LINEAR-CIRCULAR TWO-PHOTON DICHROISM IN DEGENERATE INDIUM ANTIMONIDE

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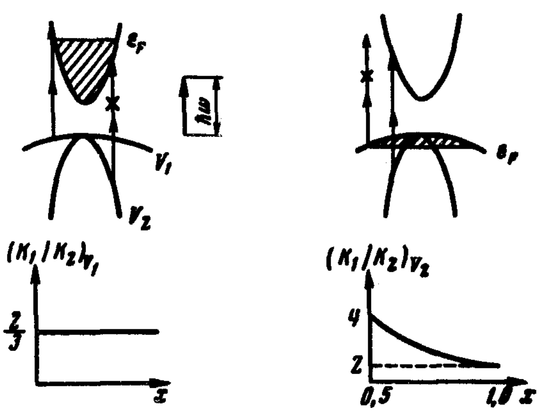
In an earlier communication [1] we considered the question whether the coefficient of two-photon absorption (TPA) depends on the polarization in cubic semiconductors[1]. It was shown, in particular, that in indium antimonide, a crystal with a practically isotropic spectrum, only one type of polarization dependence is possible (neglecting the corrugation of the valence zone), namely, linear circular two-photon dichroism (LCTD) [2]. The cause of this phenomenon is the inadequate contribution made to the absorption probability ($W^{(2)}$) by optical transitions from different initial states in the valence band for cases of linearly and circularly polarized light. In the case of transitions from the heavy-hole subband V_1, the value of $W^{(2)}$ turns out to be larger for circularly-polarized light, whereas for transitions from the subband of the light holes V_2 the TPA probability is much larger for linearly-polarized light. Under ordinary conditions when, for example, transitions from both subbands of the valence band are realized, the dependence of the TPA probability on the state of the pump-light polarization is not very strong [1].

Thus, on the TPA edge, the ratio $W_L^{(2)}/W_C^{(2)} = 0.98$, and when the parameter $x = \varepsilon_g/2\hbar\omega$ is decreased (ε_g is the width of the forbidden band and ω is the frequency of the radiation causing the two-photon transitions), this ratio increases because of the non-parabolicity of the energy spectrum of the light-hole band, reaching 1.33 at $x = 1/2$.

It would be of interest to investigate the LCTD for transitions from each subband separately. Such conditions can be realized in indium antimonide by using degenerate n- and p-type crystals at low temperature and by choosing the corresponding energy of the pump-light quanta, as shown in the figure. In this case only transitions from the subband V_1 are possible in the n-type crystal, and transitions from the subband V_2 from the p-type crystal. As follows from the expression given in [1, 2], $|W_L^{(2)}/W_C^{(2)}|_{V_1} = 2/3$ and $|W_L^{(2)}/W_C^{(2)}|_{V_2}$ ranges from 2.2 to 4, depending on the value of x, where $x \in [1, 0.5]$.

The experiments aimed at observing LCTD in degenerate indium antimonide were performed with a pulsed CO_2 laser ($t_{pulse} = 0.2$ μsec) at a crystal temperature 77°K.



Scheme of possible two-photon transitions in indium antimonide: a) $n_0 = 6.2 \times 10^{17}$ cm^{-3}, $\lambda = 9.5$ μ; b) $p_0 = 1.1 \times 10^{18}$ cm^{-3}, $\lambda = 10.6$ μ; T = 77°K.

[1] A detailed quantum-mechanical theory of TPA in cubic semiconductors was published in [2] by one of the authors.

InSb samples with concentrations $n = 6.2 \times 10^{17}$ cm^{-3} and $p = 1.1 \times 10^{18}$ cm^{-3} were prepared in the form of photoresistors in such a way that the contact placement was transverse relative to the direction of the light beam. The signals observed in the experiments were amplified and fed to a pulsed synchronous detector with a large time constant, and registered with an automatic recorder.

We measured the photoconductivity due to two-quantum excitation in the n-type samples [3, 4]. The laser regime was such that the generation at 10.6 μ was suppressed and the main emission line had a wavelength 9.5 μ ($\hbar\omega = 0.131$ eV). The radiation intensity j was decreased to a level at which the photoconductivity $\Delta\sigma$ was quadratically dependent on j. The lifetime τ of the excess carriers was determined then mainly by nonradiative processes, and their concentration Δn at constant light intensity was determined only by the value of the absorption coefficient $K^{(2)}$. Thus, by varying in the experiment the polarization of the pumping light we could determine $\Delta\sigma_L/\Delta\sigma_C = K_L^{(2)}/K_C^{(2)}$. This quantity turned out to be equal to 0.85, in quantitative agreement with the conclusions of the theory. Some quantitative difference is due to the presence of a "tail" in the distribution function, owing to the insufficiently low temperature.

In the experiments performed on the p-type samples we used a laser regime in which the spectral line $\lambda = 10.6$ μ predominated ($\hbar\omega = 0.117$ eV). The 9.5-μ intensity was not more than 0.3% of the total intensity.

We observed a transverse photo-emf whose amplitude was quadratically dependent on the light intensity, thus evidencing a two-quantum excitation of the excess carriers[2]. The intensity depended strongly on the polarization of the laser beam, and decreased by one-half on going from linear to circular polarization[3]. Since the experimental conditions corresponded closely to the TPA edge, the obtained ratio should be regarded as quite close to the theoretical one (∿2.2).

It should thus be assumed that we observed in our experiment the LCTD phenomenon for optical transitions separately from the subbands V_1 and V_2 of the valence band. The results confirm the validity of the two-quantum approximation used in the theoretical calculation [2].

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[1] A.M. Danishevskii, E.L. Ivchenko, S.F. Kochegarov, and M.I. Stepanova, ZhETF Pis. Red. 16, 625 (1972) [JETP Lett. 16, 440 (1972)].

[2] E.L. Ivchenko, Fiz. Tverd. Tela 14, No. 12 (1972) [Sov. Phys.-Solid State 14, No. 12 (1973)].

[3] A.F. Bigson, M.J. Kent, and M.F. Kimmit, Brit. J. Appl. Phys. 1, 149 (1968).

[4] A.M. Danishevskii, A.A. Patrin, S.M. Ryvkin, and I.D. Yaroshetskii, Zh. Eksp. Teor. Fiz. 56, 1457 (1969) [Sov. Phys.-JETP 29, 781 (1969)].

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[2]The mechanism whereby the observed photo-emf is produced has not been elucidated, but it can be assumed that it is connected with the presence of inhomogeneities in the sample.

[3]The amplitude of the laser radiation was unchanged when its polarization was varied, and the beam did not move over the sample.