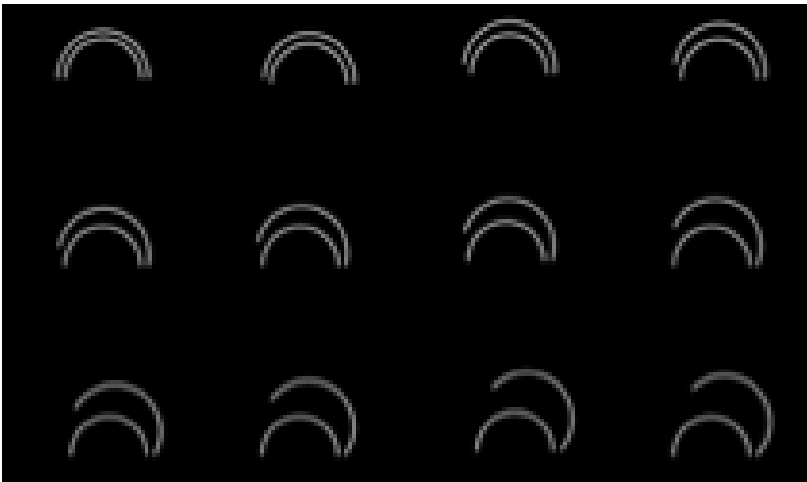
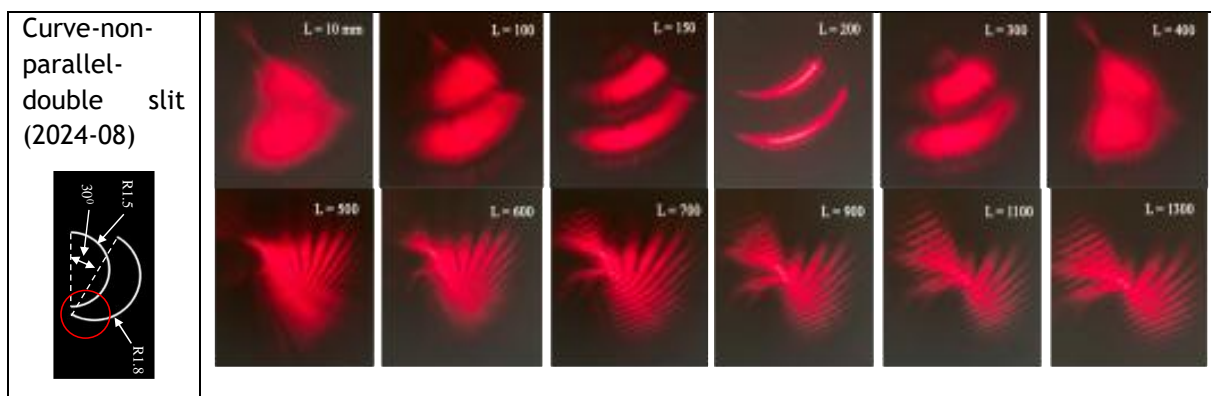


Figure 5: Curve-non-parallel-double-slits with different angles

Figure 5 shows the curve-non-parallel-double-slits with different angles. Here we only show the curve-slits with the same curvature. For clear comparison, we still show the straight-parallel-double slit in Table 6.

Table 6: Comparison of patterns of curve-non-parallel-double-slits and straight-parallel-double-slit.

| | | | | | |
|---|--|--|--|--|--|
| <div>Straight-parallel-double-slit</div> <div>Double slit</div> | | | | | |
| | | | | | |



The patterns are profoundly different: the pattern of a straight-parallel-double slit is one dimension, while the patterns of the curve-non-parallel-double slit are two dimensions, referred to it as Butterfly-interference-pattern, which is angle dependent. The Butterfly-interference-patterns are also dependent on the curvatures, which is not shown in this article.

MISSING SEGMENTS OF EACH SLIT DO NOT AFFECT FINAL INTERFERENCE PATTERNS AT FAR-DETECTOR

In this Section, utilize the fact that each slit of the cross-straight-parallel-double slit (a straight-parallel-double slit crossing another straight-parallel-double slit) is divided into three segments by other two slits crossing.

