

# What is wrong with SLASH\* ?

Karl Svozil

Institut für Theoretische Physik, University of Technology Vienna

Wiedner Hauptstraße 8-10/136, A-1040 Vienna, Austria

e-mail: [svozil@tuwien.ac.at](mailto:svozil@tuwien.ac.at)

December 16, 2013

## Abstract

In an experiment featuring nonlinear optics, delayed choice and EPR-type correlations, the possibility of faster-than-light communication appears not totally implausible. Attempts are put forward and discussed to refute this claim.

Quantum theory and special relativity theory are the cornerstones of today's physical perception. Obviously their intrinsic consistency as well as the consistency of a combined theory is of greatest relevance. Thus one of the most discomforting results of 20th century mathematics and physics is the conclusion that *with respect to consistency of theories, in general no affirmative answer can be given*— It must be clearly spelled out that the mere introduction of “manifestly covariant” entities, such as Lorentz invariant spinors and tensors in quantum electrodynamics, is an insufficient guarantee of consistency. Any attempt to “prove” consistency in nontrivial theory contexts, such as for instance Shirokov's remarkable investigation [1], must inevitably be too specific or even misleading.

Although eminent physicists and philosophers of science have conjectured the “peaceful coexistence doctrine” [2] of quantum and relativity theories, it cannot be excluded that contradictions may be “lurking behind the corner,” and with much luck and little intuitive insight every layman may find them. One is in the very

---

\*SLASH: acronym for Second Laser–Amplified Superluminal Hookup

discomforting position that a single experiment which is explicitly spelling out the inconsistency of quantum mechanics with special relativity theory may once and for all discredit the consistency conjecture. Therefore, it seems not totally unjustified to search for relevant counterexamples, at least for the reason to obtain new insights by disproving them.

Earlier attempts [3] to utilize nonlinear optical devices for signal amplification (“photon cloning”) to construct a FLASH<sup>1</sup> failed, heuristically speaking, because of the impossibility of noiseless amplification [4] (see also [5, 6, 7, 8]) and the reversibility (i.e., one-to-oneness) of the unitary quantum state evolution. In this Communication a proposal for another arrangement will be presented which at first glance seems to be able to utilize delayed choice on the basis of an EPR-type configuration for faster-than light signalling.

The proposed device consists of a photon pair source, polarizers and detectors. Let  $\theta$  be the relative angle of the polarizers. If the photon pairs emitted by the source are in a total angular momentum 0 and total parity +1 state, the normalized detection rate relative to the counting rate without polarizers is given by  $\cos^2(\theta)/2$  [9].

Consider now the same arrangement with the following change. Instead of the polarizer and the detector a nonlinear device is installed on either one of the photon paths. The nonlinear device could be thought of as a *box containing a great number of photons, all of them in the same state*. A particular realization would be a polarized laser. This device has the property of amplifying the scattering amplitude of the corresponding photon into a specific polarization state.

In a model it is assumed that there are  $n$  quanta with polarization “ $\uparrow$ ” present in the nonlinear device. Let  $|\uparrow i\rangle$  and  $|\leftrightarrow i\rangle$  denote the state of the  $i$ ’th photon for  $n = 0$  with polarization “ $\uparrow$ ” and “ $\leftrightarrow$ ”, respectively. The corresponding states with a population of  $n$  quanta are denoted by  $|\cdot, n\rangle$ . The normalized conditional amplitude that a quantum will be scattered into a state when there are already  $n$  quanta present, is [10]  $\langle n+1|n\rangle = (n+1)^{1/2}$ . Then the emitted pair wave function can be written as ( $N$  is a normalization constant)

$$\begin{aligned} |\Psi, n\rangle &= \frac{1}{N} (|\uparrow 1, n\rangle |\uparrow 2\rangle + |\leftrightarrow 1\rangle |\leftrightarrow 2\rangle) = \\ &= \frac{1}{N} (\langle n+1|n\rangle |\uparrow 1\rangle |\uparrow 2\rangle + |\leftrightarrow 1\rangle |\leftrightarrow 2\rangle) = \end{aligned}$$

---

<sup>1</sup>FLASH: acronym for First Laser–Amplified Superluminal Hookup, see ref. [3].

