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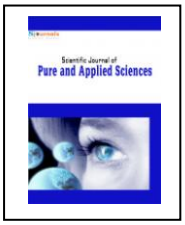

Original article

Hamiltonian multiplex interaction based on excitons effect in semiconductor QCs

A. Jahanshir

Department of Physics, Boueinzahra Technical University, Ghazvin, 3451745346, IRAN.

*Corresponding author; Department of Physics, Boueinzahra Technical University, Ghazvin, 3451745346, IRAN.

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ABSTRACT

The subject of modern technology has been the focus of extensive theoretical investigations in semiconducting nanostructures which we know as quantum dots (QCs). The possibility of monitoring and controlling the properties of QCs attracted considerable attention to these objects, as an important basic system in future technology. So, the quantum-mechanical effects play a significant role in the description of the formation mechanism QCs, determination of mass spectrum, binding energy and other characteristics. Based on QFT and by using oscillator representation method (ORM) and operator product expansion technique developed in QFT, we study the properties of electron-hole QDs, determine mass spectrum and peruse spin-spin interactions in exciton system and its multiple pair systems. This method has applications to calculate the binding energy of exciton system in ground and excited states with semi-nuclear structure in semiconductor QCs or cold atomic few-body systems and develop the general calculation's theory of few-body systems based on the Coulomb interaction between particles by forming excitonic pairs in semiconductor QCs. We investigate the binding energy of exciton bound states. It is shown that fermion particles have a very small mass, and after bonding together by dynamically force, constituent particles become massive, which is analogous to what happens in QCD.

1. Introduction

The interaction mechanism and semiconducting nanostructures QCs properties are well described in the framework of ORM that based on quantum field theory, which takes into account the quantum properties fermions type objects. ORM is based on the investigation of the polarization loop operator of scalar particles in a quantum gauge field. We introduce the representations of this loop in a form of functional integral and investigate its asymptotic behaviour for large distances. By solving the equation for the Green function of a scalar particle in an external gauge field and averaging over the gauge field, by using the propagator of the vector field $A_\alpha(x)$ that has the form (Greiner and Reinhort, 1992; Dineykhan and Efimov, 1995):

$$D_{\alpha\beta}(x-y)=\left\langle A_\alpha(x)A_\beta(y)\right\rangle_A = \delta_{\alpha\beta}D(x-y)+\partial_\alpha\partial_\beta D_1(x-y) \quad 1)$$

The function $D_{\alpha\beta}(x-y)$ defines the gauge of the field $A_\alpha(x)$ and physical characteristics do not depend on this function. It defines the character of the interaction which is realized by this vector gauge field $A_\alpha(x)$. So under gauge transformations the Green function acts as follows:

$$G(x,y|A)=\int_0^\infty \frac{ds}{(4s\pi)^2}\exp\left\{-sm^2-\frac{(x-y)^2}{4s}\right\}\times \times\int d\sigma_\beta \exp\left\{ig\int_0^1 d\xi \frac{\partial Z_\alpha(\xi)}{\partial\xi}A_\alpha(\xi)\right\} \quad 2)$$

Now, the main subject is determination the gauge-invariant loop function of multiplex scalar particles with masses $\mathrm{m_i}$, in this case we start determination for two scalar particles with different masses $\mathrm{m_1}, \mathrm{m_2}$. So loop function is (Dineykhan et al., 2003; Jahanshir, 2010) :

$$\Pi(x-y)=\left\langle G_{m_1}(x,y|A)G^*_{m_2}(y,x|A)\right\rangle_A \quad 3)$$

if the mass of the bound state of two scalar particles (M): $\mathrm{M}<\infty$, and $\mathrm{M}=\mathrm{m_1}+\mathrm{m_2}$, then a bound state with a mass M arises, and also if $(\mathrm{x}-\mathrm{y})^2\to\infty$, the loop function looks like:

$$\Pi(x-y)\cong\exp\left(-M\sqrt{\Pi(x-y)^2}\right) \quad 4)$$

Therefore the mass of bound states is:

$$M=-\lim_{|x-y|\to\infty}\frac{\ln\Pi(x-y)}{|x-y|} \quad 5)$$

And we can determine the eigenvalues of the Hamiltonian (the binding energy of system) from Schrödinger equation by using (5):

$$E(\mu_1,\mu_2)=M-\frac{1}{2}((\mu_1+\mu_2)-\frac{m_1^2\mu_2+m_2^2}{2\mu_1\mu_2} \quad 6)$$

2. Hamiltonian in QCs

Energy is absorbed by electrons presented in semiconducting nanostructures QCs, which means as activating electron from capacity band to conductive ban. Electron moves to conductive band and establish a connection

with its position in capacity band (hole: hole with positive charge) under Coulomb potential gravity. Electron and the hole start to spin around themselves and create an exciton system. Exciton system is relatively a stable structure, which in this field is considered as a long time life. Interaction and mutual effect of each layer with other layer in inhomogeneous environment is explained through electrostatic forces, electron relative potential, spin effects and particles' complementary effects. As we know, Schrödinger equation for multiplex system with Coulomb interaction is (Dineykhan, 2009; Jahanshir, 2012):

$$H = H_0 + \hat{H}_{spin} + \Delta\hat{H} = \frac{1}{2}\sum_{i=1}^{n} m_i v_i^2 + \sum_{\substack{i=1 \\ i<j}}^{n-1}\sum_{j=2}^{n} \frac{1}{k}\frac{e_i e_j}{\left|r_i - r_j\right|} + \hat{H}_{spin} + \Delta\hat{H} \quad (7)$$

3. Conclusion

In this article, having above conditions of multiplex exciton environment in semiconducting nanostructures QCs, and using oscillator representation method, mass, binding energy and Hamiltonian coefficient of spin-spin interaction in multiplex exciton system with Coulomb potential are discussed and determined. In addition we have shown that for nanostructures QCs spin-spin effects has an important role in determination of the total binding energy.

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