Torr. The optical-pumping signals were obtained both with polarization of the Kr atoms (circularly-polarized pumping light) and with alignment of the atoms (unpolarized and linearly-polarized pumping light). The signals had a maximum value when the Kr pressure in the lamp was of the order of 0.5 - 0.7 Torr, and were observed at Kr pressure in the cell from 10^{-4} to 10^{-2} Torr.

At a low amplitude of the radio-frequency field and a low value of the modulating deviation of the resonant frequency, the line width of the observed signals varied with the krypton pressure from 15 to 50 kHz in a pressure range 1 - 25 mtorr. The line width was assumed to be the distance between the extrema of the derivative of the absorption signal. An estimate of the contribution made to the line width by the inhomogeneity of the magnetic field yielded a value of 10 kHz.

The measured dependence of the line width on the Kr pressure has made it possible to calculate the cross section σ for the disorientation of the Kr atoms in the metastable $^3P_2$ states in collisions with Kr atoms in the ground $^1S_0$ state, $\sigma = 78 \pm 23$ Å^2. Worthy of attention is the fact that the obtained cross section for Kr is smaller than the value of σ published in [3] for Ar (100 ± 7 Å^2), in spite of the fact that the polarizability of the Kr atoms is larger than the polarizability of Ar. It is also of interest that the absolute width of the line (15 kHz) for Kr at 10^{-3} Torr is less than half the corresponding value for Ar (46 kHz) [3].

No magnetic-resonance signals of the odd isotope ^{83}Kr were observed in the experiment. Apparently the main obstacles were the small natural concentration of this isotope (11%) and the large spin of the nucleus, I = 9/2.

Further investigations are being continued.

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SPIN RELAXATION OF ELECTRONS ORIENTED BY LIGHT IN A GaAs CRYSTAL

V.G. Fleisher, R.I. Dzhioev, B.P. Zakharchenya, and L.M. Kanskaya
Physico-technical Institute, USSR Academy of Sciences

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It was shown in [1] that excitation of electrons in a GaAs crystal by circularly-polarized light produces spin orientation. This orientation was observed in a wide interval of photon energies $E_{h\nu}$, exceeding the energy of the spin-orbit splitting between the valence bands $^4\Gamma_8$ and $^2\Gamma_7$. An increase of $E_{h\nu}$ from the value $E_g = 1.52$ eV, corresponding to excitation at the point k = 0, is accompanied by a decrease of the degree of orientation P of the electron spins. In experiment this is manifest by a decrease in the observed degree of circular polarization ρ_e. The $\rho_e(E_{h\nu})$ curve given in [1] differs from the theoretical $\rho_T(E_{h\nu})$ plot by a factor T/τ, where τ is the lifetime of the electron and T is the time of "magnetization" of the non-equilibrium electrons ($1/T = 1/\tau + 1/\tau_s$ [2], where τ_s is the spin-relaxation time). From a comparison of

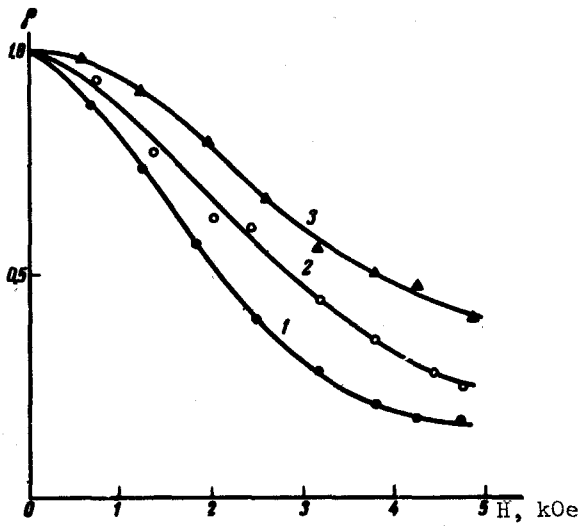

Fig. 1

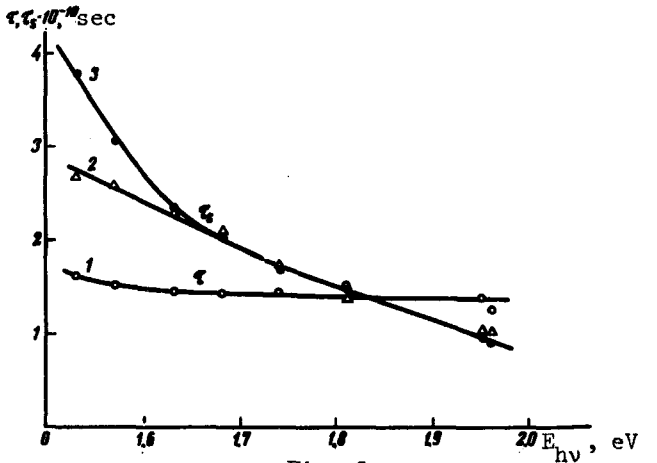

Fig. 2

Fig. 1. Dependence of the degree of circular polarization of recombination radiation in GaAs on the magnetic field for different exciting-photon energies: 1 - 1.53 eV, 2 - 1.74 eV, 3 - 1.96 eV.

