The quantities α and β in (4) can be caluclated by taking detailed account of the excitation losses, using the procedure of [5].

Table II shows a comparison of the theoretical threshold fields (E_{2T}) calculated with formula (4) with the experimental values (E_{2E}).

As seen from Table II, the theoretically calculated threshold fields are in satisfactory agreement with the experimental results.

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OBSERVATION OF THE STRUCTURE OF DIAMAGNETIC EXCITONS IN THE ELECTROABSORPTION SPECTRUM OF Ge

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Submitted 21 May 1968
ZhETF Pis. Red. 8, No. 3, 123 - 127 (5 August 1968)

It is shown in a number of theoretical [1,2] and experimental papers [3, 4] that the discrete structure of the absorption edge of semiconductors in a strong magnetic field is of exciton nature. The maxima in the magnetoabsorption spectrum should be attributed in this case to the ground exciton states connected with different Landau subbands that take part in the interband optical transitions. Naturally, there should exist besides the ground state, in general, also a number of excited states of such excitons.

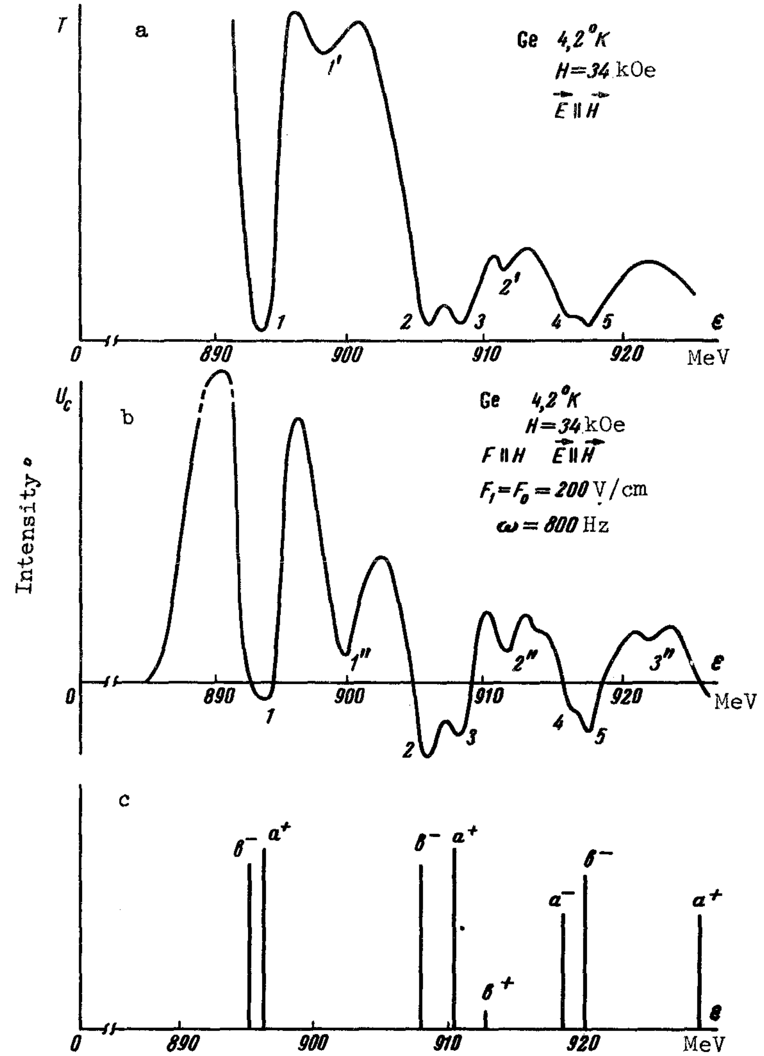
The corresponding exciton series can be excited in the simplest case by the formula

$$\mathcal{E}_{ex} = \mathcal{E}_{\ell'\ell} - \frac{R^*}{(n + \delta n)^2}, \quad n = 0, 1, 2, 3, \ldots, \tag{1}$$

where $\mathcal{E}_{\ell'\ell}$ is the energy distance between the edges of the combining Landau subbands in the valence and the electron bands, with quantum numbers ℓ' and ℓ; δ_n is the quantum defect and depends on the magnetic field and on ℓ. The Rydberg constant $R^* = \mu_n^* e^4/2h^2\kappa^2$ contains the reduced effective mass which, generally speaking, can be a function of ℓ and also of the magnetic field H; κ is the dielectric constant.

Exciton states of this kind can be called, in contradistinction to the exciton states in the absence of the field, diamagnetic states, since they are connected with the diamagnetic Landau subbands. It should be noted that the presence of a strong magnetic field distorts noticeably also the ratio of the intensities of the terms of the series, compared with the case when there is no field and when the relative intensities are given by simple relations [5].

