EMISSION OF INTERACTING EXCITONS IN Ge IN STRONG MAGNETIC FIELDS

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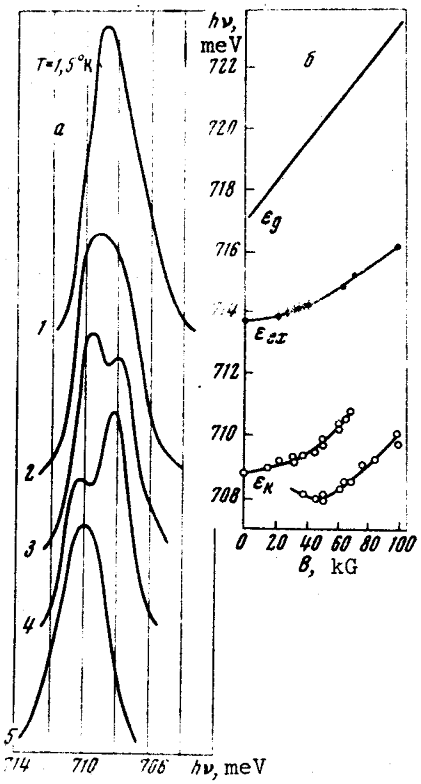
Submitted 7 July 1970
ZhETF Pis. Red. 12, No. 5, 203 - 205 (5 September 1970)

Pronounced interest has been evinced recently in questions connected with the behavior of an exciton gas at low temperatures and high densities, when $(na_0)^3 \sim 1$ (n - exciton concentration, a_0 - exciton Bohr radius). Under discussion, in the main, are two concepts of the possible state of a system of "strongly" interacting excitons, namely: either a dielectric gas consisting of exciton molecules, or electron-hole drops similar to a liquid metal. In spite of the essential differences between these two models, most experiments, and especially data on recombination radiation, are explained by different authors from either point of view.

The reason for this circumstance is apparently the fact that there exists at present a sufficiently reliable theory describing these phenomena with allowance for the real band structure of the investigated semiconductors, thus permitting a certain freedom in the choice of definite assumptions when it comes to interpretation of the experimental data. In order to limit this freedom, experiments are needed on the system of interacting excitons in the presence of a certain perturbation, making it possible to make use of those essential differences between the biexcitons and electron-hole drops. Among such perturbations are, for example, uniaxial compression [1], interaction with electromagnetic radiation [2], and magnetooptical investigations which, as is well known, are among the most effective methods in the sense of identification of optic spectra.

We present in this paper some of the results obtained in a study of recombination radiation of pure Ge at a temperature from 1.5 to 4.2°K and at high excitation levels in superstrong magnetic fields. The work was performed with the "Solenoid" apparatus of our institute, which makes it possible to produce stationary magnetic fields up to 100 kG in a cylindrical volume of 50 mm diameter. The experimental conditions and the registration system were analogous to those used in [1].



a) Spectra of recombination radiation of Ge at different magnetic field intensities: 1 - B = 0, 2 - 38.4, 3 - 46, 4 - 60, 5 - 100 kG. b) Dependence of energy position of the maxima of the emission lines ε_{k_1}, ε_{k_2}, and ε_{ex} on the magnetic field: o - data of [3], o - present data.

Figure a shows the spectra of the recombination radiation of Ge at 1.5°K as a function of the magnetic field intensity for the case $\vec{B} \parallel [100]$. It is seen from the figure that in the magnetic-field interval from 40 to 70 kG there are observed two emission lines e_k, which shift towards shorter wavelengths with increasing B. The magnitude of the "splitting" (Fig. b) increases linearly with the magnetic field, reaching 2.2 meV at B = 70 kG.

Figure b shows also the experimental data of [3] and our data concerning the position of the emission line of a free exciton at 4.2°K as a function of the magnetic field intensity.

If an attempt is made to interpret the results from the point of view of the assumed existence of an exciton molecule, then it is necessary to forego the biexciton recombination mechanism proposed in [4]. This mechanism presupposes the vanishing of both excitons that comprise the biexciton; one is destroyed radiatively, and the second disintegrates into a free electron and a free hole. Then $\varepsilon_g - \varepsilon_k$ should exceed double the exciton binding energy.

However, as seen from Fig. b, this relation is not satisfied in a magnetic field of 100 kG. Moreover, from the point of view of a biexciton that leads without doubt to the appearance of energy levels in the forbidden band, it is practically impossible to explain the observed splitting of the emission line in the magnetic field. The observed magnitude of the splitting (Δ = 2.2 meV) greatly exceeds kT (0.12 meV) and therefore the filling of the higher energy state (the short-wave line) should be negligibly small.

This contradiction is completely eliminated if one approaches the explanation of the observed effects from the point of view of metallic drops, in which there is strong degeneracy of the carriers. In this case, it is possible to observe in the emission two or more lines due to the Landau quantization, if the distance between them does not exceed the Fermi energy ε_F. In particular, if it is assumed that the equilibrium carrier density in the drop ($n_0 \sim 2 \times 10^{17}$ cm^{-3} [5]) does not depend strongly on the magnetic field, then in the case of B parallel to [100] there should actually be observed in the emission spectrum of such electron-hole drops two lines in the magnetic field interval from 40 to 70 kG. These lines are due to the recombination of the electrons filling the zeroth Landau subbands with the holes, which according to [6] fill the Landau subband with $n = 0$, $m_i = +1/2$ (long-wave line) and the degenerate Landau subbands $n = 0$, $m_i = -1/2$ and $n = 2$, $m_i = -3/2$ (short-wave line).

The extinction of the short-wave line, which occurs at field intensities B > 70 kG, corresponds precisely to the case when the magnitude of the splitting becomes comparable with the Fermi energy for holes at B = 70 kG.

The authors are grateful to V.G. Veselago for providing the opportunity of working with the "Solenoid" apparatus and to L.V. Keldysh for useful discussions.

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