Diamond based quantum repeater device
-Entanglement detection for quantum state swapping-

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Quantum entanglement, a key resource for quantum information science, is inherent in a solid. It has been recently shown that entanglement between a single optical photon and a single spin qubit in a solid is generated via spontaneous emission [1]. However, entanglement generation by measurement is rather essential for quantum operations [2]. We here show that the physics behind the entangled emission can be time-reversed to demonstrate entangled absorption mediated by an inherent spin-orbit entanglement [3] by using purely geometric qubit in a degenerate subspace of a V-Λ type spin 1 electronic system of a nitrogen vacancy center in diamond (Fig. 1) [4]. Optical arbitrary spin state preparation and complete spin state tomography revealed the fidelity of the entangled absorption to be 95% (Fig. 2). In addition to the entanglement detection, quantum repeaters require spin echo by microwave to maintain the stored quantum state and arbitrary spin rotation by lightwave within radiative lifetime. We show quantum process tomography of these operations using the optical bright state projection technique. These achievements suggest that quantum repeaters can be built with degenerate electron spin qubits based on material inherent interactions in diamond.

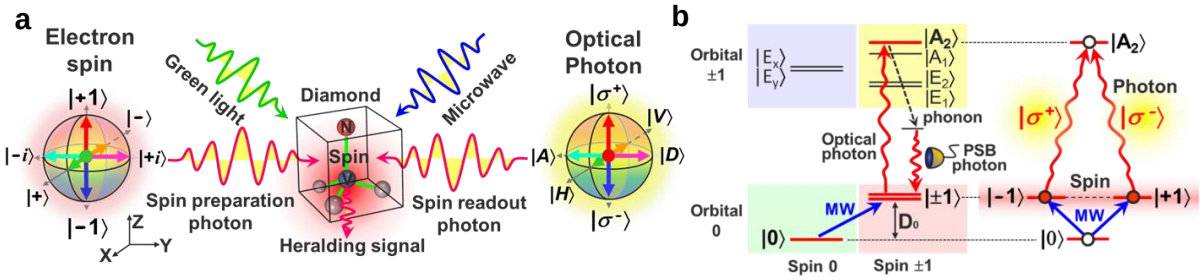

FIG. 1 (**a**) Scheme for entanglement measurement. Quantum correlation between optically stored electron spin and incoming readout optical photon is measured via resonant absorption, which is heralded by a phonon sideband photon detection. (**b**) Related energy levels of the NV center. Spin triplet sublevels $|\pm1\rangle$ are used as spin qubit bases.

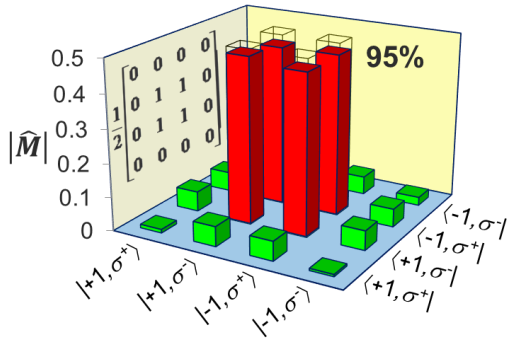

FIG. 2 The density operator represenatation of the joint measurement between the electron spin and the photon polarization. The elements at middle 2x2 matrix, which corresponds to the spin-photon entanglement originating from the spin-orbit entanglement in the A_2 state, are used for the estimation of the entanglement detection fidelity to be 95%.

Acknowledgements:
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).

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