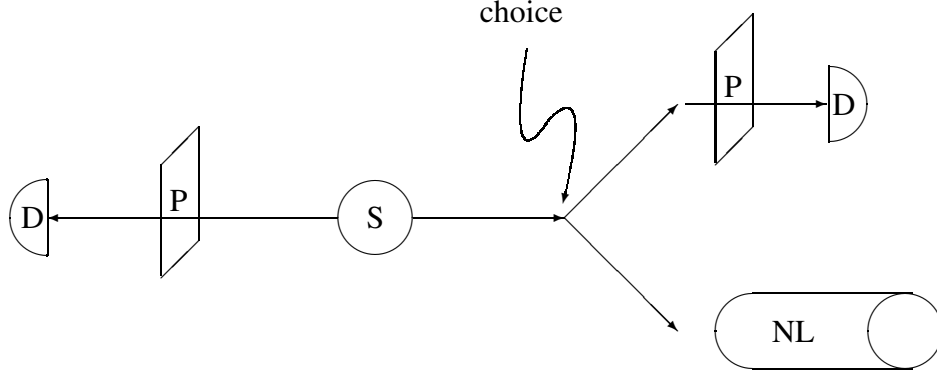


Figure 1: EPR-type configuration: entangled photons are emitted from the source S. In the right beam path, there is a choice between a polarizer (P) and a subsequent detector (D) or a nonlinear device (NL) for amplifying the amplitude of one polarization direction.

$$= \frac{1}{(n+2)^{1/2}} \left[ (n+1)^{1/2} |\uparrow 1\rangle |\uparrow 2\rangle + |\leftrightarrow 1\rangle |\leftrightarrow 2\rangle \right] \quad . \quad (1)$$

Consider the following limits: (i)  $n = 0$  corresponds to the situation with no amplifying photons in the nonlinear device. This results in the usual pair wave ansatz yielding the above mentioned relative counting rates of  $\cos^2(\theta)/2$ ; (ii)  $n \rightarrow \infty$  corresponds to an ideal amplifier. Due to the statistics of a “very large number” of Bose quanta,  $|\Psi, n \rightarrow \infty\rangle \rightarrow |\uparrow 1\rangle |\uparrow 2\rangle$ .

Assume now that the nonlinear device can be arbitrarily positioned in or out of the beam. Assume further that it has absolute efficiency, i.e. *all* photons on one path are prepared (“materialize”) in a specific direction of polarization. Let the angle between this direction of polarization and the polarizer at the path of the other photon be zero (or  $\pi/2$ ) — this guarantees maximal correlation. Such an arrangement is drawn in Fig. 1.

It looks as if information could be transferred instantaneously from a space-time region where the nonlinear device is positioned to the region of the polarizer at the end of the path of the other photon. This can be done by simply hooking the device in and out of the photon path on the one side, corresponding to different relative photon detection rates of 1 (or 0 for  $\theta = \pi/2$ ) and 1/2 on the polarizer side (with respect to the detection rate without polarizer).

The above arrangement is different from FLASH [3] since it requires only signal amplification in one photon direction and no “generic photon cloning,” producing noise and destroying coherence between the photon pair. In contradistinction, the present argument is based on the fact that the impossibility to control undecidable (“random”) single quantum events in a sense “saves” quantum theory from acausality. It is an attempt to actively gain control over such single events by *stimulated emission*, thereby producing *parameter dependence* of probability amplitudes at spatially separated points.

This is of course violating the fundamental but unproven conjecture that quantum theory is consistent with relativity theory, to which the author adheres. In what follows, four attempts will shortly be discussed to argue against faster-than-light communication with SLASH.

