On the experimental study of the Hong-Ou-Mandel effect

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Abstract

The HOM effect is based on the fundamental properties of quantum physics. Since the discovery of the effect [1], a huge amount of experimental work has been carried out to study its nature. However, the most important, interesting and simple experiment here has not yet been brought to its logical end.

Keywords: HOM effect, entanglement, time reversal noninvariance, quantum memory, nonlocality.

Introduction

The phenomenon of the HOM effect was discovered in [1]. Its essence is that when two entangled photons simultaneously arrive at the beam splitter, they exit the beam splitter together paired in the same direction. The phenomenon is called interference and the terms bunching and antibunching are assigned to it. The terms are extremely unsuccessful - they are often confused in literature.

Over the past years, a huge amount of experimental work has been carried out to study the physical nature of the phenomenon and the possibility of its various practical uses. However, there is still no understanding of the physical nature of this phenomenon in the scientific community.

A possible physical explanation of the HOM effect was previously discussed in [2]. It is based on the recognition of the experimental fact of the nonequivalence of forward and reversed processes in quantum physics [3]. A process turned into an initial state can be extremely efficient. The nonequivalence of the forward and reversed processes directly implies the need for the existence of a quantum system's memory of its initial state. This memory of quantum system (probably non-local) determines the basic properties of the HOM effect.

This physical explanation needs experimental confirmation. All accumulated experimental facts do not allow us to unambiguously interpret the physical meaning of the HOM effect. At the same time, among this set there is the experiment (direction) that allows this confirmation to be obtained [4]. The authors of this work did not understand what kind of thing they are dealing with and this experiment (direction) is practically forgotten today. Below we will discuss the details of this experiment and indicate the directions of its development.

Experimental part

Figure 1 shows the scheme of the experiment and its result [4]. 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. When photons were synchronized with quartz plates, a typical HOM effect was observed.

