Quantum teleportation transfer from a photon to a nucleon in diamond

Hiroki Kano[1], Ryota Kuroiwa[1], Yuhei Sekiguchi[1], Takaaki Nakamura[1], Riyo Enyo[1], Hideo Kosaka[1]*

[1]*Yokohama National University, 79-5 Tokiwadai, Hodogaya, Yokohama 240-8501, Japan*

*Corresponding author: kosaka-hideo-yp@ynu.ac.jp

Quantum information is carried on various kinds of quantum media such as photons, electrons and nucleus in the basis of polarization or spin states. A photon transmits a quantum state over a long distance through an optical fiber, while a nuclear spin stores a quantum state for a long time because of its long coherence time [1]. Quantum state transfer from a photon to a nuclear spin is thus required to utilize their characteristics.

We here report demonstration of quantum state transfer of a photon polarization state to a nuclear spin in a nitrogen vacancy (NV) center in diamond based on quantum teleportation scheme, which is achieved by generating electron-nuclear quantum entanglement and measuring photon-electron quantum entanglement (Fig. 1). Our experiment have two features. First, we reduce a magnetic field as low as possible to degenerate $m_s = \pm 1$ states of the electron spin serving as a logical quantum bit [2]. Then we are able to measure the photon-electron entanglement via a photon absorption [3]. Second, we receive a heralding signal upon the success of the state transfer via the single-shot measurement of the electron to be $m_s=0$. Without this heralding signal, we have to make not only a perfect optical cavity but also a perfect optical link to suppress the inevitable photon loss that lowers transfer fidelity.

We experimentally evaluated the fidelities for complete basis states of the photon polarization to be transferred into a ^{14}N nuclear spin (Fig. 2). The achieved fidelities are all over 80%, which enough exceeds the classical limit of 66%. This results indicate that the transfer we demonstrated is “quantum” state transfer.

We thank Yuichiro Matsuzaki, Kae Nemoto, William Munro, Norikazu Mizuochi, Fedor Jelezko, and Joerg Wrachtrup for their discussions and experimental help. This work was supported by National Institute of Information and Communications Technology (NICT) Quantum Repeater Project, and by Japan Society for the Promotion of Science (JSPS) Grant-in-Aid for Scientific Research (24244044, 16H06326, 16H01052) and Ministry of Education, Culture, Sports, Science and Technology (MEXT) as “Exploratory Challenge on Post-K computer” (Frontiers of Basic Science: Challenging the Limits).

References

[1] S. Yang *et al.*, *Nat. Photonics.* **10**, 507-511 (2016).
[2] Y. Sekiguchi, N. Niikura, R. Kuroiwa, H. Kano and H. Kosaka, *Nature Photon. in press* (2017).
[3] H. Kosaka and N. Niikura, *Phys. Rev. Lett.* **114**, 053603 (2015).

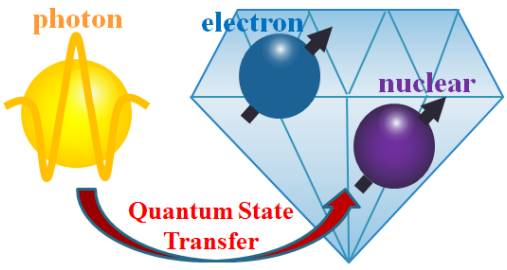

Fig. 1. Teleportation-based quantum state transfer

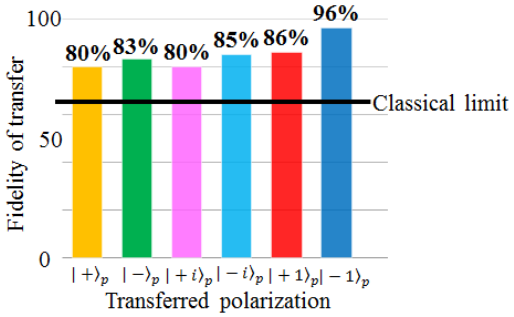

Fig. 2. Fidelities of the quantum state transfer