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The Hall Coefficient and Magnetoresistance in Rectangular Quantum Wires with Infinitely High Potential under the Influence of a Laser Radiation

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Abstract**—**The Hall Coefficient (HC) and the Magnetoresistance (MR) have been studied in two-dimensional systems. The HC and the MR in Rectangular Quantum Wire (RQW) subjected to a crossed DC electric field and magnetic field in the presence of a Strong Electromagnetic Wave (EMW) characterized by electric field are studied in this work. Using the quantum kinetic equation for electrons interacting with optical phonons, we obtain the analytic expressions for the HC and the MR with a dependence on magnetic field, EMW frequency, temperatures of systems and the length characteristic parameters of RQW. These expressions are different from those obtained for bulk semiconductors and cylindrical quantum wires. The analytical results are applied to GaAs/GaAs/Al. For this material, MR depends on the ratio of the EMW frequency to the cyclotron frequency. Indeed, MR reaches a minimum at the ratio 5/4, and when this ratio increases, it tends towards a saturation value. The HC can take negative or positive values. Each curve has one maximum and one minimum. When magnetic field increases, the HC is negative, achieves a minimum value and then increases suddenly to a maximum with a positive value. This phenomenon differs from the one observed in cylindrical quantum wire, which does not have maximum and minimum values.

Keywords—Hall coefficient, rectangular quantum wires, electron-optical phonon interaction, quantum kinetic equation.

I. Introduction

IN the past few years there have been many exciting development in the study of the Hall Effect in two dimensional systems (2D). The Hall Effect in bulk semiconductor in the presence of an EMW has been studied in much detail [1]-[5], two of which odd magnetophotoresistance effect have been observed [1], [2]. These two works only considered the case when the EMW was absent. However, the magnetoresistance was derived in the presence of a strong EMW for two cases of the magnetic field vector and the electric field vector of the EMW: perpendicular [3], and parallel [4]. The quantum kinetic equation was used to calculate the nonlinear absorption coefficients of an intense EMW in quantum wells [6], [7]. The authors of [8] showed the influence of a strong electromagnetic wave on the Hall coefficient in Doped Semiconductor Superlattices with an in-plane magnetic field. Dependence of the Hall Coefficient on Doping Concentration in Doped Semiconductor Superlattices with a Perpendicular Magnetic Field under the Influence of a Laser Radiation has been studied in [19]. The HC in quantum wires has been studied in many aspects. However, most of the previous works only considered the case when the EMW was absent.

The Hall Effect in one-dimensional systems under the influence of EMW for case that the absence has been studied in [9]-[18]. The one- dimensional Hall effect can be observed noninvasively, is quantized, and is not quenched at low magnetic fields [9]. Electrical transport is considered along a quantum wire in the presence of a perpendicular magnetic field at very low temperatures [10]. Theory of the Hall effect in quantum wires: Effects of scattering have been considered carefully [11]-[13], [17]. Comparing conductance quantization in quantum wires and quantum Hall systems are studied [15]. A quantum Hall effect was calculated without Landau levels in a quasi-one-dimensional system [14], [18]. Based on the quantum kinetic equation for electrons, we theoretically study the influence of EMW on the Hall effect in a cylindrical quantum wire with infinitely high potential [20]. The dependence of the HC under EMW in quantum wires with different directions of external fields still remains open for investigation, especially by analytical and computational methods.

In this work, we study Hall Effect in a RQW with infinitely high potential and in the presence of a laser radiation, subjected to a crossed dc electric field and magnetic field in the presence of a strong EMW characterized by electric field. Our main tool is the quantum kinetic equation for distribution function of electrons interacting with optical phonons. Our goal is to make a comparison between our calculation and other experiments and theories. In cylindrical quantum wire, the HC also depends on magnetic field, but the dependence does not have a maximum and a minimum as in RQW.

This paper is organized as follows. In the next section, we describe the simple model of a RQW and present briefly the basic formulas for the calculation. Numerical results and discussion are given in Section IV. Finally, remarks and conclusions are show briefly in Section V.

II. Hamiltonian of Electron – Phonon System in a Rectangular Quantum Wire with Infinitely High Potential in the Presence of a Laser Radiation

We consider a RQW with the sire of three axes L_x, L_y, L_z, respectively. It is assumed that the dimension z is quantized (electron can move freely in this direction), while electron detention is enforced in the remaining two dimensions (x and y). The effective mass of the electron is denoted as m. The

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RQW is subjected to a crossed dc electric field $\vec{E}=(0,0,E)$ and magnetic field $\vec{B}=(B,0,0)$ in the presence of a strong EMW characterized by electric field $\vec{E}=(0,0,E_o\sin\Omega t)$. Under these conditions, the wave function and energy spectrum can be written as:

$$\psi_{\gamma,\vec{k}}(x,y,z)=\sqrt{\frac{1}{L_z}}e^{ikz}\sqrt{\frac{2}{L_x}}\sin\left(\frac{n\pi x}{L_x}\right)\sqrt{\frac{2}{L_y}}\sin\left(\frac{l\pi y}{L_y}\right)\quad \text{when}\ \begin{cases}0\le y\le L_y\\ 0\le x\le L_x\end{cases}$$

and $\psi_{\gamma,\vec{k}}(x,y,z)=0$ if else.

