On the physical nature of the Hong-Ou-Mandel effect

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It is noted that widely known Hong-Ou-Mandel (HOM) effect is one of numerous manifestations of fundamental property of quantum physics – its time reversal noninvariance.

The HOM effect was discovered in work [1]. Fig. 1 shows the schematic diagram of the experiment. In the nonlinear crystal, the initial photon is split into two - signal and idler. The beam splitter directs falling photons randomly to a particular detector with a 50:50 probability. However, when the path lengths of the signal and idler photons coincide, this randomness disappears and both photons jointly arrive at one of the detectors. This is the surprising essence of the discovered phenomenon. Its physical explanation is still missing. The idea of photons interference is quite convenient for mathematical description of the phenomenon. But its physical basis is not clear enough (vacuum fields – what is this?) [2].

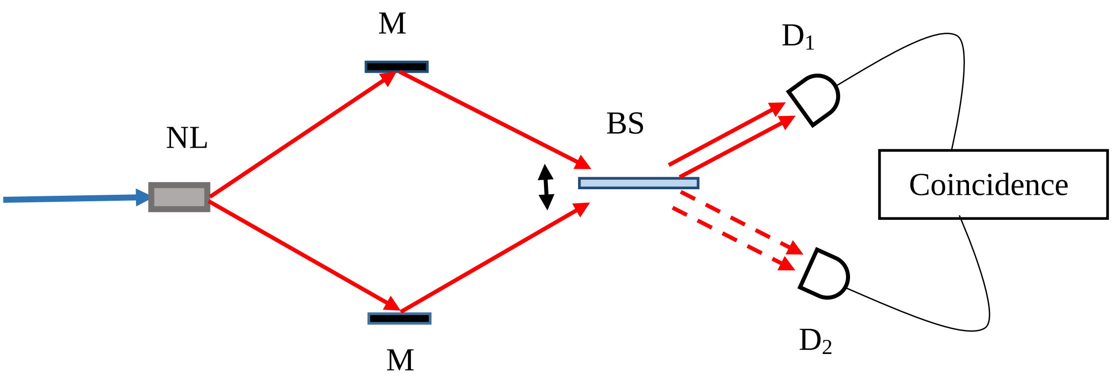

Figure 1. Schematic diagram of the experiment. NL – nonlinear crystal, M – mirror, BS - beam splitter, D_1 and D_2 – detectors.

On the other hand, there are a large number of direct and indirect experimental facts testifying the inequality of forward and reversed processes in quantum physics [3]. Such a nonequivalence presupposes the existence of a certain memory of a quantum system (as a whole) about its initial state. Quantum processes, which lead to the return of the quantum system to its initial state, have a maximum differential cross-section. Within this conception, there is a simple explanation of the physical nature of the HOM effect. This is a partially reversed process that has a large differential cross section.

The next step to the fully reversed process is the regeneration from the signal and idler photons of the initial photon. Such experiment was carried out in work [4]. The schematic diagram of this experiment is shown in Fig. 2. Here, the second nonlinear crystal is used instead of the beam splitter. As a result, instead of the expected appearance of radiation in a wide spectral range, the authors observed the regeneration of the initial narrow radiation. This is the direct experimental evidence of inequality of forward and reversed processes.

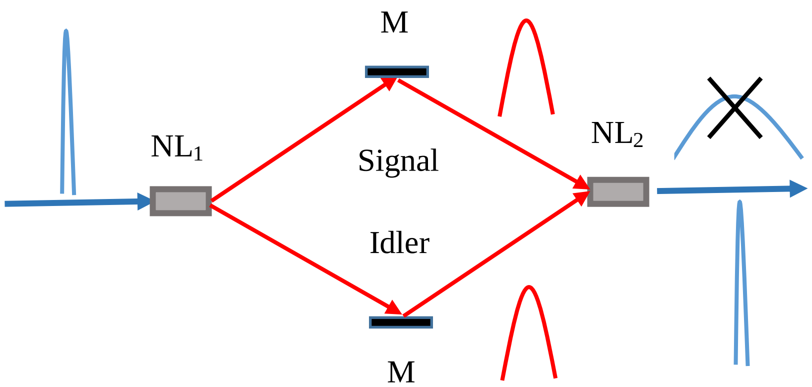

Figure 2. Schematic diagram of the experiment. NL_1 and NL_2 – nonlinear crystals, M – mirrors.

Atoms that absorb radiation can play the role of the second nonlinear crystal [5]. In this case, the two-photon absorption of signal and idler photons is equivalent to the absorption of the initial photon.

In all three cases, an important requirement is the coincidence of the signal and idler photons in the space, time, polarization.

In the same direction, we should probably look for a physical explanation of the behavior of single photons in the Mach-Zander interferometer [6]. The macro quantum system (splitters, mirrors, vacuum, dark matter or energy, any other hidden matter) has a memory of the initial state. This memory looks like the physical equivalent of the used concept of "entanglement with the vacuum" [2, 7]. And this memory (maybe non-local) controls the movement of photons in the interferometer through differential cross sections of the processes.

Thus, we need the beginning of a directed experimental study of the memory of quantum systems, the differential cross sections of forward, reversed and partially reversed quantum transitions. For today, the best object for such experiments seems to be the Bloch oscillations of cold atoms in a vertical optical lattice [3]. Unfortunately, our physicists cannot still grasp the obvious today experimental fact that we practically everywhere deal with manifestations of fundamental property of quantum physics – its time reversal noninvariance.

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