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INFLUENCE OF MIXING VALENCE BAND STATES TO THE CONDUCTION BAND STATES ON TWO-QUANTUM LINEAR-CIRCULAR DICHROISM IN SEMICONDUCTORS

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A quantitative theory of two-photon linear-circular dichroism caused between the subbands of light and heavy holes of the valence band and conduction band is constructed, which takes into account the admixture of valence band states to the conduction band states and the temperature dependence of the band gap ($E_g(T)$) in semiconductors of tetrahedral symmetry in the multiband Kane model. It is shown that the type of oscillatory angular dependence or the amplitude values of the probabilities of two-photon optical transitions depend on the state of light polarization. This is due to the fact that, under the influence of linearly polarized light, alignment along the pulse occurs, and under the action of circularly polarized light, the moments of current carriers are oriented. It has been determined that the probability of two-photon optical transitions from the heavy hole subband to the conduction band of semiconductors at a fixed temperature increases with increasing frequency, passes through a maximum, and sharply decreases regardless of the degree of polarization of light, as well as the band gap.
Keywords: *Probability of two-photon absorption of light; Frequency; Temperature; Oscillation dependence; Degree of polarization of light; Linear-circular dichroism; Semiconductor; Multiband Kane model*
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INTRODUCTION

Currently, the main research in the field of multiphoton (multiquantum) light absorption is carried out in wide-gap semiconductors, as a number of their physicochemical properties have been studied in depth and in more detail. In this regard, multiquantum effects occurring in narrow-gap crystals have been less studied in both theoretical and experimental aspects. The main reason for this is that the theoretical study of a number of optical phenomena in narrow-gap crystals requires the use of not only the Luttinger-Kohn approximation but also the Kane multiband approach.

The first work on two-quantum interband transitions in crystals was carried out in the early 60s, shortly after the advent of lasers [1-3]. When calculating the matrix elements of two-quantum transitions in crystals, perturbation theories based on the field of an unpolarized electromagnetic wave were used [2, 3], where the two-band Kane model was used.

In [4-11], linear-circular dichroism (LCD) of two- and three-quantum light absorption in crystals was studied both theoretically and experimentally. Nonlinear interband single-quantum absorption of polarized light in Weyl semimetals was studied in [12]. However, the question of the polarization and frequency-polarization dependence of two-quantum interband linear-circular dichroism in zinc blende crystals, caused between the subbands of light and heavy holes of the valence band and conduction band in the Kane approximation, taking into account the admixture of valence band states to the conduction band states, remained open to study, which this work is devoted to.

BASIC RELEATIONSHIPS

It is known [4] that the coefficient of multiquantum light absorption is determined by the probability of a N quantum optical transition from the $|n,\vec{k}\rangle$ state to the $|n',\vec{k'}\rangle$ state, determined by the relation

$$W^{(N)} = \frac{2\pi}{\hbar}\left\langle \sum_{n,n',\vec{k}} \left| M^{(N)}_{n\vec{k},n'\vec{k}} \right|^2 \right\rangle \left(f_{n\vec{k}} - f_{n'\vec{k}}\right)\delta\left(E_{n'}(\vec{k}) - E_n(\vec{k}) - N\hbar\omega\right), \quad (1)$$

where $f_{n\vec{k}}(f_{n'\vec{k}})$- is the equilibrium distribution function of current carriers in the initial (final) state, $M^{(N)}_{n\vec{k},n'\vec{k}}$- is the composite matrix element of the N- quantum optical transition.

It can be seen that $W^{(N)}$, in turn, is assigned a value of $M^{(N)}_{n\vec{k},n'\vec{k}}$. In particular, to calculate the $M^{(N=1)}_{n\vec{k},n'\vec{k}}$ - composite matrix element of a single-quantum optical transition from the subband of light holes to the conduction band, one must know the Hamiltonian, since [13, 14]

$$M^{(1)}_{c,s;\,V,\Gamma_8,m} = \left(\frac{eA_0}{cm_0}\right)\vec{e}\cdot\vec{p}_{c,s;\,V,\Gamma_8,m}, \quad (2)$$

