

# Influence of Resonant Optical Phonons on Intersubband Magnetoabsorption in Nanowires

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**Abstract**— The investigation concerns the influence of the electron-phonon interaction on the form of bands of the intersubband absorption of a weak electromagnetic wave in quantum wires in a transverse magnetic field. The interaction of the electrons with the long-wavelength acoustic vibrations is taken into account using the relaxation time approximation; the interaction with the optical vibrations is considered in the resonance approximation (the energy of an optical phonon is the difference of the energies of the electronic states between which the transition occurs). In the paper the case of low temperatures is considered, when only the processes with an emission of a non-dispersion optical phonon are realized. It is shown that under these conditions the magnetoabsorption peak splits into two: the half-width of the long-wavelength peak is almost entirely determined by the interaction of electrons with the acoustic vibrations, and the half-width of the short-wavelength peak mainly depends on the interaction of electrons with the optical vibrations. The coefficients of the intersubband absorption of a weak electromagnetic wave for various polarizations were calculated. The influence of polarization of the electromagnetic wave on its absorption was analyzed.

**Keywords**— parabolic quantum wires, intersubband transitions, transverse magnetic field, half-width of optical absorption bands, polarization of light.

## I. INTRODUCTION

Calculation of the optical and kinetic characteristics of quantum wires can be significantly simplified using the model of the parabolic profile of the potential energy carriers in nanowires [1, 2]. This model has a reliable theoretical foundation [2] and is useful for the analysis of experimental data and comparing them with theoretical simulations [1-3].

While investigating the optical properties of a parabolic quantum wire (PQW) in an external magnetic field  $\mathbf{H}$  directed along the Z-axis and perpendicular to the axis of the nanowire (X-axis), it is convenient to use the calibration of the vector potential in the form  $\mathbf{A}(-By, 0, 0)$ . Therefore, the energy spectrum of electrons in the PQW in the transverse magnetic field is described by the following expression:

$$E_\alpha \equiv E_{mn}(k_x) = \frac{\hbar^2 k_x^2}{2m_e^*} + \hbar\omega \left(m + \frac{1}{2}\right) + \hbar\Omega_e \left(n + \frac{1}{2}\right), \quad (1)$$

$$m_e^* = m_e \left(\frac{\Omega_e}{\omega}\right)^2, \quad \hbar\omega = \frac{\hbar}{R} \left[\frac{2\Delta E_c}{m_e}\right]^{1/2},$$

$$\Omega_e = [\omega^2 + \omega_c^2]^{1/2}, \quad \omega_c = \frac{eB}{m_e c}$$

here:  $\alpha = \{k_x, m, n\}$  is a set of quantum numbers describing the state of the band carriers,  $k_x$  is the electron wave vector with the effective mass  $m_e$ ,  $\omega_c$  is the cyclotron frequency,  $c$  is the speed of light,  $\hbar\omega$  is the quantum confinement energy, associated with the height parabolic potential profile  $\Delta E_c$  at the border of the PQW having radius  $R$ , and  $\hbar\Omega_e$  is the energy quantization for the hybrid electron states. It should be noted that for the nanowires with a magnetic permeability  $\mu = 1$ , i.e. for the PQW made from nonmagnetic materials, the magnetic induction vector  $\mathbf{B}$  coincides with the magnetic field vector  $\mathbf{H}$ .

As it follows from (1), the energy spectrum of electrons (Fig. 1) is the additive composition of two sets of equidistant parabolas with the energetic distances  $\hbar\omega$  and  $\hbar\Omega_e$ , respectively.

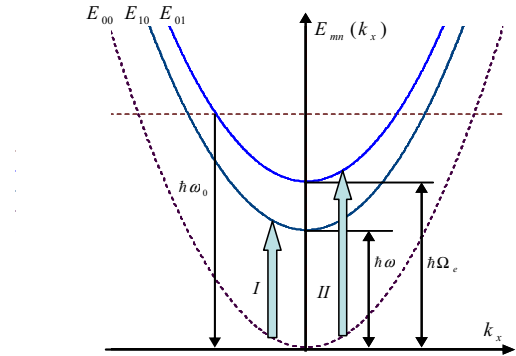


Fig. 1 Energy spectrum of electrons in a parabolic quantum wire in a transverse magnetic field, and studied optical transitions.

