Delayed Choice and Nonlocal Memory of Quantum Systems

V. A. Kuz`menko

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

One else possible variant of experimental study of the memory properties of quantum systems is proposed.

A number of experimental facts indicate the non-equivalence of forward and reversed processes in quantum physics [1]. This nonequivalence directly implies the existence of some memory (probably nonlocal) of the quantum system about its initial state. It looks like the physical equivalent of entanglement and entropy. This memory can be studied by measuring the differential cross-sections of forward and reversed quantum processes. Experiments with beam splitters are suitable for studying some properties of nonlocality of the memory of quantum systems [2].

The purpose of this note is to suggest another possible way to study the nonlocal properties of quantum memory using beam splitters. The basic scheme of the installation is shown in Figure 1a. The laser (1) radiation is directed to the beam splitter (2). One beam enters the screen with a pinhole (3). The other beam is directed through the mirror (4) to the same screen. In this second beam, an optical shutter (5) is located near the screen. If one beam reach the screen, then uniform illumination of the screen is observed (1b). If two beams reach the screen, then an interference pattern with antinodes and nodes is observed (1c).

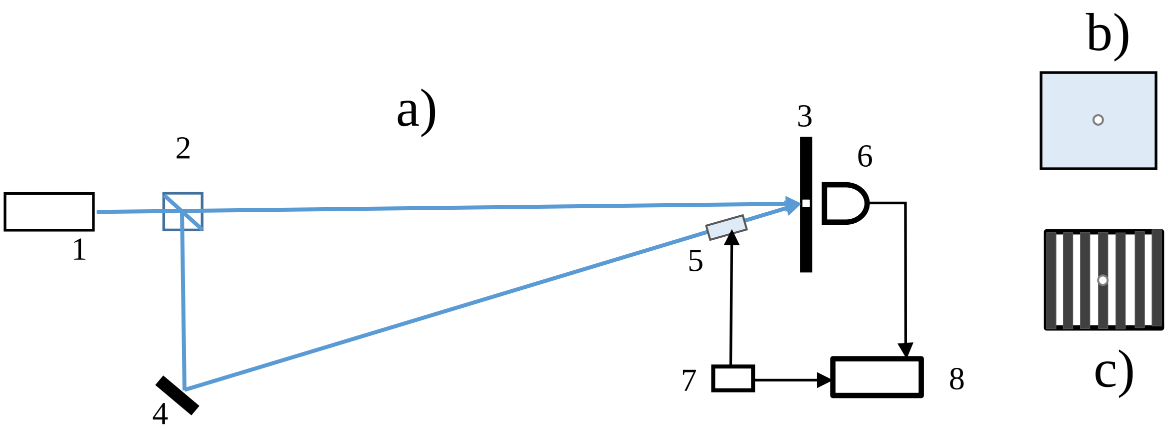

Figure 1. a) The basic scheme of the proposed installation. 1 – laser, 2 - beam splitter, 3 - screen with a pinhole, 4 – mirror, 5 - optical shutter, 6 – detector, 7 - shutter control source, 8 - registration system. b) View of the illuminated screen with a single beam. c) View of the illuminated screen with two beams.

The wave theory easily and naturally explains the physical nature of the interference pattern. When the phases of the beams coincide, the intensities of the waves are summed up. When the beams are in antiphase, the intensities are subtracted (annihilated).

But for the quantum theory, the physical explanation of this interference is a big problem. Photons cannot annihilate. The energy does not disappear anywhere. Here we are talking about changing the probability of a photon hitting a given point on the screen. This probability is determined by the direction of motion and the position of the photon in space from the beam splitter to the screen. The direction can change when the photon interacts with the beam splitter. Or the direction and position of the photon can somehow change already near the screen. This is what is supposed to be verified in experiments like delayed choice [3 – 5].

A locking pulse is applied to the optical shutter. One laser beam remains and the interference disappears. The screen is illuminated evenly. If the pinhole in the screen is located in the node region, the detector (6) will show an increase in the light intensity.