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where $\vec{e}\cdot\vec{p}_{c,S;\,V,\Gamma_8,m}=\left(\frac{eA_0}{cm_0}\right)\frac{m_0}{\hbar}\frac{\partial}{\partial\vec{k}}\left[\widehat{\mathrm{H}}(\vec{k})_{c,S;\,V,\Gamma_8,m}\right]$-is the matrix elements of the momentum operator, $\vec{e}(A_0)$-is the polarization vector (amplitude value of the potential vector) of the light wave, $\widehat{\mathrm{H}}(\vec{k})$- is the Hamiltonian of current carriers, the remaining quantities are well known. Note here that $\widehat{\mathrm{H}}(\vec{k})$ - is a quadratic matrix whose dimension depends on the choice of model. For example, in the Kane approximation, $\widehat{\mathrm{H}}(\vec{k})$ - can be represented as an 8x8 matrix, the form of which is given in [13, 14] in the Luttinger-Kohn approximation. However, in [13, 14], when calculating band matrix elements, the substitution of states of the valence band (Γ_8) to states of the conduction band (Γ_6) was not taken into account, taking this into account gives the following matrix elements of the momentum operator, presented in Tables 1 and 2.

Table 1. Interband matrix elements $\frac{m_0}{\hbar^2 k}\vec{e}\cdot\vec{p}^{(\Gamma_8)}_{m',m}$, calculated from $m',m=3/2,+1/2,-1/2,-3/2$ taking into account the substitution of valence band states to conduction band states, where $p_{c,V}=\langle S|\mathrm{p}_z|Z\rangle$, $e'_{\pm}=e'_x\pm ie'_y$, e'_x,e'_y, e'_z - are projections $\vec{e}$ relative to the coordinate system x',y',z', dependent on the direction of the wave vector of current carriers $\vec{k}$ $(\vec{k}\|z')$.

	$\langle hh,+3/2\|$	$\langle lh,+1/2\|$	$\langle lh,-1/2\|$	$\langle hh,-3/2\|$
$\langle c,+1/2\|$	$-\frac{e'_+}{\sqrt{2}}$	$e'_z\sqrt{\frac{2}{3}}$	$\frac{e'_-}{\sqrt{6}}$	0
$\langle c,-1/2\|$	0	$-\frac{e'_+}{\sqrt{6}}$	$e'_z\sqrt{\frac{2}{3}}$	$\frac{e'_-}{\sqrt{2}}$

Table 2. Intraband matrix elements of the momentum operator $\left[\vec{e}\cdot\vec{p}^{(\Gamma_8)}_{m',m}/(\hbar k)\right]$ for crystals of cubic symmetry. Here $\zeta_g=\left|p_{c,V}\right|^2/(m_0E_g)$, E_g- is the band gap.

	$\langle hh,+3/2\|$	$\langle lh,+1/2\|$	$\langle lh,-1/2\|$	$\langle hh,-3/2\|$
$\langle hh,+3/2\|$	e'_z	$\zeta_g\frac{e'_-}{\sqrt{3}}$	0	0
$\langle lh,+1/2\|$	$\zeta_g\frac{e'_+}{\sqrt{3}}$	$\left(1-\frac{4}{3}\zeta_g\right)e'_z$	0	0
$\langle lh,-1/2\|$	0	0	$\left(1-\frac{4}{3}\zeta_g\right)e'_z$	$-\frac{\zeta_g e'_-}{\sqrt{3}}$
$\langle hh,-3/2\|$	0	0	$-\frac{\zeta_g e'_+}{\sqrt{3}}$	e'_z

Let us note here that taking into account the substitution of valence band states for conduction band states leads to the following hole Hamiltonian:

$$H^{(\Gamma_8)}=E^0_{\Gamma_8}+\frac{\hbar^2k^2}{2m_0}-\frac{\hbar^2}{m_0^2}\frac{|p_{eV}|^2}{E_g}\begin{bmatrix}\frac{k_1^2}{2} & -\frac{k_zk_-}{\sqrt{3}} & -\frac{k_-^2}{\sqrt{12}} & 0\\ -\frac{k_zk_+}{\sqrt{3}} & \frac{2}{3}k_z^2+\frac{k_1^2}{6} & 0 & -\frac{k_-^2}{\sqrt{12}}\\ -\frac{k_+^2}{\sqrt{12}} & 0 & \frac{2}{3}k_z^2+\frac{k_1^2}{6} & \frac{k_zk_-}{\sqrt{3}}\\ 0 & -\frac{k_+^2}{\sqrt{12}} & \frac{k_zk_+}{\sqrt{3}} & \frac{k_1^2}{2}\end{bmatrix}, \tag{3}$$

which differs from the Luttinger-Kohn Hamiltonian (see, for example, formula (26.12) in monograph [13]).