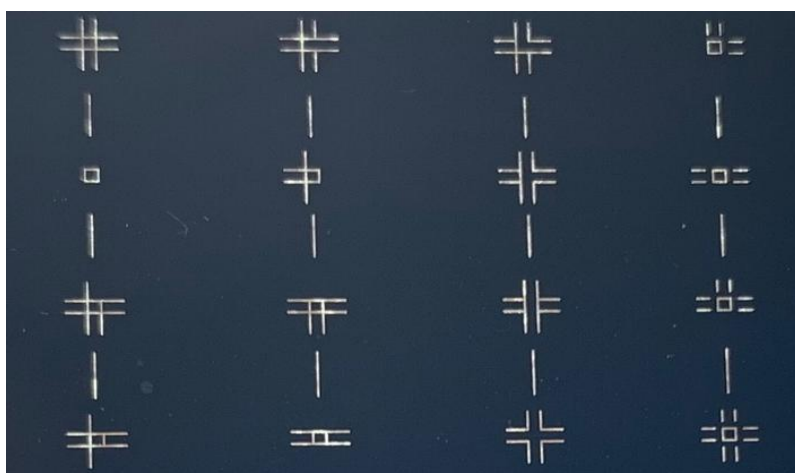

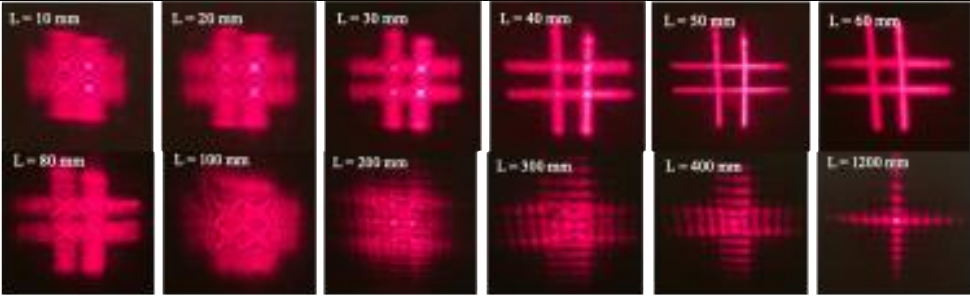

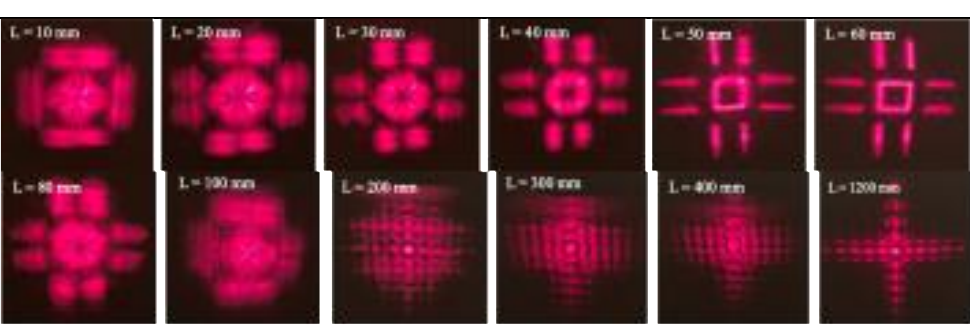

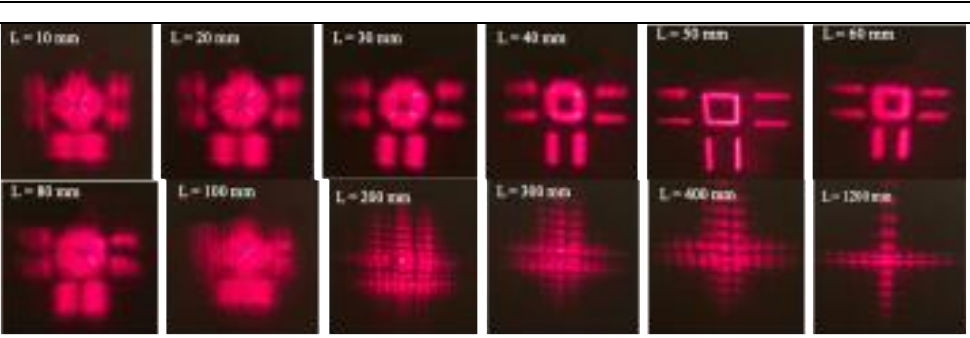