Note that according to (1) a curvature of the parabolas depends on the value of the magnetic field strength due to the dependence of the effective mass  $m_e^*$  on the magnitude  $\mathbf{H}$ .

## II. THEORETICAL APPROACH

In this paper, the absorption coefficient of weak electromagnetic wave (EMW) for the electron transitions between the quantized states of the conduction band (transitions I, II in Fig. 1) is calculated with the account of the interaction of electrons with two types of phonons – acoustic and optical. So that the interaction of band carriers with the long-

wavelength acoustic vibrations is considered in the relaxation time approximation [3] and their interaction with the optical phonons is considered in the resonance approximation. In this paper, the case of low temperatures is considered when the processes with absorption of a dispersionless optical phonon can be neglected [4]. Also, note that the indirect optical intersubband transitions associated with the intraband scattering of the optical phonons are neglected.

The most interesting cases are when either the energy of size quantization  $\hbar\omega$  or the energy of hybrid quantization  $\hbar\Omega_e$  is equal to the energy of optical phonon  $\hbar\omega_0$  (the resonance case). For example, if  $\hbar\omega_0 = \hbar\omega$ , then the first size-quantized state  $E_{10}(k_x)$  (see Fig. 1) becomes doubly degenerate and splits into two due to the interaction of electrons with the optical vibrations. A similar situation is in the case of  $\hbar\omega_0 = \hbar\Omega_e$ . This is why the band of the intersubband light absorption for the considered electronic states (transition I, II in Fig. 1) splits into two optical absorption bands. In this approximation, using the method developed in [4], for the coefficient of the intersubband absorption of the weak EMW with the frequency  $\Omega$  and polarization  $\mathbf{\eta}$ , the following expression is obtained:

$$K(\Omega) = \frac{8\pi e^2}{\hbar c V n_0 \Omega} \sum_{\alpha, \alpha_1} \left| \frac{\mathbf{P}_{\alpha\alpha_1} \mathbf{\eta}}{m_e} \right|^2 n_\alpha \times \frac{\Gamma_\alpha + \Gamma_{\alpha_1} + \Gamma_{\alpha\alpha_1}^{opt}}{(\Gamma_\alpha + \Gamma_{\alpha_1} + \Gamma_{\alpha\alpha_1}^{opt})^2 + \hbar^{-2} (E_{\alpha_1} - E_\alpha - \hbar\Omega)^2} \quad (2)$$

here:  $V$  is the volume of the nanostructure,  $n_0$  is the index of light refraction in the given sample,  $\mathbf{P}_{\alpha\alpha_1}$  is the matrix element of the momentum operator on the smoothed wave functions of electrons in the conduction band of the PQW,  $n_\alpha$  is the equilibrium distribution function of electrons in the initial electron state  $\alpha$  with energy  $E_\alpha$ ,  $2\Gamma_\alpha$  is the quantum mechanical probability of elastic scattering of electrons per unit time on the long-wavelength acoustic vibrations of the PQW lattice in a magnetic field.

The calculations [1, 3] show that  $\Gamma_\alpha \sim |k_x|^{-1}$ : this dependence on the wave vector is typical for the one-dimensional quantum systems due to the peculiarities in the energy density of the states of band carriers. The value  $\Gamma_{\alpha\alpha_1}^{opt}$  describes only the effect of optical phonons on the frequency dependence  $K(\Omega)$  because, as it follows from the performed calculations, the contribution of the interaction of electrons with the acoustic oscillations in the value  $\Gamma_{\alpha\alpha_1}^{opt}$  is negligible. At recording (2) it was assumed that in the state  $E_{\alpha_1}$ , in which the optical transition of an electron occurs, there are no band carriers and therefore  $1 - n_{\alpha_1} \cong 1$ . This corresponds to the case of low temperatures  $T$ , i.e.  $k_0 T \ll \hbar\omega$  ( $k_0$  is Boltzmann's constant), hence at the studied optical

