Real-time spin detection of single photo-electrons with a double quantum dot in a g-factor engineered quantum well

T. Fujita [1], K. Morimoto [1], S. Teraoka [1], G. Allison [1,2], A. Ludwig [3], A. D. Wieck [3], A. Oiwa [1] and S. Tarucha [1]

[1] *Department of Applied Physics, The University of Tokyo, Tokyo, Japan*
[2] *Department of Physics, Princeton University, Princeton, New Jersey, USA*
[3] *Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany*

We present spin detection of single photo-electrons with a GaAs based double quantum dot (DQD) fabricated in a g-factor engineered quantum well (QW). We resonantly photo-excited single electron-light holes (or heavy holes) in the DQD and performed real-time detection of electron spin using Pauli spin blockade (PSB) in the DQD. This experiment gives insight into the spin relaxation dynamics of optically excited single electrons, which is an essential ingredient for the realization of quantum state transfer from single photons to single electron spins.

We chose a near zero electron g-factor wafer to prepare gate-defined DQDs. We used a nearby charge sensor to perform real-time detection of single photo-electrons [1] and measured the wavelength dependence of the single photo-electron absorption efficiency of the dot. Comparing the absorption efficiency spectrum with the photoluminescence result we have realized the capture of single photo-electrons resonantly generated in pairs with single electron-light holes (or heavy holes).

Next we setup the condition of PSB in the double dot at the (1,1)-(0,2) charge transition region. By fitting the magnetic field dependence of the leakage current of PSB-lifting we obtained the fluctuating hyperfine field of 23 mT. This value is much larger than that in conventional GaAs HEMT wafer QDs, reflecting the small g-factor of our QDs. In the time resolved inter-dot tunneling measurements we observed fast tunneling and slow tunneling, each resulting from anti-parallel and parallel spin configuration, as featured in a bi-exponential histogram of the tunneling event count. This result supports the proposal that the present setup can discriminate single photo-electron spins.

Finally, we performed single-shot detection of single photo-electron spins. We tuned the DQD to the (0,1) region and irradiated laser pulses to generate just one photo-electron to instantly reach the PSB condition. Then, as predicted from the above described inter-dot tunneling experiment, we could distinguish between the parallel and anti-parallel spins from the difference in the first inter-dot tunneling time, slow for parallel spin and fast for anti-parallel spin. This is an important step towards single photon to single spin coherent state transfer.

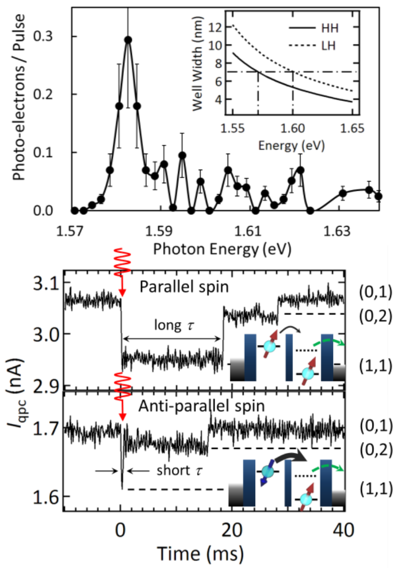

Figure: (Top) Determination of light and heavy hole excitation from single photo-electron detection efficiency. (Bottom) Single-shot single photo-electron spin detection.

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