Cross-Double-Slit Apparatus

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Abstract

We propose the Cross-Double-Slit apparatus for studying wave-particle duality and postulate that the particle nature of photons is intrinsic, while wave-like is an appearing behavior due to observation apparatus.

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- or particle-like behavior "complementarity" and states that the type of measurement performed on a quantum system determines its behavior.

We argue and show later in this article that those two statements may not be equivalent. For this aim we distinguish both statements by different names:

(A) Bohr's statement A: "two complementary natures, wave and particle, of photons cannot all be observed or measured simultaneously".

(B) Bohr's statement B: "the type of measurement performed on a quantum system determines its behavior".

In this article, to study wave-particle duality and test its interpretations, we propose new apparatuses and design new experiments as below

(1) Cross-double-slit apparatus, which is an extended Young-double-slit apparatus;

(2) Cross-double-slit experiment to push the puzzled situation to more severe situation, i.e., whether a photon passing through four slits at once, instead of two slits;

(3) Which-Way-Cross-Double-Slit Experiment to study whether photons show the two complementary natures, wave and particle, in the same experimental configuration simultaneously; and focus on how to determine whether a photon is either a wave or a particle or both, instead of pure "which way" measurement;

2. Cross-Double-Slit Apparatus and Experiment

2.1. Cross-Double-Slit Apparatus

We propose Cross-Double-Slit apparatus (Fig.1), which contains a source capably emitting one photon at a time, 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.

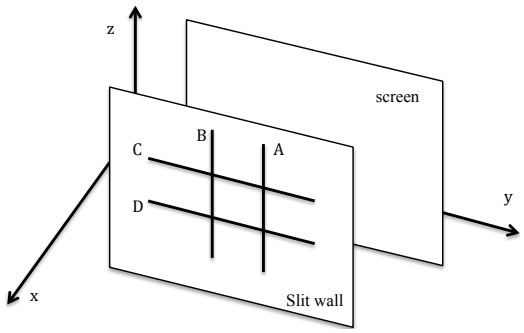

Fig. 1 Cross-Double-Slit Apparatus

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. The aims of the Cross-Double-Slit Experiment are to determine:

(A) Whether a photon is passing through 4 slits, instead two slits, simultaneously?

(B) Whether slits A and B, and slits C and D cause two set of interference patterns perpendicular to each other?

(C) Whether slits A and C cause some kind of "interference" pattern, as well as slits A and D, slits B and C, and slits B and D?

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

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

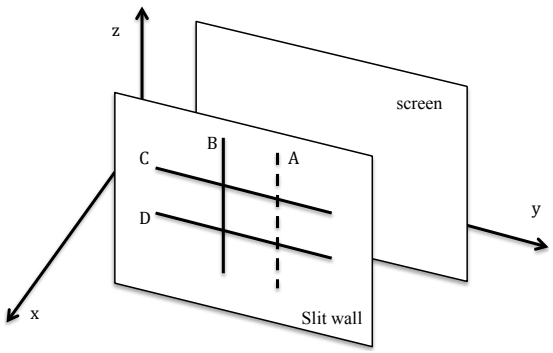

Fig. 2 Which-Way-Cross-Young-Double-Slit Experiment

Since it is known that the "observation" would make the interference pattern disappear, we are not focus on observation of "which way". So in the proposed experiment, one can use an object to block the propagation of photons coming out from slit A (represented by dotted line A in Fig. 2).

What we expect to observe are the following.

(A) Whether the interference pattern due to slits C and D still exists?

(B) If we DO have the interference pattern due to slits C and D, which implies that, a photon acting as wave goes through slits C and D and form interference pattern. However, at the same time, the photons acting as particles pass through slits A and B. In this situation, photons are manifesting both nature of particle (passing through Slits A and B) and wave (passing through Slits C and D) simultaneously, which is a paradox.

(C) If we DO NOT have the interference pattern due to slits C and D, which implies that photons acting as particles go through one of slits B, C and D at a time.

(D) If there are "interference" patterns caused by slits B and C, and by slit B and D, respectively, as mentioned in Cross-Double-Slit Experiment of Section 2.2, we want to find out: Whether the "interference" patterns due to slits B and C, and due to slits B and D still exist? If observation answers YES, then a photon as wave goes through slits B, C and D, although photons also goes through the slit B as particles, which is a paradox.

Therefore, Which-Way-Cross-Double-Slit Experiment discloses deeper nature of wave-particle duality.

3. Conclusion

We have proposed an experimental apparatus, Cross-Double-Slits, for studying wave-particle duality. Also design several experiments, such as "which-way"-Cross-double-slit experiment and Cross-double-slit experiments. Based on those experiments, we postulate that the particle nature of photons is intrinsic, while wave-like is an appearing behavior due to observation apparatus.

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