Then the effective mass of electrons in the conduction band is expressed as

$$\frac{1}{m_c}=\frac{1}{m_0}+\frac{2}{3m_0^2}\left|p_{c,V}\right|^2\left(\frac{2}{E_g}+\frac{1}{E_g+\Delta_{SO}}\right), \tag{4}$$

and the Kane parameter is determined by the relation

$$\left|p_{c,V}\right|^2=\frac{3}{2}m_0\frac{m_0-m_c}{m_c}\frac{E_g(E_g+\Delta_{SO})}{2(E_g+\Delta_{SO})+E_g}, \tag{5}$$

Δ_{SO} - is the width of the spin-orbit splitting of the valence band. In this case, the value that describes the substitution of valence band states to conduction band states $\zeta_g=3m_0(m_{hh}-m_{lh})/(4m_{hh}m_{lh})>>1$ for a number of semiconductors (see Table 3), where $m_{hh}(m_{lh})$ - are heavy (light) holes. This means that taking into account the substitution of valence band states for conduction band states should lead to a significant contribution to the coefficient of both single and multi-quantum absorption of light, depending on the frequency of light and temperature, the study of which is the subject of this work.

Table 3. Numerical values of quantity ζ_g.

	InSb	InAs	GaAs
$\zeta_g = \frac{3m_0}{4}\frac{m_{hh}-m_{lh}}{m_{hh}m_{lh}}$	46.5	25.5	6.18

To complete the problem, in further calculations we will take into account the dependence of band parameters, for example, the band gap on temperature $[E_g(T)]$, since the Kane parameter $p_{c,V} = \left(3Bm_0^2E_g\hbar^{-2}\right)^{1/2}$ and the effective masses of current carriers (see formulas (5) and (6)) also depend on $E_g(T)$. In particular, the $E_g(T)$ dependence is expressed by the Varshni formula [15]

$$E_g(T) = E_g(T=0) - \gamma_T \frac{T^2}{T+T_V} \tag{6}$$

and Passler's formula [16]

$$E_g(T) = E_g(T=0) - \frac{\alpha\Theta_p}{2}\left[\left(1+\left(\frac{2T}{\Theta_p}\right)^p\right)^{1/p} - 1\right]. \tag{7}$$

Here γ_T, T_V, α, Θ_p-are constant values depending on the physicochemical properties of the semiconductor, the numerical values of which are given in Tables 3 and 4.

$E_g(T)$ dependences determined by relations (6) and (7), it is clear that with increasing temperature, the band gap width described by the Varshni formula changes very slowly, and determined by the Passler formula decreases noticeably.

In particular, the temperature dependences of the effective masses of electrons $m_c(T)$ in the conduction band and holes $m_{SO}(T)$ in the spin-orbit splitting zone can be represented as [15]:

$$\frac{m_0}{m_{SO}(T)} = \gamma_1 - \frac{E_P\Delta_{SO}}{3E_g(E_g+\Delta_{SO})}, \frac{m_0}{m_c(T)} = 1 + 2F + \frac{E_P(E_g+2\Delta_{SO}/3)}{3E_g(E_g+\Delta_{SO})} \tag{8}$$

(see Fig. 2a and b). From Fig. 2 it can be seen that with increasing temperature, $m_c(T)$ for narrow (wide) band gap semiconductors decreases (increases), and $m_{SO}(T)$ increases in semiconductors with an arbitrary band structure, where the calculation is carried out using the Varshni formula. This temperature behavior of the effective masses leads to a noticeable change in the temperature and frequency dependence of the optical properties of semiconductors, for example, the light absorption coefficient. We will consider the analysis of this case later.