Fig. 2. Dependence of the lifetime τ and of the spin-relaxation τ_s on the exciting-photon energy. Curve 2 - τ_s calculated from the function $\rho_e/\rho_T(E_{h\nu})$ (Fig. 1 of [1]). Curve 3 - calculated from the function $H_{1/2}(E_{h\nu})$.

the values of ρ_T and ρ_e given in [1] we see that ρ_e/ρ_T decreases systematically with increasing $E_{h\nu}$. The energy relaxation of the "hot" electrons occurred within times $\tau_\varepsilon \ll \tau$. Indeed, τ_ε is of the order of 10^{-12} sec according to [3] and of the order of 10^{-10} sec according to the measurements of [1]. It is natural to assume that τ is practically independent of $E_{h\nu}$. Then the decrease of T/τ with increasing $E_{h\nu}$ should mean a decrease of τ_s. Such a decrease may be connected with acceleration of the spin relaxation when the electrons are excited high in the conduction band, owing to the spin splitting of this band. As shown by Perel' and D'yakonov [4], allowance for this splitting can lead under certain conditions to a strong dependence of τ_s on $E_{h\nu}$.

To elucidate the nature of the correlation between the spin relaxation and the photon energy of the exciting light, investigations were made on the depolarization of the luminescence in a magnetic field at different $E_{h\nu}$. The $\rho(H)$ dependence was measured at eight values of $E_{h\nu}$ (from 1.53 to 1.96 eV), on the same GaAs crystal as in [1][1)]. Figure 1 shows the results of the measurements for $E_{h\nu}$ = 1.53, 1.74, and 1.96 eV. One can clearly see a broadening of the $\rho(H)$ curves with increasing $E_{h\nu}$. The widths at $H_{1/2}$ of the Lorentz curves half-height, corresponding to the experimental $\rho(H)$, are inversely proportional to the time T. The experimentally observed broadening of the $\rho(H)$ curves with increasing $E_{h\nu}$ correspond to a decrease of T, in accord with the results of the comparison of ρ_T and ρ_e.

[1)] The luminescence was observed from the cleaved surface.

As shown in [1], measurement of ρ_e/ρ_T and of $\rho(H)$ for a given value of $E_{h\nu}$ makes it possible to determine separately the times τ and τ_s. Figure 2 shows the results of the calculation of τ_s (curve 2) and τ (curve 1) from the functions $\rho_e(E_{h\nu})/\rho_T(E_{h\nu})$ and $H_{1/2}(E_{h\nu})$. We see that τ changes little in the considered range of $E_{h\nu}$. If we postulate that τ is constant (see above) and assume $\tau = 1.4 \times 10^{-10}$ sec (a value corresponding to $E_{h\nu} > 1.65$ eV in Fig. 2), then we can compare the values of τ_s determined from two different experiments (from ρ_e/ρ_T and $H_{1/2}$). As seen from Fig. 2 (see curves 2 and 3), the independently determined values of τ_s at $E_{h\nu} \gtrsim 1.65$ eV are in good agreement. It should be emphasized here that ρ_e/ρ_T is sensitive to any process accompanied by spin relaxation and terminating within an arbitrarily small time compared with τ.

At the same time, $H_{1/2}$ is sensitive only to those spin-relaxation processes that are characterized by times on the order of $1/\nu_L$, where ν_L is the frequency of the Larmor precession in the field $H_{1/2}$. For GaAs at $H_{1/2} = 2000$ G we have $\nu_L = 1.5 \times 10^9$ Hz. If the energy relaxation terminates within a time $\tau \simeq 10^{-12}$ sec $\ll 1/\nu_L$, then the rotation of the spin by the external magnetic field during τ_ε is negligibly small. The value of $H_{1/2}$ is then determined completely by the value of τ_s characteristic of the bottom of the conduction band, and no dependence of $H_{1/2}$ on $E_{h\nu}$ should be observed[2].

