Fast optical-manipulation of a coherent hole-spin in an open microcavity

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Spin-photon interfaces are a key ingredient for quantum technologies, enabling quantum information to be mapped between stationary spins and photons travelling at the speed of light. Spin-photon interfaces are also promising as a deterministic source of entangled photonic graph-states [1], which are resource states for measurement-based quantum computation and one-way quantum repeaters. The ideal spin-photon interface combines both a highly coherent spin and coherent, efficient photon emission.

Self-assembled semiconductor quantum dots (QDs) are demonstrated excellent on-demand sources of indistinguishable, single-photons. Gated devices allow deterministic charging of the QDs, and impressive progress has been achieved in mitigating the impact of magnetic noise from the host nuclear spins on electron-spin decoherence [2]. Although the ingredients for a leading spin-photon interface (high-fidelity spin control, long coherence times, high-efficiency photon extraction) have been demonstrated in individual quantum dot experiments, combining all these components at a state-of-the-art level is an important outstanding challenge.

Here, we demonstrate a system that combines the best of all worlds: we achieve fast and high-fidelity coherent control of a QD hole-spin, a spin decoherence-time T_2^* of 500 ns, all on a QD embedded in a tunable open microcavity with an exceptionally high end-to-end single photon source efficiency. Many spin rotations can be carried out and many photons can be created before the spin loses its coherence; the photons are extracted with high efficiency. We use a microwave-modulated control scheme [3], making coherent rotations around an arbitrary Bloch sphere axis trivial and allowing all-optical cooling of the host nuclei to extend the hole spin coherence. We achieve a maximum π-pulse fidelity of 98.7%, and ultra-fast Rabi frequencies above 1 GHz. Our work demonstrates the potential for semiconductor QDs as fast, efficient, and coherent spin-photon interfaces.

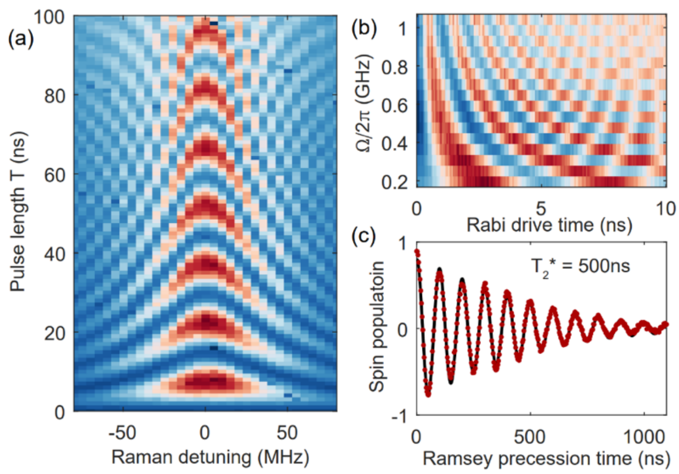

Figure 1: (a) High-quality Rabi chevron pattern obtained following nuclear bath cooling. (b) Cavity-enhanced ultra-fast spin control, showing Rabi oscillations up to 1 GHz Rabi frequency. (c) Ramsey interferometry performed after nuclear bath cooling, demonstrating T_2^*=500 ns.

References
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