$$\varepsilon_\gamma(k)=\frac{\hbar^2k^2}{2m^*}+\frac{\pi^2\hbar^2}{2m^*}\left(\frac{n^2}{L_x^2}+\frac{l^2}{L_y^2}\right)+\omega_c(N+\frac{1}{2})-\frac{1}{2m^*}\left(\frac{eE}{\omega_c}\right)^2.$$

The Hamiltonian for electron - phonon interacting system in external field can be written as:

$$\begin{aligned}H&=\sum_{\gamma,\vec{k}}\varepsilon_\gamma(\vec{k}-\frac{e}{c}\vec{A}_{(t)})a^+_{\gamma,\vec{k}}a_{\gamma,\vec{k}}+\sum_{\vec{q}}\omega_{\vec{q}}b^+_{\vec{q}}b_{\vec{q}}+\\&+\sum_{\gamma,\gamma',\vec{k},\vec{q}}\left|C_{\vec{q}}\right|^2\left|I_{\gamma,\gamma'}(\vec{q})\right|^2a^+_{\gamma,\vec{k}+\vec{q}}a_{\gamma',\vec{k}}(b_{\vec{q}}+b^+_{-\vec{q}})+\sum_{\vec{q}}\varphi(\vec{q})a^+_{\gamma,\vec{k}+\vec{q}}a_{\gamma',\vec{k}}.\end{aligned}\tag{1}$$

where $a^+_{\gamma,\vec{k}}$ and $a_{\gamma,\vec{k}}$ ($b^+_{\vec{q}}$ and $b_{\vec{q}}$) are the creation and annihilation operators of electron (optical phonon); $\vec{k}$ is the electron wave momentum ; $\vec{q}$ is the phonon wave vector; $\omega_{\vec{q}}$ are optical phonon frequency; γ and γ' are the quantum numbers (n,ℓ) and (n',ℓ') of electron. N, N' are the Landau level $(N=0,1,2,...)$.

The electron form factor $I_{\gamma,\gamma'}(\vec{q})$ can be written as:

$$I_{\gamma,\gamma'}(q)=\frac{32\pi^4(q_xL_xnn')^2(1-(-1)^{n+n'}\cos(q_xL_x))}{\left[(q_xL_x)^4-2\pi^2(q_xL_x)^2(n^2+n'^2)+\pi^4(n^2-n'^2)^2\right]^2}\times\frac{32\pi^4(q_yL_yll')^2(1-(-1)^{l+l'}\cos(q_yL_y))}{\left[(q_yL_y)^4-2\pi^2(q_yL_y)^2(l^2+l'^2)+\pi^4(l^2-l'^2)^2\right]^2}$$

$\left|C_{\vec{q}}\right|^2=\frac{2\pi e^2\hbar\omega_{\vec{q}}}{Vq^2}(\frac{1}{\chi_\infty}-\frac{1}{\chi_o})$; $A(t)=\frac{1}{\Omega}E_0\cos(\Omega t)$ is the potential vector, depending on the external field. In that formula $V,\rho,\xi,\upsilon_s,\chi_o,\chi_\infty$ are the volume, the density, the deformation potential, the sound velocity, the static dielectric constant, and the high frequency dielectric constant, respectively.

$\varphi(\vec{q})$ is the potential undirected:

$$\varphi(\vec{q})=(2\pi i)^3(e\vec{E}+\omega_c[\vec{q},\vec{h}])\frac{\partial}{\partial\vec{q}}\delta(\vec{q}).$$

Quantum kinetic equation in units of $\hbar=1$ is:

$$i\frac{\partial n_{\gamma,\vec{k}}}{\partial t}=\left\langle\left[a^+_{\gamma,\vec{k}}a_{\gamma,\vec{k}},H\right]\right\rangle_t\tag{2}$$

where $n_{\gamma,k}=\left\langle a^+_{\gamma,\vec{k}}a_{\gamma,\vec{k}}\right\rangle_t$ is the particle number operator.

