Is faster-than-light communication possible using entangled photons and a double slit?

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Abstract

A recent experiment by Dopfer was done using entangled photons in which one of each pair of photons was allowed to pass through a double slit prior to detection. Depending on how the photon's doubles were measured on the opposite end, the photons passing through the double slit either produced an interference pattern or they produced no interference pattern. The measurements were done with the aid of a coincidence circuit. It is argued here without any new theory that there is the possibility that Dopfer's experiment, after modification by among other things, removing the coincidence circuit, allows the ability to transmit signals faster than the speed of light.

In an experiment, [1] Dopfer used parametric down conversion to generate photon pairs in an entangled state. To detect the photons, Dopfer used a double slit and a "Heisenberg detector," as shown in figure 1.

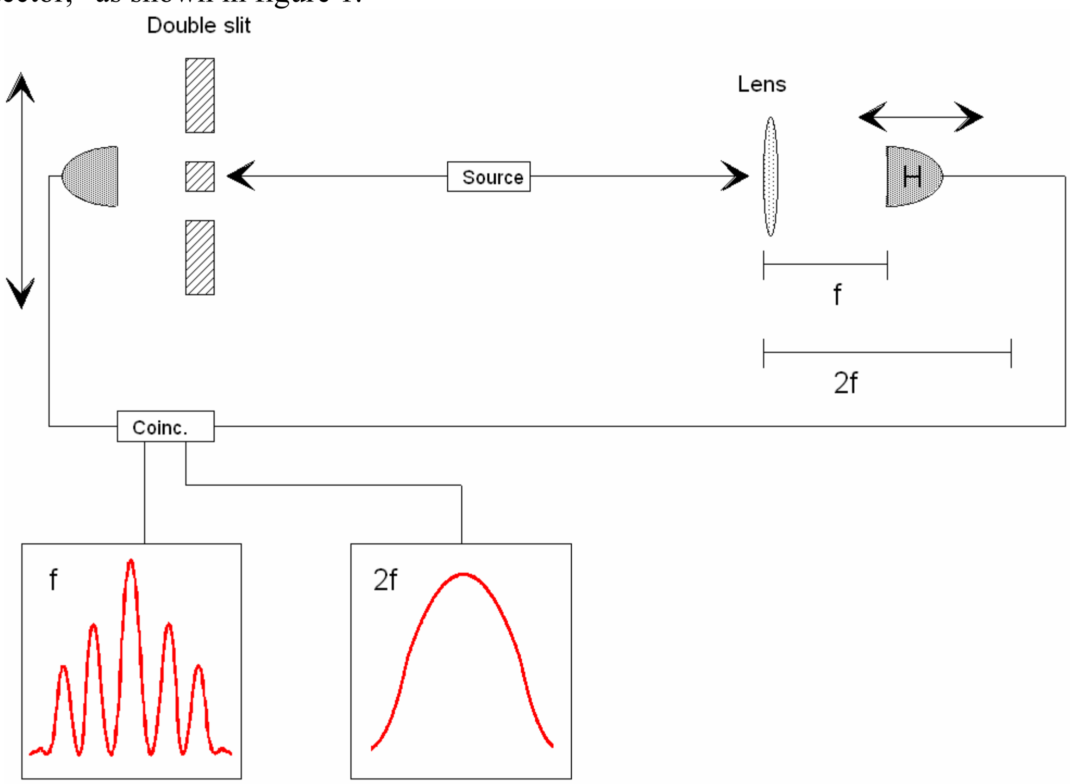

Figure 1. Dopfer's experiment. Entangled photons are emitted by a source. For every pair, the photon going left enters a double slit and is detected. The photon going right is detected by a "Heisenberg detector" H after passing through a lens. When H is placed at distance *f* behind the lens, an interference pattern is obtained (left). When H is at distance 2*f*, no interference pattern, or a "blob" is obtained (right).

For every pair of entangled photons, one would pass through the double slit, and the other would reach the Heisenberg detector. After the experiment was performed, she found that when the Heisenberg detector was placed at one focal length *f* from the lens in front of it, the corresponding twins of the photons detected by the Heisenberg detector; *i.e.* the photons passing through the double-slit, produced an interference pattern. On the other hand, when entangled photons were detected by the Heisenberg detector at distance 2*f* behind the lens, their corresponding twins produced no interference pattern. These results are summarized in table 1.

D	Result
f	Interference pattern
2*f*	No interference pattern

The results in table 1 raise the question of whether or not Dopfer's instrument can be used for faster-than-light communication; in particular when either end of the instrument is placed at great distance from one another, and for example, the digit "1" is corresponded to the appearance of an interference pattern, and the digit "0" is corresponded to the lack of an interference pattern, the latter hereafter referred to as a "blob."

Unlike in the case of polarization measurements using entangled photons, here the "sender" with the Heisenberg detector has the *choice* of whether or not to produce an interference pattern on the "receiver" end. Further, constructing a pattern from photon data collected behind the double-slit requires no information from the other end, other than the information which gives indication for which photons correspond to the Heisenberg detector placed at *f*, which correspond to 2*f*, and which photons are noise. Coordinating this information is the sole purpose of the coincidence circuit shown in figure 1. Now it is clear that if the circuit, which operates at the speed of light, can be removed, then the answer to the question regarding faster-than-light communication is "yes," at least in principle.

