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Solutions to Puzzles of Double Wheeler's Delayed Choices and Wave Collapse Velocity Measure and New Quantum Control, Oscillation and Oscillator ins Experiments

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Abstract: This paper gives solutions to puzzles of double Wheeler's delayed choice experiments, a photon's passing two paths simultaneously and wave collapse velocity measure, and shows new quantum control, new quantum oscillation and new controlling photon oscillator (that can be arranged in quantum computer and quantum network as their classical correspondences) in experiments. Furthermore, this paper obtains the measured attractive state and the new useful key technology of altering state's evolving paths for quantum systems. We discover the reason and the technological way for the present changes the past, further show their feasible experiments of new quantum control, new quantum oscillation and new quantum oscillator. Finally, this paper achieves the collapse response time t of wave, further concretely deduces the measured collapse velocity of quantum system. In the past, the collapse velocity cannot be objectively deduced and experimentally measured.

Keywords: quantum theory; delayed choice; quantum control; quantum oscillation; collapse time; collapse velocity

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1. Introduction

Classical particle property and quantum wave property can be shown by double slit experiments in modern quantum theory, which displays the probabilistic property of quantum phenomena [1].

Quantum mechanics are able to relate to implications of a single particle experiment [2], if detectors are arranged before each slit, patterns of the interference will disappear, Richard P. Feynman Said [2].

Despite importance of the thought experiment, in history of quantum mechanics, feasible realizations of the thought experiment, until the 1970s, were shown [3], and multiple experiments have been performed to show various aspects of quantum theory [4].

Ref. [5] studied wave–particle duality of C60 molecules, and ref. [6] explored plasmon-assisted Two-Slit transmission in Young's experiment.

After a particle has passed through double slits in Wheeler's delayed choice experiments, extracting the information of which path shows retroactively to change the particle's previous behavior [7].

Unification theory of classical statistical uncertainty relation and quantum uncertainty relation is given [8], and realization of quantum Wheeler's delayed-choice experiment is shown [9]. Furthermore, extending Wheeler's delayed-choice experiment to space is presented [10], and quantum wave–particle superposition in a delayed-choice experiment is explored [11], and then Wheeler's delayed-choice gedanken experiment with a single atom is shown [12].

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An improved interference experiment using a semi-silvered mirror (reflecting 50% of the light and passing 50% of the light) instead of the double slits is obtained in the same principle as the classical double-slit interference experiment, e.g., see Figure 1 in Section 2 [4].

From the photon gun, the emitted photon's both 50 percent possibility go through the mirror and 50 percent possibility are reflected [4]. According to classical mechanics, when a photon gun emits a photon by a photon, it passes through the half lens, it either reflects, it passes through, it either goes path 1 or path 2, and there is no interference image. Oddly enough, when the photon gun fires a single photon every time continuously, interference streaks appear on the screen. Can a single photon be bilocation at the same time?

According to the Copenhagen interpretation: when a single photon passes through a half-lens,

the quantum randomness must cause the photon to superimpose on the two paths, that is, the single photon must take the both paths at the same time, and an interference pattern is formed on the screen [4].

When the detector is placed in the interference experiment, the principle is the same as the double-slit interference delay experiment, the observation causes the photon's wave function to collapse and the interference pattern to disappear [4].

No arranging the detector, the photon travels two routes at the same time, which is understandable according to the Copenhagen interpretation [13].

It is difficult to understand that placing the detector after the photon has already started to take two paths at the same time causes to collapse into a classical mechanical case of taking one path. It's really amazing that photon has chosen to take one path, or two paths at the same time, after the photon has already taken one kind of paths, finally choosing which kind of paths depends on whether we put a detector in the experiment [4].

So, does the law of causality fail?

What is the result if we used the gravitational lensing effect of the sun to perform a delayed selection experiment across interstellar space, it turns out that we now do determine what distant photon did a long time ago [5,6]. Ref. [14] gives, only in N=2 Young's double slit experiments, new quantum physics, solving puzzles of Wheeler's delayed choice & a particle's passing N slits simultaneously and quantum oscillator in experiments.

For all these puzzles above, this paper tries to solve them, and generalizes Ref. [14]'s investigations to no in Young's double slit experiments.