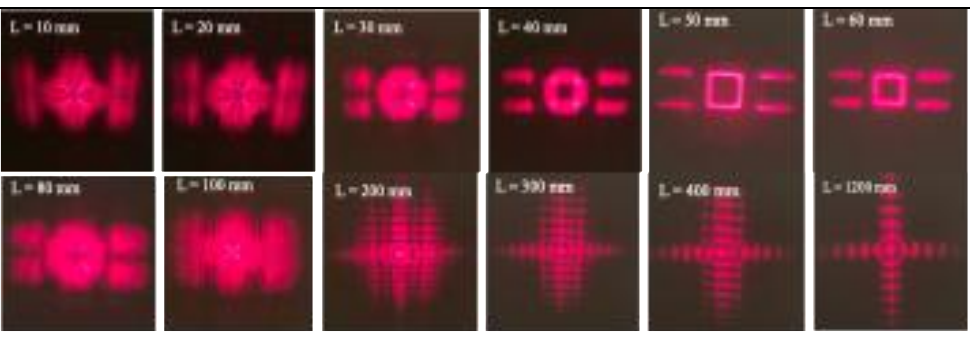
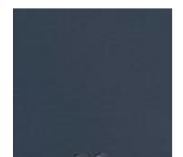
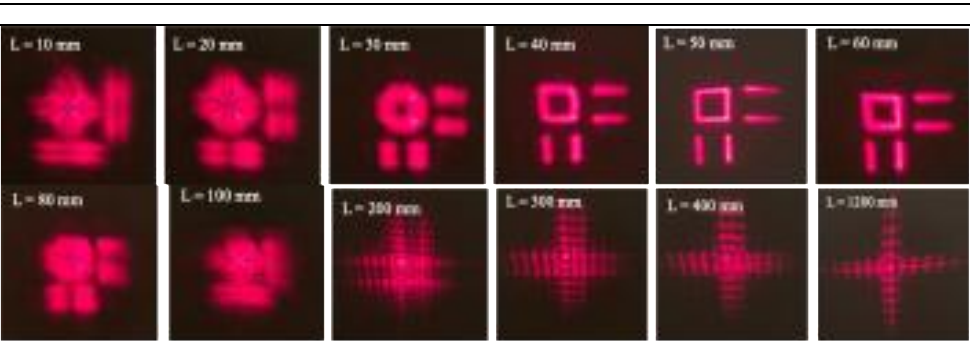
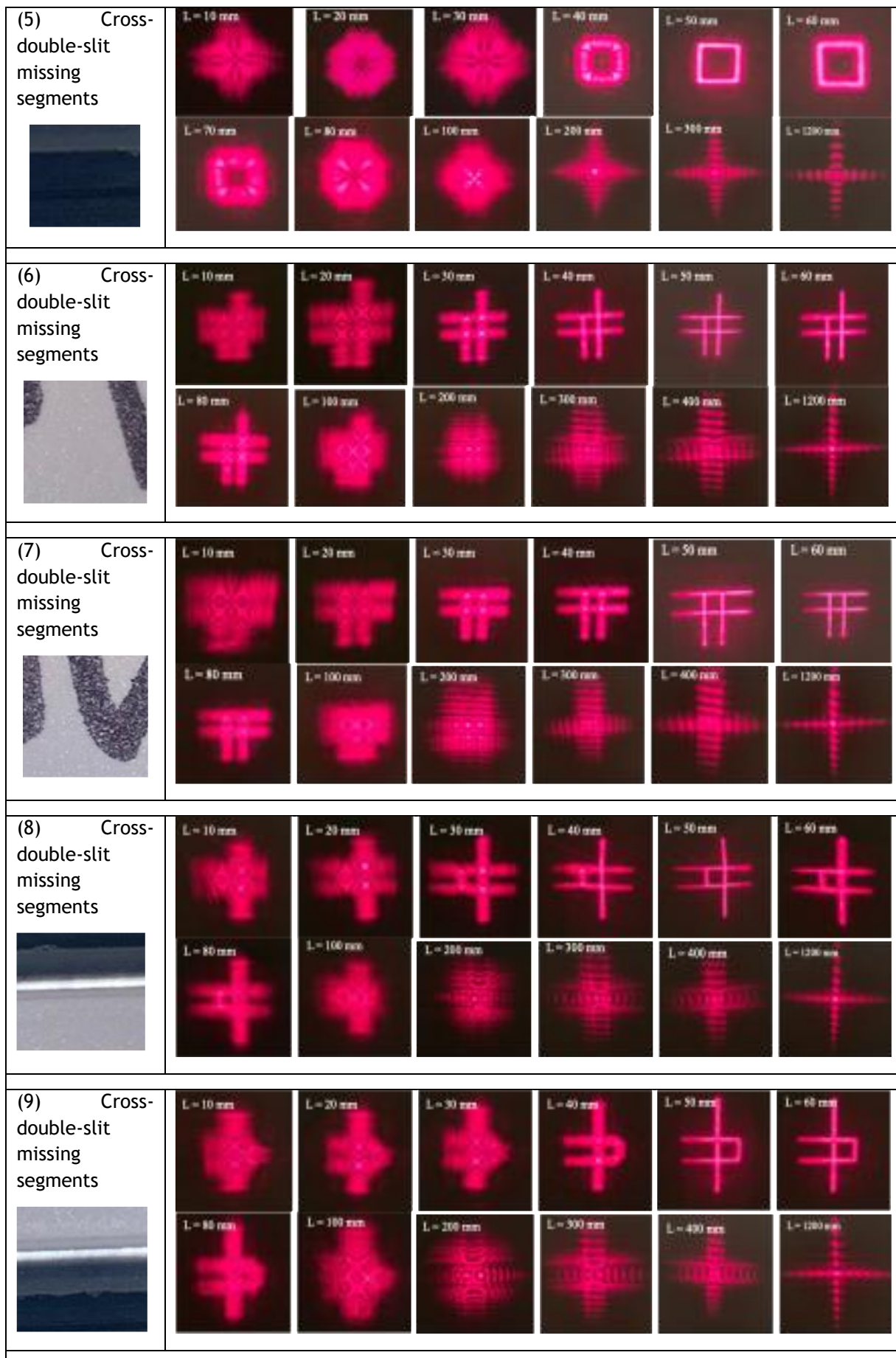