transitions the electrons in the initial state are near the bottom of the lowest subband. For the simplicity, also it is assumed that the electron gas in the PQW is non-degenerate. Due to the foregoing assumption in the case of  $\hbar\omega_0 = \hbar\Omega_e$ , an electron realizes transition only at the emission of an optical phonon from the first level ( $m_1 = 0$ ,  $n_1 = 1$ ) to the lowest level ( $m = 0$ ,  $n = 0$ ). Thus, for the value  $\Gamma_{\alpha\alpha_1}^{opt}$ , it is easy to obtain:

$$\Gamma_1^{opt} = \Gamma_0 \left( \frac{\hbar\omega}{\Delta} \right)^{1/2}, \quad (3)$$

$$\Gamma_0 = \frac{e^2 c_0 \omega_0 (1 + \delta^2)^{1/2}}{2\hbar [1 + (1 + \delta^2)^{1/4}]} \left( \frac{m_e}{2\hbar\omega} \right)^{1/2},$$

$$c_0 = \frac{1}{n_0^2} - \frac{1}{\varepsilon}, \quad \delta = \frac{\omega_c}{\omega}, \quad \Delta = \frac{\hbar^2 k_x^2}{2m_e^*} + \hbar\Omega - \hbar\omega_0$$

here:  $\varepsilon$  is the static dielectric constant.

Note that the  $\Gamma_{\alpha\alpha_1}^{opt}$  is different from zero only when  $\Delta > 0$ . So, let us consider the optical transition II in Fig. 1 (at the transition I the situation is analogous): the electron transfers into the hybrid electron state  $E_{01}(k_x)$ , but the emission of an optical phonon from this state, if  $E_{01}(k_x) < \hbar\omega_0$ , cannot take place since otherwise the energy conservation law is violated.

A direct consequence from (3) is the following: the higher the value of  $\mathbf{H}$ , the higher the value of  $\Gamma_{\alpha\alpha_1}^{opt}$ . Therefore, the increase of the carrier localization in the PQW due to the increase of the magnetic field strength leads to the enhancement of the electron-phonon interaction.

In the case when the optical phonon energy is equal to the energy of size quantization  $\hbar\omega_0 = \hbar\omega$ , for the value  $\Gamma_{\alpha\alpha_1}^{opt}$ , the following is obtained:

$$\widetilde{\Gamma_1^{opt}} = \Gamma_0 \left( \frac{\hbar\Omega_e}{\Delta} \right)^{1/2} = \frac{1}{\sqrt{\delta_0}} \Gamma_1^{opt}, \quad (4)$$

$$\delta_0 = \frac{\omega}{\Omega_e} = (1 + \delta^2)^{-1/2},$$

$$\delta_0 < 1$$

It should be noted that according to (2) the coefficient of the intersubband light absorption is essentially dependent on the polarization of the incident EMW.

The calculations of the matrix elements  $\mathbf{P}_{\alpha\alpha_1}$  for different polarizations of the incident EMW give the following expressions:

$$\begin{aligned} |p_{\alpha\beta}^x|^2 &= \frac{\hbar\omega\delta^2 m_c}{2} \delta_{k_x k_x'} \delta_{mm'} \{ (n+1) \delta_{nn'-1} + n \delta_{nn'+1} \}, \\ |p_{\alpha\beta}^y|^2 &= \frac{\hbar\Omega_e m_c}{2} \delta_{k_x k_x'} \delta_{mm'} \{ (n+1) \delta_{nn'-1} + n \delta_{nn'+1} \}, \\ |p_{\alpha\beta}^z|^2 &= \frac{\hbar\omega m_c}{2} \delta_{k_x k_x'} \delta_{nn'} \{ (m+1) \delta_{mm'-1} + m \delta_{mm'+1} \} \end{aligned} \quad (5)$$

As it follows from (5) for the  $X$ - and  $Y$ -polarization of the EMW, the direct optical intersubband transitions can take place only between the hybrid electron states, but for the  $Z$ -polarization of the EMW the direct optical intersubband transitions occur only between the size-quantized states. Also, according to (5), in the absence of a magnetic field ( $\delta = 0$ ), the absorption of the linearly-polarized EMW with the  $X$ -polarization is forbidden.

