Open Science Repository Physics

Cross-Double-Slit Experiment and Which-Way-Cross-Double-Slit Experiment

Hui Peng

35964 Vivian PL, Fremont, CA 94536, USA

davidpeng949@hotmail.com

Abstract

We have performed Cross-Double-Slits experiment and Which-Path-Cross-Double-Slits experiment. The observations: (1) show that the cross-double-slit apparatus causes not only perpendicular interference patterns, but also Cross-interference-pattern, which is generated either between two perpendicular double-slit or between one double-slit and one single slit; (2) disclose a new phenomenon of photons that photons passing through the same slit behave as both wave and particle, referred it as the Wave-Particle-Paradox, which demands extensive study; (3) suggest to re-study wave-particle duality.

Key words: wave-particle duality, quantum mechanics, double-Slits experiment, interference pattern

1. Introduction

In Young-double-slit experiments, photons form an interference pattern, even emitting one photon at a time. This result is the typical behavior of wave, which is interpreted as that each photon has arrived by both slits at the same time. Feynman stated that this wave-particle dual behavior contains the basic mystery of quantum mechanics.

To test the interpretation, Which-Path-double-slit experiments have been proposed and performed. To determine "which-path" is equivalent to try to find the particle nature of photon in the experiment. The experimental result is that once which slit a photon passing through is determined, the interference pattern disappeared, namely the photon behaviors like a particle. It is interpreted as that two complementary natures, wave and particle, of photons cannot all be observed or measured simultaneously. Bohr called this choice of exhibiting wave-like or particle-like behavior "complementarity" and states that the type of measurement performed on a quantum system determines its behavior.

Recently, for studying wave-particle duality further, the cross-double-slit and which-way-cross-double-slit experiments have been proposed [1]. The Cross-double-slit apparatus is an extended Young-double-slit apparatus. The purpose of the cross-double-slit apparatus is to study

whether photons show the two complementary natures, wave and particle, in the same experimental configuration simultaneously; and focus on whether a photon is either a wave or a particle or both.

In this article, we performed the cross-double-slit and which-way-cross-double-slit experiments.

2. Cross-Double-Slit Experiment

2.1. Review of Cross-Double-Slit Apparatus

The Cross-Double-Slit apparatus (Fig.1) contains a source, a slit wall with four slits, and a screen. Where slits A and B are in z-direction, slits C and D are in y-direction. The photons travel in negative x-direction.

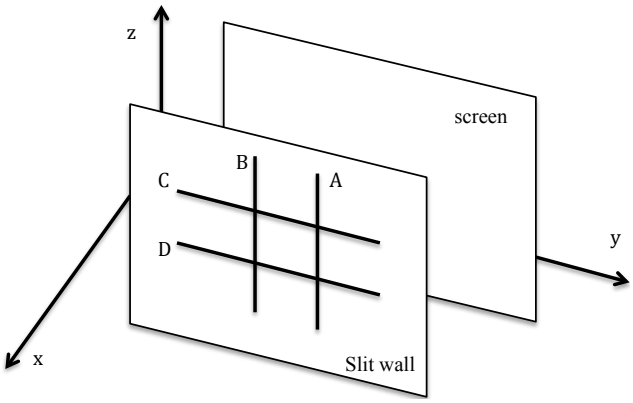

Fig. 1 Cross-Double-Slit Apparatus

2.2. Cross-Double-Slit Experiment

Based on the results of regular double-slit experiment, one knew that slits A and B alone cause an interference patter in y-direction on the screen. Similarly, slits C and D alone cause an interference patter in z-direction. What pattern the Cross-Double-Slit Experiment will show?

The setup of the experiment is the following.

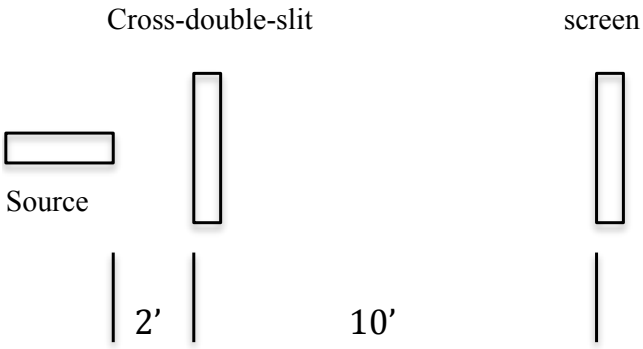

Fig. 2 Setup of Cross-double-Slit Experiment

The distance between the light source and the cross-double-slit wall is 2 feet, between the

cross-double-slit wall and the screen is 10 feet. Using a commercial laser pointer and homemade cross-double-slit wall.

We have performed the experiment and obtain the interesting and encourage results. The observed patterns (Fig. 3) are as predicted in [1]:

(A) The slits A and B cause the horizontal interference pattern, while slits C and D cause the vertical interference pattern. Two interference patterns perpendicular to each other.

