An Interpretation of Quantum Mechanics with "uncertain complex wave"

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Abstract

Some modifications of orthodox quantum mechanics were suggested. These modifications can solve the measurement problem. Base on these modifications, this paper also proposes a quantum reality with non-intuitive properties. From the suggested quantum reality, the classical picture was re-evaluated.

Keywords: quantum reality; wave function collapse; quantum property.

I. Introduction

Quantum mechanics has a long history and it has been used to explain many experiments results. Quantum mechanics passed through countless testing experiment [1] [4] and even the most rigorous experiment [2]. However, the controversy on the foundation of quantum mechanics has been never stopped [1][4]. The most outstanding debate is how does the wave function collapse happen [3] [5]? What properties are found in a particular experiment [6]? What is a quantum reality [7]?

This paper introduces a hypothesis to answer the questions above. To understand the wave function collapse I suggest to modify the axiom system in [8] of the orthodox quantum mechanics. In this modification, axioms of operators and their possible values are removed. Then I propose an axiom about the possible states. This modification can determine which property is revealed from a particular experiment. From this modification, I propose an uncertain complex wave is quantum reality. The uncertain complex wave is non-intuitive but it can drive the classical picture as an average of the quantum reality. On other words, a classical reality isn't considered a real reality.

II. Theory and discussion

1. Axiom system

In this section, I show an axiom system which is a modification from the orthodox quantum mechanics. The axiom system of the orthodox quantum mechanics is stated by E. G. Harris in [8]. The new axiom system includes two axioms from Harris's statement. I suggest a new axiom about the possible states. And I give a new form of Born rule.

The first axiom in the E. G. Harris's statement: *State of a physical system is characterized by a vector ψ in Hilbert space. The vector ψ and $\lambda.\psi$ (λ is a complex number) describe the same state. In general, ψ is normalized to the unit.*

In Hilbert space, we can define operators. Example, operators coordinate $\hat{x}$=x; $\hat{y} = y$; $\hat{z} = z$ and $\hat{t} = t$. Operators momentum $p_x = -i.\hbar.\frac{d}{dx}$; $p_y = -i.\hbar.\frac{d}{dy}$; $p_z = -i.\hbar.\frac{d}{dz}$. Operator Hamilton for a particle: $H = \frac{{p_x}^2+{p_y}^2+{p_z}^2}{2.m} + V(x, y, z, t)$. In which, $V(x, y, z, t)$ is operator potential energy, it is a function of coordinate and time. And m is mass of the particle. Relativity Hamilton operator has the form: $H = \alpha_x . p_x +$

$\alpha_y.p_y + \alpha_z.p_z + \beta.m.c^2$. In which $\alpha_x = \begin{pmatrix} 0 & \sigma_x \\ -\sigma_x & 0 \end{pmatrix}$, $\alpha_y = \begin{pmatrix} 0 & \sigma_y \\ -\sigma_y & 0 \end{pmatrix}$, $\alpha_z = \begin{pmatrix} 0 & \sigma_z \\ -\sigma_z & 0 \end{pmatrix}$, $\beta = \begin{pmatrix} I_2 & 0 \\ 0 & -I_2 \end{pmatrix}$; σ_x, σ_y, σ_z are Pauli matrices. I_2 is rank 2 unit matrix.

The second axiom from E. G. Harris's statement*: Wave function satisfies the Schrodinger equation:* $i.\hbar.\frac{d}{dt}\psi = H\psi$

The wave function also satisfies some boundary conditions. They are continuous and single-valued conditions. The continuous property of wave function relates to possible states and their possible values. If the potential energy $V(x, y, z, t)$ is not continuous, the Schrodinger equation has to be investigated in many space domains. To introduce an axiom about the possible state I will define some concepts. I divide space into the largest possible domains D_i (i=1,.n) such that the potential energy $V(x, y, z, t)$ is continuous in D_i. Then the domain D_i is called a continuous domain of the system. The Schrodinger equation has the largest symmetry group G_i in each domain D_i. It is called a basic group of the system in D_i. Solution of the Schrodinger equation in D_i is a linear space U_i. I symbol T_{in} is an any irreducible represeantation of G_i in U_i. And U_{in} is a subspace of U_i such that it is invariant with T_{in}. The space U_{in} is called a irreducible space of G_i. The space U_i equals directly total of spaces U_{in}. Vectors in U_{in} are symbolized ψ_{in}. If U_{in} is a many-dimensional space, its basic system is symbolized ψ_{inr}. And the vector ψ_{in} is considered as a combination of ψ_{inr}: $\psi_{in} = \sum_r c_{inr}\psi_{inr}$. The basis vectors of U_{in} are orthogonal, the basis vectors of U_i are so. From the first axiom, we can consider them as an orthonormal system. The axiom about the possible states has suggested the following:

Possible states of a system in a continuous domain D_i belong to irreducible spaces U_{in} of the basic group G_i.

