Light- and heavy-hole trions bound to isoelectronic centers

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Due to their spin-selective optical transitions, trions form a natural interface between spin qubits and flying qubits (photons) that will be essential to the realization of quantum networks. To be useful, a spin qubit must be initialized with a high fidelity, controlled on a short timescale compared to its coherence time and read-out in a single shot. Recently, these three operations have been demonstrated *separately* for a single electron spin in quantum dots (QDs) using trions as intermediate states [1-3]. However, these three essential operations cannot be realized *simultaneously* because they require different magnetic field configurations.

To circumvent this problem, we propose the use of nitrogen isoelectronic centers in GaAs as an alternative to QDs for optical quantum information processing [4]. In this work, we show that nitrogen pairs of C_s symmetry (represented in the inset of fig. 1), never reported before, can bind both negative light- and heavy-hole trions. Using polarization resolved magneto-luminescence, we analyze the emission fine structure of negative trions. Figure 1 shows that at zero magnetic field, the fine structure is composed of two unpolarized transitions separated by about 100 μeV: the degeneracy of light and heavy holes is lifted by the crystal field surrounding the nitrogen pair and confinement. Under high magnetic fields, these transitions evolve into two quadruplets for a total of eight transitions as expected for a system involving both types of holes. The fine structure and polarization were modeled using a symmetry-based Hamiltonian and our model indicates a weak mixing between light- and heavy-hole trion states.

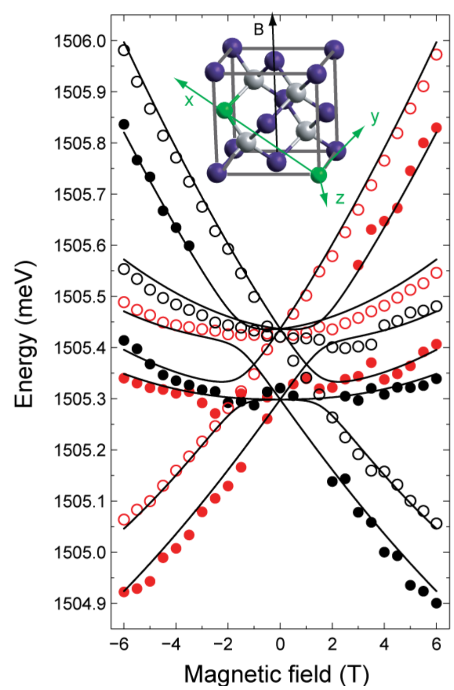

Figure 1- Emission energy as a function of the magnetic field for a negative trion bound to a nitrogen pair of C_s symmetry. Empty (full) circles represent light- (heavy) hole states and lines are fitted energies. Inset: configuration of the nitrogen pair.

In the light of these results, we propose a new scheme to *simultaneously* implement all three single qubit operations under a single magnetic field configuration: light-hole trions allow fast spin initialization and control, and heavy-hole trions provide a robust cycling transition allowing single-shot readout.

[1] Atatüre et al., Science **312**:551 (2006)
[2] Press et al, Nature **456**:218 (2008)
[3] Delteil et al., Physical Review Letters **112**:116802 (2014)
[4] Éthier-Majcher et al., Nature Communications **5**:3980 (2014)