Coherent dynamics of a strongly driven single electron spin

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Electron spin in quantum dots (QDs) is a distinguished platform for solid-state quantum computers (QCs), because of the relatively long coherence times and potential scalability. Recent experiments have demonstrated many of the prerequisite elements for QCs with realization of two single spin qubits [1] and two-qubit entanglement [2]. However, realizing sufficiently fast control over qubits compared with their couplings to the environment, a key ingredient of quantum gates, is still elusive, and this may hinder manipulations of pure spin states. In this work, we demonstrate single spin rotations on a timescale much shorter than the ensemble phase coherence time (T_2^*) via electron spin resonance (ESR) above 120 MHz in GaAs QDs, and report on the unconventional features in Rabi oscillations arising from a nearly pure spin state.

We used a double QD defined in a 2DEG of GaAs/n-AlGaAs by negatively-biased Schottky gates. A proximal Co micro magnet yields a slanting magnetic field at the double QD position and oscillating an electron inside the dot enables electrically driven ESR [1]. We have refined the magnet design and used a shallow (57 nm deep) 2DEG to raise the Rabi frequency (f_{Rabi}) by an order of magnitude or exceeding 120 MHz (the highest ever reported). The spin rotation time is now much shorter than T_2^* > 50 nsec. We found that in this regime the Rabi oscillations decay following an exponential-law with the initial phase shift of virtually zero, although it is usually reported that the initial phase is shifted by $\pi/4$ after averaging over nuclear spin statistics [3]. Note the fast Rabi oscillation can also decouple electron spin rotation from dynamical nuclear polarization. To capture the driven spin dynamics even more closely, we took magnetic field detuning dependence of Rabi oscillations, and the so-called "Chevron" interference pattern is clearly resolved in the detuning-time plane, consistent with the model of a single spin evolution within a pure state.

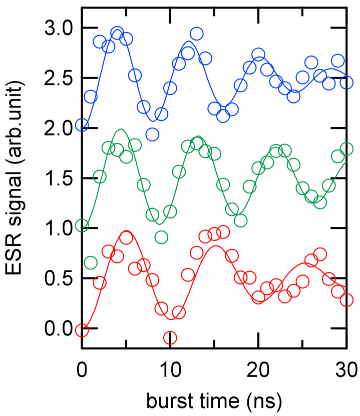

Figure: Fast Rabi oscillations. Extracted f_{Rabi} are 98, 113, 123 MHz for the bottom, middle, top traces, respectively. MW powers are attenuated by 6 dB from top to bottom. Solid lines are fit to an exponentially-damped sinusoidal function with no phase shift.

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