【Grant-in-Aid for Scientific Research (S)】
Science and Engineering (Mathematical and Physical Sciences)

Title of Project : Exploring the Novel Quantum Electronic Physics in Solid State Using Spatial Control of Paired Quantum States

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Research Project Number : 26220710 Researcher Number : 40302799
Research Area : Solid state quantum physics
Keyword : Spin physics (semiconductor)

【Purpose and Background of the Research】

The concept of quantum control has been developed to offer new classes of quantum electronics with electronic correlations in nanostructures, hybrid quantum couplings of electron-photon or superconducting-normal state. The PI has long contributed to this field in semiconductor nano-science. He has used electrical control to explore spin correlations in quantum dots (QDs), QD Josephson junctions, photon-spin interfaces, and quantum electron optics. Throughout these studies he has been convinced that quantum control combined with control of spatial degrees of freedom will help pioneer a new field of correlated electron spin systems. The concept is broken down into four research projects: ①electronic correlations in QD arrays, ② quantum electron optics with single entangled spin pairs, ③ split electron pairs in superconductor (SC)/QD (nanowire (NW)) junctions, ④entanglement of single spin-photon pairs.

【Research Methods】

The four projects are carried out in the following strategy (Fig. 1).
①We prepare three to five exchange-coupled QDs available for spin qubits and use the qubit operation to probe the spin-correlated ground and excited state. We also demonstrate fundamental quantum algorithms for quantum computing.
②We use a surface acoustic wave (SAW) technique to transfer a singlet electron pair in each wave and split the pair into two in a branching waveguide. Finally we electrically control one electron spin by means of spin-orbit interaction to verify the correlation of the split electron spins.
③We improve the double QD Josephson junctions to raise the efficiency of split tunneling, and verify the distant pair correlation. In addition, we use the NW junction to search for Majorana fermion.
④We transfer information from single photons with circular polarization to single electrons with spin orientation and finally use an entangled photon pair to transfer the information of one of the paired photons to an electron spin.

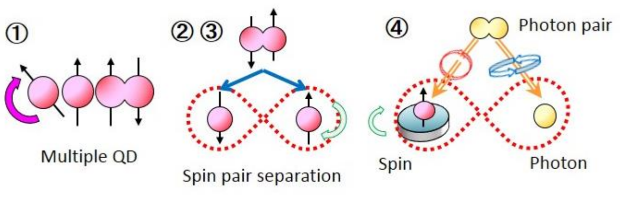

Figure 1 Spatial control in projects ① to ④

【Expected Research Achievements and Scientific Significance】

The multiple QDs with full control of the nearest neighbor interaction will help explore the physics of Heisenberg electron lattice. The spin-pair quantum electron optics with SAW for transferring a spin singlet will allow us to control non-local spin correlation and finally develop into a new field of solid state quantum electronics. The SC/QD (or NW) junctions will offer a challenging opportunity to control spatially separated but correlated electron pairs and Majorana fermion. This challenge will greatly benefit a broad range of science. The successful generation of spatially separated photon-spin pairs will strongly impact physics of hybrid quantum systems and applications to quantum information networking.

【Publications Relevant to the Project】

R. Brunner, Y.-S. Shin, T. Obata, Y. Tokura, M. Pioro-Ladrière, T. Kubo, T. Taniyama, and S. Tarucha: Two-qubit gate of combined single spin rotation and interdot spin exchange in a double quantum dot, Phys. Rev. Lett. **107**, 146801 -146804 (2011).
M. Yamamoto, S. Takada, C. Bäuerle, K. Watanabe, A. D. Wieck and S. Tarucha: Electrical control of a solid-state flying qubit, Nature Nanotechnology **7**, 247-251 (2012).

【Term of Project】 FY2014-2018

【Budget Allocation】 150,000 Thousand Yen

【Homepage Address and Other Contact Information】
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