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J. Nano- Electron. Phys.
3 (2011) No1, P. 1005-1009

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PACS numbers: 42.55. – f, 71.38. – k, 73.21. – Hb, 75.50.Pp

EFFECT OF LASER ON THE BOUND MAGNETIC POLARON IN A SEMIMAGNETIC QUANTUM WIRE

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In the present investigation binding energy of the laser dressed hydrogenic donor in a Semi magnetic Quantum Wire like $Cd_{1-x}Mn_{x2}Te/Cd_{1-x1}Mn_{x1}Te/Cd_{1-x2}Mn_{x2}Te$ *and spin polaronic shift has been computed for various magnetic and laser fields within the effective mass approximation in the finite barrier model using variational method. The results are presented and discussed.*

Keywords: *LASER, MAGNETIC SEMICONDUCTOR QUANTUM WIRE, SPIN POLARON, MAGNETICFEILD, DONOR BINDING ENERGY.*

(Received 04 February 2011)

1. INTRODUCTION

When a magnetic impurity is doped in a semiconductor, there is a strong sp-d spin dependent interaction between the localized magnetic moment of the magnetic impurity in a doped semiconductor with the (i) bound charge carrier gives rise to Bound Magnetic Polaron (BMP) [1] (ii) free charge carrier leads to Free Magnetic Polaron (FMP) [2] (iii) exciton gives rise to Excitonic Magnetic Polaron (EMP) [3]. All these polaronic effect in Semimagnetic Semiconductors (SMSC) such as $Cd_{1-x}Mn_xTe/CdTe$ show novel and potentially important phenomena such as Giant negative magneto resistance, Spin glass transition, anti ferromagnetic cluster, large Faraday rotations etc., Bound magnetic polaron has been observed both experimentally and theoretically in modulation doped SMSC material [4]. There are reports on fractional dimensional approach to BMP in Quantum Well(QW), Quantum Well Wire (QWW) [5], effect of magnetic field on exciton level [6] and effect of intense laser field [7, 8] in a QWW are available in the literature. In the present work the effect of laser and magnetic field on the Spin Polaron in a magnetic QW $Cd_{1-x1}Mn_{x1}Te$ surrounded by magnetic barrier $Cd_{1-x2}Mn_{x2}Te$ has been investigated in the effective mass approximation using variational method. We have considered mean field theory with modified Brillouin function in the above calculations.

2. THEORY

The Hamiltonian of the laser dressed hydrogenic donor in the presence of applied magnetic field along the growth axis in a $Cd_{1-x2}Mn_{x2}Te/Cd_{1-}$

$_{x1}Mn_{x1}Te$ /$Cd_{1-x2}Mn_{x2}Te$ quantum wire of fintie barrier in the effective mass approximation is given by [9],

$$H = \frac{1}{2m^*}\left(P + \frac{e\vec{A}}{c}\right)^2 - \frac{e^2}{\varepsilon_0(r+a)} + V_B(z) \tag{1}$$

where $r = \sqrt{x^2 + y^2 + z^2}$ "a" is the amplitude of electron oscillation in the radiation field $\left(a = e\vec{A}/mc\omega\right)$, which is proportional to $I^{1/2}\omega^{-2}$, I being the intensity of laser radiation. The potential barrier height of $Cd_{1-x2}Mn_{x2}Te$ Quantum Wire is given by,

$$V_B(z,a) = \begin{cases} 0 & |z| \le L/2 \\ V(z,a)V_0 & |z| > L/2 \end{cases} \tag{2}$$

with the laser dressed donor potential [10],

$$V(z,a) = \frac{1}{2}V_0\Theta\left(z^2 - L_{EW}\right) \tag{3}$$

where $\Theta(z)$ is the step function, $L_{EW} = L_W/2$ is the effective well width for a laser-dressed donor. $V_0 = 70\%\,\Delta E_g^B$; L is the width of the potential well, ΔE_g^B is the band gap difference with magnetic field and ΔE_g^0 is without magnetic field and they can be related by (4),

$$\Delta E_g^B = \Delta E_g^0\left[\frac{\eta\, e^{\zeta\gamma} - 1}{\eta - 1}\right], \tag{4}$$

