Instant Communication: Coincidence Annihilation of Polarization Entangled Photons

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I propose a thought experiment for instant communication with an action taken on a single member of two polarization entangled Bell state photons. The action is that of quenching the one entangled beam with an emission of identical photons in a 45° polarized state. It is argued that the quenching has the effect of coincidence annihilation between the entangled pair, leaving the second beam in a state of unentangled polarization where interference may be observed.

Coincidence Annihilation

I have argued elsewhere[1] that the WZM study[2,3] represents a preparation of coincidence annihilation. In the WZM study the authors find that they may produce interference between the possible sources of idler photons from two downconversion processes, a non-trivial result, by means of inducing stimulated downconversion in the two crystals with two mutually coherent reference beams. The reference beam is identical in description to the signal beams from downconversion, so by simply splitting the reference beam and directing the two outputs to propagate through the region of emission in the downconversion crystals and in alignment with the signal outputs there is a stimulated downconversion. This stimulated downconversion also has the property that the four outputs of the downconversions are mutually coherent, so interference is observed between the idlers of the two downconversions.

The visibility of interference is seen to have a dependence upon a ratio of the occupation number of the inducing reference beam, N, to the bandwidth of the downconverted signal beam, Δv_s. The authors of reference 2 describe the ratio as the injected reference beam intensity in photons per second to the bandwidth of the downconverted signal photons. If the ratio is large then the visibility is present, $N/\Delta v_s >> 1$. In reference 1 the current author has argued that the ratio may similarly be expressed in terms of the coherence length of the downconverted signal beam, $\Delta x_s \approx 1/\Delta v_s$. This would allow the criterion to be expressed as (excluding the additional factor of Planck's constant because the ratio is assumed by the WZM authors to be without units),

$$N\Delta x_S >> 1$$

This simply states that the product of the photon occupation number of the reference beam to the coherence length of the signals must be large, which (after normalization) is identical to saying that the product of the number of reference beam photons per path length with the path length per signal photon is large, which is simply saying that ***the number of reference beam photons per signal photon is large***. I agree with this analysis because it supports the claim that interference visibility is allowed between the idler photons in the WZM study under the strict condition that ***there may not be any way in principle for the path of the signal photons to infer the path of the idlers***. This ratio as I have restated it requires that many reference beam photons be coincidental with a given signal, and because of this there is no way in principle to distinguish between the signal and the reference beam photons when one wishes to compare them with the originally coincidental idler. (This also assumes the strict condition that the original signal and idler not be perfectly correlated in position, which is the case for the WZM study which uses $LiIO_3$ type I downconversion which is perfectly momentum correlated and not perfectly position correlated due to a wave vector conserving process.)

For any readers whom might wish to disagree with the above stated analysis of the WZM study I would ask, how do you propose to explain the allowance of single photon interference between the possible sources of idler photon while it's entangled partner signal photon is still available for measurement of its path which *should* infer the path of the idler? Because of the coincidence annihilation that occurs between signal and idler.

Instant Communication

The proposed thought experiment for instant communication is illustrated in Figure 1 where a pump beam is incident upon a downconversion crystal (DC) which converts the pump photons into two polarization entangled bell state photons of roughly half the frequency of the pump. The two downconverted photons are labelled s_1 and i_1 for signal and idler respectively. The exact type II downconversion crystal is not indicated as it is assumed that there are many possibilities, as long as the final Bell state of the pair is one which allows both polarizations for the signal and idler. For simplicity we assume that the final polarization Bell state of the pair is that of the symmetric state,

$$\varphi^+ = \frac{1}{\sqrt{2}}(|H>|V>+|V>|H>)$$

where the H and V polarization states in each of the two terms are ordered in a Kroneker product with the polarization of the signal first and the polarization of the idler second. This state vector assumes the coordinate space vectors to be included as would be appropriate for the propagation of the two photons. In addition, we assume that the downconversion produces entangled photons which are perfectly entangled in momentum, not position, so that we may assume the entangled photons to only be positionally entangled to within a coherence length of the signal/idler.

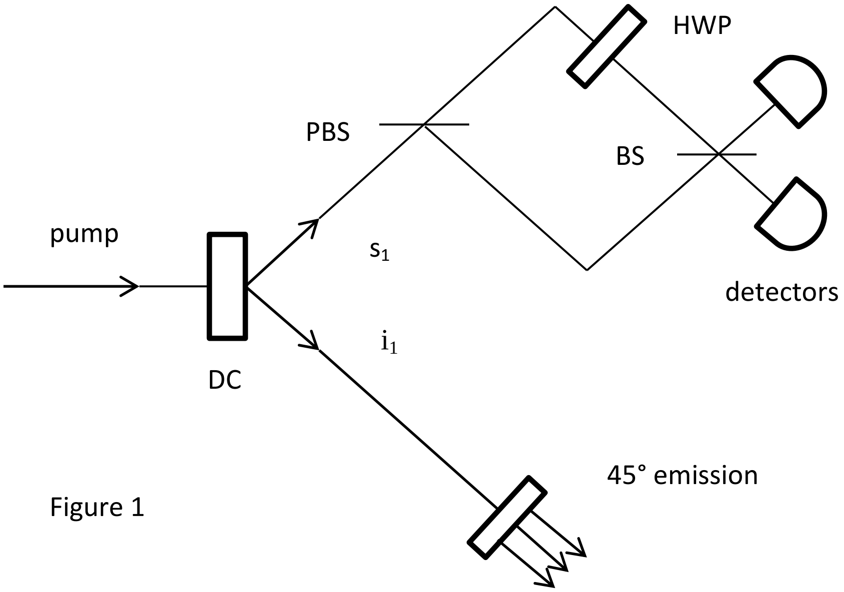

Figure 1

The idler photon is then incident on and propagated through a photon emission source with 45° polarization which is aligned in propagation with the idler and identical in description to the idler (identical bandwidth). As I have described above, this has the effect of annihilating the coincidence of the incident idlers with its entangled signal as long as the photon occupation number of the emission source is large and the coherence length of the downconverted idler is large,

