【Grant-in-Aid for Scientific Research (S)】

Broad Section D

Title of Project： Universal quantum media conversion in diamond quantum storage

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Research Project Number: 20H05661 Researcher Number：20361199
Keyword：Quantum information, Spintronics

【Purpose and Background of the Research】

In recent years, competition for the development of quantum computers using superconducting qubits has become worldwide research trend, but on the other hand, the development of the quantum internet, which enables encrypted communication with physically guaranteed security, has also begun. Furthermore, with the spread of DNA banks and Bitcoins, the need for quantum storage for the safe storage of personal information that cannot be leaked is rapidly increasing. By constructing a quantum computer network, it will be possible to perform distributed quantum computing, blind quantum computing, and quantum internet (Fig. 1). To realize these, it is indispensable to develop a large-scale quantum storage and its quantum interface, which are highly consistent with the superconducting qubit, which is the heart of the quantum computer, and can hold the quantum state for a long time.

The purpose of this study is to establish an universal quantum media conversion technology in quantum storage composed of carbon isotopes (^{13}C) distributed in a cloud shape around a single nitrogen-vacancy (NV) center in diamond. The development of 1M-bit scale quantum storage that is highly consistent with superconducting qubits and operates in the absence of a magnetic field paves the way for distributed quantum computation and blind quantum computation by quantum computer networks connected by the quantum internet, and brings dramatic evolution to the highly computerized society.

【Research Methods】

In previous research, we have developed a technology to convert the quantum state of photons into surface carbon based on quantum teleportation principle, using the surface carbons near an NV center as a quantum memory that operates under a zero magnetic field. On the other hand, in this study, the deep carbons distant from NV is used as quantum storage, and individual quantum entanglement of deep carbons by geometric decoupling,

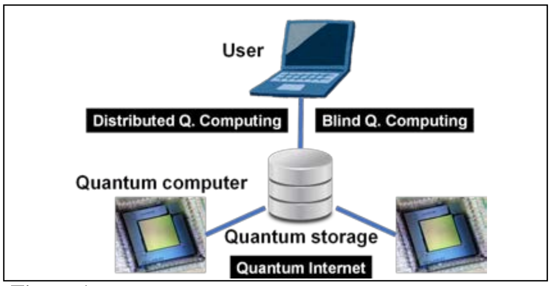

Figure 1 Concept of a quantum computer network quantum-mechanically connected by a quantum storage.

selective quantum media conversion from single photon to a single deep carbon, quantum entanglement measurement between arbitrary deep carbons, fault tolerantization by quantum coding, and large-scale quantum storage by extension to NV ensemble are realized.

At the center of the NV, there are electrons captured by the defect and a nitrogen impurity adjacent to them, and two types of carbon isotopes (^{13}C) are distributed in layers according to the distance from the electrons. The feature of this research is to use these as a quantum processor, quantum buffer, quantum memory, and quantum storage, and to increase the scale by using an ensemble (Fig. 2).

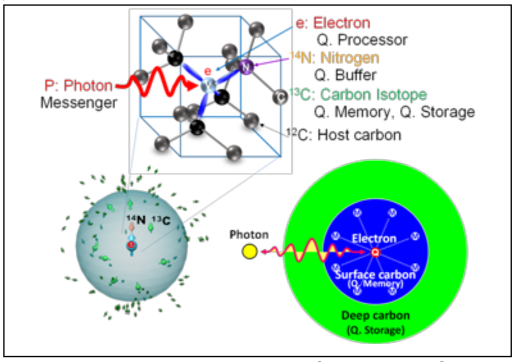

Figure 2 A layered structure consisting of electrons-surface carbons-deep carbons associated with a single nitrogen vacancy (NV) center in diamond.

【Expected Research Achievements and Scientific Significance】

Quantum storage that operates under a completely zero magnetic field is highly consistent with superconducting qubits, paving the way for distributed and blind quantum computations using quantum computer networks connected via the quantum internet

【Publications Relevant to the Project】

· Kodai Nagata, Hideo Kosaka*, et.al., “Universal holonomic quantum gates over geometric spin qubits with polarised microwaves”, Nature Communications, 9, 3227 (2018).
· Kazuya Tsurumoto, Hideo Kosaka*, et.al., "Quantum teleportation-based state transfer of photon polarization into a carbon spin in diamond", Communications Physics (Nature publishing), 2, 74 (2019).

【Term of Project】 FY2020-2024

【Budget Allocation】 150,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://kosaka-lab.ynu.ac.jp/