This paper's arrangements are: Section 2 gives solutions to puzzles of delayed choice and a single photon's passing two paths simultaneously in the semi-silvered mirror experiments; Section 3 presents new quantum control, new quantum oscillation and new quantum oscillator in the semi-silvered mirror experiments; Section 4 shows discussion and wave collapse velocity measure, Section 5 is summary and conclusion.

2. Solutions to Puzzles of Delayed Choice and a Single Photon's Passing Two Paths Simultaneously in the Semi-Silvered Mirror Experiments

We first show solution to puzzle of double delayed choices in a semi-silvered mirror experiment.

The two subwaves, coming from a semi-silvered mirror M1 reflecting 50% of the light and passing 50% of the light, of a photon are entanglement each other, and they may form interference of the subwaves, see Figure 1. The radiating single photon gun (SPG) firs a photon at every interval time T, RM1 and RM2 are whole reflection mirrors (RM), D1 and D2 are the photon detectors, M2 is the same semi-silvered mirror as M1, and S1 and S2 are the showing screens. Therefore,

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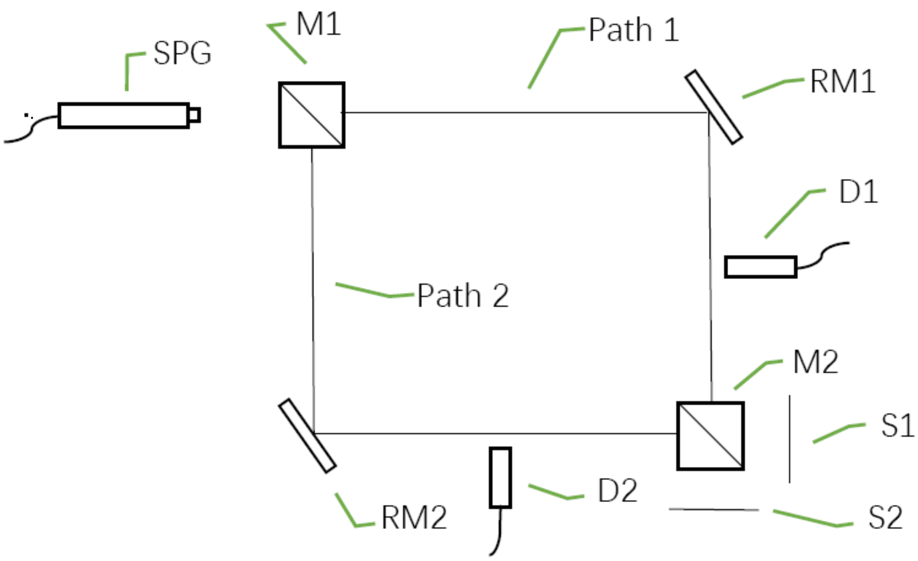

Figure 1. Interference of a photon wave in the new quantum oscillation experiment.

the function of the entanglement subwaves is [14,15]

$$\Phi(\mathbf{r}_1,\mathbf{r}_2,t)=a_1\phi(\mathbf{r}_1,t)+a_2\phi(\mathbf{r}_2,t),\ |a_1|^2+|a_2|^2=1 \quad . \qquad (2.1)$$

Utilizing Equation (2.1), the entanglement probabilistic density is deduced as

$$\rho(\mathbf{r}_1,\mathbf{r}_2,t)=\Phi^\dagger(\mathbf{r}_1,\mathbf{r}_2,t)\Phi(\mathbf{r}_1,\mathbf{r}_2,t)$$
$$=|a_1\phi(\mathbf{r}_1,t)|^2+a_1{}^\dagger\phi^\dagger(\mathbf{r}_1,t)a_2\phi(\mathbf{r}_2,t)+a_2{}^\dagger\phi^\dagger(\mathbf{r}_2,t)a_1\phi(\mathbf{r}_1,t)+|a_2\phi(\mathbf{r}_2,t)|^2 \ . \ (2.2)$$

Equation (2.2) shows a particle wave (2.1) passes through two ways in the experiment at time t, namely, the two subwave function (2.1) are entanglement.

