Title of Project : Spin-polarized Lasing in Quantum Dots

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Research Area : New multidisciplinary fields

Keyword : Nanostructure fabrication, Quantum dot, Nano-optical devices, Spin devices

【Purpose and Background of the Research】

A spin-polarized laser is a new optical device emitting coherent lights with circular polarizations reflecting electron-spin states in solid state circuits. This spin laser is expected to be a coherent light source to transfer the electron-spin states which are important in future electronics into the circular polarization properties of the light. Electron-spin relaxation can be significantly suppressed in semiconductor quantum dots (QDs), therefore, the spin states can be temporally conserved. This means that a spin laser with active gain media consisting of the semiconductor QDs can realize efficient transfer from electron-spin states in solid state circuits to circular polarizations in laser lights.

We study the spin-polarized laser structure, where the QD active media with sufficiently long spin-relaxation times and metallic ferromagnetic electrodes are employed (Fig. 1).

The purpose of this study is first to fabricate metallic ferromagnetic electrodes for the injection of spin-polarized electrons. Next, we study atomic-scale hetero-epitaxial growth of the ferromagnetic thin film on the surface of a semiconductor layer for the purpose of achieving efficient electron-spin injection, where electron-spin relaxation induced by electron scattering due to defects and impurities during the injection is sufficiently suppressed. Finally, we identify the physical mechanism responsible for spin-polarized lasing in semiconductor QDs.

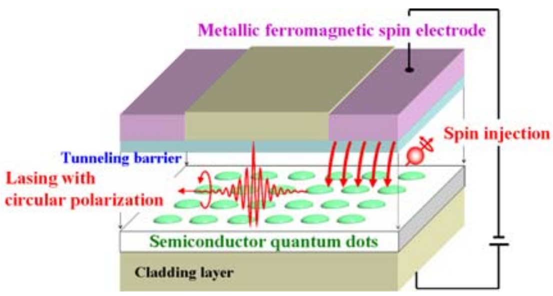

Fig. 1 A schematic drawing of the spin-polarized laser structure with active media of semiconductor QDs and metallic ferromagnetic electrodes.

【Research Methods】

Metallic ferromagnetic nanostructures will be fabricated as electron-spin-injection electrodes by using a lithography technique. Next, epitaxial growth of the ferromagnetic thin film on the surface of a compound semiconductor layer will be studied for the purpose of eliminating interfacial defects which induce electron-spin relaxation during the spin injection across the interface. Additionally, ultrafast spin-polarized electron tunneling will be studied based on coupled spin-polarized wave functions of electrons, which enables to realize efficient spin injection with the injection time faster than the spin-relaxation time.

【Expected Research Achievements and Scientific Significance】

The physical mechanism to realize spin-polarized lasing in QDs will be established. In addition to this main achievement, the following scientifically significant points will be clarified; epitaxial growth of defect-free interfaces between semiconductor surfaces and ferromagnetic ultrathin films, coupled wave functions of spin-polarized electrons between a ferromagnetic layer and QDs, efficient ultrafast tunneling of spin-polarized electrons into QDs with the discrete density of states.

【Publications Relevant to the Project】

・A. Murayama, T. Asahina, K. Nishibayashi, I. Souma, and Y. Oka,
"Efficient spin injection into self-assembled quantum dots via LO-phonon-assisted resonant electron tunneling",
Appl. Phys. Lett. **88**, 023114 (2006).

・A. Murayama, T. Furuta, K. Hyomi, I. Souma, Y. Oka, D. Dagnelund, I. A. Buyanova, and W. M. Chen,
"Dynamics of exciton-spin injection, transfer, and relaxation in self-assembled quantum dots of CdSe coupled with a diluted magnetic semiconductor layer of $Zn_{0.80}Mn_{0.20}Se$",
Phys. Rev. **B 75**, 195308 (2007).

【Term of Project】 FY2010-2014

【Budget Allocation】 150,800 Thousand Yen

【Homepage Address and Other Contact Information】

http://mars-ei.eng.hokudai.ac.jp/