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

Science and Engineering (Interdisciplinary Science and Engineering)

# Title of Project : Interconversion of Quantum States Between Photon and Electron Spin Using Electrically Controlled Quantum Dots

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Research Project Number : 17H06120 Researcher Number : 10321902
Research Area : Semiconductor Quantum Physics
Keyword : Electron spin, Photon, Quantum State Conversion, Quantum dot, Lateral p-n junction

## 【Purpose and Background of the Research】

Quantum communication provides a secure communication method. Quantum repeaters (QRs) is an indispensable technology for long distance quantum communications and are actively studied in various quantum systems. This project aims to establish the interconversion of quantum states between electron spins in electrically controlled GaAs quantum dots (QDs) and photon polarization transmitting information. Quantum state conversion from photons to electron spins and entanglement conversion from photon pairs to distant electron spin pairs will be demonstrated. The light-spin conversion in group IV devices will be developed toward a quantum memory for QRs. Moreover, we will develop single photon emitters by combining a lateral p-n junction with an electrically controlled QD to realize quantum state conversion from electron spins to photons.

## 【Research Methods】

1. Quantum state conversion from single photons to single electron spins using electrically controlled QDs

Quantum state conversion from single photons to single electron spins will be achieved by realizing measurement bases rotations of the single photoelectron spin. Moreover, the conversion of entanglement from photon pairs to electron spin pairs can be performed. The evaluation and improvement of the conversion efficiencies are crucial.

In addition, we elucidate the elemental processes of the conversion from polarized light to electron spin and the influence of indirect transition in Ge quantum structures using spin valve effect.

2. Quantum state conversion from electron spins to photons in lateral p-n junctions with a QD

We realize the electroluminescence from lateral p-n junctions. Then, a QD is fabricated in the lateral p-n junction. First, we will observe single photon emission by injecting single electrons from the QD. In the next step, angular momentum conversion is demonstrated by confirming the correspondence between spin direction generated in a QD and incident circularly polarization. Finally, we tackle the quantum state conversion by developing the correlation measurement and by designing the band structure for an optical transition allowing the quantum state conversion.

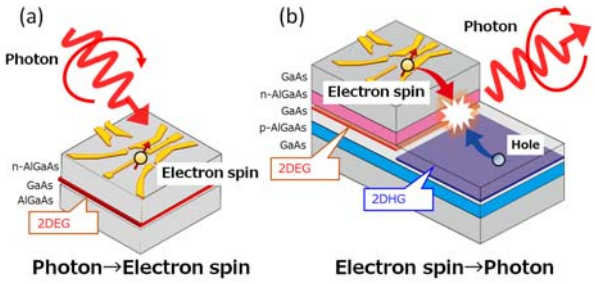


Figure 1 Schematic illustrations of quantum state conversions from photon to electron spin (a), and electron spin to photon (b).

## 【Expected Research Achievements and Scientific Significance】

Quantum state conversion from photons to electron spins in QDs and entanglement conversion from photon pairs to distant electron spin pairs will contribute greatly to realize QRs and to investigate the novel phenomena related to non-local entanglement in solids. On-demand quantum light sources emitting photons from spin states will create novel technologies for quantum information processing.

## 【Publications Relevant to the Project】

・Conversion from single photon to single electron spin using electrically controllable quantum dots, A. Oiwa *et al.*, J. Phys. Soc. Jpn. 86, 011008 (2017).
・ Non-destructive Measurement of Single Photo-electrons by Inter-dot Tunneling in a Double Quantum Dot, T. Fujita *et al.*, Phys. Rev. Lett. 110, 226803 (2013).

## 【Term of Project】

FY2017-2021

## 【Budget Allocation】

166,100 Thousand Yen

## 【Homepage Address and Other Contact Information】

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