Finally, in the case of  $\hbar\omega_0 = \hbar\Omega_e$  the intersubband absorption of the linearly-polarized EMW with the  $X$ -polarization is determined by the electron transitions from the lowest state  $E_{00}(k_x)$  to the excited hybrid state of the conduction band  $E_{01}(k_x)$  (transition II, Fig. 1). Thus, the intersubband absorption coefficient  $K^{(X)}(\Omega)$  is expressed as:

$$K^{(X)}(\Omega) = K_0 \delta^2 (1 + \delta^2)^{-1/4} \times \times \frac{\omega}{\Omega} \int_0^\infty e^{-\tau} \frac{1 + b_0 \left(\frac{\tau}{\Delta_0}\right)^{1/2}}{\left(1 + b_0 \left(\frac{\tau}{\Delta_0}\right)^{1/2}\right)^2 + \left(\frac{\Omega_e - \Omega}{\omega_f}\right)^2} \tau_0 \tau d\tau, \quad (6)$$

$$K_0 = \frac{4e^2 k_0 T}{S n_0 c \hbar \omega_f} \left[ \frac{(1 + \delta^2)^{3/2}}{2 m_e \hbar \omega_f} \right]^{1/2} e^{\frac{\xi}{k_0 T}},$$

$$\omega_f = \left[ \frac{\hbar \left(\frac{\gamma_0}{4}\right)^2}{2 m_e^*} \right]^{1/3}, \quad \gamma_0 = \frac{E_1^2 k_0 T m_e^2 \omega}{2 \pi \hbar^4 \rho v_0^2} \left( \frac{\Omega_e}{\omega} \right)^{\frac{5}{2}},$$

$$b_0 = \frac{\Gamma_0}{\omega_f} (\tau_0)^{\frac{1}{2}} \left( \frac{\omega}{\omega_f} \right)^{\frac{1}{2}}, \quad \Delta_0 = \tau_0 \tau - \left( \frac{\Omega_e - \Omega}{\omega_f} \right), \quad \tau_0 = \frac{k_0 T}{\hbar \omega_f}$$

here:  $\xi$  is the chemical potential in the studied quantum system (the value of  $\xi$  is counted from the bottom of the PQW conduction band in the magnetic field),  $S$  is the cross-section of the PQW,  $E_1$  is the constant of a deformation potential,  $v_0$  is the speed of sound in the nanostructure having the density  $\rho$ .

Calculation of the intersubband absorption coefficient for the linearly-polarized EMW with the  $Y$ -polarization (at  $\hbar\omega_0 = \hbar\Omega_e$ ) is carried out in a similar manner, giving the expression  $K^{(Y)}(\Omega)$ , which has a quite similar view as for the expression  $K^{(X)}(\Omega)$ :

$$K^{(Y)}(\Omega) = K_0 (1 + \delta^2)^{1/4} \times \times \frac{\omega}{\Omega} \int_0^\infty e^{-\tau} \frac{1 + b_0 \left(\frac{\tau}{\Delta_0}\right)^{1/2}}{\left(1 + b_0 \left(\frac{\tau}{\Delta_0}\right)^{1/2}\right)^2 + \left(\frac{\Omega_e - \Omega}{\omega_f}\right)^2} \tau_0 \tau d\tau \quad (7)$$

As it follows from (6) and (7), the expression  $K^{(Y)}(\Omega)$  differs from the expression  $K^{(X)}(\Omega)$  only by a factor, so that  $K^{(Y)}(\Omega) = \delta^{-2} (1 + \delta^2)^{1/2} \cdot K^{(X)}(\Omega)$ .

