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Increasing the electron spin coherence time by coherent optical control of the nuclear spin fluctuations[1]

XIAODONG XU[2], H. M. Randall Laboratory, The University of Michigan

A single electron spin plays a central role for spin-based quantum information science and electronic devices. One crucial requirement for the future success is to have a long quantum coherence time. It has been demonstrated that in III-V materials, the electron spin coherence time deteriorates rapidly due to the hyperfine coupling with the nuclear environment. Here, we report the increase of the electron spin coherence time by optical controlled suppression of nuclear spin fluctuations through coherent dark-state spectroscopy. The experiment is performed in a single negatively charged InAs self assembled quantum dot (SAQD). The dynamic nuclear spin polarization manifests itself as a hysteresis in the probe absorption spectrum and in the spectral position of the dark state as a function of the frequency scanning direction of the probe field. We demonstrated that the nuclear field can be locked to the maximum trion excitation by observing a flat-top of the trion absorption lineshape, and the switching of the nuclei from unstable to stable configurations by fixing the laser frequencies and monitoring the coherent optical response as a function of time. The optically controlled locking of the nuclear field leads to an enhancement of the electron spin coherence time, which is measured through dark state spectroscopy. The suppression of the nuclear field fluctuations result from a hole spin assisted dynamic nuclear spin polarization feed-back process. We further demonstrated the electron spin coherence enhancement by a three-beam measurement, where two-pump beams lock the nuclear field and the third probe measures the coherence time through the dark state. The inferred spin coherence time is increased by nearly 3 orders of magnitude compared to its thermal value. Our work lays the groundwork for the reproducible preparation of the nuclear spin environment for repetitive control and measurement of a single spin with minimal statistical broadening.

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[2]Current Address: Center for Nanoscale Systems, Cornell University