III. Quantum Kinetic Equation for Electrons in a Rectangular Quantum Wires with Infinitely High Potential

By using Hamiltonian equation (1) for electron - phonon interacting system in a RQW with infinitely high potential, and quantum kinetic equations (2), we obtain quantum kinetic equations in which the equation for optical phonon can be written as:

$$\begin{aligned}&\frac{\sum_{\gamma,\vec{k}}\frac{e}{m}\vec{k}n_{\gamma,\vec{k}}\delta(\varepsilon-\varepsilon_{\gamma,\vec{k}})}{\tau(\varepsilon_{\gamma,\vec{k}})}+\omega_c\left[\vec{h},\sum_{\gamma,\vec{k}}\frac{e}{m}\vec{k}n_{\gamma,\vec{k}}\delta(\varepsilon-\varepsilon_{\gamma,\vec{k}})\right]=\\&=-\frac{e}{m}\sum_{\gamma,\vec{k}}\vec{k}\left(\vec{F}\frac{\partial n_{\gamma,\vec{k}}}{\partial\vec{k}}\right)\delta(\varepsilon-\varepsilon_{\gamma,\vec{k}})+\frac{2\pi e}{m}\sum_{\gamma,\gamma',\vec{q},\vec{k}}\left|C(\vec{q})\right|^2\left|I_{\gamma,\gamma'}(\vec{q})\right|^2N_{\vec{q}}\vec{k}\times\\&\times\Bigg\{\left[\bar{n}_{\gamma',\vec{q}+\vec{k}}-\bar{n}_{\gamma,\vec{k}}\right]\Bigg[\left(1-\frac{\lambda^2}{2\Omega^2}\right)\delta\left(\varepsilon_{\gamma',\vec{k}+\vec{q}}-\varepsilon_{\gamma,\vec{k}}-\omega_o\right)+\frac{\lambda^2}{4\Omega^2}\delta\left(\varepsilon_{\gamma',\vec{k}+\vec{q}}-\varepsilon_{\gamma,\vec{k}}-\omega_o+\Omega\right)+\\&+\frac{\lambda^2}{4\Omega^2}\delta\left(\varepsilon_{\gamma',\vec{k}+\vec{q}}-\varepsilon_{\gamma,\vec{k}}-\omega_o-\Omega\right)\Bigg]+\left[\bar{n}_{\gamma',\vec{k}-\vec{q}}-\bar{n}_{\gamma,\vec{k}}\right]\Bigg[\left(1-\frac{\lambda^2}{2\Omega^2}\right)\delta\left(\varepsilon_{\gamma',\vec{k}-\vec{q}}-\varepsilon_{\gamma,\vec{k}}+\omega_o\right)+\\&+\frac{\lambda^2}{4\Omega^2}\delta\left(\varepsilon_{\gamma',\vec{k}-\vec{q}}-\varepsilon_{\gamma,\vec{k}}+\omega_o-\Omega\right)+\frac{\lambda^2}{4\Omega^2}\delta\left(\varepsilon_{\gamma',\vec{k}-\vec{q}}-\varepsilon_{\gamma,\vec{k}}+\omega_o+\Omega\right)\Bigg]\Bigg\}\delta(\varepsilon-\varepsilon_{\gamma,\vec{k}})\end{aligned}\tag{3}$$

$\tau(\varepsilon_{\gamma,\vec{k}})$ is the recovery time of the electron momentum; k_B is Boltzman constant. Equation (3) can be rewritten as:

$$\frac{\vec{R}_{(\varepsilon)}}{\tau_{(\varepsilon)}}+\omega_c\left[\vec{h}\wedge\vec{R}\right]=\overrightarrow{Q_{(\varepsilon)}}+\overrightarrow{S_{(\varepsilon)}}\tag{4}$$

where:

$$\vec{R}_{(\varepsilon)}=\sum_{\gamma,\vec{k}}\frac{e}{m}\vec{k}n_{\gamma,\vec{k}}\delta(\varepsilon-\varepsilon_{\gamma,\vec{k}});\tag{5}$$

$$\vec{Q}_{(\varepsilon)}=-\frac{e}{m}\sum_{\gamma,\vec{k}}\vec{k}\left(\vec{F}\frac{\partial n_{\gamma,\vec{k}}}{\partial\vec{k}}\right)\delta(\varepsilon-\varepsilon_{\gamma,\vec{k}})\ ;\ \vec{F}=e.\vec{E}_1;\tag{6}$$

$$\begin{aligned}\overrightarrow{S_{(\varepsilon)}}&=\frac{2\pi e}{m}\sum_{\gamma,\gamma',\vec{q},\vec{k}}\left|C(\vec{q})\right|^2\left|I_{\gamma,\gamma'}(\vec{q})\right|^2N_{\vec{q}}\vec{k}\times\\&\times\Bigg\{\left[\bar{n}_{\gamma,\vec{q}+\vec{k}}-\bar{n}_{\gamma,\vec{k}}\right]\Bigg[\left(1-\frac{\lambda^2}{2\Omega^2}\right)\delta\left(\varepsilon_{\gamma',\vec{k}+\vec{q}}-\varepsilon_{\gamma,\vec{k}}-\omega_o\right)+\frac{\lambda^2}{4\Omega^2}\delta\left(\varepsilon_{\gamma',\vec{k}+\vec{q}}-\varepsilon_{\gamma,\vec{k}}-\omega_o+\Omega\right)+\\&+\frac{\lambda^2}{4\Omega^2}\delta\left(\varepsilon_{\gamma',\vec{k}+\vec{q}}-\varepsilon_{\gamma,\vec{k}}-\omega_o-\Omega\right)\Bigg]+\left[\bar{n}_{\gamma,\vec{k}-\vec{q}}-\bar{n}_{\gamma,\vec{k}}\right]\Bigg[\left(1-\frac{\lambda^2}{2\Omega^2}\right)\delta\left(\varepsilon_{\gamma',\vec{k}-\vec{q}}-\varepsilon_{\gamma,\vec{k}}+\omega_o\right)+\\&+\frac{\lambda^2}{4\Omega^2}\delta\left(\varepsilon_{\gamma',\vec{k}-\vec{q}}-\varepsilon_{\gamma,\vec{k}}+\omega_o-\Omega\right)+\frac{\lambda^2}{4\Omega^2}\delta\left(\varepsilon_{\gamma',\vec{k}-\vec{q}}-\varepsilon_{\gamma,\vec{k}}+\omega_o+\Omega\right)\Bigg]\Bigg\}\delta(\varepsilon-\varepsilon_{\gamma,\vec{k}}).\end{aligned}\tag{7}$$

