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Quantum Interpretation of FTL Communication Via Entanglement Property of Two Particles

Abstract

It is possible to use two particles (A and B) with entangled properties to transmit information at faster than light speeds. This can be done, not by trying to modulate the results of how particle A is measured, but by modulating whether particle A is measured or not measured. The effect of this modulating method is to place particle B in either a single value (but arbitrary) state or leave it in a superposition of states.

It is then possible for the receiver of particle B to distinguish between these two states by the use of an appropriately designed interferometer. Such a device can be designed to produce an interference pattern only when particle B is in a superposition of values and a straight simple image when the particle B has a single (arbitrary) defined value.

Under the Copenhagen Interpretation and existing experimental results, this method will produce a way of signalling faster than light. It will require the use of multiple entangled pairs of particles to effectively transmit a single bit of information.

Under the Multi-Worlds Interpretation, it will not be so easy to communicate faster than light by this mechanism, as detector B will be detecting photon B as a superposition of values in both cases.

Key Words: Quantum Mechanics, Copenhagen Interpretation, Multi-Worlds Interpretation, Superposition, Measurement, Signalling Faster than Light, Mach-Zehnder Interferometer, Quantum Entanglement.

Introduction

In quantum mechanics [1] [2] [3] [4] [5] there is the unusual physical phenomenon called quantum entanglement. This occurs when two particles are created with a shared property that has a fixed total value. This restriction means that the value one particle has for that property depends upon what value the second particle has for that property. Their values for this property are said to be entangled.

Another feature of quantum mechanics is that the value of a property for a particle is indeterminate until it is actually measured, it is said to be in a superposition of values. This does not just mean unknown but that the particle is actually in a superposition of all physically possible values for that property and could potentially take on any one of those values on being measured. The change from a superposition of values to a single measured value is called a collapse of the wave function.

The combination of these two phenomenon leads to an unusual effect. When two particles are created with a shared entangled property that is in a superposition of values for both particles and the particles are then sent off in different directions, a measurement on one particle will not only collapse its wave function to a single resolved value but it will also simultaneously cause the collapse of the wave function of the second particle to a single resolved value - preserving the shared property total value - regardless of how far away the second particle is from the first.

This simultaneous response can and does occur over large distances and has been experimentally confirmed to occur before than any light signal could travel between the two particles.

There has been discussion on the possibility of using the measurement of two entangled particles to communicate faster than light (FTL) speed but the standard interpretation is that this is not possible as there is no control as to what value the first measurement actually produces and hence no control on what the second entangled measurement produces. The correlation between the measurements can only be confirmed by standard light speed communication. The results of the measurements cannot be encoded to transmit a signal [6] [7] [8] [9].

The main premise of this paper is to send a signal by modulating particle A by either measuring or not measuring it. This will either resolve the superposition of particle A to a single value or leave particle A in its original superposition of values. The resultant effect on particle B can be observed, by noting the difference between it being in a superposition (unmeasured) or a resolved value (measured). This method is independent of what the measured value becomes. [29]

Whether this system works or not is dependent upon the second particle being observable by the second observer in either a resolved state or a superposition. In the Copenhagen Interpretation [14] [15] [16] [17], this is possible, in the Multi-World Interpretation (MWI) it is not obviously possible [10] [11] [12] [13] [28].

Experiment Design and Description By the Copenhagen Interpretation

For the purpose of this paper will we consider the case of the production of entangled polarized photons by feeding photons of light into a Beta Barium Borate crystal (BBO) in the proper way, which will produce pairs of photons (with roughly half the original energy in each) where the polarization differs by 90 degrees between members of the pair (Type II spontaneous parametric down-conversion). Both photons will be in superposition of all possible polarization states until one or other of them is measured.

