Manipulation of single electron spins in semiconductor nanowire quantum dots

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The manipulation of single electron spins in semiconductor quantum dots is a powerful paradigm in which to pursue a scalable architecture for quantum information processing [1]. I will describe our experimental and theoretical efforts to address the main challenges to building a scalable solid-state quantum bit register in which all qubit manipulations can be carried out by electrical controls. The nearest neighbor exchange interaction can be controlled by a local gate, is effectively short-range, and can be efficiently turned off, a crucial advantage for implementing two-qubit logic compared to other realizations [1]. More recently it has become clear that single-qubit manipulations can be efficiently generated using either intrinsic [2] or 'artificial' [3] spin-orbit coupling in concert with applied ac electric fields, referred to as electric-dipole spin resonance (EDSR). Our goal is to realize a device in which EDSR, gate-controlled exchange, and spin readout can all be carried out with high fidelity and at fast rates. Devices under study are based on III-V semiconductor nanowires, which provide a convenient and robust substrate for engineering a one-dimensional array of gate-controllable quantum dots. In particular, InAs nanowires possess relatively large spin-orbit couplings (to facilitate EDSR), low effective electron masses (large confinement energies), and are readily grown [4] and processed to form gated devices [5]. The Pauli spin blockade, observed in double-dot devices in the two-electron regime [6], provides a robust mechanism for spin-to-charge conversion for single-spin readout. A radio-frequency single-electron transistor [7], capacitively coupled to a dot pair for readout, facilitates non-destructive spin readout [8]. The main obstacle for devices based on III-V materials is electron spin dephasing due to the hyperfine interaction with abundant nuclear spins; I will discuss potential ways to circumvent this based on narrowing of the nuclear state distribution [9] and by increasing the bandwidth of single-spin control.

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