Solving (5) gives:

$$\vec{R}_{(\varepsilon)} = \frac{\tau(\varepsilon)}{1+\omega_c^2\tau^2(\varepsilon)}\left\{\left(\vec{Q}(\varepsilon)+\vec{S}(\varepsilon)\right) - \omega_c\,\tau(\varepsilon)\left(\left[\vec{h},\vec{Q}(\varepsilon)\right]+\left[\vec{h},\vec{S}(\varepsilon)\right]\right)+ +\omega_c^2\tau^2(\varepsilon)\left(\vec{Q}(\varepsilon)+\vec{S}(\varepsilon),\vec{h}\right)\vec{h}\right\}. \quad (8)$$

We have a full current density:

$$\vec{j} = \int_0^\infty \overrightarrow{R_{(\varepsilon)}}\, d\varepsilon. \quad (9)$$

From quantum kinetic equations, after several operator calculations, we have the link between the current density j_i and the Hall conductivity σ_{ij}:

$$j_i = L_0(Q_i) + L_0(S_i) = \sigma_{ij} E_j; \quad (10)$$

$$\sigma_{ij} = \frac{L_o(Q_i)+L_o(S_i)}{E_j}. \quad (11)$$

$$L_0(\vec{X}) = \int_0^\infty \frac{\tau_{(\varepsilon)}}{1+\omega_c^2\tau_{(\varepsilon)}^2}\left\{\vec{X} - \omega_c\tau_{(\varepsilon)}\left[\vec{h}\wedge\vec{X}\right] + \omega_c^2\tau_{(\varepsilon)}^2\left(\vec{h},\vec{X}\right)\vec{h}\right\}. \quad (12)$$

$\vec{X}$ is $\vec{Q}_i$ or $\vec{S}_i$. From electron distribution:

$$\overline{n}_{\gamma,\vec{k}} \equiv n^o_{\gamma,\vec{k}} - \vec{k}\,\vec{\chi}(\varepsilon_{\gamma,\vec{k}})\frac{\partial n^{(o)}_{\gamma,\vec{k}}}{\partial\varepsilon_{\gamma,\vec{k}}};\; n^o_{\gamma,\vec{k}} = e^{\beta(\varepsilon_F-\varepsilon_{\gamma,\vec{k}})}, \beta = \frac{1}{k_B T}.$$

After several operator calculations, we have:

$$\sigma_{ij} = \frac{ea\tau}{1+\omega_c^2\tau^2}\left(\delta_{ij} - \omega_c\tau\varepsilon_{ijk}h_k + \omega_c^2\tau h_i h_j\right) + \frac{b}{m}\frac{\tau^2}{\left(1+\omega_c^2\tau^2\right)^2}\times \times\left[\left(1-\omega_c^2\tau^2\right)\delta_{ij} + \left(3\omega_c^2\tau^2+\omega_c^4\tau^4\right)h_i h_j - \omega_c\tau\varepsilon_{ijk}h_k\right]. \quad (13)$$

where δ_{ij} is the Kronecker delta; ε_{ijk} being the antisymmetrical Levi – Civita tensor; the Latin h_k, h_i, h_j stand for the components x, y, z of the Cartesian coordinate system;

The HC is determined by [7]:

$$R_H = -\frac{1}{B}\frac{\sigma_{xz}}{\sigma_{xz}^2+\sigma_{zz}^2}. \quad (14)$$

where: σ_{xz} and σ_{zz} are given by (13).

