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

Science and Engineering (Interdisciplinary science and engineering)

Title of Project : Quantum Physics with Macroscopic Quantum Systems

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Research Area : Science and Engineering

Keyword : Atom/Molecule, Superconductivity, Spin properties, Quantum electronics, Quantum information

【Purpose and Background of the Research】

Recently, with a superconducting artificial atom, a research on light and matter at the single-photon interaction level, so called cavity quantum electrodynamics (cavity-QED) has been demonstrated in a superconducting circuit. We have demonstrated that the interaction (g) between a microwave photon and a superconducting artificial atom has been proven to be very large at least a few thousand times of the well-known atom-photon interaction with the Rydberg atoms. It is also intriguing that by way of circuit design, the relevant physical parameters of this system can be controlled at will.

We also observed time domain single photon exchanging oscillation, the vacuum Rabi oscillation, in a superconducting artificial atom LC harmonic oscillator system. Furthermore, we have succeeded in proof of principle type experiment on the quantum memory with a Dicke's single excitation superposition spin state of dense electron spin ensemble of nitrogen-vacancy centers in diamond. Thus, it is possible to do the experiment in the unexplored frontier of quantum physics if one uses the macroscopic quantum systems.

One of the main purpose of this research is to achieve controlling the interaction (g) between macroscopic artificial atom and the harmonic oscillator over the programmed time period with designed strength. With fully utilize the merits of using the macroscopic artificial atom, we can make use of the strong coupling regime and develop the method to control quantum phase transition of the many body quantum ground state.

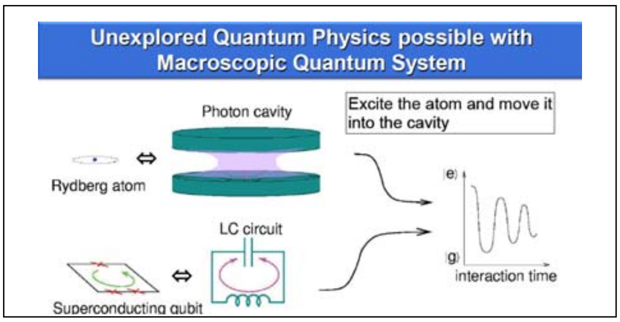

Figure 1 cavity-QED & circuit-QED

【Research Methods】

We plan to perform following researches in order to control interaction strength from weak to ultra-strong coupling regime.

- Build up the measurement system to do the interaction strength control spectroscopy.
- Generating non-classical state of macroscopic artificial atom harmonic oscillator system.
- Demonstrating ultra-strong coupling regime
- Observation and controlling the quantum phase transition of the quantum ground state.

【Expected Research Achievements and Scientific Significance】

Superconducting quantum circuits attract a lot of expectation to achieve quantum simulation and/or quantum computation. However, in order to give full scope to it's ability, still some breakthrough is needed. Our research will provide a big step forward to control phase transition of the quantum ground state of the many-body quantum system.

【Publications Relevant to the Project】

・K. Semba, et al.,"Experiment of Cavity Quantum Electrodynamics is Now Possible in a Superconducting Circuit! : Josephson Cavity-QED", Butsuri **64**,37-41(2009).
・S. Ashhab, F. Nori, "Qubit-oscillator systems in the ultrastrong-coupling regime and their potential for preparing non-classical states", Phys. Rev. A**81**, 042311(2010).
・X. Zhu et al., "Coherent coupling of a superconducting flux-qubit to an electron spin ensemble in diamond", Nature **478**, 221-224 (2011).

【Term of Project】FY2013-2017

【Budget Allocation】170, 600 Thousand Yen

【Homepage Address and Other Contact Information】

http://www.ryosi.com/qis/201207/01/
http://kaken.nii.ac.jp/d/r/50393773.ja.html