NOTE ON DUCH'S PROPOSAL FOR INTERFERENCE EXPERIMENT

MAREK ŻUKOWSKI
Uniwersytet Gdański,
Instytut Fizyki Teoretycznej i Astrofizyki,
ul. Wita Stwosza 57, 80-952 Gdansk, Poland

JAROSLAW PYKACZ

Uniwersytet Gdanski, Instytut Matematyki,
ul.Wita Stwosza 57, 80-952 Gdansk, Poland

A very interesting proposition for a *genankenexperiment* has been given by Duch [1]. The aim of this experiment was to obtain a violation of Bell's inequalities for linear momenta rather tham for spins or polarisations. The proposed source indeed gives correlations for space separated events. These correlations depend upon on the phase shifts within arms of a pair of Mach-Zehnder type interferometers. However the authors of this note cannot agree that quantum mechanics predicts in this case also interference, and thus the whole discussion in [1] on the possible faster than light communication is misleading.

The photons emerging from the Duch's source, in order to break the Bell's inequalities, have to be in the following state (for the whole two photon system)

$$|\Psi\rangle = (2)^{-1/2}(|\mathbf{k}\rangle_1|\mathbf{k}'\rangle_2+|\mathbf{p}\rangle_1|\mathbf{p}'\rangle_2). \tag{1}$$

The momenta **k** and **k'** have opposite directions. The same holds for **p** and **p'**. For simplicity we assume here that the photon "1" always goes to the right, *i.e.* enters the right interferometer (fig. 1 of [1]). The second one goes to the left. If each of them suffers some phase shifts on its way to the screen, the EPR-type correlations emerge (described by the formulae of Duch). However, they cannot produce an interference pattern. This is due to the fact that neither the state of the photon "1", nor that of "2" is a pure state. When the whole two photon system is in the pure state (1), the state of *e.g.* photon "1" is decribed by the following reduced density matrix

$$\rho_1 = Tr_2|\Psi\rangle\langle\Psi| = (1/2)[\,|\mathbf{k}\rangle\langle\mathbf{k}|+|\mathbf{p}\rangle\langle\mathbf{p}|\,]. \qquad (2)$$

This matrix is left unaffected by the phase shifts that may occur within an inteferometer. All coherence is wiped out. There is no interference pattern. The first formula of Duch can be recovered if one assumes that the photon is in the following pure state

$$|\phi\rangle=(2)^{-1/2}(\,|\mathbf{k}\rangle+|\mathbf{p}\rangle). \qquad (3)$$

However, this is impossible if the state of the photon pair is decribed by (1).

Finally, we would like to stress that an experimental setup for performing such an experinent as the one proposed by Duch can be given [2]. Thus, one may think of a *realexperiment* instead of a *gedanken* one. In principle one can build it by slightly modifying the equipment used by Aspect and Grangier [3] for testing the standard version of Bell's Inequalities.

The proposal given in [2] is based on the idea of using the usual source of spin-correlated particles. The source is the one used for testing the Bell's inequalities for photon polarisations. One can use the famous $J=0\rightarrow J=1\rightarrow J=0$ cascade of calcium [3]. Two *polarising beam splitters* are placed in such a way that each of them collects one photon from a cascade. Thus the direction of the photon emerging from such a beam splitter is determined by its polarisation. As the polarisations of the photons are described by

$$(2)^{-1/2}(\,|x\rangle_1|x\rangle_2 + |y\rangle_1|y\rangle_2) \qquad (4)$$

we get correlation of their momenta when they leave the beam splitters. In order to wipe out the information on the path of the photon one can suitably place a half-wave plate behind each of the beamsplitters. Thus the photons emerging from such a device are in a pure state described by (1). For further details see [2].

REFERENCES

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[2] M. Żukowski and J. Pykacz, *Phys. Lett.* A **482** (1988) (to be published)

[3] A. Aspect and P. Grangier in *Symposium on the Foundations of Modern Physics*, pp. 51-71, eds: P. Lahti and . Mittelstaedt (1985, World Scientific),