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Observations of Cross-Double-Slit Experiments

Hui Peng*

*Corresponding author: davidpeng1749@gmail.com

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Abstract Young's double-slit experiment had been performed over 200 years ago. Two- dimension cross-double-slit has been proposed recently. We report observations of two-dimension-cross-interference patterns created by two-dimension cross-double-slit apparatuses.

Keywords: *double-slit experiment, cross-double-slit experiment, optics, quantum mechanics*

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1. Introduction

The double-slit experiment was first performed by Young in 1801. It was interpreted as that light wave passed through two slits and created interference pattern, which led to wave-particle duality that is a basic mystery of quantum theory (Feynman).

Recently, for studying wave-particle duality further, the cross-double-slit apparatuses have been proposed [1]. In this article, we report the experimental results of cross-double-slit apparatuses.

2. Slides of Cross-Double-Slit

We made the slides with cross-double-slit, tilt-cross-double-slit and multi-tilt- cross-double-slit (middle and right slides in Figure 1).

The left slide in Figure 1 is a commercial product of regular double-slit. The middle slide consists of four vertical double-slits with space of 0.25, 0.5, 0.75 and 1.00mm respectively. The slide on the right consists of three vertical double-slits with space of 0.25, 0.50 and 0.75mm. Single-slit, horizontal double-slit, tilt-double-slit and multi-tilt- double-slit cross to each vertical double-slit respectively. All slits have the same width of 0.15mm. A disc of diameter of 0.5mm is located at the up-left corner of the middle slide and surrounded by a transparence ring of 0.15mm width.

3. Experimental Observations

The configurations of experimental apparatuses are: a laser source points to a slide two feet away. A detection screen is 20 feet away from the slide. We draw briefly illustrations of cross-double-slits on the left of Figure 2 to Figure 6, respectively, and experimental observations on the right correspondingly.

For comparison, we review the regular double-slit experiment first.

Experiment (A) (Figure 2): Regular one-dimension (1D) double-slit and its 1D- interference pattern.

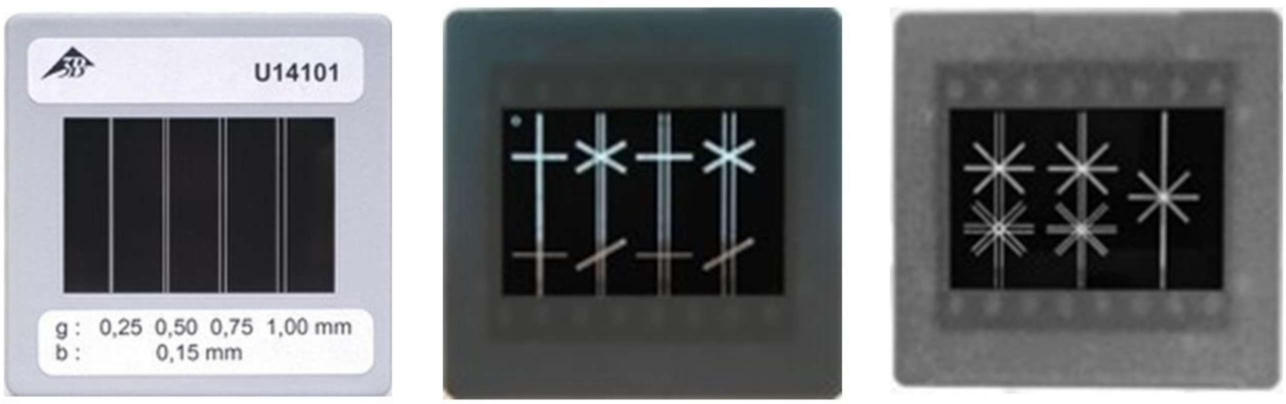

Figure 1. Slide of regular double-slit vs. slides of cross-double-slit

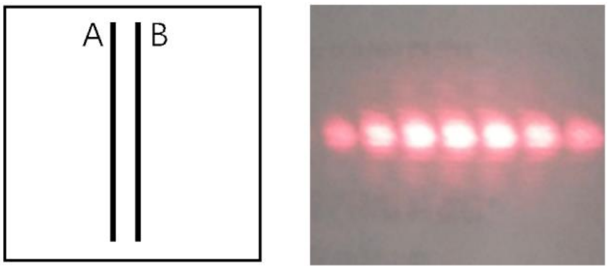

Figure 2. Regular 1D-double-slit and its 1D-interference pattern

The classical interpretation is that light wave passes through two slits simultaneously, interferes to each other and creates an 1D-interference pattern.