$$a = \frac{e\beta L_x}{4m\sqrt{\pi}}\left(\frac{2m}{\beta\hbar^2}\right)^{1/2}\exp\left\{\beta\left[\varepsilon_F + \frac{1}{2m}\left(\frac{eE_1}{\omega_c}\right)^2 - \frac{\pi^2\hbar^2}{2m}\left(\frac{n^2}{L_x^2}+\frac{l^2}{L_y^2}\right) - \omega_c\left(N+\frac{1}{2}\right)\right]\right\},$$

$$b = \frac{2\pi e N_o}{m}\sum_{\gamma,\gamma'}(A_1+A_2+A_3+A_4+A_5+A_6+A_7+A_8),$$

$$A_1 = \frac{\beta L_x k_B T e^2}{8\sqrt{2}\pi^3}\left(\frac{1}{\chi_\infty}-\frac{1}{\chi_o}\right)I_{\gamma,\gamma'}e^{-\beta\frac{B_{11}}{4}}\left(\sqrt{\frac{\pi}{2\beta m}}e^{-\beta\frac{B_{11}}{2}} + (2B_{11}m)^{1/2}K_{\frac{1}{2}}(\beta\frac{B_{11}}{2})^2\right)e^I,$$

$$A_2 = \frac{\beta L_x k_B T e^4 E_o^2 B_{11}\sqrt{\pi}}{16m^2(\beta/8m)^{3/2}}\left(\beta+\frac{1}{B_{11}}\right)\left(\frac{1}{\chi_\infty}-\frac{1}{\chi_o}\right)I_{\gamma,\gamma'}.e^I,$$

$$A_3 = \frac{\beta L_x k_B T e^4 E_o^2 B_{13}\sqrt{\pi}}{16m^2(\beta/8m)^{3/2}}\left(\beta+\frac{1}{B_{13}}\right)\left(\frac{1}{\chi_\infty}-\frac{1}{\chi_o}\right)I_{\gamma,\gamma'}.e^I,$$

$$A_4 = \frac{\beta L_x k_B T e^4 E_o^2 B_{14}\sqrt{\pi}}{16m^2(\beta/8m)^{3/2}}\left(\beta+\frac{1}{B_{14}}\right)\left(\frac{1}{\chi_\infty}-\frac{1}{\chi_o}\right)I_{\gamma,\gamma'}.e^I,$$

$$A_5 = \frac{\beta L_x k_B T e^2}{8\sqrt{2}\pi^3}\left(\frac{1}{\chi_\infty}-\frac{1}{\chi_o}\right)I_{\gamma,\gamma'}e^{-\beta\frac{B_{15}}{4}}\left(\sqrt{\frac{\pi}{2\beta m}}e^{-\beta\frac{B_{15}}{2}} + (2B_{15}m)^{1/2}K_{\frac{1}{2}}(\beta\frac{B_{15}}{2})^2\right)e^I,$$

$$A_6 = \frac{\beta L_x k_B T e^4 E_o^2 B_{15}\sqrt{\pi}}{16m^2(\beta/8m)^{3/2}}\left(\beta+\frac{1}{B_{15}}\right)\left(\frac{1}{\chi_\infty}-\frac{1}{\chi_o}\right)I_{\gamma,\gamma'}.e^I,$$

$$A_7 = \frac{\beta L_x k_B T e^4 E_o^2 B_{17}\sqrt{\pi}}{16m^2(\beta/8m)^{3/2}}\left(\beta+\frac{1}{B_{17}}\right)\left(\frac{1}{\chi_\infty}-\frac{1}{\chi_o}\right)I_{\gamma,\gamma'}.e^I,$$

$$A_8 = \frac{\beta L_x k_B T e^4 E_o^2 B_{18}\sqrt{\pi}}{16m^2(\beta/8m)^{3/2}}\left(\beta+\frac{1}{B_{18}}\right)8\left(\frac{1}{\chi_\infty}-\frac{1}{\chi_o}\right)I_{\gamma,\gamma'}.e^I,$$

$$B_{11} = \frac{\pi^2\hbar^2}{2m}\left(\frac{n'^2-n^2}{L_x^2}+\frac{l'^2-l^2}{L_y^2}\right) - \omega_c\left(N'-N\right) - \omega_o,$$

$$B_{13} = B_{11}+\Omega\ ,\ B_{14} = B_{11}-\Omega\ ,\ \beta = 1/(k_B T)$$

$$B_{15} = \frac{\pi^2\hbar^2}{2m}\left(\frac{n'^2-n^2}{L_x^2}+\frac{l'^2-l^2}{L_y^2}\right) - \omega_c\left(N'-N\right) + \omega_o,$$

$$B_{17} = B_{15}+\Omega\,,\ B_{18} = B_{15}-\Omega\,,\ I_{\gamma,\gamma'} = \int_{-\infty}^{+\infty}\left|I_{\gamma,\gamma'}(\vec{q})\right|^2 d\vec{q},$$

$$I = \beta\left(\varepsilon_F - \frac{\pi^2\hbar^2}{2m}\left(\frac{n^2}{L_x^2}+\frac{l^2}{L_y^2}\right) - \omega_c(N+\frac{1}{2}) + \frac{1}{2m}\left(\frac{eE}{\omega_c}\right)^2\right),$$

ε_F is the Fermi level. τ is the momentum relaxation time; $I_{\gamma,\gamma'}(\vec{q})$ is The electron form factor; k_B is Boltzmann constant; T is temperature. $K_i(x)$ are modified Bessel functions.