(4)

where $\eta = e^{\zeta\gamma_0}$ is chosen with ζ as a parameter(= 0.5) and γ_0 as the critical magnetic field which depends upon the value of the composition 'x' (= $x_2 - x_1$). The critical magnetic field for different composition is given in Tesla as $B_0 = Ae^{nx}$ with $A = 0.734$ and $n = 19.082$ which gives the best fit to the extrapolated experimentally available critical fields [11]. The band gap of $Cd_{1-x}Mn_xTe$ is given to be $1606 + 1587x$ (meV). The variational ansatz for the donor in a finite Quantum Wire is chosen as,

$$\psi = N\begin{cases} \cos\alpha x\,\cos\alpha y\; e^{-\lambda r} & |z| \le L/2, \\ \\ B\, e^{-\beta(x+y)}\; e^{-\lambda r} & |z| > L/2, \end{cases} \tag{5}$$

where N is the normalisation constant and λ is the variational parameter and,

$$\alpha = \left[2m\cdot E/2\hbar^2\right]^{0.5} \quad \text{and} \quad \beta = \left[2m\cdot\left(V_0 - E\right)/2\hbar^2\right]^{0.5} \tag{6}$$

The dimensionless form of Eq. (1) can be written as,

$$H = -\nabla^2 + \gamma L_z + \frac{\gamma^2}{4}(x^2 + y^2) - \frac{2}{r+a} + V_B(z,a)R^*. \quad (7)$$

The dimensionless quantity of magnetic field parameter is defined as,

$$\gamma = \frac{\hbar}{2R^*}\left(\frac{e\vec{B}}{m\cdot c}\right) \quad (8)$$

where R^* is the effective Rydberg which is $R^* = e^2/2\varepsilon_0 a_B^*$ and the effective Bohr radius is $a_B^* = \hbar^2\varepsilon_0/m^*e^2$, with m^* and ε_0 are the effective mass of electron and static dielectric constant for the CdTe respectively. The donor binding energy of a Quantum Wire in the presence of magnetic field is given by [9],

$$BE = E + \gamma - (H)S \quad (9)$$

where E is the subband energy which can be obtained by solving the transcendental equation,

$$\alpha \cdot \tan(0.5\alpha L) = \beta \quad (10)$$

2.1 Spin Polaronic effect

The exchange interaction between the carrier and Mn^{2+} ion in the presence of an external magnetic field $\vec{B}$ can be calculated using modified Brillouin function [12]. The spin polaronic shift is given by,

$$E_{sp} = \frac{1}{2}\beta S N_0 \left\{\left\langle \psi_1 \left| x_1 B_s(y_1) \right| \psi_1 \right\rangle + \left\langle \psi_2 \left| x_2 B_s(y_2) \right| \psi_2 \right\rangle\right\} \quad (11)$$

where $B_s(y)$ is the modified Brillouin function and it is given by,

$$B_s(y_j) = \frac{2S+1}{2S}\coth\frac{2S+1}{2S}y_j - \frac{1}{2S}\coth\frac{y_j}{2S} \quad (12)$$

$$y_j = \frac{S\beta\left|\psi_j\right|^2}{2KT} + \frac{g\mu_B S\beta}{KT} \quad (13)$$

where β – exchange coupling parameter, S is the spin of Mn^{2+} (= 5/2), and xN_0 is the Mn ion concentration with $N_0 = 2.94 \times 10^{22}$ cm^{-3} and $\beta N_0 = 220$ meV for CdTe[12]. Also $g_{Mn} \approx 2$, K is the Boltzmann constant.

3. RESULTS AND DISCUSSIONS

Fig. 1 gives the variation of barrier height with magnetic field for laser amplitudes a = 0 Å (i.e. without laser) and $a = 150$ Å. It shows that the application of laser field also reduces the barrier height in addition to the magnetic field.