If the coincidence circuitry is to be removed, then there are essentially three problems which must be overcome, in order to be able to use Dopfer's device for communication:

1. Both receiver and sender must establish a protocol for information transmission, without the aid of the coincidence circuit.
2. Removal of the coincidence circuit will prohibit the receiver from filtering out noise. Consequently, the signal-to-noise ratio must be large enough, so that the receiver is able to discriminate between the two types; *i.e.* bits of information being sent by the sender.
3. It must be shown that removal of the coincidence circuit does not, in some way, cause all photons to become disentangled.

We first consider problem 1. This can be overcome by laying down rules for sender and receiver, and standardizing times at which bits of information are to be sent. Times can be standardized by installing a beacon near the source, which emits pulses of ordinary light to either end, at given time intervals. Now for the rules:

a. The Heisenberg detector is placed at *f* if a "1" is to be sent, and at 2*f* if a "0" is to be sent.

b. Upon receiving a pulse of light from the beacon, the transmission of one bit is finished, and the transmission of the next bit is begun. Hence the Heisenberg detector can only be switched at the times at which a pulse of light from the beacon is received.

c. Upon receiving a pulse of light from the beacon on the receiving end, data collection for one bit is finished, and data collection for the next bit is begun.

d. The data are collected into "bins;" *i.e.* one bin for each bit. If the data from one bin is plotted and shown to develop an interference pattern, then the bit that was sent is interpreted as a "1." If a blob is produced from plotting the data, than this means that a "0" was sent.

Thus, if entangled photons 1, 2,…, *N* are received by the Heisenberg detector between times demarcated by two consecutive light pulses from the beacon, and hence the Heisenberg detector is held fixed between those two times, then ideally those *N* photons' twins will be received after passing through the double slit on the other end, and the data collected from those photons will be put into a single bin. Further, the receiver will know that all entangled photons received between the two consecutive time stamps either contribute to a pure interference pattern or a pure blob. Thus problem 1 is surmountable, using a set of rules which both sender and receiver have agreed upon beforehand.

Problem 2, how to filter out noise, is a technical issue, like the first. There is no theory which indicates that the level of "random photons" emitted from entangled-photon sources in general is so great that effects due to entangled photons cannot be singled out without the aid of a coincidence circuit. In fact, if there were such a theory, then any faster-than-light communication scheme using entangled photons would fail due to excess noise, and hence the "no-signaling" theorem of Eberhard and Ross [2] would be pointless in the demonstration of no faster-than-light communication.

Nevertheless it has been demonstrated using parametric down conversion that coincidence counts as high as 86% [3] are obtainable, as a percentage of total photon counts. It is clear that if 86% of the photons received behind the double-slit of figure 1 are entangled, then it is possible for the receiving end of the apparatus of figure 1 to distinguish between interference pattern and a blob, using the above protocol, *sans* coincidence circuit.

The last issue that needs to be addressed is problem 3. The supposition that the coincidence circuit is necessary for entanglement is false. This was shown in an experiment [4] using entangled photons, polarizers and electrically-independent counting mechanisms.

It thus appears that it is possible for the device in figure 1 to be used in faster-than-light communication, since all three difficulties listed above, appear to be surmountable. There are however, two additional issues which should to be addressed, and these are (1) how the proposed method of faster-than-light communication described here circumvents the "no-signaling" theorem of Eberhard mentioned earlier, and (2) how such faster-than-light communication is compatible with relativity theory:

(1) Eberhard's "no-signaling" theorem operates under two hypotheses: by orthodox quantum theory (a) the probabilities of eigenvalues measured on one end of a two-photon measurement apparatus are unaffected by anything done on the opposite end, and (b) since measurement of probabilities of eigenvalues is the only conceivable method of extracting information faster than the speed of light using entangled photons, such faster-than-light communication is forbidden. In light of the earlier discussion, the weakness in this argument is clearly the hypothesis (b). In the apparatus of figure 1, the eigenvalue measured on the receiving end is the wavelength (*i.e.* momentum) of the [monochromatic] photons. Regardless of what is done on the opposite end, the probability of measuring this eigenvalue is always 100%. Therefore, hypothesis (a) of the theorem is satisfied. However, as Dopfer [1] has explained, when the Heisenberg detector is at distance $2f$ from its lens, the interference pattern each photon contributes to is shifted from that of the previous, which results in an incoherent sum of several interference patterns; *i.e.* a blob. When the Heisenberg detector is placed at position f, the interference patterns become coherent again, and hence an overall interference pattern is observed. Since the coherent interference pattern and blob are distinguishable, there exists a possible alternative method of faster-than-light communication; one which does not rely on measurements of eigenvalue probabilities. Hence hypothesis (b) is invalid.

(2) It has already been proposed by Costa de Beauregard [5] that (whether faster than light communication is possible or not) in order to reconcile the nonlocal quantum theory with the local relativity theory, it is necessary to discard the idea that causality always proceeds forwards in time. In particular, Dopfer [1] has argued that the entangled photon behavior is better explained as a single-photon system, where the single photons are "emitted" by the Heisenberg detector, pass through the source and double slit, and are finally detected behind the double slit. In this picture, causes and effects proceed both backwards and forwards in time, but never does any interaction occur along a spacelike curve. Causes always "precede" effects through null geodesics; *i.e.* by the photons.

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