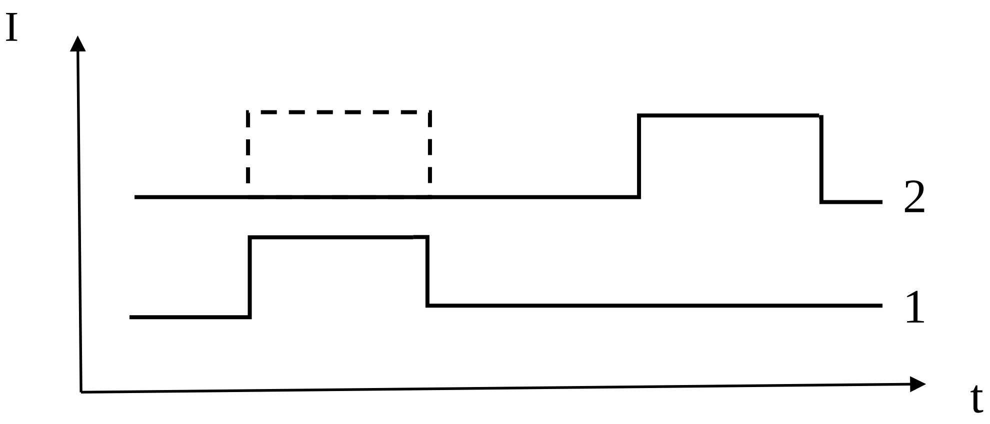

Figure 2. The expected results of the experiment. 1 - oscillogram of the voltage applied to the optical shutter. 2 - radiation intensity recorded by the detector.

Figure 2 shows the expected results of the experiment. Here 1 is an oscillogram of the voltage applied to the optical shutter. 2 - shows the radiation intensity recorded by the detector. If there is a delay in time between the shutter operation and the appearance of radiation on the detector, then the change in the direction of the photons occurs on the beam splitter and the delay value characterizes the speed of information transfer in quantum system from the shutter to the beam splitter. If there is no such delay (dotted line), then this means that either information is transmitted instantly (faster than the speed of light), or the change in direction and position of photons in space somehow occurs already near the screen. Well, there is also a variant of complete superdeterminism: the quantum system "knows" that we are going to apply a locking pulse to the optical shutter [6, 7].

In general, the situation is similar to the interference of photons from two slits. The advantage of the discussed scheme is that we can control photons far behind the beam splitter, near the place of their registration. And here it is not necessary to record individual photons. On the other hand, the proposed scheme is close to numerous experiments with the Mach-Zander interferometer. But, there is no second beam splitter here. This makes it easier to interpret the results of the experiments.

We hope that such experiments will be carried out. This will allow us to better understand the memory properties of quantum systems.

---

1. - V. A. Kuz'menko, "Time reversal noninvariance in quantum physics", e-print, viXra:2004.0160
2. -V. A. Kuz'menko, "On the physical nature of Hanbury-Brown-Twiss and Hong-Ou-Mandel effects", e-print, viXra:2012.018
3. -T. Hellmuth, H. Walther, A. Zajonc, and W. Schleich, "Delayed-choice experiments in quantum interference", Phys. Rev., A **35**, 2532 (1987).
4. -V. Jacques, E. Wu, F. Grosshans, F. Treussart, P. Grangier, A. Aspect, and J. F. Roch, "Delayed-Choice Test of Quantum Complementarity with Interfering Single Photons", Phys. Rev. Lett., **100**, 220402 (2008).
5. -X. Ma, J. Kofler, and A. Zeilinger, "Delayed-choice gedanken experiments and their realizations", Rev. Mod. Phys., **88**, 015005 (2016).
6. -S. Hossenfelder, "Superdeterminism: A Guide for the Perplexed", e-print, arXiv:2010.01324
7. – I. Sen, and A. Valentini, "Superdeterministic hidden-variables models II: conspiracy", e-print, arXiv:2003.12195