When having measured the single photon passes path p1 and at time t1, then one must deduce $\phi(\mathbf{r}_2,t_1)=0$ due to Equation (2.1), thus, utilizing Equation (2.2), one gets

$$\rho(\mathbf{r}_1,\mathbf{r}_2,t)=\rho(\mathbf{r}_1,t)=|a_1\phi(\mathbf{r}_1,t)|^2 \ , \qquad (2.3)$$

where $\int \rho(\mathbf{r}_1,t_1)d\mathbf{r}_1=1$. Namely, there exists no the interference term in Equation (2.3), which shows the interference disappears, that is, function density (2.2) of the entanglement wave instantly collapses as Equation (2.3), which displays that a single photon doesn't simultaneously finally pass through the two paths p1 and p2 by the disentanglement collapsing in quantum theory.

When measuring a single photon wave passes path p2, the investigations are analogous.

When no measuring which path single photon wave passes, one has that Equation (2.2) just shows there exist interference terms, these mean a single photon wave (2.1) does passe simultaneously through the two paths vis the probabilistic entanglement in quantum mechanics, i.e., one has the two subwaves via Equations (2.1) and (2.2).

Delayed choice puzzle: after a photon passes through the semi-silvered mirror, extracting which path information in a semi-silvered mirror experiment can retroactively change a photon's previous behavior, e.g., see Figure 1.

Consequently, one discovers that Equations (2.1)–(2.3) for the delayed selection experiment mean quantum entanglement and disentanglement. We show further that quantum disentanglement retroactively changes the single photon's previous passing through the paths' behaviors via Equation

(2.2) with $\phi(\mathbf{r}_2,t)\neq 0$ collapsing as Equation (2.3) with $\phi(\mathbf{r}_2,t_1)=0$ in the delayed selection experiment with $t_1>t$. Thus, this paper solves the delayed selection puzzle by the exact quantum theory's expressions (2.1)–(2.3).

Since distribution of wave function $\phi(\mathbf{r}_2,t)\neq 0$ is of distribution of the whole space, the whole space includes automatically the space of the subwave's returning from the previous path p2 and the subwave's entering through path p1. Usually, the probabilities taking these paths are small, but because the measured photon state has passed through path p1, which makes this photon state $\phi(\mathbf{r}_1,t_1)$ equivalent as an attractor state, probability for $\phi(\mathbf{r}_2,t)\neq 0$ and the all other probabilities alter for satisfying the physics reality of this photon's having passed through p1's path at time t1. These are the consistent demands for probability conservation.

Since the collapse of wave function (2.1) is the collapse for all the possible states into the measured state of density (2.3), in fact, the measured collapsed state is just equivalent to the measuring like-attractor's state of density (2.3). Thus, the measured state through path p1 can be called as the measured like-attractor's state, or for simply called as the measured attractive state. The collapsing process actually is the collapsing process of all the possible states to the measured like-attractor's state of density (2.3). All these are just new physics for collapse of all the possible states (naturally including state $\phi(\mathbf{r}_2,t)\neq 0$ returning backwards through path p2 state and the states merged into path p1 state) into the measured like-attractor's state $\phi(\mathbf{r}_1,t_1)$.

Consequently, we obtain new useful key technology of altering state's evolving path for quantum mechanics systems.

Therefore, this paper finds both the quantum entanglement and quantum disentanglement about Equations (2.1)–(2.3).

Thus, the delayed choice puzzle is just solved via physics processes for probabilistic quantum entanglement and disentanglement Equations (2.1)–(2.3). That is, after the photon wave passes through the paths, extracting a path's information in a single photon's simultaneously passing two paths in a semi-silvered mirror experiment can just show retroactively to change the photon's previous behavior, which comes from the quantum disentanglement collapse that $\phi(\mathbf{r}_2,t)\neq 0$ having passed through path p2 at once collapses to $\phi(\mathbf{r}_2,t_1)=0$, and is merged into $\rho(\vec{r}_1,\vec{r}_2,t_1)=\rho(\vec{r}_1,t_1)=\left|a_1\phi(\mathbf{r}_1,t_1)\right|^2$, $\int \rho(\vec{r}_1,t_1)d\vec{r}_1=1$, due to having tested that the photon has just passed through path p1 at time t1 (> t , this just is the delayed choice's measuring test).

