論文の内容の要旨

Terahertz resonators and their applications to large-amplitude operation of semiconductor superlattices

(テラヘルツ共振器とその半導体超格子交流大振幅動作への応用に関する研究)

酒瀬川　洋平

This thesis presents the development of terahertz resonators, and their application to the control of electrical conduction in semiconductor superlattices. The motivation for the latter application is to overcome the superlattice high-field domain problem originated from their negative dc conduction, by which realization of the semiconductor Bloch oscillator has been hindered for more than 40 years since Esaki and Tsu's proposal. Thesis consists of two main parts.

In the first part, we describe the feasible solution to the high-field domain problem by using theoretically proposed large amplitude operation scheme, in which superlattices are irradiated with intense altering fields. This chronologically modulates their dc negative differential conductivities, yielding time average positive ones. We designed a doped superlattice in GaAs/AlAs system and also showed that such operation scheme could be implemented in a real system by combining a carefully designed superlattice with a suitable terahertz resonator. We actually fabricated such coupled devices with a semiconductor processing technology and observed dc current suppressions in devices under the irradiation from 10-Watt class sub-THz fields from a gyrotron.

The second part of this thesis is devoted to the development of photonic crystal micro-resonators suitable for superlattices in lasing condition (Bloch oscillators). Lacking of photonic bandgaps in candidate waveguide structures, cavity resonators had not been obtained yet. At first we realized photonic band gap for the transverse-magnetic modes using a novel mode decouple scheme. We inserted a semitransparent conductive film between the PhC electrode and the waveguide core for applying uniform bias voltages. We found that such layers with optimized sheet conductance clearly suppress the coupling between the waveguide mode and the surface leaky mode, making possible for us to obtain a clear photonic band gap. We also designed a high-quality factor microcavity with a very small mode volume. Besides, we discussed the degradation mechanism of light extraction from cavity modes trapped in such a microcavity.