IV. Numerical Results and Discussions

In this section, we present detailed numerical calculations about the dependence of the HC on the frequency of EMW, the magnetic fields and length of the RQW GaAs/GaAsAl. The parameters used for the computation are as follows [10]-[14]:

$$\chi_\infty = 10.9, \chi_0 = 12.9, \varepsilon_0 = \frac{10^{-9}}{36\pi}, m = 0.067m_0, \varepsilon_F = 50meV, \hbar\omega_0 = 36.25meV,$$

$$\Omega = 3\times10^{13}s^{-1}, n = 1, n' = 1, l = 1, l' = 1, \tau = 10^{-12}s, \rho = 5320kgm^{-3}.$$

Fig. 1 shows the dependence of the HC on frequency EMW at different values of the magnetic field: length quantum wires

$$L = 90.10^{-8} m,$$
$$L_x = 8.10^{-9} m, L_y = 7.10^{-9} m, B = 4T, B = 4.4T, B = 4.6T.$$

The HC can be seen to oscillate slightly with the change of EMW frequency in the small region. When the frequency increased continuously, the HC saturates. This behavior is different from the case of the in-plane magnetic field with optical phonon interaction in doped semiconductor superlattices [8]. In doped semiconductor superlattices, the HC can be seen to increase strongly with increasing EMW frequency for the region of small value and reaches saturation as the EMW frequency continues to increase. In rectangular quantum wire, as the frequency rises, the HC increase before reaching a peak at certain frequency after which it falls sharply. And if the EMW frequency keeps increasing, the HC will remain constant. At these values from different the magnetic fields, different shape figures. There is no difference between the maximum values of the HC. It seems that the main resonant peaks, as in the case of the absence of the EMW, is due to the contribution of a photon absorption / emission process that satisfies the condition $\hbar\omega_c = \hbar\omega_o \pm \hbar\Omega$. In this case, the HC has both negative and positive values. As frequency EMW increases, the HC is positive, reaches the maximum value and then decreases suddenly to a minimum with a negative value. That's the difference for HC in 2D (quantum wells, Doped semiconductor superlattices [6]-[8]) systems only positive values.

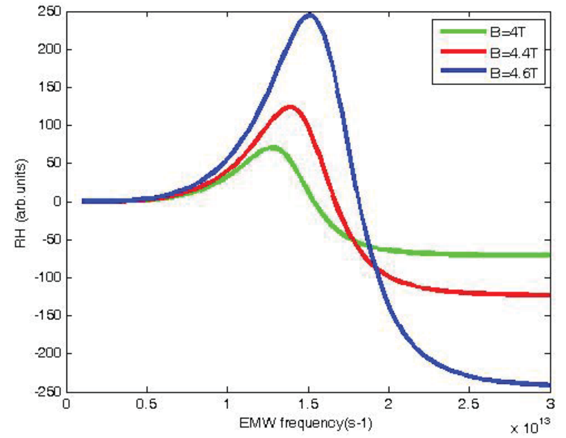

Fig. 1 The dependence of the HC on frequency EMW at different values of the magnetic field

Fig. 2 shows dependencies of the MR on the ratio Ω / ω_c at $B = 6T$ for different values of E_o. The MR is shown as a function of Ω / ω_c at a fix ω_c. When Ω / ω_c increases, the MR has saturation value. We can see very clearly the minima are at $\Omega / \omega_c = 5/4, 6/4, 7/4$ when $E_o = 4.10^6 V/m, 2.10^6 V/m, 10^6 V/m$, respectively.

Fig. 3 (a) shows the dependence of the HC on the magnetic field $\vec{B}$ of the system when the temperature changes $T = 250K$, T = 200K, T = 250K; The graph shows the HC is negative or positive. When magnetic field increases, the absolute value of the HC increases. This character may explain similar [10]-[13]. The HC seems to decrease with increasing the magnetic field and reach saturation at large magnetic field ($> 4T$). However, for the small magnetic field the HC shows an oscillation in the range of small magnetic field. The oscillation disappears when magnetic field becomes much larger. This behavior is different to the case of in two dimensional electron system [6]-[8], [19] and in cylindrical quantum wire [20].

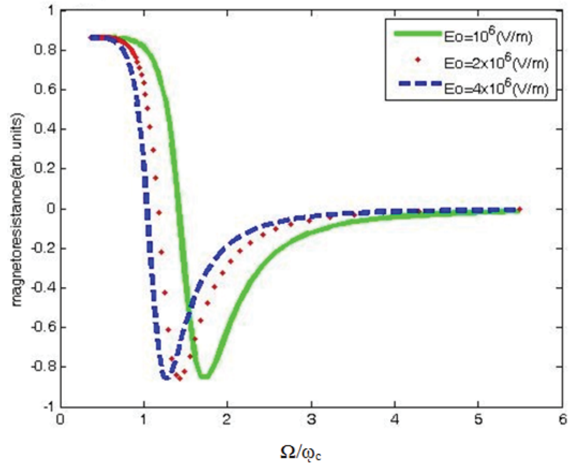

Fig. 2 Dependencies of the MR on the ratio Ω / ω_c at $B = 6T$ for different values of E_o

Survey dependence of the HC on the length quantum wires of the system when the temperature changes. The parameters used for the computation are ([10]-[14]): T = 100K; $T = 1500K$ T = 200K, the magnetic field B = 2T, $L_x = 8.10^{-9}$m, $L_y = 7.10^{-9} m$.