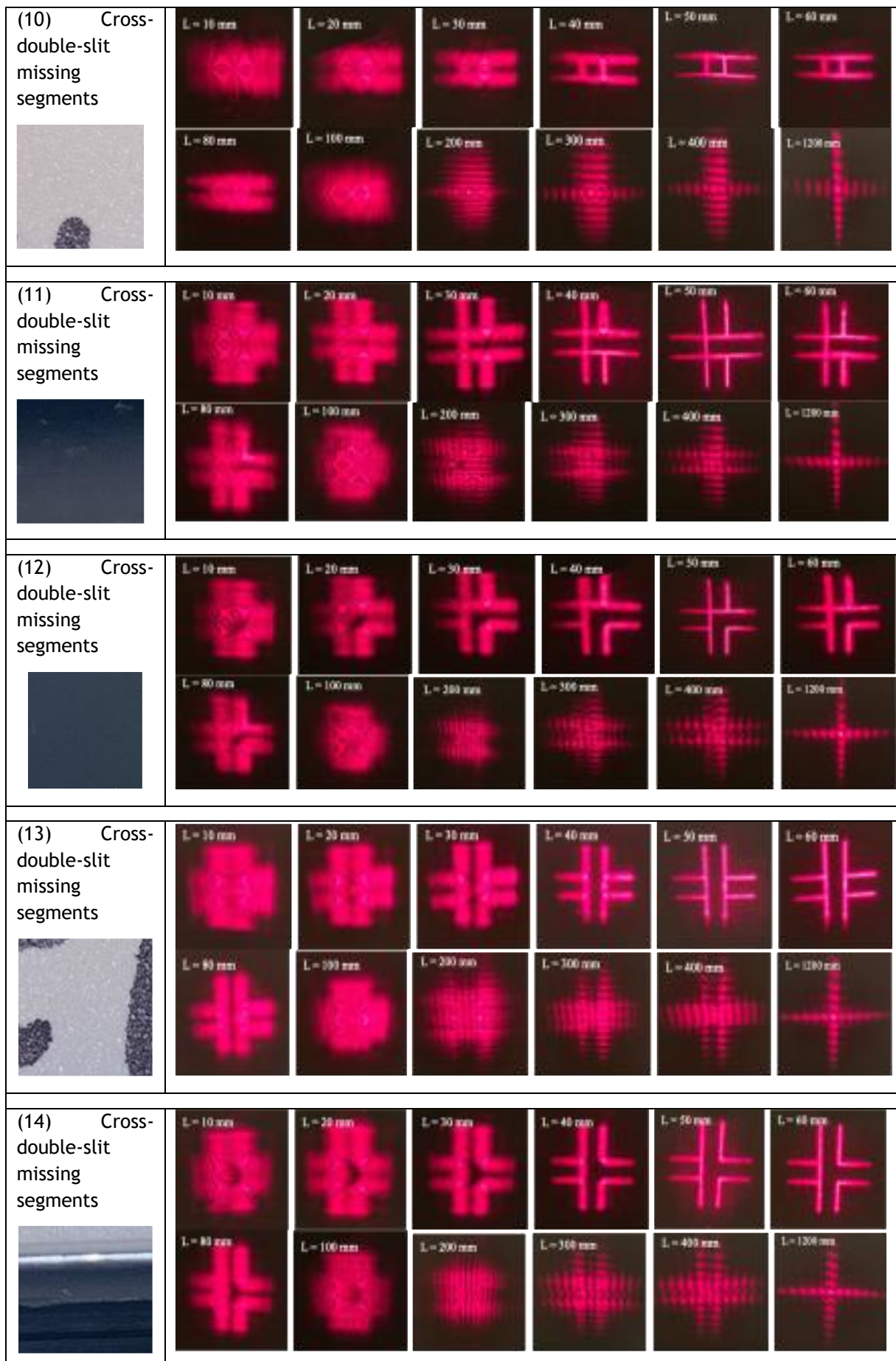
Figure 6: Cross-straight-parallel-double slit with missing segments

