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Ultrafast Coherent Control of a Single Electron Spin in a Quantum Dot[1]

MAIKEN H. MIKKELSEN[2], Center for Spintronics and Quantum Computation, University of California, Santa Barbara, CA 93106

Practical quantum information processing schemes require fast single-qubit operations. For spin-based qubits, this involves performing arbitrary coherent rotations of the spin state on timescales much faster than the spin coherence time. While we recently demonstrated the ability to initialize and monitor the evolution of single spins in quantum dots (QDs)[3], here we present an all-optical scheme for ultrafast manipulation of these states through arbitrary angles. The GaAs QDs are embedded in a diode structure to allow controllable charging of the QDs and positioned within a vertical optical cavity to enhance the small single spin signal. By applying off-resonant optical pulses, we coherently rotate a single electron spin in a QD up to π radians on picosecond timescales [4].We directly observe this spin manipulation using time-resolved Kerr rotation spectroscopy at $T = 10$K. Measurements of the spin rotation as a function of laser detuning and intensity confirm that the optical Stark effect is the operative mechanism and the results are well-described by a model including the electron-nuclear spin interaction. Using short tipping pulses, this technique enables one to perform a large number of operations within the coherence time. This ability to perform arbitrary single-qubit operations enables sequential all-optical initialization, ultrafast control and detection of a single electron spin for quantum information purposes.

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[2]Work performed in collaboration with J. Berezovsky, N. G. Stoltz, L. A. Coldren, and D. D. Awschalom.

[3]M. H. Mikkelsen, J. Berezovsky, N. G. Stoltz, L. A. Coldren, D. D. Awschalom, *Nature Physics* **3**, 770 (2007); J. Berezovsky, M. H. Mikkelsen, O. Gywat, N. G. Stoltz, L. A. Coldren, and D. D. Awschalom, *Science* **314**, 1916 (2006).

[4]J. Berezovsky, M. H. Mikkelsen, N. G. Stoltz, L. A. Coldren, D. D. Awschalom, *Science* **320**, 349 (2008).