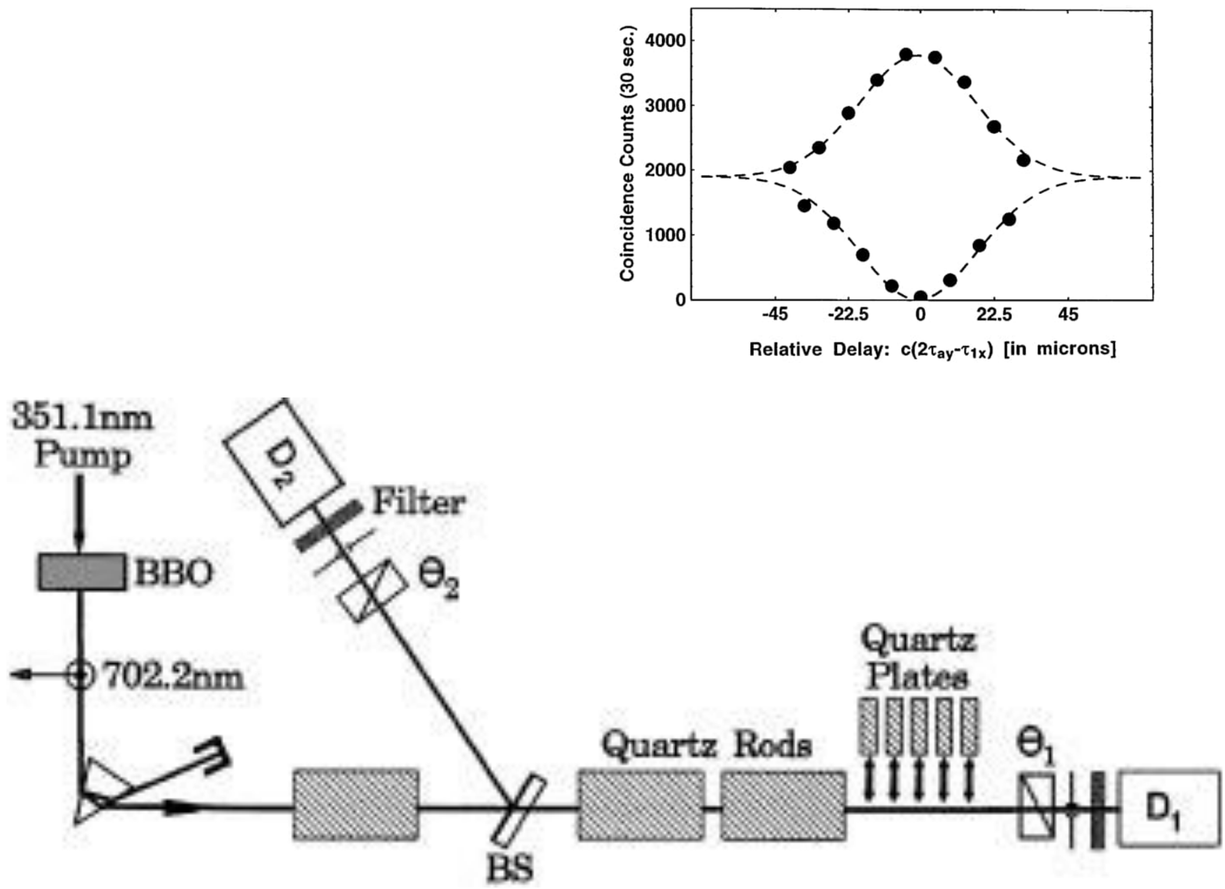

Fig. 1 Scheme of the experiment and its result [4].

The experiment shows that photons can arrive at the beam splitter 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 a manifestation of nonlocality. The photons, coming to the beam splitter, in some mysterious way "know" what will happen next and behave accordingly. This is probably a manifestation of the nonlocal memory of a quantum system about its initial state.

In this experiment we are dealing with both the consequence of the nonequivalence of forward and reversed processes in quantum physics, and with the manifestation of non-local properties of the memory of a quantum system about its initial state. Unfortunately, this experiment was not continued. There are two directions here:

1) Nonequivalence of forward and reversed processes

It is necessary to measure the statistics of paired photons arriving at detectors D1 and D2 under the conditions of the HOM effect. The fact is that photon synchronization occurs only in front of the D1 detector. This situation corresponds to a partially reversed process. The initial state of the quantum system here is the initial photon before down conversion. The situation will be close to a completely reversed process if another nonlinear crystal is placed in front of the D1 detector, in which the initial photon can be regenerated (as in [5]).

Detector D2 receives unsynchronized paired photons. This process is not even partially reversed. Its efficiency should be significantly lower than any version of the reversed process. Measuring the statistics of photon distribution between detectors is not a difficult task - such experiments were carried out in [6]. The discovery of a significant asymmetry in the distribution of paired entangled photons between detectors D1 and D2 will be further evidence of the non-equivalence of the forward and reversed processes. In other areas of research there is already more than enough such evidence [2, 3].

2) Nonlocality of the memory of a quantum system about its initial state

It is necessary to study the dependence of the observed HOM effect on the distance between the beam splitter and the device for synchronizing entangled paired photons (in this case, these are quartz plates) in front of the D1 detector. 10 m, 100 m, 1000 m, 10 km. At what distance will the HOM effect disappear? This is information about the degree of nonlocality of the memory of a quantum system.

There are a large number of experimenters who have all the necessary equipment for such experiments. We hope that someone will at last carry out these important, interesting and simple experiments.

Conclusion

The HOM effect is based on the nonequivalence of forward and reversed processes in quantum physics (in other words, on its time reversal noninvariance [7]). This implies the existence of a nonlocal memory of quantum systems about their initial state, which determines the properties of the HOM effect. The simple experiments discussed will allow to confirm this interpretation and study some of properties of nonlocal memory of quantum systems.

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