CALCULATION OF THE ABSORPTION COEFFICIENT OF A WEAK ELECTROMAGNETIC WAVE BY FREE CARRIERS IN QUANTUM WIRES BY USING THE KUBO-MORI METHOD

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Abstract: Analytic expressions for the high-frequency conductivity tensor and the absorption coefficient of a weak electromagnetic wave (EMW) due to free carriers for the case of electron-acoustic phonon scattering in Quantum Wires are calculated by using the Kubo-Mori Method in two cases: the absence of a magnetic field and the presence of a magnetic field. In comparation with bulk semiconductors, different dependence of the high-frequency conductivity tensor and the absorption coefficients on the electromagnetic wave frequency ω, the temperature T of the system, the cyclotron frequency Ω (when a magnetic field is present) and characteristic parameters of a Quantum Wires is obtained. The analytic expressions are numerically evaluated, plotted and discussed for a specific Quantum Wires of the GaAs/ GaAsAl.

1. Introduction

The caption of electrons in the low-dimensional system significantly reduced the versaltility of the electrons. This leads to several optical and electrical properties, differing to those of usual semiconductors[1-5]. The calculations of the absorption coefficient of weak electromagnetic wave in quantum wells [6], and in the doped superlatices [7] were studied.

In this paper we study the high-frequency conductivity tensor and the absorption coefficient of a weak electromagnetic wave (EMW) (weak electromagnetic wave has the form: $\vec{E} = \vec{E}_0 e^{i\omega t}$) due to free carriers confined in quantum wires in the cases of the absence of magnetic field and the presence of a magnetic field applied perpendicular to its barriers. The electron - acoustic phonon scattering mechanism is assumed to be dominant. The results were calculated numerically for a typical quantum wire GaAs/GaAsAl.

2. High-frequency conductivity tensor and the absorption coefficient of weak electromagnetic wave by free carriers in quantum wires in the case of the absence of a magnetic field

A cylindrical quantum wire: the radius R_0, the length L, the infinite confined potential: $V(\vec{r}) = 0$ inside the wire and $V(\vec{r}) = \infty$ elsewhere.

Based on the Kubo-Mori method with the fractions cut-off within second order approximation of the interaction, we obtained following formula for the absorption coefficient of weak electromagnetic wave in the quantum wires with electron-acoustic phonon scattering mechanism [8-9]:

$$\alpha_{xx}(\omega)=\left(\frac{4\pi}{cN^{*}}\right)\mathrm{Re}\,\sigma_{xx}(\omega) \tag{1}$$

Here, N^{*} is the index of refraction and c is the light velocity, $\sigma_{xx}(\omega)$ is the perpendicular component of the high- frequency conductivity tensor in the absebce of magnetic filed which is a function of frequency ω of the electromagnetic field, temperature T and parameters of quantum wires, which is non-linear.

3. High frequency conductivity tensor and the absorption coefficient of weak electromagnetic wave by free electrons in quantum wires in presence of magnetic field

In the case of presence of magnetic field (magnetic field $\vec{B}//OZ$), using Kubo-Mori method, the components of the absorption coefficient of electromagnetic wave in quantum wires with electron-acoustic phonon scattering mechanism in presence of external magnetic field:

$$\alpha_{xx}(\omega,\Omega)=\frac{4\pi}{cN^{*}}\mathrm{Re}\,\sigma_{xx}(\omega,\Omega), \tag{2}$$

Where $\Omega=\dfrac{eH}{mc}$ is the frequency cyclotron, $\sigma_{xx}(\omega,\Omega)$ is the perpendicular components of the high frequency conductivity tensor in presence of external magnetic field which is a function of frequency ω of the electromagnetic field, cyclotron frequency Ω of external magnetic field, temperature T and parameters of quantum wires, which is non-linear.

4. Numerical calculation and discussion

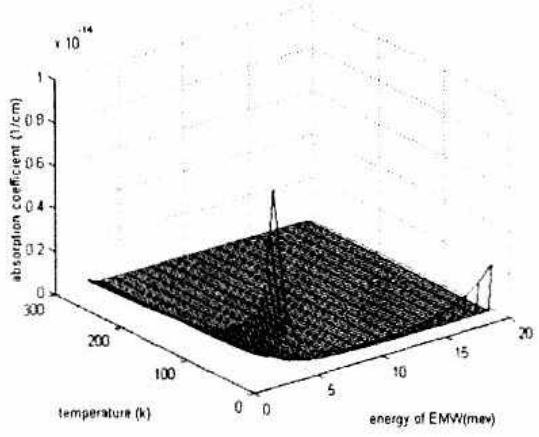

Figure 1. Dependence of the absorption coefficient of EMW on the energy of EMW and temperature in the case of the Absence of a Magnetic Field

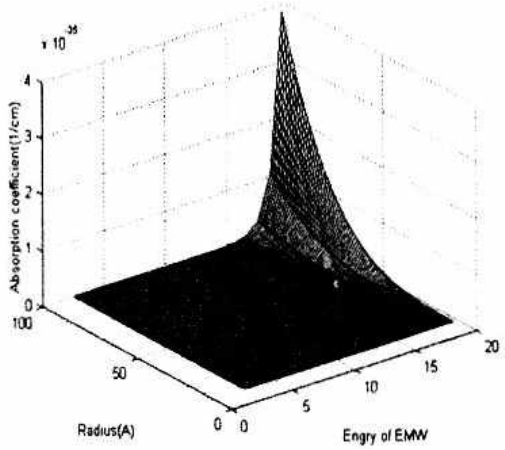

Figure 2. Dependence of the absorption coefficient of EMW on the energy of EMW and radius in the case of the presence of a Magnetic Field

Based on the analytical expressions for the perpendicular components of the high frequency conductivity tensor, the absorption coefficient of weak electromagnetic wave by free electrons in quantum wires with electron-acoustic phonon scattering mechanism in the cases of presence (2) and absence (1) - (3) of external magnetic field for a typical quantum wire GaAs/ GaAsAl with values: $\mu = 0.01meV; m = 0.067m_0, e = 2.07e_0$; $r = 50A^0$ and the system is assumed to be as room temperature ($T = 300^0K$).

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