Teleportation-based Quantum Media Conversion from photons to a nuclear spin in diamond

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Quantum information is carried on various kinds of quantum media such as photons, electrons, and nucleus in the basis of polarization or spin states [1, 2]. Photons transfer a quantum state over long distance, while nuclear spins store a quantum state for long time. Quantum media conversion between them will be required as an interface for hybrid quantum systems [3]. The only way to achieve faithful quantum media conversion is to use the quantum teleportation scheme, which utilize a prepared electron-nucleus entanglement and post-selection of photon-electron entanglement [4]. The redundancy is required to distillate less frequent event into only the success event with the help of quantum non-demolition measurement, which makes probabilistic process into deterministic. Without the post-selection mechanism, we have to make not only a perfect optical cavity [5] but also a perfect optical link to suppress the inevitable photon loss that lowers the conversion fidelity.

We here report the experimental demonstration of quantum media conversion from photons to a nuclear spin by preparing an entangled state between an electron spin and a nuclear spin and successive photon absorption. The demonstration relies on the measurement of an entangled state between the photon polarization and the electron spin through the previously demonstrated entangled absorption [3]. The entangled absorption utilizes an electronic orbital exited state which is entangled with the spin state to select photons whose polarization state corresponds to the spin state to absorb. Another important mechanism is the quantum non-demolition measurement called the single-shot measurement of an electron spin state by spin-dependent photoluminescence measurement, which post-selects only the success event without destroying the stored nuclear spin state to make probabilistic conversion into deterministic without any optical cavity.

Figure 1 shows the conditional probability of the transferred state from a photon polarization state to a nuclear spin state. The bright state indicates the photon polarization state that is converted into the nuclear spin state to be measured. The fidelity of the conversion is over 90%, which enough exceeds the classical limit of 50%. Although we used a photon ensemble that consists of around 100 to 1000 photons for the input to speed up the measurement, the averaged photon number to be absorbed is around one and the scheme is independent of photon number even well below one since the distillation mechanism is built in the scheme.

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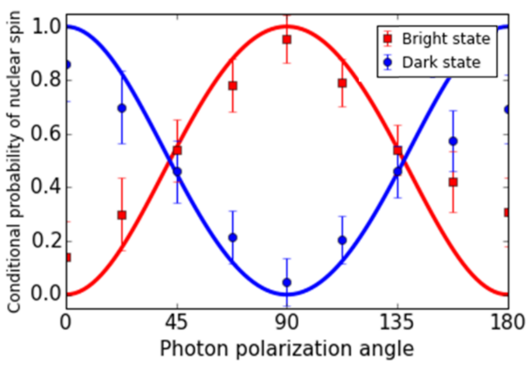

Fig. 1: Conditional probability of transferred states from a photon polarization state to a nuclear spin state. Red squares (blue circles) show the probability of nuclear spin bright state of $|1\rangle + |-1\rangle$ (dark state of $|1\rangle - |-1\rangle$).