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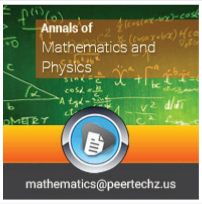

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Mini Review

Physical contradictions ruling out photonic quantum nonlocality

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Abstract

A series of physical contradictions can be identified in an opinion article published in December 2015 (A. Aspect, "Closing the Door on Einstein and Bohr's Quantum Debate," Physics **8**, 123, 2015) claiming definitive proof of quantum nonlocality based on entangled pairs of photons. For example, experimental results published simultaneously in Physical Review Letters (250401 and 250402, 2015) were theoretically fitted with distributions containing a dominant unentangled component, contradicting the need for maximally entangled states underpinning quantum nonlocality. Such contradictions were ignored by the 2022 Nobel Prize Committee raising doubts about the validity of their decision.

Over the last two decades, large amounts of resources have been invested in the research and development of quantum computing based on the concept of quantum nonlocality. Yet, no such functional or operational device is expected in the near future. Nevertheless, photonic quantum nonlocality - despite being substantially rebutted in the professional literature [1-8] has been the subject of the 2022 Nobel Prize Committee. This approach may actually lead to a dead end.

While the three physicists deserve credit for performing experiments with entangled photons, their interpretations of the experiments do not stand up to physical scrutiny in so far as the following four aspects are concerned.

Entangled pairs of photons

Quantum entanglement of states or photons is the consequence of a common past interaction between states or photons and those properties generated in the common interaction can be carried away from the position and time of that interaction. A single photon cannot propagate in a straight line inside a dielectric medium because of the quantum Rayleigh scattering associated with photon-dipole interactions. Groups of photons are created through parametric amplification in the nonlinear crystal in which spontaneous emissions first occur. Such a group of photons will maintain a straight line of propagation by recapturing an absorbed photon through stimulated Rayleigh emission [7,9].

The assumption that spontaneously emitted, parametrically down-converted individual photons cannot be amplified in the originating crystal because of a low level of pump power would, in fact, prevent any sustained emission in the direction of phase-matching condition because of the Rayleigh spontaneous scattering [7,9].

Quantum nonlocality upon sequential measurements

Quantum nonlocality is claimed to influence the measurement of the polarization state of one photon at location B, which is paired with another photon measured at location A. The two photons are said to be components of the same entangled state. Maximally entangled states, represented in the same frame of coordinates of horizontal and vertical polarizations, would deliver the strongest correlation values

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between separate measurements of polarization states recorded at the two locations A and B.

If a collapse of the wave function is to take place for entangled photons upon detection of a photon at either location, then the two separate measurements do not coincide. In this case, a local measurement vanishes for the maximally entangled Bell states- see Appendix below. This leads to a physical contradiction as local experimental outcomes determine the state of polarization to be compared with its pair quantum state. This overlooked feature of maximally entangled Bell states renders them incompatible with the polarimetric measurements carried out to determine the state of polarization of photons, thereby explaining the experimental results [10] which were obtained with independent photons.

As already mentioned above, the rebuttal of the concept of quantum nonlocality has seen a growing body of analytic work which the legacy journals have chosen to ignore, e.g. references 1-8. [11,12], the optimal experimental states identified in their equations (2) contain a large unentangled component that provides the non-zero values for the correlation function – see Appendix for details.

Correlation functions

Maximally entangled states, represented in the same frame of coordinates of horizontal and vertical polarizations, would deliver the strongest correlation values of the correlation function $E_C = \cos\,[2(\theta_A - \theta_B)]$, for identical inputs to the two separate apparatuses, with the polarization filters rotated by an angle θ_A or θ_B, respectively, from the horizontal axis. However, quantum-strong correlations with independent photons have been demonstrated experimentally [10] but ignored by legacy journals because they did not fit in with the theory of quantum nonlocality. The same correlation function $E_C = \cos\,[2(\theta_A - \theta_B)]$ is obtained 'classically', as a result of the overlap of two polarization Stokes vectors of the polarization filters on the Poincaré sphere. The Stokes parameters correspond to the expectation values of the Pauli spin operators [8].

Polarimetric measurements made in the quantum regime are based on the Pauli spin operators whose expectation values are displayed on the Poincaré sphere. However, these operators act on the state of polarization regardless of the number of photons carried by the radiation mode, instantaneously. The correlation functions needed to evaluate various Bell-type inequalities take the same form in both the quantum and classical regimes and correspond to the overlap of the polarization states in the Stokes representation [8].

Bell-type inequalities

Quantum measurements violating Bell-type inequalities are supposed to be based on entangled states of single photons and prove the existence of quantum nonlocality. But the violations of inequalities rely on the correlation functions of the two ensembles of measurements as opposed to the same pair of photons, that is, the correlations are obtained as a result of a numerical comparison and are not a physical interaction. The photonic properties were carried away from the space and time of the original interaction, with the *measurement identifying* which of the two photons possessed the respective states of polarization.

Bell-type inequalities can also be violated classically because the same correlation function is derived for both the quantum and classical regimes, as explained in the previous section 3. Thus, from a technological perspective, functional devices needed for strong correlations between two separate outputs can be achieved with multiple photons, thereby obviating the need for complicated and expensive single-photon sources and photodetectors.

Consequently, quantum-strong correlations which are needed for quantum data processing can be produced by means of uncorrelated and multiphoton states as well as 'classically' by means of Stokes parameters on the Poincaré sphere. In this way the complicated and expensive single-photon sources and photodetectors become unnecessary.

(**Appendix**)

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