# Cross-Double-Slit Experiments and Wave-Particle Duality


## Abstract

We report observations of Cross-Double-Slit Experiment and Which-Path-Cross-Double-Slit experiment. Cross-Double-Slit apparatus contains two double-slit, where first double-slit is perpendicular to second double-slit. The first double-slit and the second double-slit generate not only their own interference pattern perpendicular to each other, but also generate "Cross-interference-patterns". When we do which-way experiment with one of two double-slit, say first double-slit, then its interference pattern disappeared, i.e., photons behave as particles; but the second double-slit's interference pattern and the cross-interference-pattern still exist; which implies an significant phenomenon that in the same experiment, photons behave as both wave and particle, which is first time caught on film. Thus we suggest to re-study wave-particle duality, which is the basic mystery of quantum mechanics. We postulate that the particle nature of photons is intrinsic; while the wave-like of photons is manifest-behavior



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


## 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, and test interpretations, the cross-double-slit

and which-way-cross-double-slit experiment 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 to determine 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.

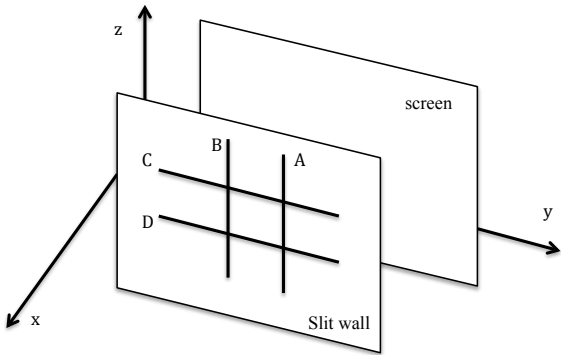


Fig. 1 Cross-Double-Slit Experiment

### 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.

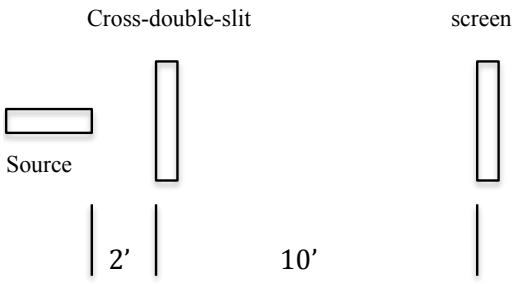


Fig. 2 Setup of Cross-double-Slit Experiment

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.

We have performed the experiment and obtain the interesting and encourage results. We observed the following patterns (Fig. 3), 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.

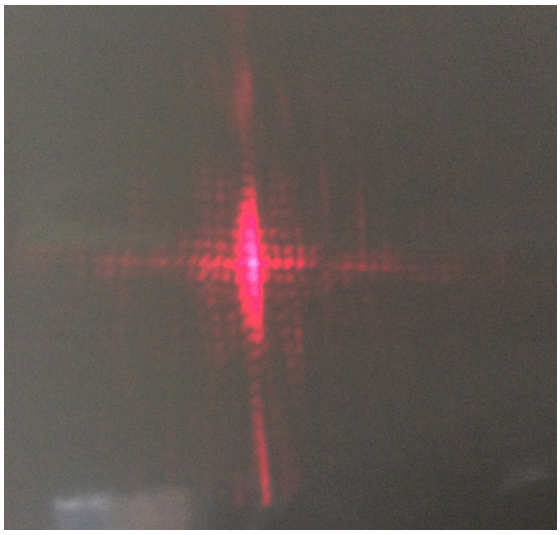

Fig. 3 Interference Patterns of Cross-Double-Slit Experiment

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.

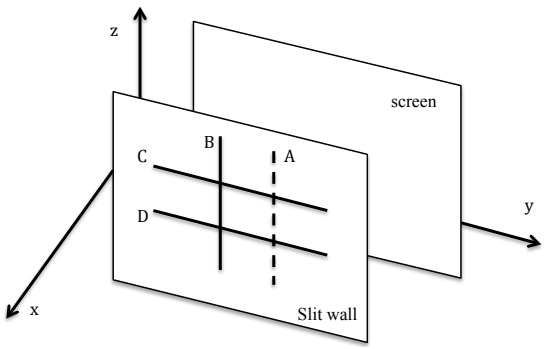


Fig. 4 Which-Way-Cross- Double-Slit Experiment

Since it is known that the "observation" would make the interference pattern disappear, in this

experiment, we are not focus on “which way”. So in the experiment, we block the propagation of photons coming out from slit A (represented by dotted line A in Fig. 4).

The observed patterns are shown in Fig. 5:

(1) The horizontal interference pattern due to the slit 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 kind of “interference patterns” in all of Four coordinate system quadrants, same or similar to that shown in Fig. 3, 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.

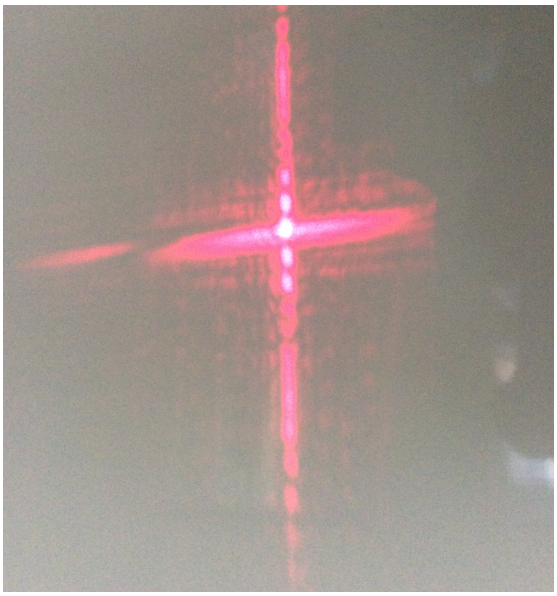

Fig. 5 Interference pattern of Which-Way-Cross-Double-Slit Experiment

3. Wave-particle Paradox

Photons, as wave, pass through slits B, C and D, and form kind of “interference” patterns, while photons pass through slits A and B as particles. This is a wave-particle paradox, which challenges us: (1) how and why photons pass through the same slit B behave as both wave and particle? (2) how and why 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?

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

patterns.

## 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 kind of "interference pattern"; (2) disclose a new feature of photons, called as the wave-particle paradox; and (3) suggest to re-study wave-particle duality. Based on the observations reported in this article, we postulate that the particle nature of photons is intrinsic; while the wave-like of photons is manifest-behavior.

## Reference

(1) Hui Peng, WE4690-1905.0267v1(2019).

Hui Peng, open-science-repository.com/physics-45011872.html (2019).