Namely, the quantum system just collapses into the having measured state when the quantum system is only measured just at time t1.

Meanwhile, the puzzle for a single photon's simultaneously passing through two paths in the semi-silvered mirror experiment is just resolved by entanglement wave (2.1) and entanglement wave density (2.2) about wave-particle duality in quantum general theory, i.e., by physics processes for exact quantum theoretical expressions (2.1) and (2.2) no the delayed selection measure. Namely, we show that photon's wave of wave-particle duality passes through the two paths, but a single photon particle.

3. New Quantum Control, New Quantum Oscillation and New Quantum Oscillator in the Semi-Silvered Mirror Experiments

For quantum delayed selection experiment investigated in Sect 2, two detectors are further symmetrically installed on every side of every path in Figure 1, D1 and D2 are the symmetrically installed detectors. When D1 has measured photon passing through path p1, D1 is at once automatically turned off (namely, taking the measure off, this system is just restored as a new state),

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and D2 is just automatically opened only after time t (namely, this system at once collapses again via the measurement).

When D2 detects a photon passing through path p2 , D2 at once is automatically closed (for restoring this system as a new state), and then after time t opening D1 for measuring (to, at once, cause this system for collapsing again). In terms of the delayed selection law and the measurement's collapse law studied in Section 2, by adjusting the symmetrical D1 and D2 positions relative to their paths and the time t, the photon's oscillation between path p1 and path p2 must emerge since the achieved theory and the shown experiments exactly are founded upon the having checked experimental foundations for the measuring state's collapse and the reverting to one new state after abolishing the measuring in quantum theory [1,2], factually, which is just based on the skillful combinations between double Wheeler's delayed choice experiments, i.e., two Wheeler's delayed choice experiments, and which are just the generalization of quantum oscillator of Young's double slit experiments [14]. Especially, this paper's thought experiment related to Wheeler's delayed choice experiments is easier to realize than the realization of quantum oscillator experiment (related to Wheeler's delayed choice experiments) of Young's double slits [14].

Via the new important quantum control, one can modulate the photon's new important quantum oscillation via the semi-silvered mirror experiment.

Especially, the gap time t is with the rather important physics meanings. When the gap time t equates zero, namely, a detector is closed and another detector is opened at the same time. When the gap time t doesn't equate zero, which displays the quantum system's response degree, it is a very important response key parameter of quantum mechanics. The response parameter t just shows the time effect of this system's physics reaction.

According to the instant collapse effect of the measuring, the response time would be rather small, almost approaches to zero. We may automatically just control the interval time T, the switch of the two detectors and the delayed detecting time t for the two detectors and the radiating single photon gun via programing design for the computer of connecting the radiating single photon gun and the two detectors.

For the delayed choice experiment of a single photon, when the above new important quantum control and the above new important quantum oscillation are very well realized, we cannot see any signal of the photon on the two screens S1 and S2 due to the new quantum oscillation between the two oscillation path p1 and path p2 . All these investigations mean when one is unable to see the photon's signal on the two screens S1 and S2 in the experiments of the new quantum oscillation, we, then, obtain the objective key criteria that the new key quantum control and the new key quantum oscillation are very well realized.

For the concrete experiment: first, we close the two detectors D1 and D2, we can see the photon interference signal on the screens S1 and/or S2 in Figure 1, which just show the photon's wave property; second, we open the detector D1 or D2 and taking the semi-silvered mirror M2 off, we can see the photon point on S1 or S2, which just show the photon's particle property; third, all the above studies mean via, in Figure 1, taking M2 backward the original position and adjusting the response time parameter t, the interval time T and the symmetrical positions of two detectors D1 & D2 relevant to the semi-silvered mirror, such that we are unable to see any photon signal on the two screens S1 and S2 in Figure 1 in the new quantum oscillation experiments, then the new quantum control and the new quantum oscillation between the two oscillation path p1 and path p2 are very well realized.