Thus, from the fact that ρ_e/ρ_T and $H_{1/2}$ yield the same values of τ_s, we conclude that the spin orientation is conserved in electron-phonon interactions accompanied by energy relaxation in the investigated crystal. How can we explain in this case the observed dependence of ρ_e/ρ_T and $H_{1/2}$ on the excitation energy?

These dependences can be qualitatively understood by assuming that there is a difference between the crystal parameters inside the volume and in the surface layer. Then the experimentally measured quantities $f_1 = \rho_e/\rho_T$ and $f_2 = H_{1/2}$ are the results of averaging of the values of f in the volume (f^V) and near the surface (f^S), taken with differing weighting factors determined by the function $\alpha(E_{h\nu})$, where α is the absorption coefficient of the light. If we assume the existence of a surface region with an effective thickness d for which $f_1 = f_1^S$ and $f_2 = f_2^S$, then $f_{1,2} = f_{1,2}^S + (f_{1,2}^V + f_{1,2}^S)e^{-\alpha d}$, without allowance for the carrier diffusion. Figure 3 shows plots of ρ_e/ρ_T and $H_{1/2} \sim 1/T$ against α (the values of α were taken from [5]). Both plots were well approximated by straight lines, thus indicating that αd is a small quantity. Allowance for the diffusion length ℓ_D does not change the linear form of the dependence of f on α

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[2]If we make the unlikely assumption that τ_ε is nevertheless comparable with the observed value of τ_s (and consequently with τ) in the employed crystal, then $H_{1/2}$ depends on $E_{h\nu}$. In this case, however, the luminescence line should broaden noticeably, something not observed in experiment.

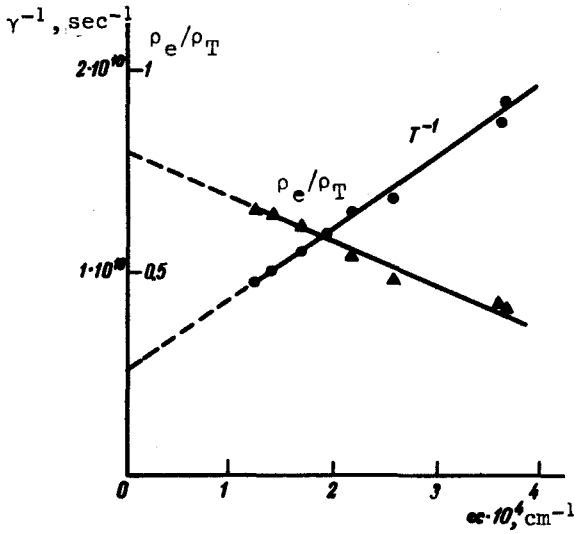

Fig. 3. Plot of ρ_e/ρ_T and of the reciprocal "magnetization" time vs. the absorption coefficient in GaAs.

at $l_D \ll 1/\alpha$ and $d \ll 1/\alpha$. Linear extrapolation of f_1 and f_2 to the value $\alpha = 0$ makes it possible to determine the values τ and τ_s corresponding to the volume (τ_v and τ_{sv}). We obtained $\tau_v = (2.5 \pm 0.3) \times 10^{-10}$ sec and $\tau_{sv} = (9.6 \pm 1.2) \times 10^{-10}$ sec. The quantity τ_s in the surface layer can be determined if there is additional information concerning the quantities d and l_D. For example, neglecting carrier diffusion, we can explain the experimental results as being due to the presence of a near-surface layer with thickness on the order of 10^{-5} cm, in which τ_s is smaller by one order of magnitude than τ_{sv}.

It should be noted that an indication that the spin-relaxation time changes on going from the surface to the volume in semiconductors exposed to light is contained in a paper dealing with an EPR investigation [6].

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NEW DATA ON THE STRUCTURE OF OPTICAL ABSORPTION IN THE REGION OF ISOTOPIC-IMPURITY EXCITON STATES OF NAPHTHALENE CRYSTALS

V.L. Broude and A.V. Leiderman
Institute of Solid State Physics, USSR Academy of Sciences
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We have previously reported that the production of impurity excitons in mixed isotopic molecular crystals is accompanied by a smooth variation of the Davydov splittings in the electronic transition with increasing concentration of one of the mixture components. The corresponding conclusions were based on a qualitative analysis of the form of spectrum of optical absorption of such crystals as benzene [1] and naphthalene [2] at 20.4°K.

We have made detailed quantitative measurements of the low-temperature (4.2°K) exciton absorption in isotopically mixed naphthalene-h_8 (H_8) and naphthalene-d_8 (D_8) (DFS-13 spectrograph with linear dispersion 2 Å/mm). We used samples with thickness larger than 4 μ, in which neither cooling from the