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.

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


Term of Project: FY2010-2014

Budget Allocation: 150,800 Thousand Yen

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