Thus, we obtain objective criteria realizing very well the new quantum control and the new quantum oscillation between the two oscillation path p1 and path p2. Therefore, we achieve a new controlling photon oscillator that can be arranged into quantum computer and quantum network liking the now computer and the usual network for needing the oscillator's work. All these are useful in quantum theory, quantum computer, quantum communications and so on. Thus, anyone doing research in the domain is able to repeat the experiments of the new quantum control and the new quantum oscillation.

Therefore, this paper presents the new important quantum control, the new important quantum oscillation and a new controlling photon oscillator coming from the new useful key technology for

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altering the evolution paths of the states of quantum systems in general quantum theory, quantum communications, quantum computer and so on.

4. Discussion and Wave Collapse Velocity Measure

From the above research, one can discovers that it makes no difference in quantum experiments to decide whether a photon behaves before or during its journey.

Now people think that the present changes the past, and the delayed selection experiment reverses causality. We also find that the measured collapse forms an attractive state, it can change all possible quantum states of the past into attractive quantum states formed by collapsing in the present. That is, it can change all the possible quantum states in the past into the quantum states that are now measured.

So, we've discovered the reason and the technological way for the present changes the past. We thus give a new theory of quantum control and quantum oscillation as well as their related experiments. These are consistent with Bohr's argument below. Bohr said: any fundamental quantum phenomenon is a phenomenon only after it has been recorded. History is not definite and real until it has been physically recorded [4].

Using the measured response time parameter t, we can calculate the measuring collapse velocity of this quantum system

$$V_{collapse} = \frac{p_1+p_2}{t} = 2\frac{p_1}{t} \quad , \qquad (4.1)$$

where $p_1 = p_2$ are because the detectors D1 and D2 are symmetrically installed about the semi-silvered mirror, e.g., see Figure 1. When t approaches to zero, $V_{collapse} \to \infty$. In the past, the collapse velocity cannot be objectively deduced.

5. Summary and Conclusion

This paper gives solutions to puzzles of double Wheeler's delayed choice experiments, a single photon's passing two paths simultaneously and wave collapse velocity measure, and this paper shows new quantum control, new quantum oscillation and new quantum oscillator in experiments. And then we achieve new controlling photon oscillator that can be arranged in quantum computer and quantum network liking the now computer and the usual network for needing the oscillator's work.

The collapsing process in general quantum theory actually is the collapsing process of all the possible states to the measured attractive state, thus, we obtain the measured attractive state. All these are just new physics for collapse of all the possible states into the measured attractive state. Therefore, we obtain the new useful key technology of altering the state's evolving paths for quantum mechanics systems.

We discover the reason and the technological way for the present changes the past in both single and double Wheeler's delayed choice experiments. We thus give a new theory of quantum control, quantum oscillation and quantum oscillator as well as their related experiments.

This paper achieves the collapse response time parameter t of the wave, further using the collapse response time t of quantum system, we deduce the measuring collapse velocity of the quantum system. In the past, the collapse velocity cannot be objectively deduced and experimentally measured.

By the way, the investigations of this paper are also just the generalization and development of Ref. [14]'s studies, and the investigations of this paper can be largely generalized to many kinds of different particles, e.g., electron, proton, neutron and so on, which would give new physics and new useful practical applications about electron, proton, neutron and so on. Furthermore, this paper achieves their useful practical technology in quantum control, quantum oscillation and quantum oscillator. Therefore, these new key useful physics related to photon, electron, proton, neutron and

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so on would interestingly appear, which would cause the practically useful technology, their developments and so on for the related physics.

For example, this paper's investigations can be effectively applied to the investigations about neutron interferometry [16] and so on.

Therefore, this paper's important innovations are not only the solving the puzzles of double Wheeler's delayed choices, wave collapse velocity measure (that is seen as almost impossible in the past) and how the now concretely changing the past (which is viewed as very interesting now), but also the giving new useful quantum control, new quantum oscillation and new quantum oscillator in experiments or thought experiments.

All these innovations are not only related to photon, but also related to lots of quantum particle, e.g., electron, proton, neutron and so on. Thus, the investigations in this paper have the interesting impacts in quantum mechanics, quantum control, quantum communication and so on.

Therefore, this paper contains significant and novel results in the related fields of research, be of very interest to real physics, and be recognized as interesting contributions to the literature.

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