Coherent Coupling of Spin and Light

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Tremendous progress has been achieved in the coherent control of single quantum states (single charges, phonons, photons, and spins). At the frontier of quantum information science are efforts to hybridize different quantum degrees of freedom. For example, by coupling a single photon to a single electron fundamental light-matter interactions may be examined at the single particle level to reveal exotic quantum effects, such as single atom lasing. Coherent coupling of spin and light, which has been the subject of many theoretical proposals over the past 20 years, could enable a quantum internet where highly coherent electron spins are used for quantum computing and single photons enable long-range spin-spin interactions. In this colloquium I will describe experiments where we couple a single spin in silicon to a single microwave frequency photon. The coupling mechanism is based on spin-charge hybridization in the presence of a large magnetic field gradient. Spin-photon coupling rates $g_s/2\pi > 10$ MHz are achieved and vacuum Rabi splitting is observed in the cavity transmission, indicating single spin-photon strong coupling. These results open a direct path toward entangling single spins at a distance using microwave frequency photons.