The intersubband absorption of the linearly-polarized EMW with the  $Z$ -polarization (i.e., light propagates along

the axis of the nanowire) is determined by the electron transitions in the conduction band from the lowest state  $E_{00}(k_x)$  to the excited size-quantized state  $E_{10}(k_x)$  (transition I, Fig. 1). Thus, the expression for the intersubband absorption coefficient  $K^{(Z)}(\Omega)$  in the case of  $\hbar\omega_0 = \hbar\omega$  has the following form:

$$K^{(Z)}(\Omega) = K_0 (1 + \delta^2)^{-1/4} \times \times \frac{\omega}{\Omega} \int_0^\infty e^{-\tau} \frac{1 + b_1 \left(\frac{\tau}{\Delta_1}\right)^{1/2}}{\left(1 + b_1 \left(\frac{\tau}{\Delta_1}\right)^{1/2}\right)^2 + \left(\frac{\omega - \Omega}{\omega_f}\right)^2} \tau_0 \tau d\tau, \quad (8)$$

$$b_1 = (1 + \delta^2)^{1/4} b_0, \quad \Delta_1 = \tau_0 \tau - \left( \frac{\omega - \Omega}{\omega_f} \right)$$

Note that the structure of the expression  $K^{(Z)}(\Omega)$  is also similar to that of the expression  $K^{(X)}(\Omega)$ . As it follows from the comparison of formulas (6) and (8), they can be converted into each other. So, (8) is obtained from (6) taking into account (3) and (4), then the value  $b_0$  is replaced by  $b_1$  and the value  $\Delta_0$  is replaced by  $\Delta_1$ . Thus, the expression  $K^{(Z)}(\Omega)$  is obtained from the expression  $K^{(X)}(\Omega)$  if the substitution  $\hbar\Omega_e \rightarrow \hbar\omega$  in integral in (6) is performed. Also, the expression  $K^{(X)}(\Omega)$  unlike the expression  $K^{(Z)}(\Omega)$  contains in a front of the integral the additional factor  $\delta^2$ , which appears since, according to (5), the value  $|P_{\alpha\alpha_1}^X|^2$  for the  $X$ -polarized EMW and the value  $|P_{\alpha\alpha_1}^Z|^2$  for the  $Z$ -polarized EMW differ from each other by this factor.

### III. RESULTS AND DISCUSSION

For an implementation of the numerical calculations and subsequent estimates, the following parameters, typical for semiconductor quantum wires, are considered:  $m_e = 0.06 m_0$ ,  $E_1 = 10$  eV,  $\Delta E_c = 0.255$  eV,  $c_0 = 0.014$ ,  $\rho = 5.4$  g/cm<sup>3</sup>,  $v_0 = 3 \cdot 10^5$  cm/s. In this case  $\hbar\omega = 8.05 \cdot R_0^{-1}$  eV (here,  $R_0$  is the numerical value of the PQW radius  $R$  given in Å) and, therefore, the energy of the limiting optical phonon  $\hbar\omega_0 = 0.03$  eV is equal to the energy of size quantization  $\hbar\omega$  if  $R \approx 270$  Å.

Note that when the magnetic field  $\mathbf{H}$  is increased, the energy of the hybrid quantization  $\hbar\Omega_e$  increases respectively, and the resonance case occurs at larger values of the PQW radius. (For example, if  $\delta = 1$ , then  $R \approx 380$  Å). Also, note that at smaller values  $\hbar\omega_0$  the resonance value of the nanowire radius increases.

Curves 1 and 2 in each of the cases considered below (see Figs. 2, 3, and 4) are normalized on the identical value  $K_0$ . For this, the reduced chemical potential  $\tilde{\xi} = \frac{\xi}{k_0 T}$  is chosen so that it has the same value in each of these cases.

Note that the pre-exponential factor in  $K_0$  is not changed at varying  $\mathbf{H}$  and  $T$ , since the value  $(\hbar\omega_f)^{3/2} \sim T \cdot (1 + \delta^2)^{3/4}$ .

