Comment on “Coherent and incoherent light scattering by single-atom wavepackets”

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Abstract

The e-print arXiv:2410.19671 [1] presents new, interesting results of the experimental study of scattered light by cold atoms. Here we propose an alternative explanation of the physical nature of anisotropic radiation scattering and a simple protocol for its experimental verification.

In [1], the test pulse radiation, the optical trap, and the scattered radiation detector were apparently located in a horizontal plane. With an increase in the delay of the probing test pulse, an increase in the intensity of scattered radiation was observed. Isotropic and anisotropic components of scattered radiation are distinguished here. In this case, the detector registered precisely the isotropic component. The authors call the anisotropic component coherent and associate it with the Bragg scattering of light from the lattice of cold atoms [2 - 4].

We would like to draw attention to the fact that Bregg scattering is not the only and probably not the main source of anisotropic scattered radiation. There is also a spatially asymmetric scattering of radiation by cold atoms [5]. Our scientific community is in no hurry to recognize this concept, as well as its origin [6]. However, this does not make the concept any less real or significant.

One of the manifestations of spatially asymmetric photon scattering is the well-known forward scattering [7]. In turn, this forward scattering is the physical basis of the well-known optical precursor effect [8 – 10].

However, in its purest and most explicit form, spatially asymmetric photon scattering is manifested in the studied in detail effect of Bloch oscillations of cold atoms in a vertical optical lattice [11 - 13]. Here, a cold atom falls freely in a vacuum under the influence of gravity. At a certain point in time, a photon is absorbed from a laser beam directed upward, and a photon is emitted with a laser beam directed downward. As a result, the atom receives a doubled upward recoil pulse and returns to its starting point in space. The amplitude of Bloch oscillations of cold atoms is determined by the wavelength of laser radiation, the mass of the atom and the magnitude of gravity [13]. This amplitude of oscillations does not correlate in any way with either the nudes or the antinudes of the vertical optical lattice. There are no potential barriers there. There is only highly asymmetric scattering of photons. The differential cross-section of photon scattering downwards is many orders of magnitude larger than the differential cross-section of isotropic photon scattering.

A similar downward scattering of photons should also exist under operating conditions [1]. It's not difficult to verify this. A similar experiment was conducted in [14]. There was observed the appearance of rather powerful scattered radiation in a vertical resonator, which slowed down the falling atoms. Unfortunately, the mirrors of the vertical resonator destroyed information about the original direction of the vertically scattered radiation.

Obviously, this experiment should be repeated without the vertical resonator mirrors. Separate detectors must record the upward and downward scattered radiation. The upward scattered radiation should have the same dependence of intensity on the delay time of the probe pulse as the sideways scattered radiation. And for the downward scattered radiation, the opposite situation should be expected: the intensity of the recorded scattered radiation will decrease with the increase of this delay.

The discussed experiments are very simple today. 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. Experiments of this kind are interesting because their results contain information about some properties of non-local memory of many-body quantum systems [15]. How quickly does the many-body quantum system "forget" about its initial state?

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