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Quantum Entanglement Results from Quantum State Transition at Fast-Than-Light Speed with Matter Wave's Phase Velocity

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Abstract

The quantum entanglement, that violates the local realism and other classical physics theories, leads to various counterintuitive phenomena, is a primary feature of quantum mechanics and probably results from the quantum state's conservation and the quantum state's transition with the matter wave's phase velocity at the fast-than-light speed.

The quantum state transition of entangled particles proceeds with the phase velocity, while the observer measures the process with the electromagnetic or the light speed. This speed difference makes the causality law no longer fully valid everywhere except in certain areas.

Keywords: Quantum Entanglement; Wave-Particle Duality; Quantum State Transition; Matter wave's Phase Transition; Causality Law

Introduction

The quantum entanglement is a primary feature of quantum mechanics and is defined to be one system whose quantum state cannot be described as individual but as an inseparable whole, even the particles are separated by a large distance [1].

Measurements of physical properties on entangled particles such as position, momentum, spin and polarization can be found perfectly correlated. For example, if a pair of entangled particles is generated, their total spin is known to be zero, and one particle is found to have clockwise spin on an axis, then the spin of the other particle on the same axis is found to be counterclockwise.

The counterintuitive performance of quantum mechanics that violates the local realism theory or causality law, were verified [2-4]. The measuring result at one point can be transmitted to a remote point very quickly, in some cases, the transmission speed can exceed over 10,000 times of the light speed [2-6].

The work summarized in this article is to explore the mechanism of quantum entanglement and deals with some problem about causality law.

Quantum Entanglement Obeys Quantum State's Conservation

Quantum system can become entangled through various methods, the total momentum, angular momentum, energy, spin and so forth remains unchanged before and after the process. This process obeys conservations law.

As an example, a neutral π meson with zero spin decays into an entangled pair of an electron and a positron, the total spin and electric charge keep unchanged before and after decay [5].

Quantum States of Entangled Particles Transit with Matter Wave's Phase Velocity at Fast-Than-Light Speed

According to the quantum mechanics theory, all particles from elementary particles to big molecules perform wave-particle duality property [7], the wave's property and the particle's property are equivalent, the wave's phase transition and the particle's state transition are closely related.

The speed of quantum state transition is faster than the light speed [2,5] and the speed of matter wave's phase transmits at the phase velocity is also faster than the light speed [8], (13), therefore, it can be supposed that the quantum state's transition proceeds with the matter wave's phase velocity.

The phase velocity is equal to the product of the frequency multiplied by the wavelength. If λ is wavelength, f is frequency, ω is angular frequency, $\hbar$ is reduced Planck constant, E is energy, P is momentum and $\omega = 2\pi f$, $k = 2\pi/\lambda$, the phase velocity v_p is:

$$v_p = \lambda f \quad (1)$$

By the de Broglie hypothesis [9]:

$$p = h/\lambda \quad (2)$$

Formula (2) also can be written as

$$p = \hbar k \quad (3)$$

$$E = \hbar\omega \quad (4)$$

The phase velocity V_p can be written as below:

$$v_p = \lambda f = \frac{\omega}{k} = \frac{E/\hbar}{P/\hbar} = \frac{E}{P} \quad (5)$$

According to the special relativity theory, particle's total energy E is

$$E^2 = \left(m_o c^2\right)^2 + \left(pc\right)^2 \quad (6)$$

Where m_o denotes rest (intrinsic) mass, p is momentum, c is light speed in vacuum. If v denotes particle's moving speed and γ represents Lorentz factor:

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \quad [9]\ (7)$$

The group velocity, Vg is

$$Vg = \frac{\partial E}{\partial P}$$

$$= \frac{\partial}{\partial p}\sqrt{\left(m_o c^2\right)^2 + \left(pc\right)^2}$$

$$= \frac{pc^2}{E}$$

$$= \frac{\gamma m_o V c^2}{\gamma m_o c^2}$$

$$= v \quad (8)$$

From (7),

$$\gamma^2 = \frac{1}{1-\frac{v^2}{c^2}} = \frac{c^2}{c^2-v^2} = \frac{E^2}{m_o^2 c^4} \quad (9)$$