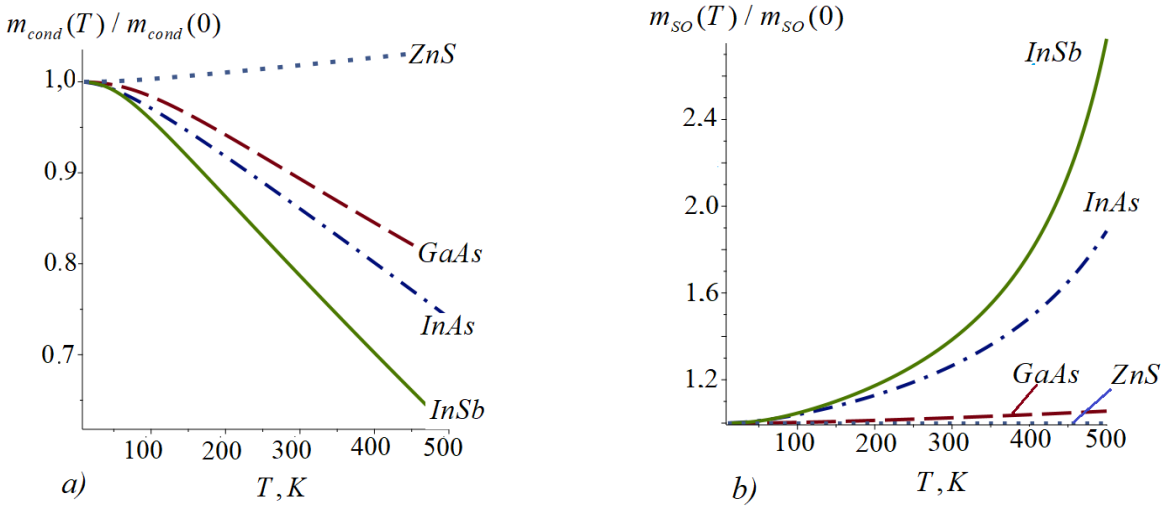

Figure 1. Temperature dependence of the effective masses of electrons (a) in the conduction band and holes (b) in the spin-orbit splitting zone of a semiconductor, calculated using the Varshni formula. Numerical values of zone parameters and thermoelectric quantities are obtained from Tables 3 and 4.

Table 3. Numerical values of band and thermoelectric quantities of some semiconductors [16]

Crystals	$E_g(T=0), eV$	Θ_p, K	$\alpha, meV/K$	p	Θ_D, K
GaAs	1.519	230	0.472	2.44	360
InAs	0.414	143	0.281	2.1	262
InSb	0.234	136	0.250	2.68	205
ZnS	3.841	240	0.532	2.76	440

Table 4. Numerical values of band parameters of some semiconductors at T=0 K[2] [15].

	GaAs	InAs	InSb	ZnS
E_g, eV	1.519	0.417a	0.235a	3.54
Δ_{SO}, eV	0.34	0.39	0.81	0.06
E_P, eV	28.8	21.5	23.3	20.4
$\gamma_T, meV/K$	0.46	0.276	0.32	
T_V, K	204	93	170	
γ_1	6.98	20.0	34.8	
γ_2	2.06	8.5	15.5	
γ_3	2.93	9.2	16.5	
m_c/m_0	0.067	0.026	0.0135	
m_{SO}/m_0	0.172	0.14	0.11	
F	-1.94	-2.9	-0.23	

3. FREQUENCY, ANGULAR AND TEMPERATURE DEPENDENCES OF THE PROBABILITIES OF TWO-QUANTUM INTERBAND OPTICAL TRANSITIONS IN CRYSTALS OF TETRAHEDRAL SYMMETRY

Since the probability of optical transitions (see formula (1)) is determined by the composite matrix element, therefore, we will further calculate the matrix elements of the following two quantum optical transitions (without taking into account coherent saturation): a) the initial states of holes are in the heavy hole subband, where the conservation law written as $\delta(E_{cond}-E_{hh}-2\hbar\omega)$, then the matrix elements of optical transitions of type $|V,\pm 3/2\rangle \to |m\rangle \to |c,\pm 1/2\rangle$ have the form $\left(\frac{eA_0}{c\hbar}\right)^2 \frac{1}{\sqrt{2}} p^*_{c,V}\hbar k \frac{e'_{\mp}e'_z}{(\pm\hbar\omega)}\left[1+\frac{2}{3}\frac{\hbar\omega\zeta_g}{(E_{lh}-E_{hh}-\hbar\omega)}\right]$, and optical transitions of type $|V,\pm 3/2\rangle \to |m\rangle \to |c,\mp 1/2\rangle$ are prohibited; b) the initial states of holes are in the bottom of light holes, where the conservation law is written as $\delta(E_{cond}-E_{lh}-2\hbar\omega)$, then the matrix elements of optical transitions of type $|V,\pm 1/2\rangle \to |m\rangle \to |c,\pm 1/2\rangle$ have the form $\left(\frac{eA_0}{c\hbar}\right)^2 \hbar\frac{k}{\sqrt{6}}\frac{1}{(-\hbar\omega)}\left[\left(1-\frac{4}{3}\zeta_g\right){e'_z}^2 \pm \frac{\hbar\omega\zeta_g|e'_\perp|^2}{(E_{hh}-E_{lh}-\hbar\omega)}\right]$, and optical transitions of type $|V,\pm 1/2\rangle \to |m\rangle \to |c,\mp 1/2\rangle$ are prohibited.

