Microscopic theory of electromagnetic pulses slowing in a Bose condensate of alkali-metal atoms

Yu.V. Slyusarenko

Akhiezer Institute for Theoretical Physics, NSC KIPT, 1 Akademichna Street, Kharkiv 61108, Ukraine

A physical and mathematical basis for a description of interaction of a condensed Bose gas of alkali-metal atoms with a weak electromagnetic field is developed. The microscopic approach allows to construct a theory that can describe the ultraslow light phenomenon in a gas with Bose-Einstein condensates. Now this phenomenon is known and realized in the experimental conditions. In the framework of the developed microscopic theory we demonstrate new possibilities in the study of the resonance characteristics of the gases consisting of alkali-metal atoms. The proposed approach is based on the Green-function formalism and an approximate formulation of the method of second quantization for quantum many-particle systems in the presence of bound states of particles. We also show that the model of an ideal gas of hydrogenlike atoms can be correctly used for a description of the effects relating to the response of a condensate. In terms of the Green functions we find macroscopic characteristics of a system, such as conductivity, permittivity and magnetic permeability. By the use of these quantities we get the dependencies for the velocity of the pulse propagation and its absorption rate on the microscopic characteristics of a condensed gas. For a Bose-Einstein condensate of alkali-metal atoms we find the conditions when the group velocity of weak electromagnetic waves of both the optical and microwave regions is strongly reduced. We also analyze the Zeeman splitting of the hyperfine levels of alkali-metal atoms and show that the group velocity can strongly depend on the magnetic field intensity. The possibility of controlling the ultraslow light phenomenon in this system by a bias field is discussed.