So

$$V = \sqrt{c^2 - \frac{m_o^2 c^6}{E^2}} \quad (10)$$

From (8) and (10)

$$Vg = V < C \quad (11)$$

From (5)

$$v_p = \frac{E}{P} = \frac{mc^2}{mv} = \frac{\gamma m_o c^2}{\gamma m_o v} = \frac{c^2}{v} \quad (12)$$

Thus

$$V_p > C \quad (13)$$

From (11), the particle's moving speed v is equal to the group velocity, Vg and the value is always lower than the light speed in vacuum [8] and from (11) and (12), the phase velocity, v_p is always higher than the light speed in vacuum (13).

Take a pair of entangled electrons as an example, the electron's rest mass, $m_e = 9.109\times10^{-31}$ kg, the light speed in vacuum, c = 299,792,458m.s^{-1}., the Planck constant, h = 6.62607015×10^{-34} J.s.

If the electron with energy, E = 9.612×10^{-14} J, from (10), the electron's moving speed is

$$V = \sqrt{c^2 - \frac{m_o^2 c^6}{E^2}} = 1.571\times10^8 \text{m.s}^{-1} \qquad \gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = 1.174$$

From (2), the related wavelength is

$$\lambda = h/p = h/(\gamma m_o V) = 3.944\times10^{-12}\ \text{m}$$

From (5), the phase velocity, v_p is

$$v_p = \lambda f = \frac{\omega}{k} = \frac{E/\hbar}{P/\hbar} = \frac{E}{P}$$

Thus, the time needed for the quantum phase transition from one electron to its entangled electron, covering the distance S, is

$$t = \frac{S}{v_p} = \frac{SP}{E} = \frac{Sh}{E\lambda}$$

If the distance between two entangled electrons is 1,200 km

$$t = \frac{S}{v_p} = \frac{Sh}{E\lambda} = 2.097\times10^{-3}\text{s}$$

While the time needed for light travelling through the same distance, tc is

$$tc = \frac{S}{C} = 4.002\times10^{-3}s$$

$$tc = 1.908t$$

It will take about double times for light to travel from one electron to its entangled electron, 1,200 km apart, to that for the quantum state's transition with matter wave's phase velocity in the same distance.

The quantum entanglement's mechanism can be regarded as the quantum state transition with the matter wave's phase velocity at the fast- than- light speed. Perhaps the so called "spooky action at a distance" (referred by Einstein) is exactly the matter wave's phase velocity.

Quantum Entanglement's Impact on Causality Law

According to causality law, events occur in chronological order. The event of cause happened before; the event of effect happens after [5].

Suppose that the entangled particle Pa and particle Pb are located at place A and place B, the observer Oc is located at place C. Place A,B,C join together to form a triangle, the distance between place A and place B is Sab, the distance between place A and place C is Sac, the distance between place B and place C is Sbc:

Let the time when the Pa's spin just turns to clockwise as the start point of time.

If the total spin of Pa and Pb is zero, when Pa's spin turns to clockwise, Pb responds quickly with the phase velocity, v_p to turn its spin to counterclockwise.

At place C, the observer Oc spends time Tc-ac

$$Tc-ac = \frac{Sca}{c} \quad (14)$$

to find Pa's spin just turns to clockwise and spends time Tc-bac

$$\text{Tc-bac} = \frac{Sab}{Vp} + \frac{Scb}{c} \quad (15)$$

to find the Pb's spin just turns to counterclockwise.

