Quantum Repeater Approach based on Diamond Spin Qubit

Hideo Kosaka
Tohoku University, Research Institute of Electrical Communication, 2-1-1 Katahira, Aobaku, Sendai 980-8577, Japan
Yokohama National University, Graduate School of Engineering, 79-1 Tokiwadai, Hodogaya, Yokohama 240-8501 JAPAN
kosaka@ynu.ac.jp

Abstract: Challenges for building a quantum repeater system using a nitrogen vacancy center in diamond are overviewed and the futures are discussed. Our approach for further development of quantum repeater network is also presented with experimental demonstrations of quantum entanglement detection between a photon and an electron spin in an NV center for quantum entanglement swapping.
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A nitrogen vacancy (NV) center in diamond is expected to be an ideal solid-state quantum memory since the spin coherence of an electron or nuclear spin can be kept over 1 second and those spin states are coherently controlled with a lightwave, microwave or radiowave [1-5]. Quantum entanglement generation between remote quantum memories interfaced by a photon is first required not only for quantum repeaters but also for distributed quantum computers [6,7]. Quantum entanglement detection between two adjacent nodes then swaps the entanglement to prolong the entanglement with the help of quantum teleportation mechanism.

The quantum entanglement is inherent in an NV center at the spin-orbit double excited state via the spin-orbit interaction. The spin-orbit entangled state called A_2 state has been used to generate entanglement between a photon emitted from the A_2 state and an electron spin at the orbital ground state [5]. Entanglement generation between two electron spins at remote NV centers has been also demonstrated by the measurement-based entanglement scheme with using a beam splitter [6]. We here demonstrate that the A_2 state can be also used for the entanglement detection between a photon absorbed in an NV center and an electron spin at the orbital ground state. The entanglement detection enables the entanglement swapping via the absorption of a photon emitted from an NV center at the next repeater node to prolong the prepared entanglement, which is a key function of quantum repeaters.

By successively swapping the entanglement from both sides symmetrically, we will be able to create long haul entanglement at a reasonable repetition rate for quantum key distribution without the need of quantum memory time over the whole system.

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