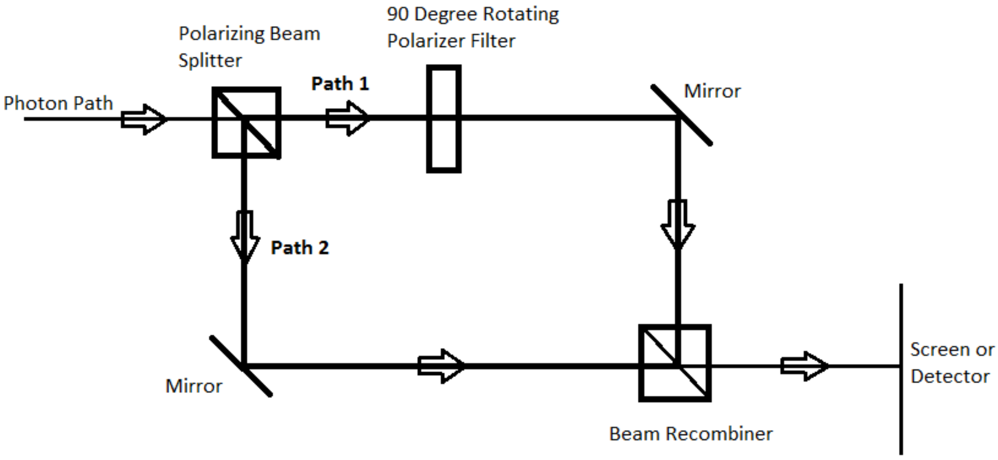
Naming the two photons in the pair as A and B, they will be sent in two different directions to two different experimenters and their equipment, conventionally called Alice and Bob. The experiment is designed so that photon A reaches Alice's measuring equipment first. Alice then chooses whether or not to measure the polarization of photon A using a polarization filter, a vertical polarization filter for the purpose of this paper.

If Alice does the measurement, photon A will have its superposition of values collapsed down to a single value, which here will either be vertically polarized and registered with Alice (measured value 1), or horizontally polarized and not detected directly by Alice (measured value 0). If Alice does not make the measurement, the photon is left undisturbed and remains in its superposition of values.

After Alice has had the opportunity to measure photon A, photon B will arrive at Bob's measuring device. Bob will not be doing a standard polarization measurement but instead direct the photon into a Mach-Zehnder interferometer with the use of a 90 degree polarization rotating filter inserted along one path of the interferometer [26] [27].

At the first polarizing beam splitter crystal, the vertically polarized part of the photon will be sent along path 1, while the horizontally polarized part will be sent along path 2. Path 1 has the 90 degree polarization rotating filter which will rotate the vertically polarized part into the horizontally polarization orientation. Mirrors on each path will then direct each part of the photon to a beam recombiner, so that both parts are sent on the same path and can now interfere with each other and produce an interference pattern - if there were both vertical and horizontal polarization components to the photon.

Diagram 1. Mach-Zehnder Interferometer



Bob now sets up his detection apparatus, either a screen to display the possible interference pattern or a simple illuminated spot, or a photon detector set at the position of maximum destructive interference closest to the central line of the photon path.

When Alice makes a measurement and collapses the wave function of photon A (with either value 1 for vertical polarization or 0 for horizontal polarization), due to the entanglement property of the two photons, photon B's wave function will also collapse to a single value. The polarization value for photon B will be horizontal if A was vertical, or vertical if A was horizontal.

In the case for when photon B is horizontally polarized it will pass solely along path 2 and on entering the beam recombiner will not be merged with any wave function from path 1 and so will not produce an interference pattern at the screen but just a simple illuminated spot.

In the case for when photon B is vertically polarized it will pass solely along path 1 and on entering the beam recombiner will not be merged with any wave function from path 2 and so will not produce an interference pattern at the screen but just a simple illuminated spot.

When Alice does not make a measurement of photon A it remains in its superposition of all possible polarization values, as does photon B. So photon B enters Bob's Mach Zehnder interferometer in a superposition of all possible polarization values and at the polarizing beam splitter it will be split and its wave function will travel along both path 1 and path 2.