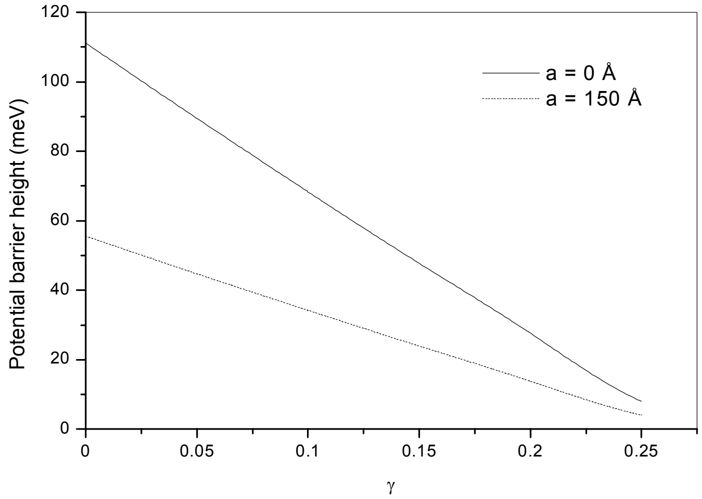

Fig. 1 *–Variation of potential barrier height with magnetic field*

Fig. 2 gives the variation of binding energy with well width for two laser fields $a = 0$ Å and $a = 150$ Å with three different magnetic fields of $\gamma = 0$, $\gamma = 0.1$ and $\gamma = 0.25$ for the Mn composition $x = 0.1$. It is observed that the binding energy decreases with increase of well width and the application of magnetic field. This is due to the reduction of potential barrier height with γ which in turn reduces the confinement of the carrier. The application of laser field also reduces the binding of the donor which is due to reduction in the well width and also due to dressed donor potential. At higher well widths the variation of binding energy due to magnetic field is not appreciable and the same trend is observed for higher laser intensity.

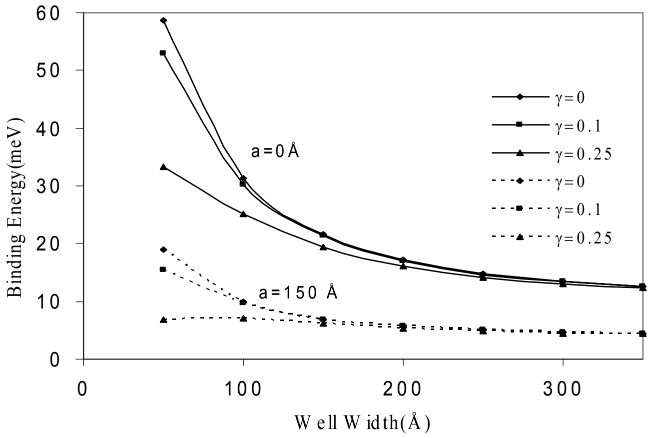

Fig. 2 *– Variation of Binding Energy with Well width*

The variation of magnetic polaronic shift of the donor for $a = 0$ Å and $a = 150$ Å and for $x = 0$, $x = 0.1$ and $x = 0.25$ is given in Fig. 3 for $x = 0.1$. It is noticed that there is a competition between laser field and magnetic field on the bound magnetic polaron, since application of magnetic field increases the polaronic shift in contrast to laser field which decreases the binding of spin polaron. It is also noticed that there is a drastic variation of magnetic polaronic shift with well width and also with magnetic field. When the magnetic field is increased, spin polaron effect is increased. This is due to the reduction in barrier height which in turn increases the interaction between the carrier ion and the magnetic ions due to smaller confinement.

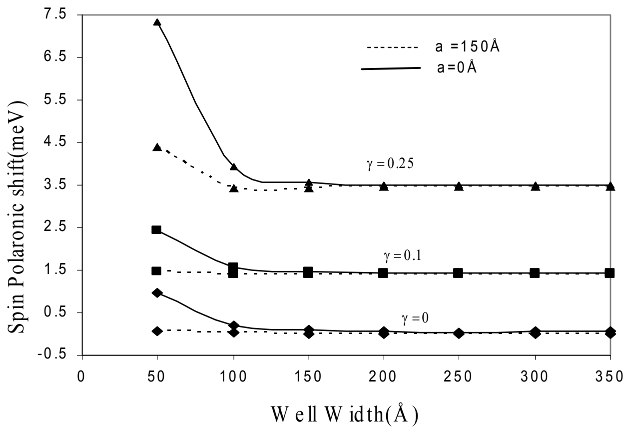

Fig. 3 – *Variation of Spin Polaronic Shift with Well width*

The effect of laser decreases the magnetic polaronic shift. The same trend is observed for all the magnetic fields. To conclude, the effect of laser and magnetic field in SMSC like CdMnTe system plays a vital role in the spin related phenomena. We hope the present investigation may through some light on spintronics applications and optoelectronic devices. More experimental results should come to prove these facts.

One of the authors K. Jayakumar thanks the University Grants Commission, New Delhi, India for the financial support under Major Research Project.

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