Rise of exciton luminescence of GaAs in a magnetic field

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An anomalously large (nearly 20-fold) increase in the intensity of exciton luminescence, has been discovered in magnetic fields up to 7 T. It is suggested that the effect stems from an influence of the magnetic field on the kinetics of excitons.

The magnetooptic research which has been carried out on GaAs has so far dealt primarily with magnetoabsorption[1] and magnetoreflection.[2] The purpose of these studies was to determine how the magnetic field affects the energy structure of excitons. In the present letter we report a study of how the magnetic field affects the kinetics of excitons.

We studied the low-temperature ($T = 1.7$ K) polariton luminescence of very pure epitaxial films of n^0-type GaAs, in which previous experiments have revealed an intense and clearly expressed polariton luminescence.[3] The sample was placed in a superconducting solenoid. The magnetic field was applied in the Faraday geometry (perpendicular to the surface) and reached a value $B \sim 7$ T.

We observed a pronounced rise in the polariton luminescence intensity (Fig. 1). In fields $B = 6.7$ T the intensity of the emission line of the lower polariton branch increases by a factor of nearly 20, under certain conditions. In addition to the change in intensity, there is a change in the shape of the polariton luminescence spectrum: The dip between the lines of the lower and upper polariton branches shrinks and eventually disappears, and the relative intensity of the line of the upper branch decreases. The extent to which the luminescence intensity increases in the magnetic field depends on

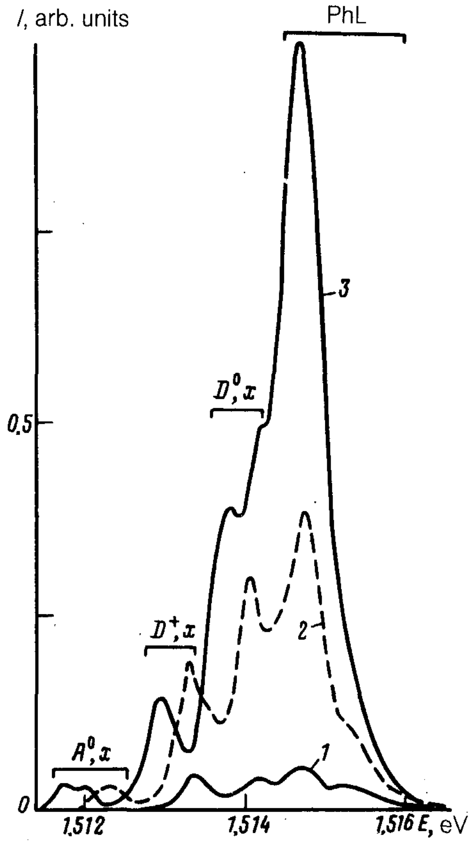

FIG. 1. Photoluminescence spectra of GaAs near an exciton resonance in various magnetic fields: 1—$B = 0$; 2—$B = 2.7$ T; 3—$B = 6.7$ T ($I_{exc} = 0.3$ W/cm^2). The diamagnetic shift has been eliminated from these spectra.

the purity of the n^0-type GaAs, decreasing with increasing density of shallow donors. This circumstance can apparently explain why the effect which we are reporting here has not been observed previously.[4] The intensity of the photoexcitation has a very strong effect on the intensification of the exciton luminescence in a magnetic field. The degree to which the luminescence intensity increases depends in a nonmonotonic way on the excitation intensity, going through a maximum at certain intermediate excitation intensities.

The polariton luminescence spectrum depends substantially on the spatial distribution of the polaritons.[5] To eliminate a possible influence of a change in the spatial distribution of polaritons on the effect under study, we examined the influence of a magnetic field on the emission of excitons accompanied by the emission of an *LO* phonon (Fig. 2). We can clearly see a narrowing and intensification of the phonon repetition with increasing magnetic field.

