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Spin-Lattice Relaxation Rate in Lateral Quantum Dots

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Laterally gated quantum dots (QDs) fabricated on AlGaAs/GaAs heterostructures show promise for spin-based quantum computation. One limit to the coherence time in QDs, which sets the timescale on which quantum operations must be completed, comes from the spin-orbit interaction. In a magnetic field B the spin states of a single electron in a QD are split by the Zeeman energy $g\mu_B B$; the spin-orbit interaction couples the spin states of a QD to its orbital degrees of freedom, which in turn can interact with piezoelectric phonons to relax the spin from the excited state to the ground spin state. The time scale over which this happens is the relaxation time T_1. We present measurements of the relaxation rate $W = T_1^{-1}$ of one electron in a single laterally gated QD at magnetic fields down to 1 T, much lower than previously measured. These measurements are possible because of the good stability of the AlGaAs/GaAs heterostructure we have used combined with an active feedback system that compensates for residual drift and switches of the dot energy levels. We find that T_1 is as long as 1s at 1 T. We compare our measurements to theoretical predictions of W caused by spin-orbit coupling to phonons and extract the spin-orbit length, which describes the strength of the spin-orbit interaction. This demonstrates that spin-orbit coupling to phonons can account for W down to fields as low as 1 T in laterally gated QDs and establishes an upper limit to the spin coherence time. This work is in collaboration with K. MacLean, D. M. Zumbühl, I. P. Radu, M. A. Kastner, M. P. Hanson, and A. C. Gossard. This work has been supported by the ARO (W911NF-05-1-0062), the NSF (DMR-0353209), and in part by the NSEC Program of the NSF (PHY-0117795).