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Effect of spin on the ground-state energy of strong-coupled magnetopolaron in triangular quantum well

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Abstract. The properties of strong-coupled magnetopolaron are studied by using the linear combination operator and unitary transformation methods in triangular quantum well (TQW). Considering the influence of the spin, the ground-state energy of polaron is obtained. The expressions for the ground-state energy as functions of the vibration frequency, the electron areal density and the magnetic field were derived. Numerical calculation on the TlBr TQW, as an example, is performed and the results show that the ground-state energy is composed of three parts. And the ground-state energy of magnetopolaron increase with enlarging the magnetic field and the electron areal density.

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Key words: triangular quantum well, spintronics, ground-state energy, polaron

1 Introduction

The spin effect in semiconductors has attracted great attention in recent years as it plays a key role in the field of semiconductor spintronics[1,2]. The spin effect is a major branch of the spintronics because of its potential impact on the information technology[3-5]. More and more physicists worldwide are paying considerable attention to the research of the local electron in a quantum dot and the supperlattice heterojunction by many theoretical and experimental methods. The induced potential and the self-energy of an interface magnetopolaron were studied by Wei[6] using the Green-function method. Liu and Xiao[7,8] and Li and Xiao[9] investigated the influence of a perpendicular magnetic field on a bound polaron near the interface of a polar-polar semiconductor with Rashba effect

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by using variational method and calculated the influences of spin on the properties of a weak-coupled magnetopolaron in quantum dot by using a linear combination operator and a unitary transformation methods, respectively. Zhang *et al.*[10] researched the properties of the strong-coupling bound polaron in a triangular quantum well induced by the Rashba effect using the Tokuda modified linear-combination operator method and the unitary transformation method.

There has been much work about the influence of the spin on the electron system, the study of the effect of the spin on the magnetopolaron in TQW, however, is quite rare so far. In this paper, we researched the ground-state energy of the polaron considering the effect of the spin in TQW. First, we drew the expression of the ground-state energy by using the linear combination operator and the unitary transformation methods. Then, numerical calculation is performed and the results are presented and discussed. Finally, a brief conclusion is drawn in our investigation.

2 Theory and model

We consider the system that the electrons are much more confined in one direction (taken as the z direction) than that in other two directions, x and y. Therefore, only the electrons moving on the $x-y$ plane need to be considered. In the presence of a magnetic field in the z direction, and we take the magnetic field B as $B=(0,0,B)$. On the basis of the effective mass approximation, the electron-phonons system Hamiltonian can be written as

$$H=H_e+H_{ph}+H_{e-ph}+H_{SO} \tag{1}$$

where H_e is the energy of the electron

$$H_e=\frac{(p+\frac{eA}{c})^2}{2m^*}+U(z) \tag{2a}$$

$$U(z)=\begin{cases} eF_z z, & z\geq 0 \\ \infty, & z<0 \end{cases} \tag{2b}$$

$$F_z=\frac{4\pi n_s}{\varepsilon_0} \tag{2c}$$

where $U(z)$ is the triangular potential; p and m^* stand for the momentum and mass of the electron, respectively. n_s refers to the electron area density and A is vector potential of the magnetic field. The Hamiltonian of the phonons H_{ph} is given by

$$H_{ph}=\sum_w[\hbar\omega_{LO}a_w^+a_w \tag{3}$$

Here $a_w^+(a_w)$ is the creation (annihilation) operator of the bulk longitudinal-optical (LO) phonons with wave vector w. H_{e-ph} is the Hamiltonian of the electron-phonon interaction

$$H_{e-ph}=\sum_w[a_wV_w\exp(iw\cdot r)+h\cdot c] \tag{4}$$