The vertically polarized component of the wave function will pass along path 1 and be rotated 90 degrees to become horizontally polarized, it will then be directed to the beam recombiner by a mirror. The horizontally polarized component of the wave function will pass along path 2 and be directed to the beam recombiner by a mirror.

At the beam recombiner, the two parts of the wave function are reunited and as they now have the same polarization value they can cross interfere and produce an interference pattern at the screen. The interference pattern comes from the tiny differences in distance travelled through the Mach Zehnder interferometer by the wave function taking slightly different paths from the central line path.

The difference in the observation between the two cases of measurement and no measurement allows for the signalling of data faster than light, in the Copenhagen Interpretation.

Multiple entangled photons will have to be sent in order to unambiguously produce an interference pattern. It is though more reliable to have a signal encoded by multiple photons than by a single photon (pair). All that is required is for a sufficiently fast method of producing entangled photons so that enough can be sent in a short space of time to signal and still beat the light speed limit [18] [19] [20] [21] [22] [23] [24] [25].

Everett Multi-World Interpretation Analysis

Start with the creation of a pair of entangled photons (A and B), of differing polarization, one will be noted as value 1 (say for up/down) and the other as value 0 (say for left/right), which is undetermined initially. Both photons will be in a superposition of the two values.

Experiment A for the measurement of photon A is closest to the source and will operate first. It will measure photon A and then form a superposition of measured states with photon A. That is, there will be a sum of two states: state one being Experiment A detecting the value of 1 for photon A and photon A having the value of 1, state two being Experiment A detecting the value of 0 for photon A and photon A having the value of 0. Photon A goes from being a one world set of a superposition of two states to being part of a two world superposition of single resolved states, of the photon and the detector and also of photon B.

Due to the entanglement property, in state one, photon B will now have value 0, while for state two, photon B will have value 1. This change in photon B occurs simultaneously with that of photon A.

Photon B goes from being a one world set of a superposition of two states to being a two world superposition of single resolved states along with photon A and detector A. The crucial aspect here is that until the detector of experiment B takes on this two world superposition itself, it will still see a superposition of states of photon B.

This two world superposition of photon B will reach experiment B and it will pass through both paths of the interferometer and produce an interference pattern. Detector B will observe this pattern, unless the two world superposition of the photon extends to include experiment B.

In the case of there being no measurement of photon A by detector A, the results are the same as in the Copenhagen Interpretation, both photons remain in their own superposition of values and an interference pattern is observed.

In the MWI, both experimental cases produce the same interference pattern if the superposition of the two world states is not expanded to include the detector B before the interference pattern is produced.

No FTL signalling can be achieved unless the two world superposition of photon B is expanded to include experiment B before the measuring of the interference pattern is done.

However in most experiments of this kind that have been performed, the photon B is observed being in a resolved state after photon A is measured in experiments, because this is what entangled states is all about. This seems to make the MWI less likely as a theory, however this could just be because all previous such experiments have used some form of direct measurement of photon B and so immediately enter into a co-superposition with the possible resolved states of B.

Possibilities

Note that in the MWI it seems possible that two different observers can examine the same particle and one could see it in a resolved state - sharing its superposition and another could see it in a superposition of states, when not sharing the superposition. This is if the transposition of the superposition to observers can be restricted to just one observer.

Reliability of Results

Observer B will take on the two world superposition created by observation A at some point. At that point it will see the same results as A, communications between them on the values of photons A and B will confirm each other and be fully compatible with the entanglement restrictions.

The critical problem is when will observer B enter into the two world superposition and see a resolved value for photon B rather than a superposition of values? One possibility is that the observer B will take on one of three possible states, two resolved states of photon B and one superposition of photon B.

Summary

Under the Copenhagen Interpretation, it will be possible to communicate faster than light using the Quantum collapse mechanism of a measurement, signalling by means of either measuring or not measuring. The resulting signal in photon B being in the form of either a single value or a superposition of values.

Under the Multi-Worlds Interpretation, it will not be so easy to communicate faster than light by this mechanism, as detector B will be detecting photon B as a superposition of values in both cases.

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