(B) There are some kind of "interference patterns" caused by slits A and C shown at First coordinate system quadrant, by slits A and D shown at Fourth coordinate system quadrant, by slits B and C shown at Second coordinate system quadrant, and slits B and D shown at Third coordinate system quadrant. We refer this kind of "interference patterns" as ***"Cross-Interference-Patterns".***

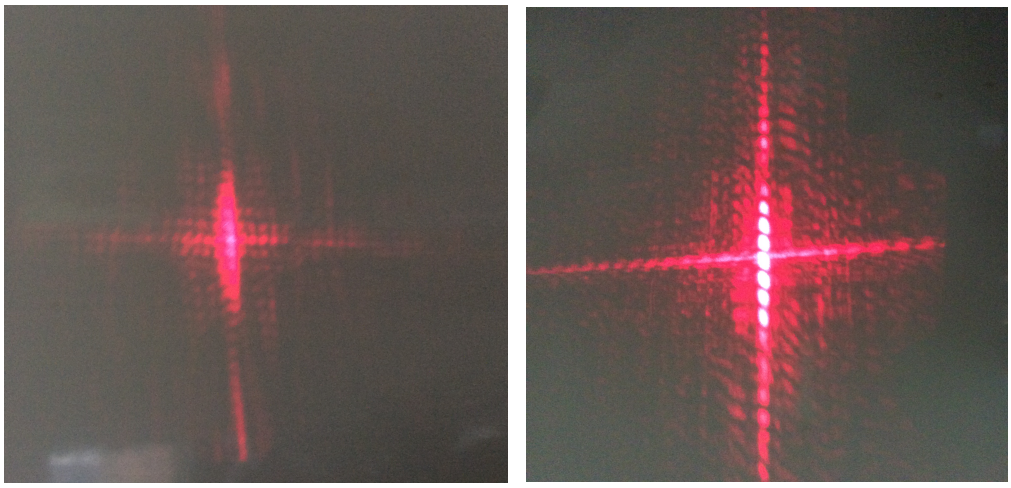

Fig. 3 Interference Patterns of Cross-Double-Slit Experiments

To my knowledge, "Cross-Interference-Patterns" is first time observed.

2.3. On "Cross-Interference-Pattern"

Now let's study what causes the Cross-Interference-Pattern. Considering a cross-single-slit, which contains a vertical slit A and a horizontal slit C, as shown in Fig. 4.

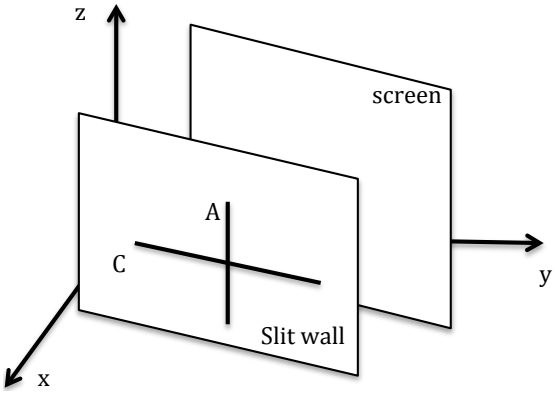

Fig. 4 Cross-Single-Slit

This cross-single-slit causes a pattern as in Fig. 5.

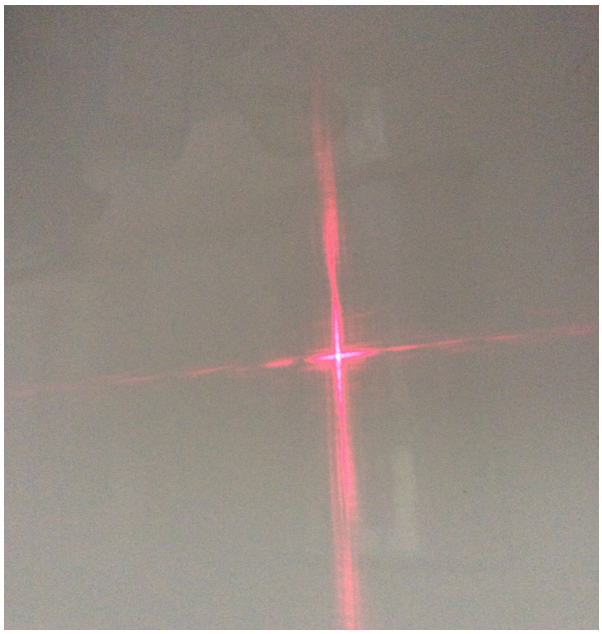

Fig. 5 Pattern of Cross-Single-Slit-Wall

Note there is no “Cross-Interference-Patterns”, which implies that two perpendicular single slits A and C do not create Cross-Interference-Patter.

