Theoretical analysis of a possible method to quantum communication of exceed velocity of light

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If the projection of two photon entangled state in two orthogonal state basis are not equal,the direction of observation of one photon would have influence on the probability distribution of the polarization state of the other photon, which affects the statistical results of a large number of photons. non-local communication can be realized with this method. To get these type of two photon entangled state, this paper designs a method: put the calcium atoms in strong magnetic field.According to the Zeeman effect,calcium atoms would have energy level splitting. Then if the angle between the direction of observation and magnetic field is acute angle, the π light of the calcium atoms' cascade radiation from $4p^2\ {}^1S_0 \rightarrow 4s4p\ {}^1P_1 \rightarrow 4s^1\ {}^1S_0$ would meet the requirement. Thus we demonstrate the method of non fixed domain transfer information is feasible.

I. INTRODUCTION

The EPR paradox was raised by A.Einstein, B.Podolsky and N.Rosen in 1935.[1] E.Schrodinger point that Quantum Entanglement is significant in quantum mechanics.[2-3] Since Bell's inequality was proved by experiments,Scientists gradually accept that the essence of quantum entanglement is a non fixed domain rather than the existence of hidden variables.[4] Although the non-locality is an objective existence, but the quantum system are random,it can not carry real information, which makes the information transmission through the quantum entanglement directly impossible. The current method of quantum communication is only transfer random secret key, and then transfer the encrypted information through classical channel, and then decrypted with quantum secret key. The current method of quantum communication is quantum cryptography, rather than the non-local communication.

However, since the non-locality is an objective existence, there would be the possibility of the non-local communication. This paper use the correlation of entangled photons to create a new method of quantum communication. We design a type of two photon entanglement state that the x-component and y-component of the probability distribution of polarization state are not equal. Through the analysis of this paper, we demonstrate that observe one bundle of entangled photon pairs or not can make a difference of the probability distribution of polarization state of another bundle of photon, and the effect of the observation mode on the other beam can be achieved,which can produce the effect of non-local communication.

II. METHODS

A. two photon entanglement state

Firstly, assume a fundamental form of the states of a pair of entangled photons in Cartesian coordinates as follows :

$$\left|\psi\right\rangle = \frac{1}{\sqrt{r_1^2 + r_2^2}}[r_1\left|x(1)\right\rangle \otimes \left|x(2)\right\rangle + r_2\left|\mathrm{y}(1)\right\rangle \otimes \left|y(2)\right\rangle] = \begin{pmatrix} r_1 \\ 0 \\ 0 \\ r_2 \end{pmatrix} \quad (1)$$

In the formula,r_1 and r_2 should not be equal which is the key point of this article. assume we use Analyzer A and B to observed light 1 and light 2, the angle between the parallel direction of the analyzer and the polarization direction of light are “a” and “b”. And the Matrix representation of the polarization state along the “a” direction and “b” direction is respectively:

$$\left|\mathrm{a}\right\rangle = \begin{pmatrix} \cos a \\ \sin a \end{pmatrix} \qquad \left|\mathrm{b}\right\rangle = \begin{pmatrix} \cos b \\ \sin b \end{pmatrix}$$

So the expectation of photon 1 and 2 passing the analyzer is respectively:

$\left\langle \psi_1 \middle| \mathrm{a} \right\rangle \left\langle a \middle| \psi_1 \right\rangle$ and $\left\langle \psi_2 \middle| \mathrm{b} \right\rangle \left\langle \mathrm{b} \middle| \psi_2 \right\rangle$

We calculate the normal situation first,the intensity of lights that passing analyzer B when b=0.The intensity here refers to the statistical result of a large number of single photons, rather than the classical intensity.

$$I_b = I_0 \left\langle \psi_2 \middle| \mathrm{b} \right\rangle \left\langle \mathrm{b} \middle| \psi_2 \right\rangle = \frac{r_1^2}{r_1^2 + r_2^2} \cdot I_0$$

There is also a special case: when the analyzer A to observe photon 1 entangled photons before photon 2 was observed to let the system decohere. And let the angle between the parallel direction of the analyzer and the polarization direction of light be π/4. It is clear that half of the photons would pass through the analyzer, half of them would not. These two types of photons is respectively:

$$\begin{cases} \psi_{a} = \frac{1}{\sqrt{2}}(|x\rangle + |y\rangle) \\ \psi_{a'} = \frac{1}{\sqrt{2}}(|x\rangle - |y\rangle) \end{cases}$$

According to the formula one,the polarization state of each photon in the light beam 2 is the same as a photon corresponding to it in the light beam 1, which means half of photon in light beam 2's polarization state is ψ_b and the other half is $\psi_{b'}$. And their polarization state is respectively:

$$\begin{cases} \Psi_{b} = \frac{1}{\sqrt{2}}(|x\rangle + |y\rangle) \\ \Psi_{b'} = \frac{1}{\sqrt{2}}(|x\rangle - |y\rangle) \end{cases}$$

At this point, let the parallel direction of the analyzer B is coincident with the X axis again, and the intensity that pass the analyzer B is:

$$I_b' = \frac{1}{2} \cdot I_0 \cdot \langle \varphi_a | \mathrm{b} \rangle \langle \mathrm{b} | \varphi_a \rangle + \frac{1}{2} \cdot I_0 \cdot \langle \varphi_{\bar{a}} | \mathrm{b} \rangle \langle \mathrm{b} | \varphi_{\bar{a}} \rangle = \frac{1}{2} \cdot I_0$$

According to the previous assumption, r_1 dose not equal r_2. Therefore I'_b does not equal I_b, which means that when the analyzer A observe the light 1 before light 2 was observed by analyzer B the intensity of the light that pass the analyzer B is different from that without he analyzer A observing the light 1. And that difference was determined by analyzer A in a non-local way. Thus, place a optical battery after the analyzer B, and two different intensity of light can represent 0 and 1. By these method we can produce the effect of non-local communication.