We experimentally show the function of each segment of each slit in producing both non-interference patterns (including Pre-Particle patterns, Particle patterns and Transition Patterns) and the Interference patterns by eliminate the segment respectively. Then, we compare with the patterns of the standard cross-double-slit experiment.

Table 7: Function of each segment of a slit in producing patterns

| | |
|---|--|
| <p>(0) Cross-double-slit</p>  |  |
| <p>(1) Cross-double-slit missing segments</p>  |  |
| <p>(2) Cross-double-slit missing segments</p>  |  |
| <p>(3) Cross-double-slit missing segments</p>  |  |
| <p>(4) Cross-double-slit missing segments</p>  |  |





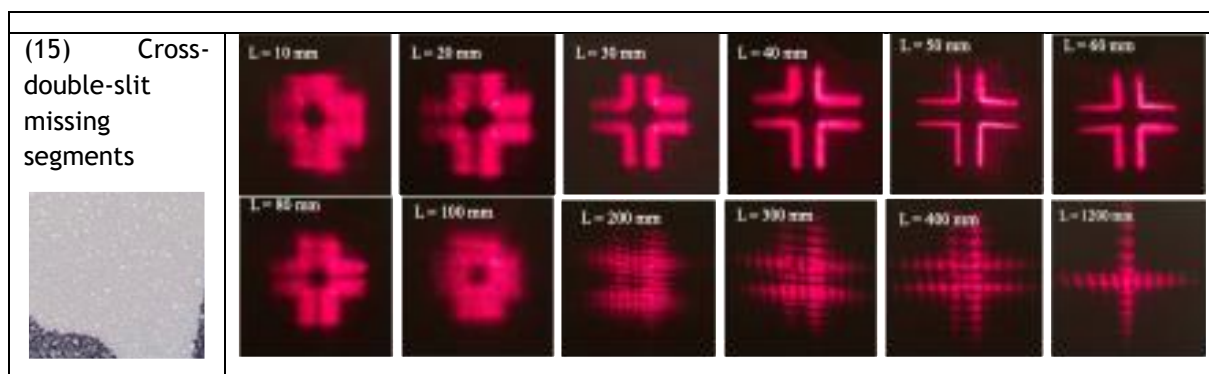


Table 7 shows that although the non-interference patterns of the different modified cross double-slits are different, for example, by placing the lens between $L = 10 \text{ mm}$ and $L = 400 \text{ mm}$, the final interference patterns are surprisingly similar, at $L \geq 1200 \text{ mm}$. This phenomenon is a new mystery and needs a consistent theoretical interpretation.

SUMMARY AND CONCLUSION

Experiments in this article show the following:

1. A curve-slit, including curve-single-slit, curve-parallel-double-slit, and curve-non-parallel-double-slit produces significantly different 2D patterns and completely different pattern evolutions.
2. A straight-non-parallel-double-slit produces a 2D Hybrid-interference pattern.
3. Missing segments of each slit of a double slit do not affect the final interference pattern.
4. A complete and consistent interpretation of above experiments is needed.