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The Reduction of *g* factor at different quantum states

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The study of quantum information has caught a lot of attention in the ten years. The electron spin in a confined semiconductor, quantum dot, is an expected candidate for quantum bit, because the spin-flip processes in quantum dots accompany transitions between different discrete energy levels was studied. [1] The spin relaxation time of the electrons in quantum dots differs strikingly from that of the delocalized electrons. The most effective spin-flip mechanisms related to the absence of the inversion symmetry appear to be strongly suppressed for localized electrons. Electron spin states in quantum dots are much more stable then in bulk semiconductor due to the suppression of spin-flip decoherence mechanisms.

An important issue in quantum computing or spin-dependent transport is that spin is often not an independent variable. The coupling with the environment, for instance confined effect, spin orbital interaction, and hyperfine interaction, will alter the response of the magnetic field. [2]

In this paper, we studied the Zeeman splitting energy at several electron quantum states. The electron *g* factor change with quantum states. The several spin orbit interaction and the subband Landau levels effect will be discussed.

We have measured the vertical double dot employing the conventional excitation spectroscopy technique in temperature ≈100mK with magnetic field up to 15T applied parallel to the current. [3] In order to observe the clear excited states, hard-entering and easy-leaving the dot is a critical point in the experiment. A co-tunneling processing, which the electron tunnels through the first dot and enters the second dot directly, is also used in measuring the excited states properly.

At the total three electrons transition spectrum, fig. 1, the ground state transition from $1s^2$ singlet to 1s2p triplet states is seen at 5T. A Zeeman-splitting excited state with g-factor ≈0.36 is clearly seen in the higher magnetic fields. The observation of *two* total Zeeman sublevels instead of *three* for the triplet states is explained by the spin selection rules for the S_Z components between N_{total}=2 and 3 spin states. Transition from N_{total}=2 in spin state (N_1, N_2) = (↑, ↑) to the N_{total}=3 in spin state (N_1, N_2) = (↑, ↓↓) is forbidden. [4] Note in the nonlinear transport regime, electrons tunnels through the dots in a short time (<< μsec.), which is much shorter than the Zeeman-sublevels spin relaxation time (>>μsec.). [5] Therefore both of the spin doublet states, spin up and spin down, can be the initial state from the N_2=1 to N_2=2 spin transitions. Remaining there are totally four transitions contribute to the tunneling processes, but only two energy differences lead to the two Zeeman sublevels in the excitation spectrum.

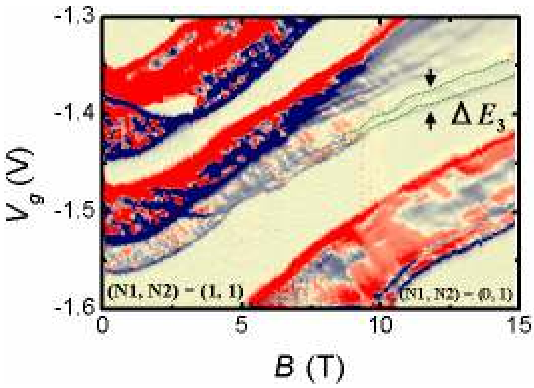

Figure 1: The total three electrons transition spectrum.

Figure 2 shows the electrons transition spectrum of N_{total}=0 to N_{total}=1 and N_{total}=1 to N_{total}=2. There are also two Zeeman splitting lines, with g-factor ≈0.52 observed in the spectrums. The extracted Zeeman splitting energy were listed in the fig. 3. The g-factor of first two electron spectrums, 1S state, is obviously larger then the third electron spectrum, 2P state. The spin of an electron moving in an electric field experiences an internal magnetic filed. The internal magnetic field acting on the spin depends on the orbital the electron occupies, spin and orbital coupling. The Dresslhaus and Rashba spin-orbit interaction [6] and the subband Landau levels [7] were discussed trying to explain the deviation of g-factor in different quantum states.

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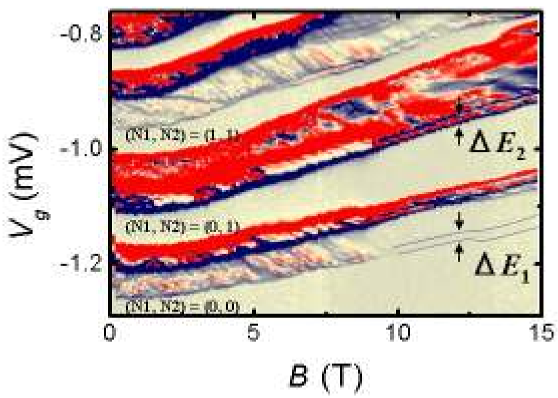

Figure 2: From the bottom up, the total one and two electrons transition spectrum.

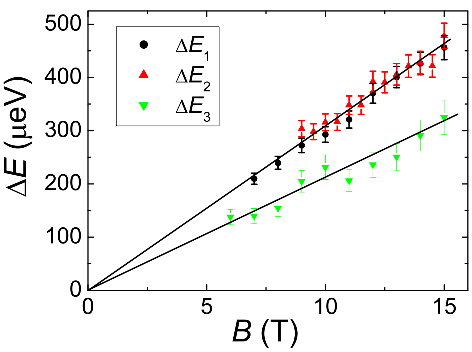

Figure3: The extracted Zeeman splitting energy.