Comment on "Franson Interference Generated by a Two-Level System"

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In a recent Letter [Phys. Rev. Lett. **118**, 030501 (2017)], Peiris, Konthasinghe, and Muller report a Franson interferometry experiment using pairs of photons generated from a two-level semiconductor quantum dot. The authors report a visibility of 66% and claim that this visibility "goes beyond the classical limit of 50% and approaches the limit of violation of Bell's inequalities (70.7%)." We explain why we do not agree with this last statement and how to fix the problem.

In a recent Letter [1], Peiris, Konthasinghe, and Muller report a Franson interferometry experiment using pairs of photons generated via frequency-filtered scattered light from a two-level semiconductor quantum dot. The authors report a visibility of 66% and claim that this visibility "goes beyond the classical limit of 50% and approaches the limit of violation of Bell's inequalities (70.7%)." In the following we explain why we do not agree with this last statement.

A violation of the Clauser-Horne-Shimony-Holt (CHSH) Bell inequality [2] without supplementary assumptions (so that it is loophole-free and therefore potentially usable for device-independent applications) using a maximally entangled state is only possible in a very small region of values of the overall detection efficiency η and the visibility V. Specifically, it must occur that $V \geq (2/\eta - 1)/\sqrt{2}$ [3]. Therefore, the 70.7% visibility bound mentioned by Peiris, Konthasinghe, and Muller only holds under the assumption that $\eta = 1$.

The problem is that this value is impossible to achieve in the Franson interferometer, even ideally. As the authors correctly point out, in the Franson interferometer there is a crucial post-selection step which requires discarding, on average, 50% of the recorded photons. Therefore, *even in the ideal case that the detectors and couplings were perfect*, the effective η falls to 50%. This implies that it is possible to produce a classical local hidden variable models while retaining the same output statistics as predicted by quantum theory [4–6].

In fact, the above problem has recently been exploited to experimentally show that the security proof in Franson-based quantum key distribution schemes can be circumvented, exposing its users to eavesdropping [7]. In these attacks, tailored pulses of classical light are used, which indicates that the 50% "classical limit" can be beat even in a purely classical setting.

However, as described in [4], there is a possibility of detecting a genuine violation of a Bell inequality in the setting of Peiris, Konthasinghe, and Muller. It requires using a *different* Bell inequality, namely, a three-setting chained Bell inequality introduced by Pearle [8]. This modification allows for a genuine violation of local realism, but requires a higher visibility: At least, 94.63% [4, 6]. Although demanding, a recent work [9] shows that such an experiment is feasible.

In conclusion, while the setup in [1] is promising, the experimental data does not rule out all classical descriptions. A test of the three-setting chained Bell inequality could be a more suitable application for this correlated photon pair source. However, the corresponding experiment would be much more challenging as it requires a visibility of, at least, 94.63%.

This work was supported by the project "Photonic Quantum Information" (Knut and Alice Wallenberg Foundation, Sweden) and Project No. FIS2014-60843-P, "Advanced Quantum Information" (MINECO, Spain), with FEDER funds.

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