PREFACE

Over the last two decades or so the field of semiconductor layered structures (heterostructures) with ultra-thin dimensions (~ 10 nm) has evolved into one of the most active areas of research and development in condensed matter physics. After the pioneering work by Esaki and Tsu for the transport properties and by Dingle for optical properties this field got sudden impulse and breakthrough in fundamental science and applications at the end of 1970s.

Modern growth technologies like molecular beam epitaxy (MBE) and metal organic chemical vapour deposition (MOCVD) made it possible to grow the layered structures with unprecedented purity and crystalline perfection on nanometer scale. Often these structures are called 'low dimensional semiconductor structures' (LDSS) or 'quantum semiconductor structures' or nanostructures. In these structures carriers (electrons or holes) are confined in one or more than one directions and they are free to move in other directions. This act of quantum confinement leads to the quantization of energy and formation of discrete subbands in the direction of confinement without altering the energy in the other
directions. Energy levels and density of states become very much dimensionality dependent. Quantum confinement in layered structures produces not only quantitative but also qualitative differences in physics from that in bulk semiconductors. LDSS have offered many new physical phenomena such as quantum Hall effect (integer and fractional), Fermi level correlation singularities, real space charge transfer, ballistic transport, quantization of conductance in quantum point contacts etc.

It has now been realized that tailoring of the properties of these quantum structures for specific purposes is possible. As a result they have the potential and revolutionary applications in electronic and opto-electronic devices and researchers are motivated to study the basic physics of these devices. Heterostructure electronic devices such as modulation doped field effect transistors (MODFET), bipolar transistors, high electron mobility transistors (HEMT), quantum well lasers etc. are now being commercially exploited.

The quantization effects due to reduced dimensionality are observable if the layer thickness is smaller than the de Broglie wavelength of the carriers and both are smaller than mean free path of the carriers in the layer.
Moreover, relaxation time of the carriers should not be too small to broaden the quantized energy levels, due to collisions, to the extent of smearing out quantization.

A quasi-two-dimensional (Q2D) electron gas, with confinement in one direction, was first realized in Si-MOSFET and later in semiconductor single heterojunction (HJ) and quantum wells (QWs). Subsequently, combination of epitaxy, etching and lithography lead to fabrication of quantum wires and quantum boxes where carrier motion is confined in two and three directions, respectively, leading to realization of quasi-one-dimensional and quasi-zero-dimensional electron gas.

Understanding of the electronic properties of these man-made heterostructures has steadily progressed over the years. They have become ideal test structures for the study of many physical phenomena on short length scales (~ de Broglie wavelength, Fermi wave vector and magnetic lengths) in condensed matter physics. There are several reviews, book chapters, text books, and proceedings of the conferences on the electronic properties of these semiconductor structures.

In this thesis we study two important optical properties of Q2D electron gas in QWs which are given less
attention in the literature. One of them is 'interband magneto-optical absorption' in QWs of indirect band gap semiconductors. Other one is 'photon-drag effect' in QWs. Besides the above mentioned two optical properties, we study the effect of confinement of polar optical phonons on the electron energy loss rate in QWs in a quantizing magnetic field. It is a property which is not yet well resolved.

In Chapter 1 we briefly give the electronic structure of quantum well. Also we discuss the electron-phonon interactions in quantum well.

Spectroscopic techniques such as absorption and luminescence are being widely used as tools in understanding the basic physics of these layered structures. Most of the linear and non-linear optical properties are studied mainly on QWs because they are single layer simplest structures showing clear quantum confinement effects and their band structures can be tailored. Widely studied QW structures are from III-V compounds in general and GaAs/GaAlAs in particular. They have direct energy gap. Less attention is given to the study of linear and non-linear optical properties of QWs of indirect band gap materials such as Si$_x$Ge$_{1-x}$/Si. Recently Si$_x$Ge$_{1-x}$/Si QWs have become the subject of intense scientific and
technological interest due to their enhanced capabilities. In Chapter 2 we give the theory of one- and two-photon interband magneto-optical absorption in QWs of indirect energy band gap, without excitonic effects. With magnetic field along the growth direction, energy of the carriers is quantized into series of Landau levels. In QWs of indirect band gap the optical absorption is assisted by phonons, impurities and other imperfections. We study the phonon-assisted magneto-absorption. Selection rules are evaluated for Landau level transitions and subband transitions. Expressions for the phonon-assisted one- and two-photon absorption coefficients are derived and they are studied as a function of energy of the radiation, well width and temperature. These calculations are compared with those of direct band gap QWs.

We study the photon-drag effect, a light induced drift of free carriers due to transfer of momentum from the absorbed photons, in QWs. It is an intraband absorption phenomenon. This work is presented in Chapter 3. Polarization of the radiation is taken in the plane of the layer. Transfer of momentum is taken through the photon-carrier-phonon interaction. Photon-drag current is studied, with the involvement of different types of phonons, as a function of
energy of radiation, well-width and temperature.

Study of energy loss rate (ELR) of a Q2D hot electron gas in QWs is of current interest. It is used as a probe to investigate different types of electron-phonon interactions. The observed ELR in QWs is not explained by simple electron-3D phonon Fröhlich interaction. Though there exist numerous calculations, the study of ELR in QWs is by no means well resolved. We study ELR of Q2D electrons due to confined polar optical phonons and interface optical phonons in GaAs/AlAs QW in a quantizing magnetic field. This work is presented in Chapter 4. We compare our calculations with those of Q2D electron-3D phonon interactions.

Summary and conclusions of the present work are given at the end of the thesis.