Here $E_{cond}=\frac{\hbar^2k^2}{2m_c}+E_g$- is the energy spectrum of electrons in the conduction band, $E_L=-\frac{\hbar^2k^2}{2m_L}$ - is the energy spectrum of holes in the valence band, $L=lh$ $(L=hh)$ corresponds to light (heavy) holes, symbol → describes a single-quantum optical transition. Then the composite matrix of a two-quantum interband optical transition $M^{(2)}_{L,\vec{k};\,SO,\vec{k}}$, taking into account the admixture of valence states Γ8 (valence band) and Γ7 (spin-orbital splitting band) into the Γ6 states (conduction band) is described by the following expression

$$M^{(2)}_{lh,\vec{k};\,c,\vec{k}}=\frac{1}{3}\left(\frac{eA_0}{c\hbar}\right)^4\frac{|p^*_{c,V}|^2\hbar^2k^2}{(\hbar\omega)^2}\left[\left(1-\frac{4}{3}\zeta_g\right)^2{e'_z}^4-\left(\frac{\hbar\omega\zeta_g}{E_{hh}-E_{lh}-\hbar\omega}\right)^2|e'_\perp|^4\right], \tag{9}$$

$$M^{(2)}_{hh,\vec{k};\,c,\vec{k}}=3\left(\frac{eA_0}{c\hbar}\right)^4\frac{|p^*_{c,V}|^2\hbar^2k^2}{(\hbar\omega)^2}\left(1+\frac{2}{3}\frac{\hbar\omega\zeta_g}{E_{lh}-E_{hh}-\hbar\omega}\right)^2{e'_z}^2e'^2_\perp, \tag{10}$$

where $\left(\frac{eA_0}{c\hbar}\right)^2=\frac{2\pi e^2}{n_\omega c}\frac{I}{(\hbar\omega)^2}$, $I(\omega)$-is the intensity (frequency) of light, n_ω- is the refractive index of light at frequency ω,$p_{c,V}=\left(3Bm_0^2E_g/\hbar^2\right)^{1/2}$- is the Kane parameter, $B=\hbar^2(m_{hh}-m_{lh})/(4m_{hh}m_{lh})$, $m_{hh}(m_{lh})$-is the effective mass of light (heavy) holes.

Let us note here that if we do not take into account the admixture of valence states Γ8 and Γ7 to the Γ6 states, then the results obtained are [14, 15]. Since the probabilities of intersubband two-quantum interband optical transitions are determined by relation (9) and (10), therefore, based on this expression, it is possible to calculate the frequency-temperature dependence of both the coefficients of two quantum light absorption and its linear-circular dichroism, taking into account the temperature dependence m_c(T), m_{SO}(T) and E_g(T) [15]3. Then, by substituting (9) and (10) into (1), we can determine the frequency and polarization dependence of the probability of a two-quantum optical transition, where it is taken into account that to calculate the angular dependences of the optical parameters of a semiconductor it is convenient to use the following relations [4]: for linearly polarized light

$$|e'_z|^2=\cos^2(\vec{e}\cdot\vec{k}),\ \ |e'_\pm|^2=1-|e'_z|^2=1-\cos^2(\vec{e}\cdot\vec{k}), \tag{11}$$

and for circularly polarized light

$$|e'_z|^2=\frac{1}{2}\sin^2(\vec{q}\cdot\vec{k}),\ |e'_\pm|^2=\frac{1}{2}\left[1+\cos^2(\vec{q}\cdot\vec{k})\right]\mp P_{circ}\cos(\vec{q}\cdot\vec{k}), \tag{12}$$

and also $\left(\frac{eA_0}{c\hbar}\right)^2=\frac{I}{\hbar\omega}\frac{e^2}{c\hbar}\frac{2\pi}{n_\omega\omega}$, where $\vec{q}-$ is the wave vector of the photon, $P_{circ}-$ is the degree of circular polarization, I- is the light intensity, n_ω - is the refractive index of the semiconductor at frequency ω.

