Once again about the optical precursor in cold atoms

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The physical nature of the optical precursor is further explained as a consequence of the nonequivalence of forward and reversed processes in quantum physics.

In work [1] the authors observed in cold atoms a high-transmission nanoseconds-long spike with near 100 % transmission, which decays to a constant value expected from Beer's law. The authors have called this phenomenon an optical precursor by analogy with the known Sommerfeld - Brillouin precursors. There was a discussion about whether this phenomenon should be called a precursor [2]. It is obvious that this precursor and Sommerfeld - Brillouin precursors have different physical nature. The shape of the precursor can be described using a suitable mathematical model. However, often such descriptions do not make the nature of the physical phenomenon more clear. The physical explanation of the nature of the observed optical precursor in general form was proposed in work [3] as rather direct consequence of nonequivalence of the forward and reversed quantum processes. Now this physical explanation can be concretized.

In work [4] the authors experimentally observed in cold atoms highly directional forward emission with a peak intensity that is enhanced by > 10^3 compared with that in the transverse direction. Earlier such superradiant forward scattering was detected experimentally by indirect evidences and was described theoretically as a result of some interference [5, 6]. *This forward scattering is the physical essence of the optical precursor.*

At first atom absorbs a photon, passes into the excited quantum state and receives a recoil momentum. In the second stage, instantaneous stimulated emission of the photon in the forward direction can occur. In this case, the atom returns to its original quantum state and to the initial point of space. This process is a fully reversed (or closest to it) quantum transition. It has the highest possible differential cross section of the quantum transition [7].

If stimulated emission does not occur instantaneously, but with some delay, then the atom returns no longer to the initial point of space. In this case, the process becomes only partially reversed and its differential cross section becomes smaller. As a result, the atom holds in an excited state. At this point in space the phase of laser radiation also becomes different. In fact, this is a variant of atom interferometry.

Thus, *the optical precursor is a direct manifestation of the extremely high efficiency of reversed quantum processes.* From this physical explanation it follows that the velocity of the atoms or the temperature of the atomic gas is of great importance here. Unfortunately, the influence of the gas temperature on the parameters of the optical precursor has not been studied experimentally yet. Although in hot atomic gas such a precursor previously, seems, not was observed [8]. Here one can change the temperature of the cold atoms or the speed and direction of the motion of the entire cloud of atoms as a whole.

It is also worth noting that the precursor was observed earlier in the warm molecular gas [9]. However, in this case, the wavelength of the radiation was more than three orders of magnitude greater.

In works [10, 11] the optical precursor in cold atoms was studied also with the addition of control laser radiation. This is the case of so-called electromagnetically induced transparency or four-photon mixing [7]. This mechanism supports the return of atoms to their initial quantum state and the regeneration of laser radiation. But this physical mechanism is, probably, more complex and its details are not clear enough today.

In any case, we need a detailed study of the differential cross sections of forward, reversed and partially reversed quantum transitions. As a whole, it is not very difficult work. Unfortunately our experimenters are not in a hurry to perform it. And most theorists still believe that the laws of physics are symmetric in time. So, let's stockpile popcorn and wait further when our physicists at last realize the quite obvious today experimental fact that we are dealing with a strong time reversal noninvariance in quantum physics [7].

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