Experiment (B) (Figure 3): 2D-cross-double-slit and its 2D-cross-interfernce pattern.

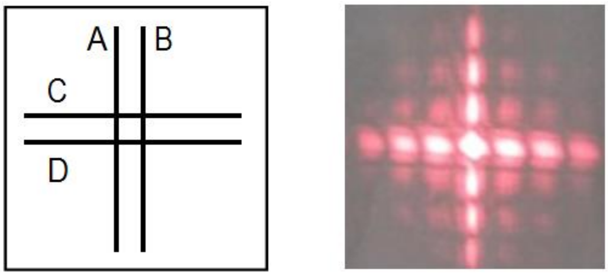

Figure 3. 2D-cross-double-slit and its 2D-cross-interference pattern

In this experiment, slits A and B pair up to form double-slit-AB, while slits C and D pair up to form double-slit-CD that is perpendicular to the double-slit-AB. The space between slits A and B is equal to that between slits C and D and is 0.25mm. The intersection has shape of square.

We observe a 2D-cross-interference pattern. The distance between two fringes of interference pattern created by double-slit-AB is the same as that by double-slit-CD correspondingly.

There is a kind of "interference pattern" as shown in First, Second, Third, and Fourth coordinate system quadrants respectively. We referred to this kind of "interference pattern" as "Secondary-Interference Pattern".

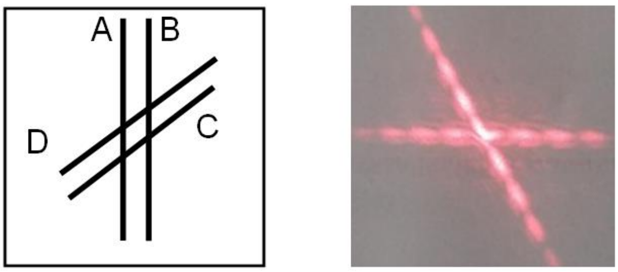

Figure 4. 2D-tilt-cross-double-slit and its 2D-tilt-cross-interference pattern

It is a challenge to interpret how photons "sense": (1) which slit they pass through; (2) what photons they will interfere with, then to create either interference pattern or secondary-interference pattern accordingly. Namely, photons passing through slits A and B create the horizontal interference pattern; photons passing through slits C and D create the vertical interference pattern; while photons passing through slits B and C, slits A and C, slits D and A, and slits B and D create "secondary-interference pattern" respectively. So, photons passing through one slit, say slit A, will interfere not only with those passing through slit B to create the horizontal interference pattern, but also with those passing through other slits to create the secondary-interference pattern.

Experiment (C) (Figure 4): A 2D-tilt-cross-double-slit and its 2D-tilt-cross- interference pattern.

The space between slits A and B is equal to that between slits C and D. Figure 4 shows that the interference pattern is perpendicular to the double-slit that creates it.

Experiment (D) (Figure 5): A 2D-multi-tilt-cross-double-slit and its 2D-multi-tilt- cross- interference pattern.

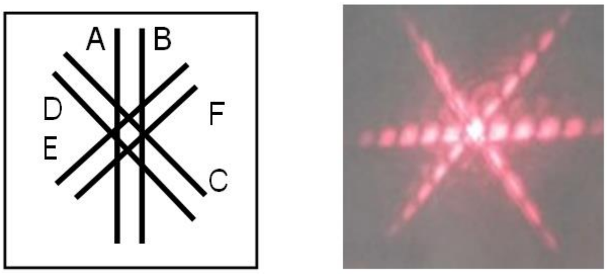

Figure 5. Multi-tilt-cross-double-slit and its interference pattern

The space between slits A and B, between slits C and D and between slits E and F are equal. The intersection has a shape of hexagon.

Photons passing through one slit, say slit A, interfere with its paired slit, slit B, to create the horizontal interference pattern. How can photons make this "decision"?

