

Comment on “Experimental evidence that a photon can spend a negative amount of time in an atom cloud”

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Abstract

Several interesting publications have appeared in the literature on the so-called “negative time” or “negative group delay” in experiments on the interaction of photons with cold atoms [1 - 6]. The physical meaning of this phenomenon is unclear. Such a physical explanation is proposed here and simple experiments for its further study are discussed.

In the published experiments, a resonant laser beam passed through a cloud of cold rubidium atoms. It is known that photon forward scattering is very effective under these conditions [7]. The transit time of photons through the atomic cloud was recorded by measuring the phase change of a non-resonant probe laser beam. The experiments measured the so-called group delay, which can take on positive or negative values. The positive value of group delay corresponds to the deceleration of photons due to their resonant interaction with cloud atoms, which corresponds to a certain positive time spent by atoms in the excited state. The negative value of group delay formally corresponds to the "acceleration" of photons and the "negative time" of atoms being in an excited state.

The latter phenomenon has not received a clear physical explanation. These are only appeals to the ideas of the weak-value formalism and interference.

The proposed physical explanation of the “negative time” or “negative group delay” phenomenon is based on the assumption that a quantum system can react to some event before this event has happened. At first glance, this is an absurd and impossible physical explanation. However, for many years now we have had a simple and obvious example of this phenomenon.

We are talking about the Hong-Ou-Mandel (HOM) effect in the case when the synchronization of entangled photons occurs after the beam splitter [8 - 9]. It looks like a violation of causality: the consequence (splitting of photons on the beam splitter) precedes the cause (synchronization of entangled photons in the Pockels cell). The photons, coming to the beam splitter, in some mysterious way “know” what will happen later 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 [10]. The mysterious “knowing” is a manifestation of nonlocality in quantum physics. More precisely, this is a manifestation of the non-local memory of a quantum system about

its initial state [11]. In turn, the nonlocal memory of a quantum system is a natural consequence of a fundamental property of quantum physics - the nonequivalence of forward and reverse processes in it [12].

It is easier and more convenient to study the properties of nonlocal memory of quantum systems in experiments with a beam splitter. 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 Pockels cell at least several kilometers away [13]. We can experimentally study in this way nonlocality of quantum memory. At some distance the HOM effect should disappear. In this case, we will get an idea of the degree of nonlocality of the memory of this quantum system.

Then we can try to determine how fast this “knowledge” spreads. If a high-speed Pockels cell is used, then in the version of the so-called “delayed choice” [14 - 15], the speed of information (memory) propagation in space from the Pockels cell to the beamsplitter can be measured. Could this speed be greater than the speed of light?

Conclusion

The concept of the proposed physical explanation of the phenomenon of “negative time” or “negative group delay” can be studied in experiments with a beam splitter. This experiments are very simple. There are many 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 [16].

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