In Fig. 2 shows the frequency-angular dependences $W_{linear}^{(2)}$ and $W_{circ}^{(2)}$ for light of linear (a, e) and circular (b, e) polarization for optical transitions from the heavy hole subband to the conduction band in GaAs. The results presented in Fig. 2a,b were obtained for $E_g(\mathrm{T}=0\ \mathrm{K})$, and the results in Fig. 2d,c – for $E_g(\mathrm{T}=330\ \mathrm{K})$. From these figures it is clear that the appearance of the graph, for example, the symmetry of oscillations of the angular dependence or the change in the amplitude values of $W_{linear}^{(2)}$ and $W_{circ}^{(2)}$, depends on the state of light polarization. This is due to the fact that since under the influence of linearly polarized light the alignment of pulses occurs, and under the action of circularly polarized light the moments of current carriers are oriented, and also taking into account dependencies $m_c(\mathrm{T})$, $m_{SO}(\mathrm{T})$ and $E_g(\mathrm{T})$ leads to the temperature dependence of the wave vector of photoexcited current carriers.

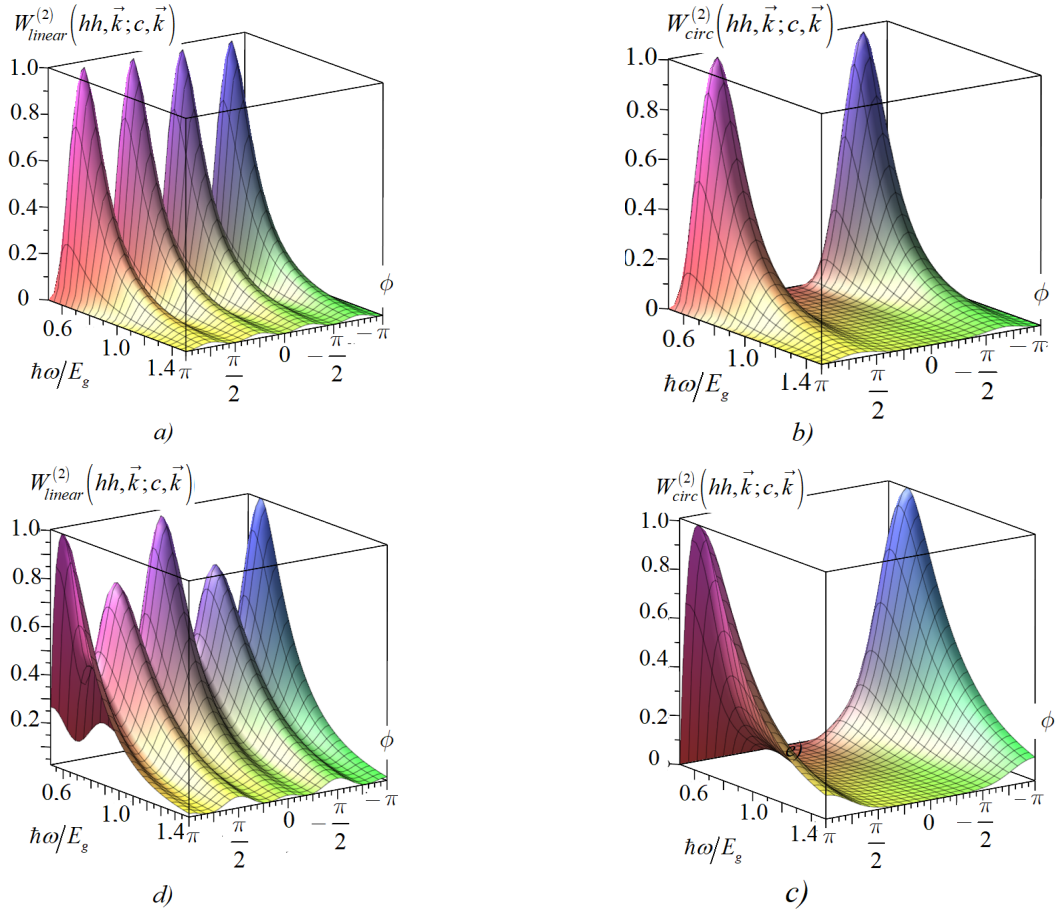

Figure 2. Frequency-angular dependences $W^{(2)}$ for light of linear $W_{linear}^{(2)}$ (a, d) and circular $W_{circ}^{(2)}$ (b, c) polarization for optical transitions from the heavy hole subband to the conduction band in GaAs. In figures a, b it was assumed that $E_g(\mathrm{T}=0\ \mathrm{K})$, and in d, c - $E_g(\mathrm{T}=330\ \mathrm{K})$.