(i) One might argue that the ansatz (1)—(3) is rather *ad hoc* and not based upon any trustworthy (quantum amplification) model, such as Glauber’s amplifier model. In this view, one incorrectly does not take into account the correct signal-to-noise ratio. For instance, one might put forward that the nonlinear device would produce additional noise in the form of photons directed towards the other beam, thereby scrambling the correlated pair signal. This could be circumvented by the insertion of a filter between the source and the nonlinear device which is transparent for the photons from the source but reflects photons coming from the nonlinear device. However, whether such a semitransparent filter can be made noiseless is an open question.

(ii) One might perceive the production of the EPR correlated photon pair at the source as somehow “actual”, in the sense that the direction of polarization of each correlated photon pair at the source is independent of what happens with either one or both of the beams “afterwards”. This essentially boils down to local realism. Although local realism will not be critically discussed here, it should be mentioned that the configuration is similar to a delayed choice type experiment, where this argument fails.

(iii) One modification of the above argument is that since (1)—(3) are essentially valid for processes in which quanta are produced and scattered into  $n$ -quanta states only if these subsystems are “very close by”, i.e., not spatially separated. The statistical properties of manybody processes decrease with the distance of two subsystems and effectively vanish for all practical purposes. The exact form of such a signal attenuation remains unknown and may be the subject of further studies.

(iv) A further attempt to disprove SLASH has been put forward [11]: assume a

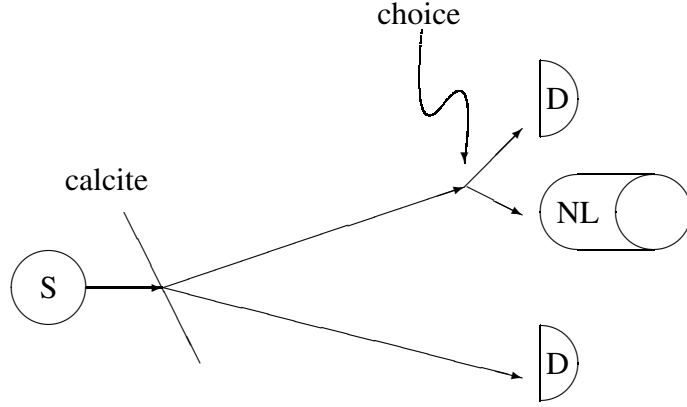


Figure 2: Delayed choice configuration featuring nonlinear photon gaintube.

modification of the previous setup by insertion of an anomalous refractor such as a calcite crystal into the beam pass of the (optional) nonlinear device. The calcite would split the beam, directing photons of one polarization direction to a properly adjusted nonlinear device which could be effectively perceived as a polarization analyzer, and photons of the other beam (with perpendicular polarization direction) to a detector. As a consequence of the perception of the nonlinear device as a passive analyzer, the SLASH requirement as an active element of the setup would then be discredited.

To stress this point, a simplified version of the experimental setup is suggested (see Fig. 2), in which the EPR-source is substituted by an unpolarized photon source. This source is directed towards an anomalous refractor. One outgoing beam is then directed towards a photon detector, whereas the other beam is *optionally* directed towards a nonlinear device (whose polarization axis is parallel to the polarization axis of the second beam), *or* towards a detector. According to the SLASH argument, a decrease of the photon detection rate in the first detector can be expected if the nonlinear device is inserted into the second beam pass.

In yet another experimental setup (see Fig. 3), two calcite crystals are used to recombine the beam from an originally unpolarized source. Inbetween those anomalous refractors, one polarized beam pass can optionally be intersected by the a nonlinear device. (The beam is not dumped into the device but *passes* it. In this respect the device acts merely as “environment” or “populated vacuum”.)