Fig. 2 (in arbitrary units) shows the influence of temperature on the frequency dependence of the intersubband absorption coefficient for the X-polarized EMW in the case of  $\hbar\omega_0 = \hbar\Omega_e$  (transition II, Fig. 1) at the fixed magnitudes of  $\mathbf{H}$  and  $R$ , respectively:  $\delta = 1$  and  $R = 380 \text{ \AA}$ . Curves 1 and 2 in Fig. 2 were calculated at  $T = 40 \text{ }^\circ\text{K}$  and  $T = 60 \text{ }^\circ\text{K}$ . For curve 1 –  $\hbar\omega_f = 3.14 \cdot 10^{-4} \text{ eV}$ ,  $b_0 = 72.89$ ,  $\tau_0 = 10.97$ , and for curve 2 –  $\hbar\omega_f = 4.12 \cdot 10^{-4} \text{ eV}$ ,  $b_0 = 52.00$ ,  $\tau_0 = 12.56$ . Here, the appropriate graphs only for the value  $K^{(X)}(\Omega)$  are provided, since the influence of temperature on the value  $K^{(Y)}(\Omega)$  is completely identical.

Fig. 3 (in arbitrary units) shows the influence of the magnetic field on the frequency dependence of the intersubband absorption coefficient for the Z-polarized EMW in the case of  $\hbar\omega_0 = \hbar\omega$  (transition I, Fig. 1). Curves 1 ( $\delta = 0$ ) and 2 ( $\delta = 1$ ) in Fig. 3 were obtained at  $R = 270 \text{ \AA}$ ,  $T = 40 \text{ }^\circ\text{K}$ . This corresponds to  $b_1 = 71.54$ ,  $\tau_0 = 12.35$ ,  $\hbar\omega_f = 2.79 \cdot 10^{-4} \text{ eV}$  for curve 1 and  $b_1 = 54.96$ ,  $\tau_0 = 8.74$ ,  $\hbar\omega_f = 3.95 \cdot 10^{-4} \text{ eV}$  for curve 2.

Fig. 4 (in arbitrary units) shows the influence of temperature on the value  $K^{(Z)}(\Omega)$ . Curves 1 ( $T = 40 \text{ }^\circ\text{K}$ ) and 2 ( $T = 60 \text{ }^\circ\text{K}$ ) in Fig. 4 were obtained at  $R = 270 \text{ \AA}$ ,  $\delta = 1$ . This corresponds to  $b_1 = 54.96$ ,  $\tau_0 = 8.74$ ,  $\hbar\omega_f = 3.95 \cdot 10^{-4} \text{ eV}$  for curve 1 and  $b_1 = 39.20$ ,  $\tau_0 = 10.00$ ,  $\hbar\omega_f = 5.17 \cdot 10^{-4} \text{ eV}$  for curve 2.

As it follows directly from Figs. 2, 3, and 4, the magnetoabsorption band of the linearly-polarized EMW splits into two peaks. Without an account of the resonant optical phonons, the band of the intersubband light absorption is

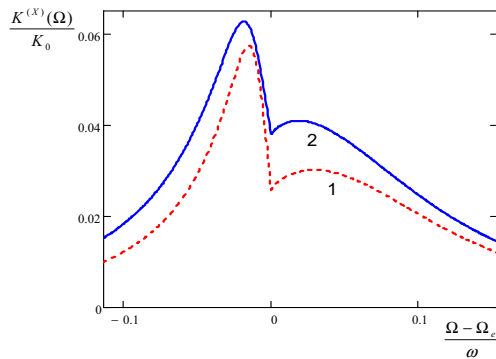


Fig. 2 Frequency dependence of intersubband absorption of linearly-polarized EMW with the X-polarization (arbitrary units) at different temperatures. Curve 1 – at  $T = 40 \text{ }^\circ\text{K}$  and curve 2 – at  $T = 60 \text{ }^\circ\text{K}$ .

centered at a frequency of  $\Omega = \omega$  (or  $\Omega = \Omega_e$ ) which corresponds to the transition I (or II) in Fig. 1. The rise of magnetic field strength  $\mathbf{H}$  results in the broadening of both peaks and their shift away from each other (see Fig. 3), so that the maximum of the 1<sup>st</sup> peak (long-wavelength) moves into the low-frequency domain of the spectrum, and the maximum of the 2<sup>nd</sup> peak (short-wavelength) moves into the high-frequency domain of the spectrum. It should be noted that with the rise of temperature (see Figs. 2, 4) the half-width of the long-wavelength peak increases, but the half-width of the short-wavelength peak is weakly dependent on temperature. Also, with the rise of temperature both peaks are shifted into the low-frequency domain of the spectrum (this trend continues up to  $T = 100 \text{ }^\circ\text{K}$ ).