To see the effect of this axiom, we build a combination $\psi_i = \sum_k c_{ik}.\psi_{ik}$. This combination, in general, doesn't belong an irreducible representation space of G_i. So it isn't possible states. So, the axiom about the possible states isn't compatible with the superposition principle. However, in some cases, the superposition principle is satisfied. These cases, the basic group G_i has many-dimensional irreducible representations. Then the combinations of two vectors in U_{in} are still possible states of the system.

With stationary systems, each space U_{in} corresponds to a stationary energy level. Vectors in U_{in} correspond to the same energy level. The degenerate degree of this energy level equals the number of dimensions of U_{in}. Of course, with a stationary system, combinations of two possible states which aren't the same energy level are not a possible state. These combinations, even aren't stationary states. Note that D_i is a 4-dimensions domain. So the axiom about possible states also helps to choice time-dependent possible states.

Now, we investigate two vicinity domains D_1 and D_2. In D_1 we build combination $\psi_1 = \sum_k c_{1k}.\psi_{1k}$. In D_2 we build combination $\psi_2 = \sum_k c_{2k}.\psi_{2k}$. The continuous condition for wave function between D_1 and D_2:

$$\sum_{k} c_{1k}.\psi_{1k}\Big|_{S_{12}} = \sum_{p} c_{2p}.\psi_{2p}\Big|_{S_{12}}$$

In which, S_{12} is the boundary between D_1 and D_2. Because of vectors ψ_{1k} are orthogonal and vectors ψ_{2p} are too, we can determine c_{2p} from c_{1k} and vice versa. With a specific experiment, coefficients c_{1k}, c_{2p}, .. c_{in}.. are uniquely determined. They were named continuous coefficients. If space U_{in} has N dimensions, the coefficients c_{in} were considered as a set of coefficients $\{c_{in1,}\, c_{in2,} .. c_{inr,} .. c_{inN}\}$. I give the new form of the Born rule as follow:

In each continuous domain D_i, in general, we can't know exactly state of the system. Each possible state ψ_{in} has a possibility of $|c_{in}|^2$. In which c_{in} are continuous coefficients in domain D_i.

2. The state during the measurement

Now, we use the axioms above to discuss the measurement problem in quantum mechanics. When the system was observed, it is affected by an apparatus. In this paper, the effect of the apparatus is considered as any other interaction. This effect is described by a measurement potential energy V_{mea}. There is no separation between the micro-system and macro-system. The apparatus isn't considered as a classical system. Before measurement, the physical system has Hamiltonian H, during the measurement, the physical system has Hamiltonian $H_{mea} = H + V_{mea}$. And the continuous domains of the system are symbolized D_{i_mea}. The basic groups are symbolized G_{i_mea}. The possible states of the system during the measurement are symbolized ψ_{in_mea}. These states satisfy the equation: $i.\hbar.\frac{d}{dt}\psi_{in\_mea} = (H + V_{mea})\psi_{in\_mea}$, they belong to the irreducible representation space of G_{i_mea}. And these spaces are symbolized U_{in_mea}. The directly total of U_{in_mea} are U_{i_mea}. If U_{in_mea} has many dimensions, its basic system is symbolized ψ_{inr_mea}, and the vectors ψ_{in_mea} are considered as a combination : $\sum_r c_{inr\_mea}.\psi_{inr\_mea}$. During the measurement, the continuous coefficients are symbolized c_{1k_mea}, c_{2p_mea},.. c_{in_mea}..If the spaces U_{in_mea} has many dimensions, the coefficient c_{in_mea}.. are considered as a set of coefficients $\{\, c_{inr\_mea}\}$.

In general, the state of the system during the measurement ψ_{in_mea} is different from the state without measurement ψ_{in}. If measurement potential energy V_{mea} and H are commutative, and the system is stationary, then $\psi_{in_mea}$is an eigenvector of both V_{mea} and H. With observed operator $A = f(V_{mea})$ is a function of V_{mea}, ψ_{in_mea} is also an eigenvector of A. In this case, we see the wave function collapse. Before the measurement, the state of the system ψ_{in}, isn't an eigenvector of A. During the measurement, the state of the system becomes an eigenvector of operator A. The changing from ψ_{in} to ψ_{in_mea} is suddenly and uncertain. However, the effect of the apparatus isn't a bit secret. Like any interaction, the apparatus makes the change symmetry group, it due to the change of state of the system. In some case, the measurement potential energy V_{mea} breaks the symmetry, it builds a smaller symmetry group for the system. So before measurement, the state of the system ψ_{in} is a combination of ψ_{in_mea}. And during the measurement, the state of the system becomes

ψ_{in_mea}. This process is like the wave function collapse of the orthodox quantum mechanics.