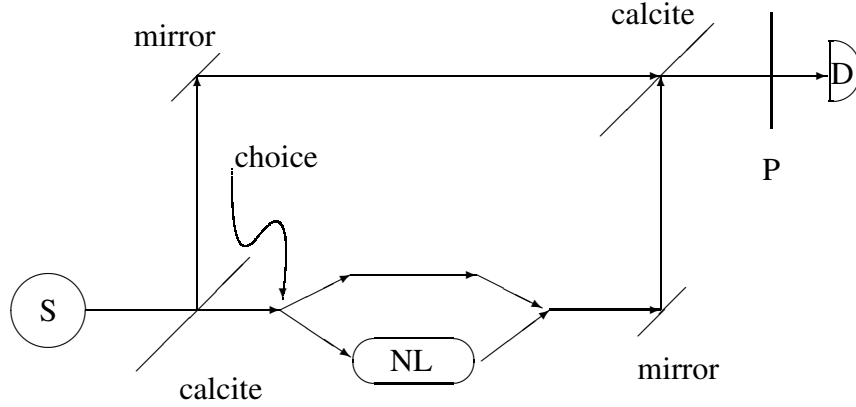


Figure 3: Study of the polarization of a recombined beam of an originally unpolarized light source in a Mach-Zehnder type interferometer.

The polarization direction of the recombined light is then analyzed. It could be expected that if the nonlinear device intersects with the beam, then amplification of the polarization direction corresponding to the polarization direction of this nonlinear device is detected. (Qualitatively the same argument also holds if the calcite crystals are replaced by two semitransparent mirrors.)

Very similar arguments apply if the EPR-source radiates *fermions* instead of bosons. In this case one could think of the nonlinear device as a box of fermions in states which become forbidden for the EPR-decay. Signalling is then obtained by *attenuation*.

In summary it can be said that it is the author's believe that the proposal most certainly will turn out to be incorrect or unrealizable. However, it is his hope that it yields stimulus and new insight to some aspects of the ongoing debate on the foundations of quantum theory, in particular with respect to quantum amplification, the spatial behavior of stimulated emission, and the generation of noise.

## 1 Acknowledgements

This work was supported in part by the Erwin-Schrödinger-Gesellschaft für Mikrowissenschaften. It was written long time ago in 1989, distributed casually within the community, and even made its way to a class at Yale University. (There

the task was to prove it is a hoax.)

## References

- [1] M. I. Shirokov. Signal velocity in quantum electrodynamics. *Sov. Phys. Usp.*, 21(4):345–358, 1979.
- [2] Abner Shimony. Controllable and uncontrollable non-locality. In S. Kamefuchi *et al.*, editor, *Proceedings of the International Symposium on the Foundations of Quantum Mechanics*, pages 225–230, Tokyo, 1984. Physical Society of Japan. See also J. Jarrett, *Bell’s Theorem, Quantum Mechanics and Local Realism*, Ph. D. thesis, Univ. of Chicago, 1983; *Nous*, **18**, 569 (1984).
- [3] Nick Herbert. FLASH—a superluminal communicator based upon a new kind of quantum measurement. *Foundation of Physics*, 12(12):1171–1179, 1982.
- [4] R. J. Glauber. Amplifiers, attenuators and the quantum theory of measurement. In E. R. Pike and S. Sarkar, editors, *Frontiers in Quantum Optics*. Adam Hilger, Bristol, 1986.
- [5] W. K. Wootters and W. H. Zurek. A single quantum cannot be cloned. *Nature*, 299:802–803, 1982.
- [6] Peter W. Milonni and M. L. Hardies. Photons cannot always be replicated. *Physics Letters*, 92A(7):321–322, 1982.
- [7] L. Mandel. Is a photon amplifier always polarization dependent? *Nature*, 304:188, 1983.
- [8] P. J. Bussey. “Super-luminal communication” in Einstein-Podolsky-Rosen experiments. *Physics Letters*, 90A(1,2):9–12, 1982.
- [9] J. F. Clauser and A. Shimony. Bell’s theorem: experimental tests and implications. *Rep. Prog. Phys.*, 41:1881–1926, 1978.
- [10] Richard P. Feynman, Robert B. Leighton, and Matthew Sands. *The Feynman Lectures on Physics. Quantum Mechanics*, volume III. Addison-Wesley, Reading, MA, 1965.

[11] Nick Herbert. private communication, 1989.