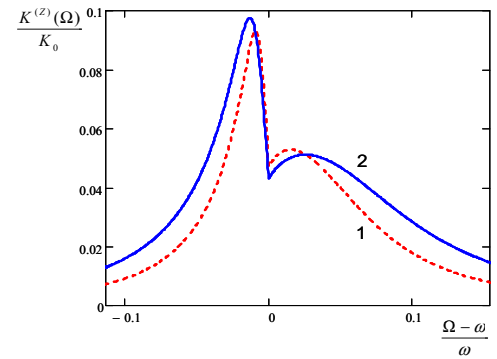


Fig. 3 Frequency dependence of intersubband absorption of linearly-polarized EMW with the Z-polarization (arbitrary units) at different values of magnetic field strength. Curve 1 – at  $\delta = 0$  and curve 2 – at  $\delta = 1$ .

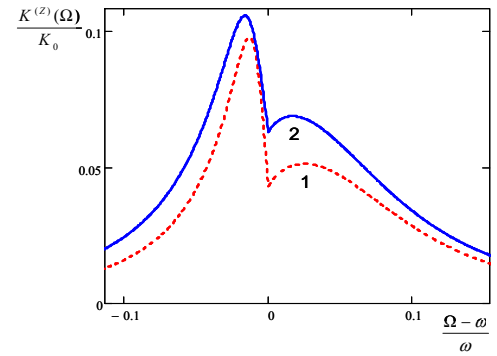


Fig. 4 Frequency dependence of intersubband absorption of linearly-polarized EMW with the Z-polarization (arbitrary units) at different temperatures. Curve 1 – at  $T = 40 \text{ }^\circ\text{K}$  and curve 2 – at  $T = 60 \text{ }^\circ\text{K}$ .

From the obtained results it follows that the half-width of the 1<sup>st</sup> absorption peak is almost completely determined by the interaction of electrons with the acoustic phonons, and

the half-width of the 2<sup>nd</sup> absorption peak mainly depends on the interaction of electrons with the optical phonons.

In the case of a circularly-polarized EMW, the intersubband absorption coefficient is equal to a half of the sum of corresponding components. So, for the EMW with the  $XY$ -polarization (light propagates in the direction of the magnetic field vector  $\mathbf{H}$ ):  $K^{(XY)}(\Omega) = \frac{1}{2}[K^{(X)}(\Omega) + K^{(Y)}(\Omega)]$ . Hence, the frequency dependence of the intersubband absorption coefficient for the circularly-polarized EMW has the features similar to those shown in Figs. 2, 3, and 4.

#### IV. CONCLUSIONS

The results presented in this paper show that the interaction of band carriers with the resonance optical phonons is an important factor, which should be taken into account in the study of the optical properties of nanowires. The resonance optical phonons essentially change the energetic spectrum of the carriers in the nanowires and that, as a result, leads to the emergence of the features in the frequency dependences of the absorption coefficients of a weak EMW. So, it was shown that the peak of the intersubband light absorption splits into two due to the resonance optical phonons. Herewith, the interaction of electrons with the resonance optical vibrations gives the main contribution into the half-width of the short-wavelength peak, and the interaction of electrons with the long-wavelength acoustical vibrations gives the main contribution into the half-width of the long-wavelength peak.

Thus, the offered theoretical approach is quite acceptable to describe the intersubband absorption of the light with different polarizations in the semiconductor nanowires and to investigate the influence of the external parameters (magnetic field, temperature) and the internal parameters of nanowires on their optical absorption spectra.

Finally, basing on the fact that the quantum wires along with other size-quantized systems (quantum dots and films), as the basic elements, are widely used in optoelectronics and nanoelectronics, it should be noted that the performed research is actual for biotechnological applications. Since, the results obtained here can be claimed at designing of the various biosensors and at creating of the new nanostructured

biocomposites whose properties are controlled by the external fields. Also, the given results are interesting for the empowerment of diagnostic methods of organic materials, such for example, as a method of organic mass spectrometry [5], in which the quantum wires have found an effective implementation.

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#### CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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