On the experimental study of nonlocality in quantum physics

V.A. Kuz`menko,
Troitsk Institute for Innovation and Fusion Research, Moscow, Troitsk, 108840,
Russian Federation. e-mail: kuzmenko@triniti.ru

It is proposed to continue the experimental study of the Hong-Ou-Mandel (HOM) effect in order to identify the nonlocal properties of the memory of quantum systems.

The problem of nonlocality has been widely discussed practically since the creation of quantum mechanics. At first, it was about the possibility of action at a distance. This was strongly opposed by Einstein. Later the discussion shifted to the area of mathematical statistics. The famous Bell inequality and its modifications were proposed. If these inequalities are violated, it means that there is a certain nonlocality. At the same time, the physical essence of this nonlocality remains unclear. Moreover, the correctness of the application of these inequalities is challenged by a number of theorists [1, 2]. Today, nonlocality is a kind of elusive entity: it seems to be there, but what exactly it consists of is not clear.

Now not theoretical, but experimental research are important here. The purpose of this note is to draw the attention of colleagues to the need for further development of experimental work on the study of the HOM effect. The effect was found accidentally in 1987 [3]. Its essence lies in the fact that when the light flux splits on a non-polarized beam splitter, the some photons show a tendency to stick together (so called anti-bunching effect).

Despite the fact that the HOM effect has been intensively studied for more than 30 years, its physical nature remains unclear. It seems that it is the most thoroughly studied from all sides. However, there is one important work that has not received proper development. It is about work [4] (later it was in fact repeated in [5]). Here, the HOM effect was studied using collinear entangled photons obtained by down conversion in a nonlinear type II crystal. The delay between photons was regulated by quartz plates, in which photons with different polarizations propagate at different speeds.

The experiment shows that photons can arrive at the beam splitter a little not at the same time. However, this is not the most interesting here. The most interesting thing here is that the manipulations with quartz plates are carried out after the beam splitter, but not before it (as in the vast majority of works). It looks like a violation of causality. The splitting of photons by a beam splitter (consequence) precedes the cause (plates manipulation). However, it is not about the violation of causality, of course. We are dealing with an obvious manifestation of nonlocality. The photons, coming to the beam splitter, in some mysterious way “know” what will happen next and behave accordingly.

This situation is completely analogous to that which exists in the classical two-slit interference. When a photon or electron passes through a slit, it somehow mysteriously "knows" about the existence of the second slit [6]. In the case of slits, for various reasons, we cannot spread them far apart. However, in the case of the HOM effect, we can separate the beam splitter and quartz plates at least several kilometers away [7]. If the effect persists, then we can try to determine how fast this “knowledge” spreads. These are experiments like delayed choice [8].

The use of quartz plates to control the delay between photons is rarely used. Usually the photons are separated in space (including by means of polarizing beam splitters) and adjust the delay by moving the mirrors. Will such a scheme work in the conditions of [4]?

In [9] it was suggested that the HOM effect is one of the numerous manifestations of the fundamental property of quantum physics – its time reversal noninvariance. Today we have a number of direct and indirect experimental facts indicating the nonequivalence of forward and reversed processes in quantum physics [10]. Such a nonequivalence presupposes the existence of a certain memory of a quantum system (as a whole) about its initial state. And this memory is the physical equivalent of the “knowledge” discussed above. It can also be considered as some equivalent of the nonlocal Bohm quantum potential [11]. We believe that the question of the carriers of this memory and its nonlocality should be one of the most important in the study of the fundamental principles of quantum physics.

We hope that further proper development of the experimental study of the HOM effect in the conditions of the discussed work [4] will allow to determine some properties of the nonlocal memory of quantum systems

References

1 – K. Hess, *Journal of Modern Physics*, **9**, 1573 (2018)

2 – K. Hess, H. De Raedt, and A. Khrennikov, *Open Physics*, **15**, 572 (2017)

3 – C.K. Hong, Z.Y. Ou, and L. Mandel, *Phys. Rev. Lett.*, **59**, 2044 (1987).

4 - T.B. Pittman, D.V. Strekalov, A. Migdall, M.H. Rubin, A.V. Sergienko, and Y.H. Shih, *Phys. Rev. Lett.,* **77**, 1917 (1996).

5 – Y.H. Kim, M.V. Chekhova, S.P. Kulik, and Y.H. Shih, *Phys. Rev. A* **60**, R37 (1999)

6 – G. Greenstein and A.G. Zajonc, *The Quantum Challenge*, Jones and Bartlett Publ., Boston (2006)

7 - P.R. Tapster, J.G. Rarity, and P.C.M. Owens, *Phys. Rev. Lett.*, **73**, 1923 (1994).

8 – T. Hellmuth, H. Walther, A. Zajonc, and W. Schleich, *Phys. Rev. A* **35**, 2532 (1987)

9 – V.A. Kuz`menko, , *e-print*, viXra:1810.0410

10 – V.A. Kuz`menko, *e-print*, viXra:1804.0359.

11 – D. Bohm, *Phys. Rev.* **8**5, 166 (1952).

Can Two-Photon Interference be Considered the Interference of Two Photons?

T. B. Pittman, D. V. Strekalov, A. Migdall, M. H. Rubin, A. V. Sergienko, and Y. H. Shih
PHYS, REV. LETT. **77**, 1927, 1996