In Fig. 3 shows the frequency-temperature dependences of the probability of $W_{circ}^{(2)}$ two-quantum optical transitions from the subband of light holes to the conduction band of semiconductors InSb (a), InAs (b), GaAs (c) under by the action of circularly polarized light, averaged over the solid angles of the wave vector of the current carriers, where the dependence $E_g(\mathrm{T})$ is taken into account (see Varshni's formula).

Calculations show that taking into account $E_g(\mathrm{T})$ leads to a sharp increase in $W_{circ}^{(2)}$ in low frequency regions and a transition through a maximum, then a hump-shaped dependence (see Fig. 3a) and b)) with increasing frequency at arbitrary temperatures. Note that the greater the width of the band gap, the greater the depth of the hump.

It should be noted that the probability of two-quantum optical transitions under the influence of linearly polarized light $W_{linear}^{(2)}$ exactly repeats the frequency-temperature dependence $W_{circ}^{(2)}$, but the amplitude value is four times smaller.

Calculations show that the probability of two-quantum optical transitions from the heavy hole subband to the conduction band of semiconductors at a fixed temperature increases with increasing frequency and passes through a maximum and sharply decreases regardless of the degree of polarization of light, as well as the band gap. This can be explained by a similar frequency-temperature dependence of the current carrier distribution functions.

It is known [4-10] that the coefficient of two-quantum linear dichroism of light absorption is determined by the probability ratio of $W_{circ}^{(2)}$ to $W_{linear}^{(2)}$, i.e. ratio $\eta^{(2)}=W_{circ}^{(2)}/W_{linear}^{(2)}$. In Fig. 4 shows the frequency-angular dependences $\eta^{(2)}$ caused by optical transitions from the branch of light holes to the conduction band of semiconductors InSb (a),

InAs (b), GaAs (c), where graphs 1 correspond to $E_g(T = 0\ K)$, and graphs 2 - $E_g(T = 30\ K)$ (graphs 2). From Fig. 4 it can be seen that at certain values of the angle $\eta^{(2)}$, regardless of the width of the band gap, it takes on a very large value, which, firstly, is due to the fact that these angles $W^{(2)}_{linear}$ have small values, and secondly, such an anomalous value decreases sharply at $\zeta_g = |p_{c,V}|^2/(m_0 E_g) = 0$, i.e. when we do not take into account the admixture of valence band states to the conduction band states.

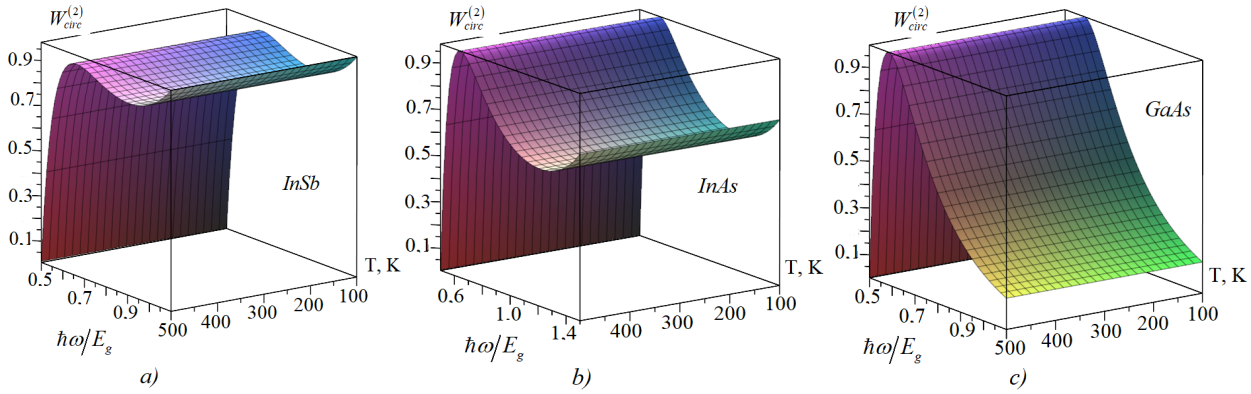

Figure 3. Frequency and temperature dependence of the probability of two-quantum optical transitions $W^{(2)}_{circ}$ from the light hole branch to the conduction band of semiconductors InSb (a), InAs (b), GaAs (c) under the influence of circularly polarized light. The calculations took into account the temperature dependence of the band gap.