$$N\Delta x_i >> 1$$

The signal beam emitted from the downconversion crystal is prepared to be incident upon a polarizing beam splitter which allows the horizontally polarized (H) signal photons to transmit and reflects the vertically polarized (V) signal photons. This would imply that the two output paths of the PBS are marked with polarization. The transmitted beam with horizontal polarization is then incident upon a half wave plate (HWP) which rotates the polarization of the beam to that of vertical polarization (V). This now implies that the two beams that exit the PBS will both have vertical polarization, so the two paths are no longer marked with polarization. The two beams are then made to be recombined at a normal 50/50 beam splitter (BS) which adds the two vertically polarized beams to look for interference with optical path difference at the two detectors. As long as the optical paths are equal to within a coherence length of the signal photons then we would expect interference to be observed as we modulate one of the two path lengths. Or would we?

The original state vector which describes the downconverted system is that of a two term state vector with a vacuum state and an occupied state. If we consider only the occupied state then we essentially have the Bell state that is given above, which expresses the polarization entanglement. If we write this state vector with the coordinate space vectors included we might expect the total state vector to take the form,

$$\varphi^{+} = \frac{1}{\sqrt{2}}(|H, \varphi_s > |V, \varphi_i > + |V, \varphi_s > |H, \varphi_i >)$$

where the φ_s and φ_i are the coordinate space vectors for the signal and idler respectively. With this total state vector we may now calculate the correlation function at the signal end which indicates the detection probability for any detector we might use to collect interference. We would expect that there will not be interference between the two signal beams at the final detection because the polarization of the idler is always able to be measured and it will indicate the path of the signal. This is obvious in the above expression. So how do we get interference? The intuitive speculation that is presented by the current author is that the preparation of the idler beam to be incident upon and propagated through a 45° polarized emission will have the desired effect of coincidence annihilation. Exactly how this changes the mathematics of the state vector is unknown. It is my guess that the state vector is modified in its coordinate space vectors for each term, because this is where the system is modified. The system is prepared to have its *coincidental* or *spatially entangled* nature destroyed. One simply cannot gain meaningful coincidence between the signal and idler after the idler has propagated through the emission. The idler might be horizontally or vertically polarized, with equal likelihood. The same could be said of the emitted 45° polarized photons. So we cannot distinguish between the idler and the idlerlike emission. The idler beam is quenched and as a result there is no longer any meaningful coincidence between signal and idler. For this reason I speculate that there is a final pure state for both idler and signal, and that these states are to be assigned as the closest pure state to the reduced density operator of the given photon. For the idler, the reduced density operator is given as,

$$\rho = \frac{1}{2}(|H >< H| + |V >< V|)$$

for which the closest pure state is that of a 45° polarized photon. The exact same analysis stands for the idler which is also assumed to take upon the state of 45° polarization.

As we have mentioned earlier, the Bell state of φ^+ will not allow interference at the signal detectors for the simple reason that the signal paths are always distinguishable by virtue of a measurement of the polarization of the idler. But in the case of our newly established 45° polarization states for the signal and idler both, we should expect that the signal detectors will display interference with optical path difference when we vary one of the signal path lengths. The only optical path limitation that we would have is that the path from the DC crystal to the emission source along i_1 is shorter than the path from the DC crystal to the signal detectors (along any interferometry path of s_1), which ensures that the signal photon detection of the interferometer takes place **after** the idler propagates through and comes into alignment with the 45° emission. This all relies on the assumption that the propagation of the idler through the emission source causes *coincidence annihilation*.

Assuming all reasoning up to here to be correct, we may create instant communication by having an Alice/Bob type signalling protocol. Alice receives the signal from Bob by doing nothing more than collecting interference at the signal detectors for an exact time interval that has been prior agreed to by both parties. If she gets interference then she establishes that Bob is signalling 1, and if she gets no interference then she establishes that Bob is signalling 0. Bob sends the signal to Alice by choosing to either have coincidence annihilation (signal 1) or not (signal 0). His method of choice can be produced with the simple addition to the preparation of adding an attenuation filter (100%) in the idler path prior to its arrival at the emission source. This will have the desired effect of not allowing coincidence annihilation. So by Bob choosing to or not to attenuate the idler he is actually choosing to send message 0 or 1 to Alice respectively.

References

1) Thomas Alexander Meyer, *Instant Communication : Induced Coherence with Coincidence Annihilation*. www.vixra.org/pdf/1311.0052v1.pdf

2) Z. Y. Ou, L. J. Wang, X. Y. Zou, and L. Mandel, *Coherence in two-photon down-conversion induced by a laser*, *Phys. Rev. A*, **41**, 1597 (1990).

3) L. J. Wang, X. Y. Zou, and L. Mandel, *Observation of induced coherence in two-photon downconversion*, *J. Opt. Soc. Am. B*, **8**, 978 (1991).