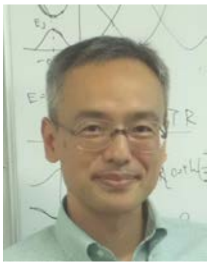
【Grant-in-Aid for Scientific Research (S)】

Science and Engineering (Interdisciplinary Science and Engineering)



Title of Project : Hybrid Quantum Systems Using Collective Modes in Solids with Broken Symmetry

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Research Project Number : 26220601 Researcher Number : 90524083
Research Area : Physics in nanostructures
Keyword : Quantum information

【Purpose and Background of the Research】

Traditionally, quantum state engineering has been studied in microscopic systems such as atoms, electrons, and spins. Here, we aim at technologies for quantum state control of collective degrees of freedom in solids. Based on our research background in superconducting quantum circuits, we will develop hybrid quantum systems and establish the new fields of quantum magnonics and quantum nanomechanics.

【Research Methods】

We use superconducting quantum circuits as a tool for controlling other collective quantum degrees of freedom in solids, such as magnons in ferromagnets and phonons in nanomechanical devices. The well-established superconducting qubit technology gives us flexibility in the designs of the coupling schemes in the microwave domain.

1. Generation and characterization of non-classical microwave quantum states in superconducting circuits
2. Quantum-state control of a single magnon in a ferromagnetic single crystal
3. Cooling toward the ground state and control of the photon quantum state in a mechanical oscillator with opto-electro-nanomechanics

As shown in Fig.1, Items 2 and 3 are also pursued from the optical side, which will eventually help coupling superconducting circuits indirectly, but still coherently, to optical degrees of freedom.

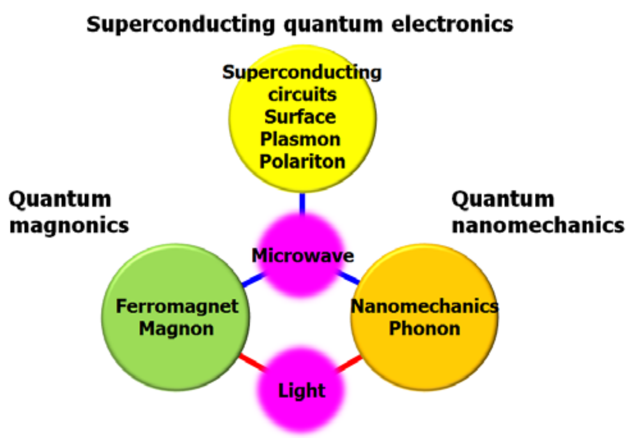

Figure 1 Hybrid quantum systems

【Expected Research Achievements and Scientific Significance】

The outcome of our research will extend the scope of quantum state control and quantum engineering from microscopic world to macroscopic collective degrees of freedom. Applications of quantum mechanics to macroscopic systems are of long-standing interest and allow us to investigate the quantum-classical boundary.

Collective modes extending in macroscopic dimensions in space result in a large transition moment and accordingly strong coupling with electromagnetic field. As we have seen in superconducting quantum circuits, the strong interaction often brings new physics and applications.

Quantum interface between superconducting circuits and optical communication channels is still lacking. The hybrid quantum systems we are developing will be a candidate towards the goal.

【Publications Relevant to the Project】

- "Breakthroughs in microwave quantum photonics in superconducting circuits," Y. Nakamura and T. Yamamoto, IEEE Photonics Journal **5**, 0701406-1-6 (2013).
- "Quantum Computing," T. D. Ladd, F. Jelezko, R. Laflamme, Y. Nakamura, C. Monroe, and J. L. O'Brien, Nature **464**, 45-53 (2010).
- "Coherent control of macroscopic quantum states in a single-Cooper-pair box," Y. Nakamura, Yu. A. Pashkin, and J. S. Tsai, Nature **398**, 786-788 (1999).

【Term of Project】 FY2014-2018

【Budget Allocation】 151,000 Thousand Yen

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