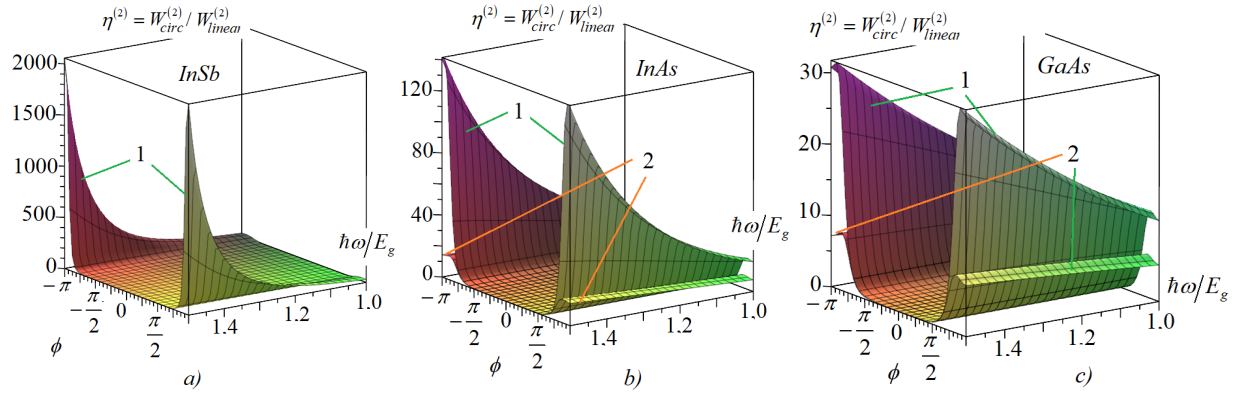

Figure 4. Frequency-angular dependence of the two-quantum coefficient of linear-circular dichroism $\eta^{(2)}$, caused by optical transitions from the branch of light holes to the conduction band of semiconductors InSb (a), InAs (b), GaAs (c), where graphs 1 correspond to $E_g(T = 0\ K)$, and graphs 2 - $E_g(T = 30\ K)$ (graphs 2). The calculations did not take into account the contribution of the coherent saturation effect in $\eta^{(2)}$.

CONCLUSIONS

In conclusion, we note that in Kane's three-band approximation:

A quantitative theory of two-quantum interband linear-circular dichroism in InSb, InAs and GaAs semiconductors is constructed, which takes into account the admixture of valence band states to conduction band states and the temperature dependence of the band gap in the multiband Kane model.

It is shown that the probabilities of interband two-quantum optical transitions in both narrow- and wide-bandgap semiconductors with a frequency rostrum at a fixed temperature first increase, then, passing through a maximum, decreases, regardless of the degree of polarization of the light.

Frequency and temperature dependence of the probability of two-quantum optical transitions $W^{(2)}_{circ}$ from the light hole branch to the conduction band of semiconductors InSb (a), InAs (b), GaAs (c) under the influence of circularly polarized light.

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ВПЛИВ ЗМІШУВАННЯ СТАНІВ ВАЛЕНТНОЇ ЗОНИ ДО СТАНІВ ЗОНИ ПРОВІДНОСТІ НА ДВОКВАНТОВИЙ ЛІНІЙНО-КОЛОВИЙ ДІХРОЇЗМ У НАПІВПРОВІДНИКАХ

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Побудовано кількісну теорію двофотонного лінійно-кругового дихроїзму між підзонами легких і важких дірок валентної зони та зони провідності, яка враховує домішку станів валентної зони до станів зони провідності та температурну залежність ширина забороненої зони (E_g(T)) у напівпровідниках тетраедричної симетрії в багатозонній моделі Кейна. Показано, що вид коливальної кутової залежності або амплітудні значення ймовірностей двофотонних оптичних переходів залежать від стану поляризації світла. Це пояснюється тим, що під дією лінійно поляризованого світла відбувається вирівнювання вздовж імпульсу, а під дією циркулярно поляризованого світла відбувається орієнтація моментів носіїв струму. Визначено, що ймовірність двофотонних оптичних переходів із підзони важких дірок у зону провідності напівпровідників при фіксованій температурі зростає зі збільшенням частоти і проходить через максимум і різко зменшується незалежно від ступеня поляризації світла, оскільки а також ширина забороненої зони.

Ключові слова: *ймовірність двофотонного поглинання світла; частота; температура; коливальна залежність; ступінь поляризації світла; лінійно-круговий дихроїзм; напівпровідник; багатозонна модель Кейна*