Fig. 3 (b) shows the HC for case that the absence of an EMW is similar in comparison in [12]. The HC is negative or positive. When magnetic field increases, the HC has saturation value.

Fig. 4 shows the dependence of the HC on wire size L_x, L_y RQW. The HC nonlinear dependent on size limits L_x, L_y of RQW. The value of the HC increases as the reduced size of the wire, to a value determined, the HC reaches the maximum value and then decrease as the size of wire continues to decline. However, the HC in RQW get both negative values.

Fig. 5 shows the dependence of MR on a magnetic field $\vec{B}$ at different values of temperatures. Each curve has one maximum and one minimum. When magnetic field increases the MR is positive and reaches the maximum value then decreases suddenly to a minimum with a negative value. This behavior is different to the case of two-dimensional electron system (see [6], [19] and references there in). Surprisingly, the value of HC at the maximum is much smaller at the minimum.

Fig. 6 shows the dependence of the HC on the DC electric field at different value temperatures. From this figure, we can see that the dependence of the HC on the cyclotron energy is nonlinear. The HC parabolically decreases with increasing cyclotron energy and strongly depends on the temperature so that as the temperature increases, evidently the HC decreases. This confirms once again that the HC is quite sensitive to the change in the temperature.

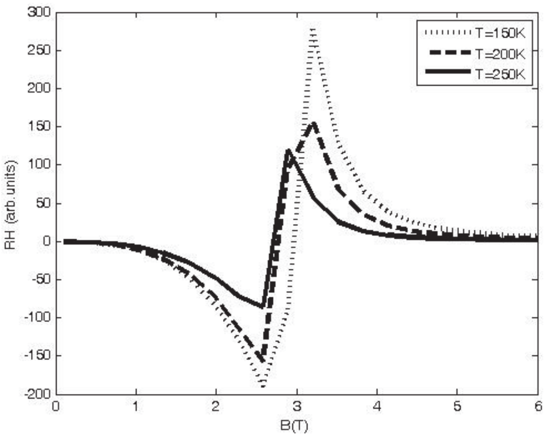

Fig. 3 (a) The dependence of the HC on a magnetic field $\vec{B}$ at different values of temperatures

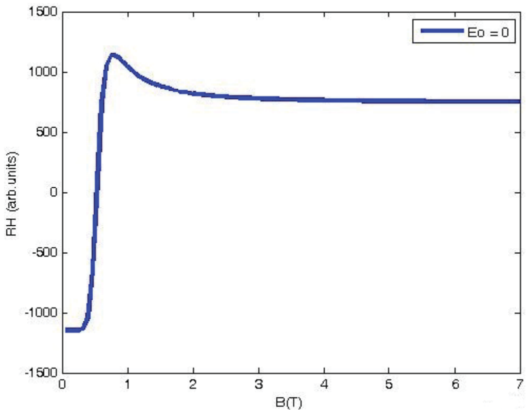

Fig. 3 (b) The dependence of the HC on a magnetic field $\vec{B}$ at values $E_o = 0$

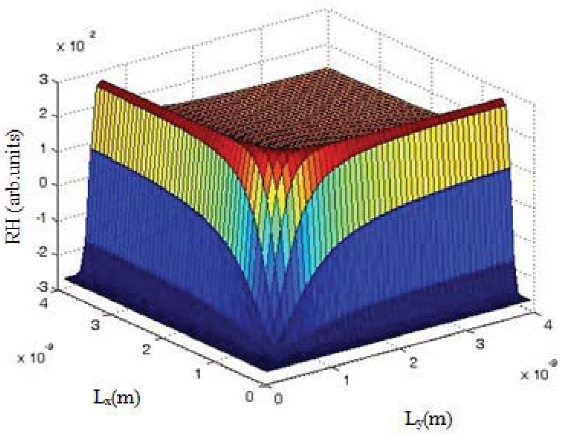

Fig. 4 The dependence of the HC on the wire size of RQW L_x and L_y at different values of temperatures

Fig. 7 shows dependence of the conductivity on the cyclotron energy shows that: each curve has one maximum and one minimum as the cyclotron energy increases. The Conductivity is positive, reaches the maximum value, and then decreases suddenly to a minimum with a negative value. When the cyclotron energy is increases further, the conductivity increases continuously (with negative values) and reaches saturation at high the cyclotron energy. When $E_o = 0$ the cyclotron energy increases, the conductivity reaches saturation. When the cyclotron energy increases further, the conductivity increases strongly. This posture graph is similar to the case absence EMW in quantum wires [16].

