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Ground state lifetime of strong-coupled polaron in an asymmetric quantum dot

Zhi-Xin Li [a,*] and Jing-Lin Xiao [b]

[a] *College of Physics and Chemical, Hebei Normal University of Science and Technology, Qinhuangdao, Hebei 066004, China*
[b] *College of Physics and Electronic Information, Inner Mongolia Normal University, Tongliao 028043, China*

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Abstract. On the condition of electron and LO-phonons strong-coupled, the ground-state energy of polaron has been obtained by using linear combination operator and unitary transformation methods in an asymmetric quantum dot. Quantum transition which causes the changes of the polaron lifetime is occurred in the quantum system due to the electron-phonon interaction and the influence of external temperature effect which is the polaron leap from the ground-state to the first-excited state absorbing a LO-phonon. Numerical calculation is performed and the results show that the ground-state lifetime of polaron increases with increasing the ground-state energy and decreases with increasing the coupling-strength. The ground-state lifetime is extented with the shorten of the temperature. It is also observed that the ground-state lifetime is a decreasing function of the transverse and longitudinal confinement lengths of the quantum dot.

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Key words: asymmetric quantum dot, strong-coupled, ground-state lifetime, polaron

1 Introduction

Recently, with the rapid development of nanofabrication technology of materials, quantum dot, quantum well and quantum wire, low dimensional electronic systems have been easily produced with molecular beam extension (MBE) technique, metal organic chemical vapor deposition (MOCVD) and chemical self-assemble technique. Due to the small structures of the quantum dot, some physical properties such as optical and electron transport characteristics are quite different from those of the bulk materials. More and more physicists worldwide are

*Corresponding author. *Email address:* zzlxx2006@126.com (Z. X. Li)

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paying considerable attention to the research of the local electron in a quantum dot (QD) by many theoretically [1–3] and experimentally [4–6] methods.

In recent years, the most feasible approach has been quantum dots for realizing the quantum computer because of the advantage of being integrated. The two quantum state of electron is employed as a single qubit in a quantum dot [7–9]. In practice, the electron-phonon interaction is essential to understand the optical absorption spectra in semiconductors. Research on the polaron effect has become a main subject in the physics of low-dimensional quantum systems. Especially in a quantum dot system, the electron-phonon interactions are enhanced by the geometric confinement. Therefore, a number of studies have been focused on the influence of the electron-phonon interactions on polaron in parabolic quantum dots.

Xie and Chen [10] studied the thickness dependence of the binding energy of an impurity bound polaron in a parabolic QD in magnetic fields by using the second-order perturbation theory. Au-Yeung *et al.* [11] investigated the combined effects of a parabolic potential and a Coulomb impurity on the cyclotron resonance of a three-dimensional magnetopolaron by using Larsen's perturbation method, under the condition of strong parabolic potential. Within the framework of Femman-haken path integral theory, Ren *et al.* [12], calculated the ground state energy of two-dimension polarons in asymmetric quantum dots for arbitrary electron-phonon coupling strengths. Employing the frame work of Feynman variational path integral theory, Chen *et al.* [13] derived an expression of the ground state energy of an electron coupled simultaneously with a coulomb potential and a longitudinal-optical phonon field in parabolic asymmetric quantum dots and quantum wires. The properties of strong-coupling bound magnetopolaron of quantum dot in an asymmetry confinement potential have been studied using Pekar's varitional method by Chen and Xiao [14]. Wang *et al.* [15] recently studied the binding energy of hydrogenised impurities in a GaAs cylindrical QD using a two-parameter variational wave function. By introducing a trail wave function constructed as a direct form of an electronic part and a part of coherent phonons. Kandemir and Cetin [16] investigated the polaronic effect on the low-lying energy levels of an electron bound to a hydrogenic impurity in a three-dimensional anisotropic harmonic potential subjected to a uniform magnetic field. Boucaud *et al.* [17] studied the polaron decay in InAs/GaAs self-assembled quantum dots by pump-probe spectroscopy and Zibik *et al.* [18] investigated the polaron decay in n-type InAs quantum dots using energy dependent, mid-infrared pump-probe spectroscopy, However, the ground-state lifetime of polaron in a parabolic QD has not been investigated so far in these works.

In this paper, the properties of the ground-state lifetime of polaron in an asymmetric quantum dot will be studied by using linear combination operator and unitary transformation methods. The effect of the ground-state energy, electron-phonons coupling-strength, external temperature and the transverse and longitudinal confinement lengths of quantum dot on the ground state lifetime will be discussed.