Therefore we conclude that the “Cross-Interference-Pattern” is generated by Cross-double-slit.

2.3. Which-Way-Cross-Double-Slit Experiment

Now let’s perform the Which-Way-Cross-Double-Slit Experiment by putting an observer near one of slits, say slit A, to observe photons passing through slit A.

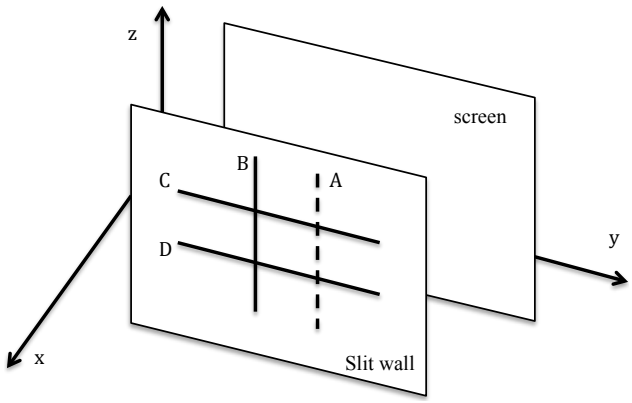

Fig. 6 Which-Way-Cross- Double-Slit Experiment

Since it is known that the “observation” would make the interference pattern disappear, in this experiment, we are not focus on “which way” and, thus block the propagation of photons coming out from slit A (represented by dotted line A in Fig. 6).

The observed pattern is shown in Fig. 7:

(1) The horizontal interference pattern due to the slits B and A *disappeared*, since slit A is blocked, which implies that photons pass through slits A and B as particles.

(2) There is still vertical interference pattern due to slits C and D, which implies that photons pass through slits C and D as wave.

(3) There are still "Cross-interference-pattern" in all of four coordinate system quadrants, caused by slits B and C, and by slits B and D, which implies that photons pass through slit B, slit C, and slit D as wave.

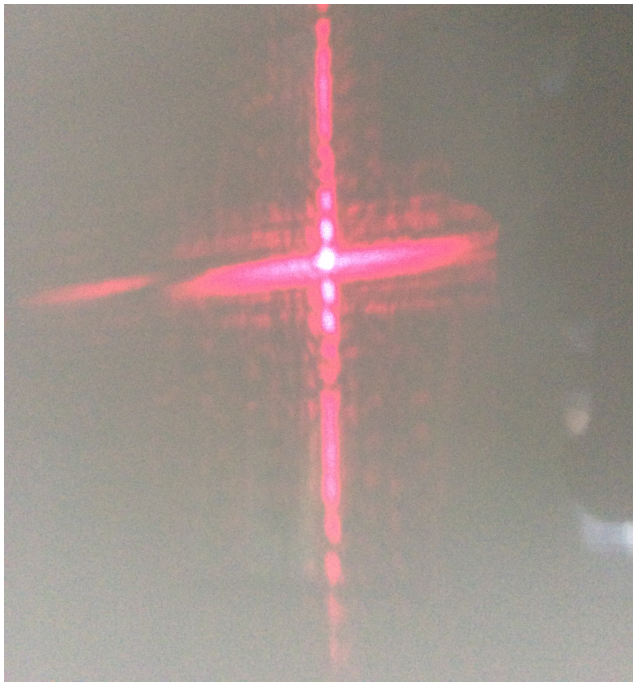

Fig. 7 Interference pattern of Which-Way-Cross-Double-Slit Experiment

Therefore we conclude that the "Cross-Interference-Pattern" can be generated between one double-slit and one single-slit, where the double-slit is perpendicular to the single-slit.

3. Wave-Particle-Paradox

Photons, as wave, pass through slits B, C and D, and form the Cross-interference-pattern, while photons pass through slits A and B as particles, denoted it as "*Wave-Particle-Paradox"*, which challenges us: (1) how photons pass through the same slit B behave as both wave and particle? (2) how photons pass through the slits A and B behave as particle when slit A is blocked, while photons pass through the slits C and D as wave? (3) how can photons tell which slit they will pass through to determine how to behave?

4. Further Experiment.

For further study, the same experiments should be done with photons emitted one at a time to determine whether a photon is passing through 4 slits simultaneously; and whether there are same interference patterns and cross-interference-patterns. Furthermore, do the same experiments with electrons.

5. Conclusion

We have performed two experiments, Cross-Double-Slits and Which-Path-Cross-Double-Slits experiments. The observations: (1) show that cross-double-slit causes not only perpendicular interference patterns, but also Cross-interference-pattern; (2) the Cross-Interference-Pattern is generated either between two double-slit or between one double-slit and one single slit; (3) disclose a new feature of photons, called as the Wave-Particle-Paradox, which demands extensive study; and (3) suggest to re-study wave-particle duality.

Reference

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