Comment on "Protocol for Direct Counterfactual Quantum Communication"

In a recent Letter, Salih *et al.* [1] claimed that "in the ideal asymptotic limit, information can be transferred between Alice and Bob without any physical particles traveling between them." This conclusion was based on a naive classical approach to the past of the photons: "the photon could not have been in the transmission channel because it could not pass through it." I will argue that actual measurement of the presence of the photon in the transmission channel will not support this claim.

Salih *et al.* build their protocol on the basis of the interaction-free measurements [2] which were implemented as counterfactual computation [3] and counterfactual cryptography [4]. In all these scenarios, blocking the wave packet of a photon spoils destructive interference and information about the blocking is obtained without the photon being near the blockade [5]. If the blockade is absent, these protocols cease to be counterfactual. Salih *et al.*, similarly to Hosten *et al.* [6], construct a protocol which is apparently counterfactual in both cases, when the blockade is present and when it is not. I have argued before [7] that the Hosten *et al.* method is not counterfactual for the null outcome and, similarly, I claim that the Salih *et al.* protocol is not counterfactual for the values of the information bit corresponding to the absence of the blockade.

Salih *et al.* are correct that the branch of the wave function of the photon reaching detector D_1 does not pass through the communication channel. However, from this it does not follow that the photon was not there. Both forward and backward evolving wave functions are present in the communication channel, see Fig. 1., and I argue that in such a case we should say that the photon was there [8]. Salih *et al.* are mistaken in saying "the probability of finding a signal photon in the transmission channel is nearly zero." Given a click at D_1, the probability for finding the photon by a nondemolition measurement of the projection operator on the transmission channel is one. Indeed, performing such a measurement and not finding the photon is impossible, since this is equivalent to blocking the channel, in which case D_2 has to click. The strong measurement of the projection completely changes the interference pattern, so the relevant question is the outcome of a weak measurement of the presence of the photon in the communication channel. But when the strong measurement outcome is certain, the weak measurement yields the same result [9]. The "logic 0" case requires the photon to be present in the transmission channel.

In contrast, a click in D_2 provides fully counterfactual information for the "logic 1" case. When Bob blocks the channel, there is no overlap of the forward and the backward evolving wave functions of the photon in the transmission channel, and the outcome of the weak measurement of the projection is zero. Thus Eve, performing weak measurements of the projection on the transmission channel can get some information about the logical bits.

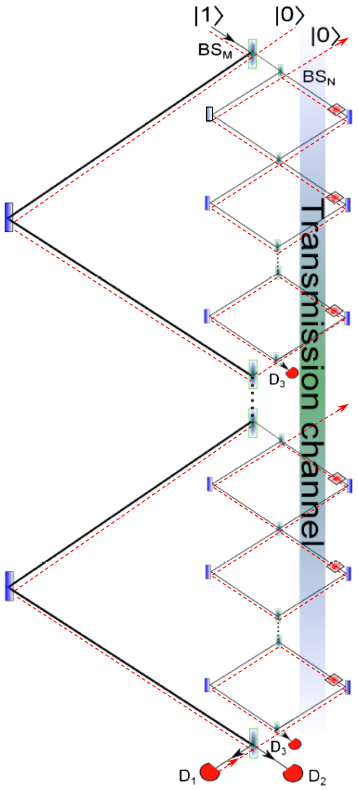

FIG. 1 (color online). Forward (continuous line) and backward (dashed line) evolving wave functions of the photon; see Fig. 2(b) of Ref. [1].

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L. Vaidman
Raymond and Beverly Sackler School of Physics and Astronomy
Tel-Aviv University
Tel-Aviv 69978, Israel

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