Electron and nuclear spin qubits based on donors in silicon

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Electron and nuclear spins of donors in silicon are promising candidates for representing quantum bits, with coherence times of up to 3 seconds for the electron spin[1] up to 3 minutes for the neutral donor nuclear spin[2], and 3 hours for the ionized donor nuclear spin[3]. Furthermore, single-shot readout of both the electron spin and nuclear spin have been demonstrated, with measurement fidelities of up to 99.8%[4, 5]. In order to scale up to more complex quantum devices based on donors, it is necessary to find a way to coherently control individual spins (or at least a defined subset of them) within a larger array. One approach is to apply global microwave fields to coherently excite resonant spins, combined with (pulsed) DC electric fields to bring different spins in or out of resonance with the control field, using the Stark shift. We present Stark shift data for all group-V donors in silicon (P, As, Sb and Bi), and show how electric fields can be used for conditional control of nuclear spins[6]. An alternative method is to apply local AC electric fields, which we show theoretically can be used to drive spin transitions in certain regimes through modulation of the hyperfine coupling.

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