Abstract

In this dissertation I carried out research on two-dimensional electron gas (2DEG) excitations in the range of electromagnetic radiation of terahertz (THz) frequencies. The aim of the work was to understand the mechanisms behind the generation and detection of THz radiation by 2DEG and to propose new semiconductor structures that can be used in construction of new sources and detectors of THz radiation. I carried out the detection and emission studies in independent series of experiments and performed them on numerous semiconductor structures, a large part of which was fabricated using the electron-beam lithography technique. In the case of emission studies, I used commercial field-effect transistors based on GaAs/GaInAs and samples made on a GaAs/GaAlAs heterostructure. For detection studies, I used samples containing double and single CdTe/CdMgTe quantum wells.

The research on THz radiation emission was inspired by theoretical works of M. Dyakonov and M. Shur, who predicted a possibility of THz radiation generation by field-effect transistors, and by experimental works in which the emission from field-effect transistors was observed. In my work, I repeated some of experiments described in experimental papers of other authors. The aim of this was, first, to better understand mechanisms behind generation of THz radiation from field-effect transistors. Secondly, I wanted to understand an existing discrepancy between scientific reports on observation of THz radiation emission from field-effect transistors and an apparent lack of transistor-based THz radiation sources almost sixteen years after the first publication in which such emission was observed. Working on the issue of THz radiation emission from field-effect transistors, I obtained experimental results the analysis of which indicates that, first of all, some nanometer field-effect transistors can be a source of quite high power microwave radiation. Second, I have shown that the use of a magnetic-field-tuned InSb detector for spectral analysis has a limitation that, if not taken into account, can lead to a wrong interpretation of spectra.

In addition to emission research from field-effect transistors, I carried out research on emission from structures made of GaAs/GaAlAs heterostructure containing a two-dimensional electron gas of a high electron mobility. These studies led to observation of a resonant THz radiation emission with a frequency of 400 GHz. The performed measurements showed that the emission was not related to the shape and geometry of the samples but to parameters of the heterostructure. The analysis of experimental results and the work of other authors suggest that the emission may be related to the impact ionization of shallow impurities in the heterostructure.

The research on the detection of THz radiation was inspired by the work of S. Mikhailov in which the author describes a possibility of enhancing plasma resonance by creating a grating on the sample surface containing a two-dimensional electron gas, with an electron concentration comparable to the concentration of electrons in a quantum well. The idea of coupling a two-dimensional electron gas in a quantum well with THz radiation using a grating with a carrier concentration similar to the concentration of carriers in the well was achieved by using an appropriately processed semiconductor structure containing a double CdTe/CdMgTe quantum well. This implementation consisted of etching grooves in the upper well such that non-etched areas of the upper well formed a series of 2DEG-containing stripes. I created a number of such structures that differed with parameters of etched areas, i.e. the parameters of the semiconductor gratings. These parameters are etch depth, etch width and the period of grating. Additionally, I created a series of single quantum well structures with a "classic" coupler of THz radiation with a 2DEG in the form of a golden grating. Structures covered with semiconductor and metal grids have been studied in magnetotransmission measurements (measurement of THz radiation transmission as a function of magnetic field) in a wide range of THz radiation and at the temperature of superfluid helium. Obtained results were interpreted in the framework of a model describing magnetoplasmon excitation (excitation of a plasmon in magnetic field) in a 2DEG. Obtained results showed that samples with semiconductor grids can be used as resonant THz radiation detectors tuned with such parameters as: magnetic field, white light and geometric parameters of the grating. The second important result was the determination of the polarization of the magnetoplasmon excited in the samples; it became possible thanks to the use of semiconductor gratings that do not act as polarizers.

Keywords: *THz radiation, THz spectroscopy, field-effect transistors, two-dimensional electron gas, magnetoplasmons, cyclotron resonance, InSb, CdTe, GaAs.*