Geometric echo of a purely geometric spin qubit in diamond

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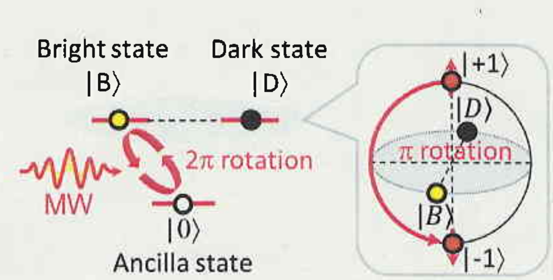
An electron spin can be a purely geometric qubit that has exclusively a geometric phase when the system is degenerate. In contrast that the conventional dynamic qubit requires an energy gap to be controlled, geometric qubit does not in principle. We here show the geometric phase control of a purely geometric qubit in a degenerate subspace of a V-type spin 1 electronic system of a nitrogen vacancy center in diamond under zero magnetic field [1]. The zero-field split state serves as an ancillary state to interact with a controlling microwave (Fig. (a)). The degenerate qubit operation is achieved by changing the geometric phase of the microwave–defined bright state while leaving the dark state unchanged [2]. We demonstrate geometric spin echo to recover the geometric spin coherence after 100 times of the free induction decay (Fig. (b)). Dependence of the echo signal on the axial magnetic field indicates that correlation between spin bath is the major decoherence source and minimized under zero magnetic field. The demonstration reveals the importance of the spin degeneracy for long-lived memory. The degenerate geometric qubit is not only resilient to environmental noise but also robust against control error and free from dynamic phase locking.

(a)



(b)

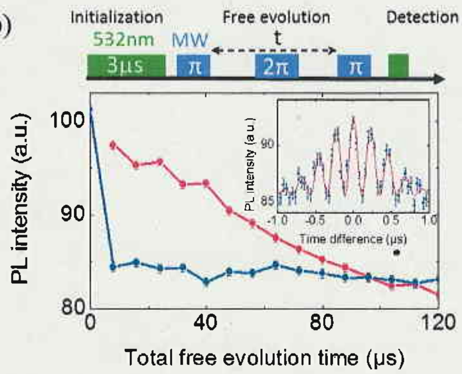


Fig. (a) The energy level diagram of a ground state electron spin system in an NV center in diamond. Inset illustrates the geometric spin bit-flip operation in degenerate space as a result of 2π rotation from the bright state |B⟩ through the ancilla state |0⟩. (b) Geometric spin free induction decay (Ramsey interference) and geometric spin echo. Inset shows refocused echo signal after 70μs of free evolution.

[1] H. Kosaka and N. Niikura, Entangled absorption of a single photon with a single spin in diamond. *Phys. Rev. Lett.* **114**, 053603 (2015).

[2] H. Kosaka *et al.* Spin state tomography of optically injected electrons in a semiconductor. *Nature* **457**, 702–705 (2009).