The Simultaneity Requirement of Quantum Superposition Principle
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Abstract. The simultaneity requirement of quantum superposition principle is firstly considered in this paper. It has large influence on many physical phenomena including the Schrodinger cat, and the transmission of one polarized photon through a polarizer. More attention should be paid to the simultaneity requirement since the results leaded by simultaneity requirement are quite reasonable.

Introduction
The superposition principle is one of the basic foundations of quantum mechanics [1]. Quantum superposition is responsible for various new phenomena [2-3]. The understanding of quantum superposition principle is very important. It is well known that there are the spatial coherence and temporal coherence requirements in the optical interference. To our own knowledge, there is no report about the temporal requirement for the superposition principle. Here we show that the simultaneity requirement of superposition of states leads large difference and reasonably understanding of some famous cases including the Schrodinger cat, the transmission of one polarized photon through a polarizer.

The Simultaneity Requirement of Superposition of States (SRSS)
The principle of superposition of states in quantum mechanics indicates that when the states function $\psi_1$ and $\psi_2$ is the solution of Schrodinger equation,

$$\hat{H}\psi_1 = i\hbar \frac{\partial}{\partial t}\psi_1. $$

$$\hat{H}\psi_2 = i\hbar \frac{\partial}{\partial t}\psi_2. $$

then a function $\psi_3$ as following is also the solution state function:

$$\psi_3 = c_1\psi_1 + c_2\psi_2. $$

in which both $c_1$ and $c_2$ are constants. It seems correct since $\psi_3$ fits the Schrodinger equation mathematically. However, it maybe not correct in physics. Although both of $\psi_1$ and $\psi_2$ are the solution of Schrodinger equation, we do not know whether they can appear at the same time. The superposition of state functions which cannot appear at the same time should be questioned. However, it is not possible to prove that the superposition of states requires the simultaneity for micro particles. Let there be the simultaneity requirement of superposition of states (SRSS). Its correction should be judged by the results generated by SRSS.

The Influence of SRSS
The Schrodinger Cat
The Schrodinger cat indicates that the cat is in a superposition state of being alive and also being dead unless the measurement is did,

$$\psi_4 = \lambda_1 \phi_1 \varphi_1 + \lambda_2 \phi_2 \varphi_2. $$
The $\varphi_1$ means the atom remains in excited state, $\varphi_2$ means that the atom returns to ground state. The $\phi_1$ shows the cat is alive. The $\phi_2$ shows the cat is dead. The $\lambda_1$ and $\lambda_2$ are constants. Takes the SRSS into considered, suppose that it is not possible that an atom can remain in excited state and return to ground state at the same time. Thus, $\psi_4$ does not present at all. The Schrodinger cat will have two separate states:

$$\psi_5 = \lambda_1 \phi_1 \varphi_1 .$$  

(5)  

$$\psi_6 = \lambda_2 \phi_2 \varphi_2 .$$  

(6)  

$\psi_5$ indicates that Schrodinger cat is alive. On the other hand, $\psi_6$ indicates that Schrodinger cat is dead. The Schrodinger cat is alive when the atom remains in excited state. Otherwise, it is dead when the atom returns to ground state. The Schrodinger cat can be expressed by one state function as following,

$$\Psi_7 = \Psi_5 \vee \Psi_6 .$$  

(7)  

$\Psi_5 \vee \Psi_6$ means that the state function $\Psi_7$ can only select one state from the two states at one time. Equation (7) is in good accordance with the daily experience.

**The Transmission of One Polarized Photon through a Polarizer**

As shown in fig. 1, the red arrow is the polarization direction of light. The black arrow is the polarizer. In classic physics, the electric field of light is the vector sum:

$$\vec{E} = E_x \vec{e}_x + E_y \vec{e}_y .$$  

(8)  

$$E_x = E \cos \theta .$$  

(9)  

$$E_y = E \sin \theta .$$  

(10)  

$$I_T/I = \sin^2 \theta .$$  

(11)  

$I_T$ and $I$ are the intensity of transmission light and incidence light, respectively. Equation (11) shows that the intensity ratio of $I_T/I$ is $\sin^2 \theta$ and independent with time. When the light is only consisted of one photon, what is the situation of the transmission light? Is the ratio of $I_T/I$ is still $\sin^2 \theta$ and independent with time? The answer is no. The intensity of ratio of $I_T/I$ should be 1 or zero because the photon cannot be separated. The measured $I_T/I$ should be dependent on time.

Suppose that the polarizer has two effects on the photon. One is to rotate the polarization of photon to the direction of y or x. It is clear that at the same time, the polarizer can only rotate the polarization of photon to one direction. The other one is to absorb the photon when the polarization of photon is along x, or let the photon transmission when the polarization of photon is alone y direction. The total effects of polarizer can be expressed as equation (12). The state function of photon and $I_T/I$ can be expressed by equation (13) and (14), respectively.

$$\hat{P} = \hat{P}_x \hat{A} \vee \hat{P}_y \hat{T} .$$  

(12)  

$$\hat{P} \Psi = \Psi_x \alpha \vee \Psi_y T .$$  

(13)
\[ I_T/I = 0 \lor 1. \qquad (14) \]

The \( \psi_{x,\alpha} \) indicates that the photon polarization is rotated into x direction and absorbed. The \( \psi_{y,T} \) indicates that the photon polarization rotated into y direction and transmitted. At one time, the \( I_T/I \) is 0 when the polarizer selects \( \hat{p}_x \hat{A} \). At another time, the \( I_T/I \) is 1 when the polarizer selects \( \hat{p}_y \hat{T} \).

**Eigenvalue**

Suppose that there is the following equation

\[ \hat{\lambda} \psi_n = \lambda_n \psi_n, \quad n = 1,2. \qquad (15) \]

If the \( \psi_1 \) and \( \psi_2 \) does not appear at the same time,

\[ \psi = a_1 \psi_1 \lor a_2 \psi_2. \qquad (16) \]

then the measurement value of \( \hat{\lambda} \) should be

\[ \lambda = \lambda_1 \lor \lambda_2. \qquad (17) \]

the mechanism is shown in fig. 2.

![Image](image.png)

**Figure 2. The measured value of a physical quantity.**

It is clear from fig. 2 that the measured value is dependent on the time. When measurement was done at the red arrow indicated time, the measured value is \( \lambda_1 \). When measurement was done at the blue arrow indicated time, the measured value is \( \lambda_2 \).

**Summary**

The SRSS has large influence on many physical phenomena. The results leaded by SRSS are quite reasonable in many areas. The new insights resulted by SRSS should be studied further.

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**References**

[1] M. Oszmaniec, A. Grudka, M. Horodecki and A. Wójcik, Creating a Superposition of Unknown Quantum States, Phys. Rev. Lett. 116 (2016) 110403.

[2] S. Nimmrichter and K. Hornberger, Macroscopicity of Mechanical Quantum Superposition States, Phys. Rev. Lett. 110 (2013) 160403.

[3] S. Ghosh, R. Sharma, U. Roy and P. K. Panigrahi, Mesoscopic quantum superposition of the generalized cat state: A diffraction limit, Phys. Rev.B. 92 (2015) 053819.