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Mode locking of electron spin coherence in singly charged quantum dots

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Fast dephasing of electron spins in an ensemble of quantum dots is detrimental for applications in quantum-information processing. We show that dephasing can be overcome by using a periodic train of light pulses to synchronize the phases of the precessing spins, and demonstrate this effect in an ensemble of singly charged (In,Ga)As/GaAs quantum dots. A periodic train of circularly polarized light pulses from a mode-locked laser synchronizes the precession of the spins to the laser repetition rate, transferring the mode-locking into the spin system. The mode-locking technique allows us to measure the single-spin coherence time to be 3 microseconds, which is four orders of magnitude longer than the ensemble dephasing time of 400 picoseconds. The technique also offers the possibility of achieving all-optical coherent manipulation of spin ensembles, in which electron spins can be clocked by two trains of pump pulses with a fixed temporal delay. The nuclei in these experiments act constructively, leading to the nuclear-induced frequency-focusing effect, which moves the electron-spin precession into dephasing-free subspace.