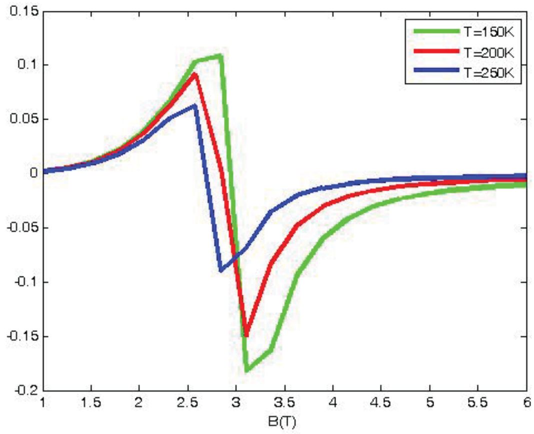

Fig. 5 The dependence of MR on a magnetic field $\vec{B}$ at different values of temperatures

V. Conclusion

Based on the quantum kinetic equation for electrons, we theoretically study the influence of a Strong EMW on the HC in a RQW with infinitely high potential. The RQW is subjected to a crossed DC electric field $\vec{E} = (0,0,E)$ and magnetic field $\vec{B} = (B,0,0)$ in the presence of a strong EMW characterized by electric field $\vec{E} = (0,0,E_o \sin\Omega t)$ (where E_o and Ω are amplitude and frequency of EMW, respectively). We obtain the expressions of HC [refer to (14)]. The result showed that the dependence of the HC and MR in RQW with infinitely high potential on the parameters of nonlinear systems and differences in comparison with the semiconductor and two-dimensional systems. The dependence of HC and MR on external variables such as temperature wire structure, intensity, and frequency of the EMW does not change in terms of quantitative versus cylindrical quantum wires. However there is a big difference compared with the cylindrical quantum wires in the dependence of HC in terms of the size and the change of size of the wire and quantitative values of this proves that the shape and size of quantum wires have a significant effect on the HC and MR.

The analytical results are numerically evaluated and plotted for a specific RQW GaAs/AlGaAs, which shows clearly the dependence of HC on the magnetic field. If the magnetic field is small, the HC has saturation value. This behavior is similar to the results obtained at low temperatures in some one dimensional electron systems. When the magnetic field continues to increase, the HC will decrease. The dependence of HC with the frequency of EMW: Initially, as the frequency rises, the HC increase before reaching a peak at certain frequency.

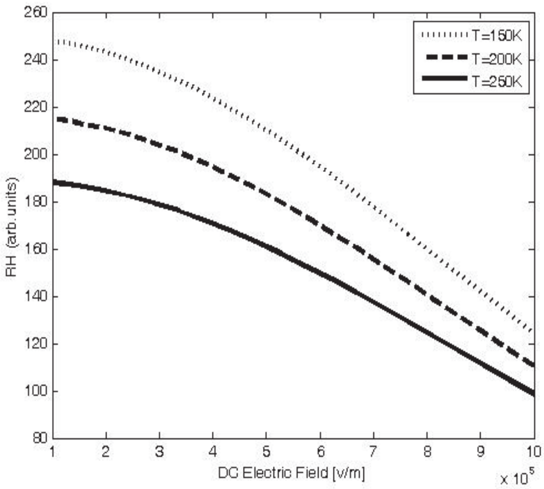

Fig. 6 The dependence of the Hall coefficient on the DC electric field at different value temperatures

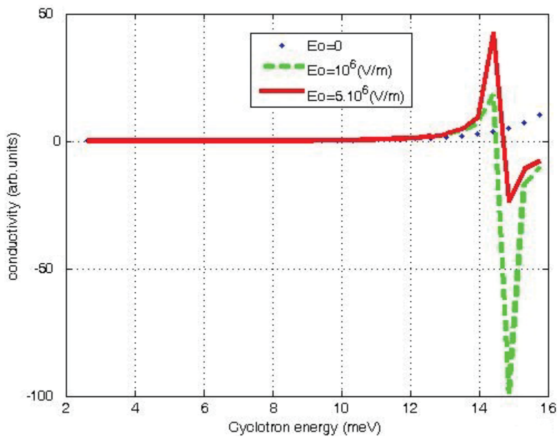

Fig. 7 The dependence of the Conductivity on the Cyclotron energy

Especially, when $E_o = 0$, the graph and analytical expressions similar of [12], [13] with a dependence on B,Ω, temperatures T of systems and the wire size L_x, L_y RQW. The dependence of MR in magnetic field to show appropriate qualitative terms with the experimental observations and theoretical calculations as well as one- dimensional systems have been studied in [14], [18]. When magnetic field increases the HC is positive and reaches the maximum value before decreases suddenly to a minimum with a negative value. As magnetic field increases, the HC reaches saturation. This behavior is different to case of two-dimensional electron system [8] and in cylindrical quantum wire. Surprisingly, the value of HC at the maxima is much smaller and at the minima.

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