B. Preparation method

As has been shown above, we can use these special type of entangled photon to realize non-local communication. So the key question is whether we can produce these type of photon entanglement state. This paper only give a feasible example: place the calcium atoms in a strong enough uniform constant magnetic field to let the anomalous Zeeman effect happen. The entangled photon come from the cascade radiation from $4p^2\ {}^1S_0 \rightarrow 4s4p\ {}^1P_1 \rightarrow 4s^1\ {}^1S_0$. When the anomalous Zeeman effect occurs, only the energy level whose angular quantum number is not 0 would split, which means that only $4s4p\ {}^1P_1$ split into three sub energy level,As shown in Figure 1:

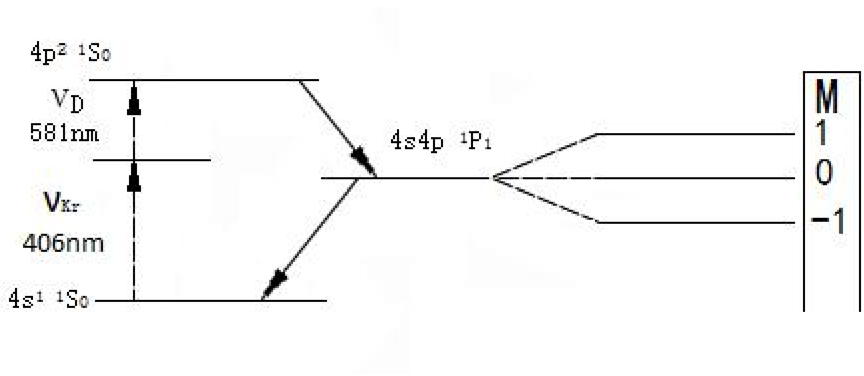

FIG.1. The energy level splitting of the calcium atoms in anomalous Zeeman effect

In the figure, ν_{Kr} and ν_D are lasers to pump electrons.4s4p $^1P_1$ split into three sub energy level. the calcium atom light source will release 6 different frequencies of photons,among which σ photons are not identical particles and are not entangled photons. Thus, we chose the π photons. The σ photons and π photons have different frequencies so it is easy to separate them. In the Zeeman effect, the photon angular momentum of π light's direction perpendicular to the magnetic field. [5]

So when the angle between the magnetic field and observation direction, the photons in angular momentum representation are elliptically polarized light. Thus, the photon has two possible quantum states:

$$\psi_{k1} = K(|x\rangle - \cos\theta \cdot i \cdot |y\rangle)$$
$$\psi_{k2} = K(|x\rangle + \cos\theta \cdot i \cdot |y\rangle) \qquad (2)$$

In the formula,"K" was the normalization constant. These two quantum states are left-handed and right-handed elliptical polarized light. Assume the photon from 4p^2 $^1S_0$→4s4p $^1P_1$ is q_1 and the photon from 4s4p $^1P_1$→4s^1 $^1S_0$ is q_2. According to the exchange symmetry of boson particles system,we can get the two photon entanglement state:

$$\psi(q_1, q_2) = \frac{1}{\sqrt{2}}[\varphi_{k1}(q_1)\varphi_{k2}(q_2) + \varphi_{k1}(q_2)\varphi_{k2}(q_1)] \qquad (3)$$

Then plug the formula 2 into formula 3:

$$|\varphi\rangle = \frac{1}{\sqrt{r_1^2 + r_2^2}}[r_1|x(1)\rangle \otimes |x(2)\rangle + r_2|\mathrm{y}(1)\rangle \otimes |y(2)\rangle] = \begin{pmatrix} r_1 \\ 0 \\ 0 \\ r_2 \end{pmatrix}$$

Thus,the π light of the calcium atoms' cascade radiation from 4p^2 ^{1}S0→4s4p $^1P_1$→

$4s^{1}\ {}^{1}S_{0}$ can meet the requirement and can produce the effect of non-local communication. In actual test, there will be some non entangled light. These light would not impact the result of test,for the intensity of those light would not change by the observed of the analyzer in the other way.

III. CONCLUSIONS

The main purpose of this paper is to prove that non-local communication can be realized by a special type of two photon entanglement state. The current method of quantum communication use the result of observation to transfer information. In that way,it is impossible to realize non-local communication. This paper use whether one of the entangled photon was observed to transfer information and find a method to realize it.

This paper only prove the two photon entanglement state have these effect. Other two-body entanglement may also have these effect, if their projection of quantum state in two orthogonal state basis are not equal. In order to make this paper more convincing,we design a feasibly experimental scheme., which is use the π light of the calcium atoms' cascade radiation in Zeeman effect. There could be other experimental scheme too. Those required further work.

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