Single-shot read-out of an electron spin qubit

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The spin of a single electron, confined in a semiconductor quantum dot, provides a natural two-level system suitable as a qubit in a quantum computer [1]. We demonstrate here recent experimental progress towards realization of an electron-spin based quantum computer: isolation of a single electron, identification of the two-level spin system and single-shot read-out of the spin state of a single electron.

Our device, defined electrostatically in a GaAs/AlGaAs heterostructure, consists of two coupled quantum dots in close proximity to a quantum point contact (QPC). Using this QPC as a charge detector, we show that we can deplete the two dots to contain just a single electron each [2]. Even in this few-electron regime, the resonant current through the two dots in series is still measurable.

By applying an in-plane magnetic field and performing large-bias tunneling spectroscopy, we can directly measure the Zeeman splitting of the orbital ground state, thereby identifying the spin qubit two-level system [3]. Furthermore, we show that the quantum dot can be operated as an electrically tunable spin filter. The polarization of the filter is opposite for electrons tunneling to the one- and two-electron ground state, and is estimated to be very close to 100% in magnitude [4].

To use this system as a spin qubit, an essential ingredient is a read-out device, i.e. a way to measure the orientation of a single electron spin. We use the Zeeman energy difference between the two spin orientations to achieve spin-to-charge conversion; spin “up” has a low energy and is trapped on the dot, whereas spin “down” has a higher energy and can escape to the leads. By measuring the charge dynamics, using the nearby QPC with a bandwidth of ~100 kHz, we are able to perform single-shot read-out of the spin. We use this method to determine the relaxation time of the spin qubit, and find T_1 = 0.85 ms for an in-plane magnetic field of 8 T.

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[2] J.M. Elzerman *et al*., Phys. Rev. B. **67**, 161308(R) (2003).

[3] R. Hanson *et al*., Phys. Rev. Lett. **91**, 196802 (2003).

[4] R. Hanson *et al*., cond-mat/ 0311414.