Manipulation of Quantum Coherence and Entanglement with Quantum Dots

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Quantum coherence and entanglement is the fundamental concept of solid state quantum mechanics as well as quantum information processing. For the latter manipulation of superposition states and entangled states provides a universal set of logical qubit operation for quantum computation. To date a lot of effort has been made to implement various kinds of solid-state qubit systems including spins and charges. We have been developing novel microwave (MW) techniques for coherently manipulating single electron spins with quantum dots and transferring single electrons in surface acoustic wave (SAW). In this talk I will review recent progress on these topics.

It is well established that spin singlet state is a typical entangled state. We previously prepared a two qubit gate of combined spin rotation and spin exchange coupling to control the degree of singlet state in double quantum dots. However, the gate operation time is comparable to or longer than the dephasing time because of the slow speed of single spin rotation, which is realized by oscillating an electron inside a quantum dot with MW in the presence of a micro-magnet induced field gradient. We have recently raised the MW power and optimized the magnet design to reduce the rotation time much shorter than the dephasing time. SAW can be used to drive an electron trapped by one of the waves to move from one dot to another dot a few micron apart. Because the transfer time is much shorter than the dephasing time, this may provide a flying qubit to connect distant quantum systems. The SAW technique can also be used to pick up one electron out of a singlet state in the first dot to transfer to the second dot which is initially empty. I will discuss a possible way to use this technique to implement non-local spin entanglement.