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Interaction of Rayleigh waves with 2D dipolar exciton gas: impact of Bose–Einstein condensation

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Abstract

The theory of the interaction of a two-dimensional gas of indirect dipolar excitons with Rayleigh surface elastic waves has been developed. The absorption and renormalization of the phase velocity of a surface wave, as well as the drag of excitons by the surface acoustic wave and the generation of bulk acoustic waves by a two dimensional gas of dipolar excitons irradiated by external electromagnetic radiation, have been considered. These effects have been studied both in a normal phase at high temperatures and in a condensed phase of the exciton gas. The calculations have been performed in the ballistic and diffusion limits for both phases.

Keywords: surface acoustic waves, condensate, excitons

(Some figures may appear in colour only in the online journal)

1. Introduction

Acoustic methods are widely used in solid state physics to study elementary excitations. A specific research field—acoustoelectronics—has appeared to investigate effects caused primarily by the interaction of elastic waves with charge carriers in crystals [1]. The measurement of the characteristics of an acoustic wave propagating in a solid provides information on the properties of excitations of semiconductor nanostructures. In particular, surface acoustic waves (SAWs) were proposed to study the properties of a two-dimensional electron gas [2]. SAW spectroscopic technique was used in recent experimental works to study two-dimensional gases of dipolar excitons [3–5] and exciton-polaritons [6, 7], in wide single or double quantum wells. Dipolar excitons in such structures, being Bose particles, demonstrate a rich variety of interesting physical effects, in particular, intriguing Bose condensation [8–14]. A significant increase in the recombination lifetime of excitons in such structures allows their accumulation in the ground state sufficient to experimentally observe a Bose condensate with the critical temperature T_c about several K [8–14]. To experimentally confirm the existence of the exciton condensate, the behavior of the exciton luminescence line of the structure under study is analyzed. A sharp narrowing of the luminescence line with decrease in the temperature or, more often, with increase in the concentration of excitons indicates the formation of a coherent state of excitons, which is usually called the Bose–Einstein condensate. Furthermore, there is the technical possibility of separating light rays from spatially separated points of the exciton gas and the observation of their interference, which also shows the formation of a macroscopically coherent state. Experimental studies of excitons by means of the action of surface acoustic waves stimulated us to develop the theory of acoustoexcitonic effects in a two-dimensional exciton gas. This theory is insufficiently developed, particularly in view of the current experimental possibilities of creating the exciton condensate and controlling the motion of the exciton fluid. In this paper, we review the theory of the interaction of surface acoustic waves with the two-dimensional exciton gas both above and below the critical temperature. Two types of surface acoustic waves, namely, Rayleigh and Gulyaev–Blushtein are usually considered. The latter type of waves exists only on the surface of piezoelectric crystals and is accompanied by a quasistatic electric field, which can

