

Diamond based quantum repeater device -Degenerate spin echo for quantum state recovery-

Yuhei Sekiguchi, Yusuke Komura, Shota Mishima, Touta Tanaka, Naeko Niikura, and Hideo Kosaka*
Yokohama National University, 79-5 Tokiwadai, Hodogaya, Yokohama 240-8501, JAPAN

An electron under symmetry without external field behaves as a purely geometric spin qubit that is inherently protected from a noise by symmetry breaking and time reversal. While the degenerate qubit is never subject to dynamic control, it is still subject to the geometric control. We here show geometric spin echo over a qubit in a degenerate subspace of a V-type spin 1 electronic system of a nitrogen vacancy center in diamond [1]. The zero-field split state serves as an ancillary state, which enables the degenerate qubit 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 found that the coherence time reaches maximum at zero magnetic field, where three-dimensional protection works (Fig. (b)). The axial zero-field splitting first protects the qubit against a transverse noise causing a bit-flip error and a transverse zero-field splitting then protects against an axial noise causing a phase-flip error. The geometric spin qubit is not only robust against environmental noise but also against control error, thus suitable for a memory qubit used in quantum information.

We thank Norikazu Mizuochi, Yuichiro Matsuzaki, Kae Nemoto, William Munro, Scharfenberger Burkhard, Joerg Wrachtrup and Fedor Jelezko for their discussions and experimental help. This work was supported by the NICT Quantum Repeater Project, by the FIRST Quantum Information Project, and by a Grant-in-Aid for Scientific Research (A)-JSPS (No. 24244044).

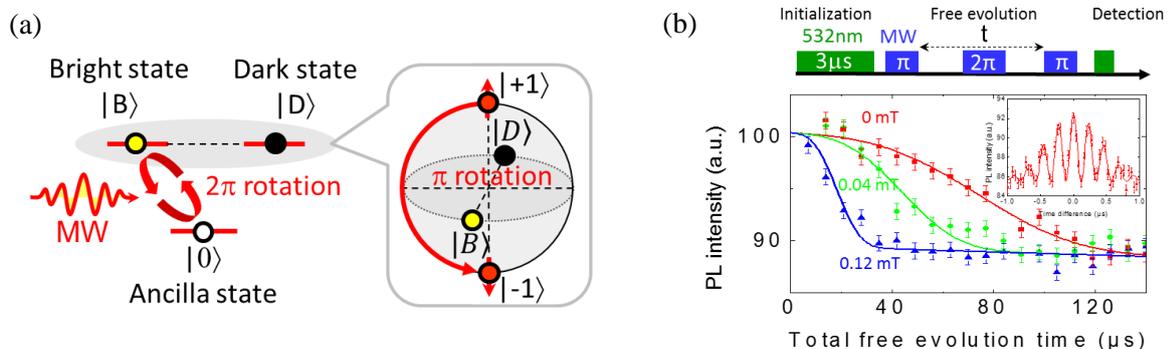


Fig. (a) The energy level diagram of a ground state electron spin system in an NV center in diamond. Inset illustrates the geometric spin bit-flip operation in degenerate space as a result of 2π rotation from the bright state $|B\rangle$ through the ancilla state $|0\rangle$. (b) Decay curves of the geometric spin echo under each magnetic fields, 0 mT, 0.04 mT, 0.12 mT. Inset shows refocused echo signal after $70\mu\text{s}$ 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).