According to the data of [1], the relative intensities of the excited states can decrease by nore than one order of magnitude, making their detection difficult. Nonetheless, Johnson [3] observed recently a structure in the magnetoabsorption spectra of InSb and Ge; this struc-



Structure of diamagnetic excitons in germanium crystals: a - long-wave section of magnetoabsorption spectrum; b - electroabsorption spectrum in parallel electric and magnetic fields for electric fields $F_1 = F_0 = 2 \times 10^2$ V/cm; c - theoretical spectrum of magnetoabsorption of germanium for transitions between Landau subbands, aligned with the principal maxima of the magnetoabsorption.

ture can be attributed to the excited states of the diamagnetic exciton connected with the upper subbands in the valence band and the lower Landau subband in the conduction band.

By investigating magnetoabsorption in relatively thick germanium crystals (10 - 15 μ), we also observed the aforementioned structure (see Fig. a). The additional weak transmission minimum, designated 1', can be attributed, in view of its location in the spectrum and its low intensity, to the excited states of the diamagnetic exciton - (002) in the notation of [3]. The relatively weak minimum of transmission, designated 2' and following the minima 2 and 3 corresponding to the transitions from the sublevels of heavy holes $b^-(3) \to a^c(1)$ and light holes $a^+(1) \to b^c(1)$, can be attributed either to transitions to the corresponding excited exc exciton states, or to transitions from another light-hole sublevel - $b^+(2) \to a^c(0)$.[1)] Apparently, for a reliable detection of the exciton excited states connected with transitions

[1)] The designations of the transitions between the Landau subbands in the valence and conduction bands are taken from [6]; see also [4].

to higher Landay levels it is necessary to use magnetic fields much stronger than in our experiment (H_{max} = 34 kOe), since an increase in the field leads to an increase in the intensity of the weakly-bound states, owing to their stabilization by the field [7].

Nonetheless, using relatively weak fields, we were able to observe a structure for several short-wave minima, using the electroabsorption technique. We used in the experiment thin germanium crystals (8 - 10 μ) of n-type conductivity with electron density $n \approx 5 \times 10^{13}$ cm^{-3} at 300°K. Tin contacts were coated on the surface of the sample and fused-in in vacuum; they were purely ohmic. The electric field F was parallel to the magnetic field in all cases. A certain constant (F_1) and alternating ($F_0 \cos \omega t$) electric field of frequency ω = 800 Hz was applied to the sample. The synchronous detection of the signal was carried out at the same frequency.

With F parallel to H, it was expected that a relatively weak electric field would cause ionization of the exciton states whose orbits are elongated along the magnetic field. It is also natural to expect the largest changes in an electric field to be experienced by the absorption maxima corresponding to large-radius excited states, as is observed in the ionization of excitons [8]. Thus, the excited states of the diamagnetic excitons should become particularly clearly manifest in the differential electroabsorption spectrum.

Figure b shows the electroabsortpion curve of germanium for the region where the first five main maxima of ordinary magnetoabsorption are observed. The minima on the electroabsorption curve marked 1 - 5 correspond obviously to transitions into the corresponding exciton ground states and coincide with the corresponding minima on the curve of Fig. a. Besides the main minima, there appear also the minima 1", 2", and 3", the positions of which in the spectrum are very close to the energies corresponding to the direct transitions between the Landau sublevles, calculated under the assumption that $\mathcal{E}_g^0$ = 0.8894 eV. When the magnetic field intensity is increased, the relative intensity of the additional minima increases. To the contrary, it decreases noticeably with increasing intensity of the constant electric field. At certain critical electric-field values the additional minima disappear completely, owing to the ionization of the corresponding exciton states. For different minima, these fields amount to $F_1 \approx (3.5 - 5.0) \times 10^2$ V/cm at H = 34 kOe.

The indicated regularities confirm that the additional minima belong to excited exciton states of large radius, which are quite sensitive to the action of an external electric field.

The energy positions of the absorption maxima for the excited states of the exciton should, according to [9], be a function of the electric field F. It can be shown that for such transitions the line shape in the differential spectrum can correspond to the derivative of the line shape in the absorption spectrum, and the maximum absorption corresponds to an inflection point in the differential spectrum. This situation obviously obtains for 1' and 1" as well as for 2' and 2". All this suggests that the second additional absorption maximum 2' is also more likely related to the excited states of the exciton, rather than the ground state connected with the transitions $b^+(2) \rightarrow a^c(0)$.

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E R R R A T A

Article by A. V. Varfolomeev et al., V. 8, No. 3, p. 74:

The line above formula (1) should read: "The corresponding exciton series can be described by the formula"