If the system is stationary, V_{mea} and H are commutative, A and V_{mea} aren't commutative, then the state ψ_{in_mea} is not eigenvector of A. From the orthodox quantum mechanics, during measurement, the state of the system has been always eigenvector of observed operator A [8]. In this case, the suggestion in this paper and the orthodox quantum mechanics give predictions different from each other. If the measurement potential energy V_{mea} and H aren't commutative, or V_{mea} is time-dependent, or the system is time-dependent, the prediction from the orthodox quantum mechanics and from the suggestion in this paper are also different.

3. Information from measurement

We can divide the measurement into two kinds. The first kind, the system affects directly on the detector. Experiment Stern-Gerlach [9], double slits [10] belong this kind. The second, the system affects on a medium system, then this medium system effect on the detector. Example, the measurement of the radiative spectrum of the atom [11], the atoms affect the radiative field, then this field affects the detector.

The possibility density of the system can be got from the first kind of measurement directly. To get any other information about the system, we have to combine the result of the measurement and a mathematical model of the system. To get quantum properties of the system, we have to combine the result of measurement and the Schrodinger equation. Example, the combination between the perturbation solution of the Schrodinger equation and experimental spectrum of the atom, we can find the structure of energy levels of the atom. In some cases, because of the difficulty to analyze the Schrodinger equation, we get a little information. Example, from the result of measurement the visible radiative spectrum of solid materials [12], we drive a little information about the system.

Qualitative quantum properties can get from the combination between the experiment and the qualitative solution of the Schrodinger equation. Example, information about the number of spin levels of an electron can be gotten qualitative solution of the Schrodinger equation for an electron.

Quantitative quantum properties only get from the combination between experiment and quantitative solution of the Schrodinger equation. There are two kinds of quantitative properties. The first are constants as mass or charge of micro-particle. The second, in a stationary system, are the eigenvalues of the operator A which it commutes with H. We can drive the value of the eigenvalues a_i of operator A because they appear in the quantitative solution of the Schrodinger equation. So we can define: "*quantitative quantum properties of the system can be described by operators, possible values of each quantity equal eigenvalues of the operator*". For sure that possible values are real, the operator has to be hermitic.

With the suggested axiom system in this paper, the observable quantities in a special experiment are indicated clearly. They correspond to operators that commute with the Hamiltonian H and V_{mea}. The state of the system during the measurement depends on the property of the system and the V_{mea} but it doesn't depend on thinking of the observer.

4. Quantum reality

From the Born rule, it is easy to find the average value of the operator $\langle A\rangle = \langle\psi|A\psi\rangle = \int \psi^* A\psi.\, dx_\mu$. Here, the integration is determined in 4-dimensional space. We define $\langle A\rangle_t = \int \psi^* A\psi.\, dV$ is 3-dimensions average. From the Schrodinger equation, the 3-dimension average satisfies Heisenberg equation:

$$i.\hbar.\frac{d}{dt}\langle A\rangle_t = \frac{\partial\langle A\rangle_t}{\partial t} + \langle[H, A]\rangle_t$$

With coordination operator we have:

$$\frac{d}{dt}\langle x\rangle_t = \frac{\langle p_x\rangle_t}{m}$$

With momentum operator we have:

$$\frac{d}{dt}\langle p_x\rangle_t = -\frac{\partial\langle V\rangle_t}{\partial x}$$

Two equations above are the motion equations in classical mechanics. It shows clearly that the classical properties are averages of the quantum properties. And the laws of the macro-world are only average of quantum laws. It is also suitable to consider that the classical picture is only average of the quantum reality. I suggest that the "uncertain, complex wave" is the quantum reality. The uncertain, complex wave is non-intuitive, but I consider as real reality. The classical picture is only a reflection image of reality on human senses. In general, reality offers an image corresponding to each sensing structure. However, the uncertain, complex wave reality is the unique origin of all images.

III. Conclusion

The measurement problem is solved elegantly by a new axiom system which is a modification of orthodox quantum mechanics. I consider that this new axiom system is a complete description of quantum reality. The quantum reality is suggested as the uncertainly complex wave. It is non-intuitive, but it covers the classical picture as a reflection image of real reality on human senses.

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