Bound magnetic polaron in 2D system with the strong spin-orbit interaction.

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Diluted magnetic semiconductors (DMS), i.e. semiconductor compounds doped with magnetic impurities (most often Mn-atoms) constitute an important branch of modern solid state physics. The coupling of localized spins with carriers, originating from the exchange interaction between the latter and the electrons of the d-shell of manganese impurities, leads to the broadband spectrum of specific optical and transport effects, such as Giant Zeeman splitting, the red shift of photoluminescence, etc [1].

The heightened sensibility of mutual orientation of the carrier spin and the neighbour manganese momentums may provide the formation of collective state (bound magnetic polaron BMP) characterized by correlated spin distribution with the lowest energy [2]. At low temperatures, when fluctuations are muted, this distribution is imposed on carrier exchange field $\mathbf{B}_{ex}$ acting on localized spins and orienting them along itself (with the energy shift $E_{ex} = -\mathrm{B}_{ex}\mathrm{M}$), thus the full information of polaron state is given in the carrier wave function. Researches of BMPs and exciton magnetic polarons (EMPs) connected with hole-states in bulk and low-dimensional semiconductor systems show that its complicated properties are due to the complex structure of the valence band in such alloys [3,4].
In quantum well systems with the valuable spin-orbital energy splitting of conductivity band states, originating from the presence of the structural inversion asymmetry (SIA), or the bulk inversion asymmetry (BIA) of quantum well material, the non-trivial behaviour of BMP is expected because of the complicated carrier states taking into account the dependence of spin on some wave-vector.

In present work the ground state of BMP formed by the bound carrier on donor center under the spin-orbit interaction (SIA or BIA) in QW is theoretically studied [5]. The two-dimensional model is used to simplify the analysis of the results. The spin-dependant localization in 2D systems was investigated in [6], particularly the energy $E_c$of the localized state was calculated depending on the type of donor potential. In this work two orthogonal wave functions $\psi_{\uparrow,\downarrow}$ of the electron bound state are received in accordance with the method of zero-radius potential, which gives only the right function asymptotics away from defect, that fits our purposes better (E_c is considered as the parameter of the model). The mentioned complication of the carrier state is that not only the absolute value of the exchange field depends on the coordinate, but also its direction changes in space (the internal structure of polaron becomes complex). The specific form of $\psi_{\uparrow,\downarrow}$ dictated by two-dimensionality and spin-orbit interaction causes $\mathbf{B}_{ex}^{\uparrow}(\mathbf{r}) = -\mathbf{B}_{ex}^{\downarrow}(\mathbf{r})$, therefore when all localized spins inside the carrier cloud are orientated along $\mathbf{B}_{ex}$ the polaron ground state is twice degenerated.

The external magnetic field removes the symmetric influence of these carrier states. The manganese spins are aligned along the resulting field $\boldsymbol{B}_{ex} + \boldsymbol{B}$, that constrains the electron to choose the state with $\mathbf{B}_{ex}$, corresponding to the lowest energy of spins system. A remarkable feature of the studied system is the dependence of such an electron state on weak magnetic field (we consider that weak field influences only the magnetic centers, i.e. the carrier is described by the same $\psi_{\uparrow,\downarrow}$ functions), originating from the mentioned complicated distribution of its exchange field. It leads to reorganization of spins orientation, thus the dependence of magnetization on the external field takes a jump, when electron state changes.

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