If $\text{Tc-bac} = \frac{Scb}{c} + \frac{Sab}{Vp} > \text{Tc-ac} = \frac{Sca}{c}$, namely the observer Oc first to find the Pa's spin just turns into clockwise and then to find Pb's spin just turns into counterclockwise i.e.

$$\frac{Scb}{c} + \frac{Sab}{Vp} > \frac{Sca}{c} \quad (16)$$

$$\frac{Sca\text{-}Scb}{c} < \frac{Sab}{Vp}$$

$$\frac{Sca\text{-}Scb}{Sab} < \frac{c}{Vp}$$

As the Triangle law, $\frac{Sca-Scb}{Sab} < 1$ and $\frac{c}{Vp} < 1$, so

$$\frac{Sca\text{-}Scb}{Sab} < \frac{c}{Vp} < 1 \quad (17)$$

When the case of (17) holds, the causality remains valid.

As special cases, if Scb=Sca or Scb>Sca , i.e. the observer Oc keeps the same distance from place B and place A or the distance between observer Oc and place B is longer than that between observer Oc and place A, it is clear from formula (17) that the causality is valid.

If $\text{Tc-bac} = \frac{Scb}{c} + \frac{Sab}{Vp} < \text{Tc-ac} = \frac{Sca}{c}$, namely the observer Oc first to find Pb's spin just turns into counterclockwise and then to find the Pa's spin just turns into clockwise i.e.

$$\frac{Sca}{c} > \frac{Scb}{c} + \frac{Sab}{Vp} \text{ i.e.}$$

$$\frac{Sca\text{-}Scb}{Sab} > \frac{c}{Vp} \quad (18)$$

As $\frac{Sca\text{-}Scb}{Sab} < 1, \frac{c}{Vp} << 1$ (in some cases, $\frac{c}{Vp} < 0.0001$) and the value of $\frac{c}{Vp} = \frac{PC}{E}$ (5) is independent of geometric position, the formula (18) is possible to be correct, depending on the values of Sca and Scb (only keeping the value Sca>Scb).

When formula (18) holds, the causality law is no longer valid.

In quantum entanglement system, if the quantum state transits with the speed that is faster than the observing or measuring speed, the causality law is no longer valid everywhere, except some areas where the formula (17) is satisfied. As special cases, the observer keeps the same distances from the place of cause event happened and the place of effect event happened or the distance between the observer and the place of effect event happened is longer than the distance between the observer and the place of cause event happened, the formula (17) must be true and the causality law remains valid.

Conclusions

The quantum entanglement probably results from the quantum state's transition with the matter wave's phase velocity that is faster than the light speed. When the observing or measuring to the process of quantum entanglement is made at the electromagnetic speed or the light speed, various counterintuitive phenomena arise. The speed difference between the quantum state transition and the measurement also makes the causality law in quantum entanglement system is no longer fully valid everywhere except in certain areas.

References

1. Frank L (2012) Do We Really Understand Quantum Mechanics?. 2nd (Edn.), Cambridge University Press, UK.
2. Yin J, Cao Y, Yong HL, Ren JG, Liang H, et al. (2013) Lower Bound on the Speed of Nonlocal Correlations without Locality and Measurement Choice Loopholes. Phys Rev Lett 110(26): 260407.
3. John M (2012) Quantum teleportation achieved over record distances. Nature 2.
4. Matthew F (2012) Quantum entanglement shows that reality can't be local. Ars Technica.
5. Griffiths DJ (2004) Introduction to Quantum Mechanics. 2nd (Edn.), Prentice Hall, New Jersey, USA.
6. Mit Technology Review (2013) Chinese Physicists Measure Speed of "Spooky Action at a Distance".
7. Edwin French AP (1978) An Introduction to Quantum Physics, W.W. Norton Inc, pp: 685.
8. Xinye W (2020) Information's Relativistic Convey with Matter Wave's Non-Dispersive Propagation. Physical Science International Journal 24(11): 1-6.
9. De Broglie L (1929) The wave nature of the electron. Nobel Lecture, Nobel Foundation.
10. Friedman Y (2004) Physical Applications of Homogeneous Balls. 1st (Edn.), Progress in Mathematical Physics, pp: 279.