Experiment (E) (Figure 6): A 2D-multi-tilt-cross-double-slit and its 2D-multi-tilt- cross- interference pattern.

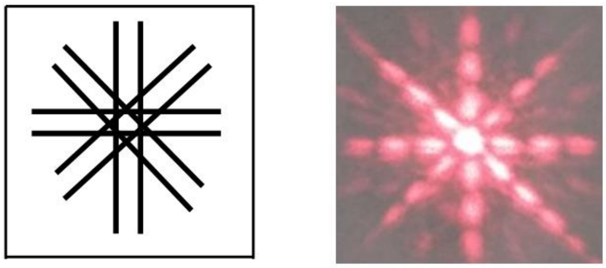

Figure 6. 2D-multi-tilt-cross-double-slit (2) and its 2D-multi-tilt-cross-interference pattern

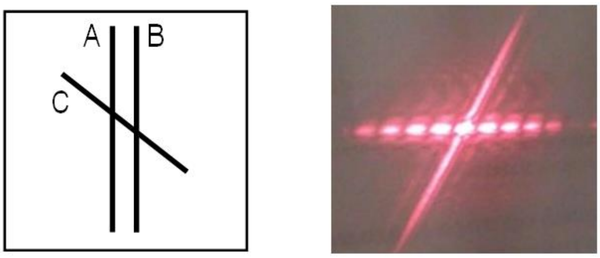

Figure 7. Single-slit crosses double-slit and its pattern

The intersection has a shape of octagon. The zero-order fringes of four interference patterns are overlapped. If using lines to connect first-order fringes of each of 1D-interference patterns created by different double-slits respectively, then the lines are closed to form an octagon. Therefore, we argue that to increase the number of double-slits, the shape of the closed line will be closer and closer to a circle. The same for the second-order fringes, and so on.

Experiment (F) (Figure 7): 2D-single-slit-cross-double-slit and its 2D-pattern.

Experiment (G) (Figure 8): Rotation Invariance and Poisson-Arago-type Spot. Combining Figure 2, Figure 3, Figure 4, Figure 5 and Figure 6 suggests that, if we increase the number of double- slits that are intersected at the same spot, the shape of the intersection will approach to a circular disc. A way to fulfil this goal is to rotate either a double-slit or cross-double- slit around its normal vector during photons passing through, therefore each slit is tangent to the intersection and forms a disc that is surrounded by a ring.

The final pattern can be obtained by rotating the double-slit and should be like that created by disc 3 with a diameter that is equal to the space between two slits, the width of ring 2 is equal to the width of a single-slit (Figure 8). The disc on the up-left corner of the middle slide (Figure 1) creates Poisson-Arago- type spot (Figure 8).

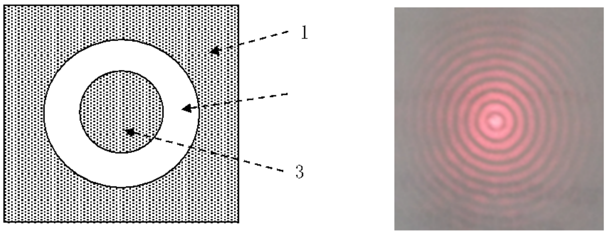

Figure 8. Disc and Poisson-Arago-type spot

We argue that the disc and its pattern indicate that double-slit and cross-double-slit have the rotation-invariance around its normal vector.

4. Summery

The equation holds for each of double-slit, respectively,

$$\lambda = \frac{xd}{mL}$$

Where λ is the wavelength, x is the distance from the zero-order fringe, d is the space between two slits of a pair of double-slit, m is the order of fringe, L is the distance from the cross-double-slit slide to screen.

The 2D-cross-double-slit, 2D-tilt-cross-double-slit and 2D-multi-tilt-cross-double- slit apparatuses have been proposed, with which experiments have been carried out and encouraging observations are obtained. We argue that those apparatuses/observations open a new door for studying optical and basic quantum phenomena. It is a challenge to consistently interpret those experiments/ observations.

Reference

[1] Hui Peng, "Cross-Double-Slit Experiment and Extended-Mach-Zehnder Interferometer", open-science-repository.com/physics-45011872.html(2019).