Coherent Control of Quantum Dot Spin and Novel Approach for Spin-Photon Entanglement.

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The spins of semiconductor quantum dot (QD) confined carriers are essential ingredients in quantum information processing, due to their compatibility with contemporary technology. Full coherent control of the electron, hole, and exciton spins using optical means, and entanglement between an exciton or an electron with a photon have been demonstrated. These achievements are based on a particular arrangement, the "lambda system," in which two qubit eigenstates are resonantly coupled optically to one common auxiliary level. Resonant pulses to this level provide control over the qubit spin, and spontaneous recombination entangles the emitted photon with the remaining QD spin. An exciton spin naturally forms a lambda system with the vacuum or the biexciton states, but the electron naturally forms a "pi system," in which the two qubit eigenstates are optically connected to different degenerate states of the trion. An in-plane magnetic field removes this degeneracy and makes the system lambda-like. In this work, we experimentally demonstrate coherent optical control of the exciton spin qubit, in both a lambda and a pi system. With the understanding gained from this comparison, we propose a novel approach for spin photon entanglement based on a natural pi system. Our proposal obviates the use of magnetic field for achieving entanglement between carrier spins and photons. It may have far reaching consequences in quantum information processing.