These results point directly at two basic effects of the magnetic field on the exciton luminescence: 1) The integrated intensity of the polariton luminescence increases with increasing B. 2) The effective temperature of the polaritons decreases. Interestingly, the effective temperature falls nearly to the lattice temperature (~ 2.8 K) under

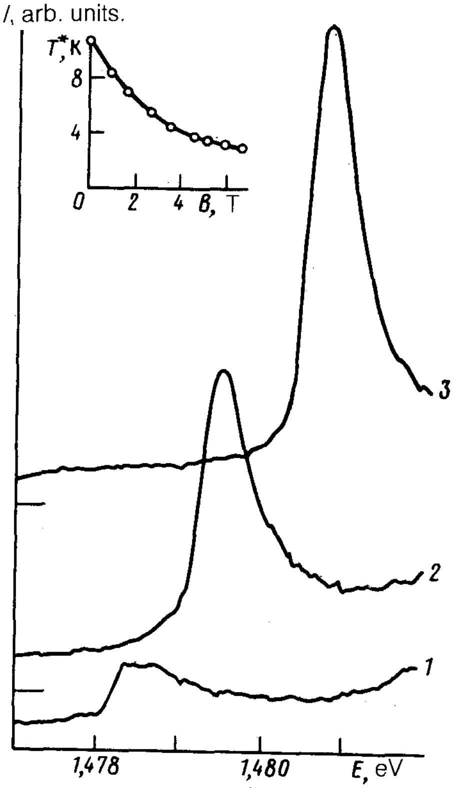

FIG. 2. Spectra of the emission of excitons accompanied by the emission of an LO phonon. 1—$B=0$; 2—$B=3.5$; 3—$B=6.7$ T ($I_{exc}=0.9$ W/cm^2). The inset shows the magnetic-field dependence of the effective polariton temperature T^*.

certain conditions. An increase in the extent to which the polaritons are thermalized results in an increase in the population of the low-energy regions in the region of the exciton resonance. This process is evidently responsible for the anomalous rise of the luminescence of the lower polariton branch and for the decrease in the contribution of the light from the upper polariton branch, which is determined by the populations of the states in the regions above the energy of a longitudinal exciton.

The effect of a magnetic field on the intensity of the luminescence of free excitons has been studied previously[6] in Ge. This effect was explained on the basis of an increase in the oscillator strength of a free exciton in a strong magnetic field as a consequence of a transverse contraction of the wave function of the relative motion of the electron and the hole.[7] However, the range of magnetic fields which was studied for GaAs was an intermediate range, by which we mean that the relation $r_B/r_0 \sim 1$ held, where r_B is the first Bohr radius of the exciton, and $r_0 = \sqrt{\hbar/eB}$, where e is the charge of an electron. For GaAs we have[8] $r_B \approx 140$ Å, while the minimum value (for $B=7$ T) of r_0 is 100 Å. At these parameter values, the oscillator strength of the exciton increases by a factor of only two according to variational calculations.[9] This factor is much smaller than the factors observed experimentally. Furthermore, in a polariton model an increase in the oscillator strength, i.e., in the energy of the longitudinal-transverse splitting, should lead to only a broadening of the spectrum near the exciton resonance.

The observed dependence of the extent to which the magnetic field affects the polariton luminescence on the purity of the material and the excitation intensity indicates that the effect stems directly from an influence of the magnetic field on the kinetics of the excitons. We will briefly discuss two possible reasons for this influence.

The first is a decrease in the probability for a radiationless destruction of polaritons in a magnetic field. In this case there would be an increase in the concentration of polaritons and thus in the integrated intensity of the polariton luminescence. Furthermore, there should be an increase in the degree to which the polaritons are thermalized over their lifetime.

The second reason might be an increase in the probability for the emission of acoustic phonons by electrons and a decrease in the electron temperature in a magnetic field. This mechanism would lead to both an increase in the exciton formation probability and a decrease in the effective temperature of the excitons, if we assume that this temperature is determined by exciton-electron scattering.

A final determination of the nature of the effect observed here will require further research.

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