Dedicated to

My Parents, Husband and Daughter

Who mean the world to me and without their support this work would have been impossible!
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Declaration

I do hereby affirm that the work presented is my unique work and has no resemblance to any other existing work in the relevant field. The research work has been ably supervised by Dr. P.A. Alvi, Associate Professor, Department of Physics, Banasthali University.

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Abstract

Semiconductor lasers, since their creation in 1960’s have assumed a very significant technological role. They have gained an important place in the class of lasers and are used in applications such as telephone and image transmission, television signal transmissions, computer interconnects and networks, bar code readers, laser printers and military applications. Recently they have gained usage in two dimensional display panels, rewritable optical data, storage of images, welding, and medical applications as well. Main reasons behind their popularity may be attributed to high optical output power, low threshold current, short optical pulse generation, high speed direct current modulation, narrow spectral line width, broad line width range, cheaper cost and miniscule electrical power consumption. These accomplishments can be ascribed to the combined progress in technologies related to growth of materials as well as theoretical understanding of a completely novel class of semiconductor lasers- the Quantum Well Lasers. There has been an extensive study of heterojunction structures leading to many Optoelectronic applications. Brief outline of the research work is presented below:

Chapter 1 deals with the introduction of heterojunctions and heterostructures. Energy band diagrams of semiconductors are studied when they are a standalone unit and when they are brought in contact with each other. Various types of heterojunctions are studied when they are classified based on the basis of conductivity, composition, band alignment and refractive index profile. Growth techniques of heterostructures and their applications have also been touched upon.

Chapter 2 is dedicated to the literature survey of the two nano heterostructures which we have explored for their lasing characteristics namely AlInGaAs/GaAs and AlGaAs/InP.

Chapter 3 talks about the theoretical aspects of quantum wells, calculation of energy levels in valence and conduction bands, quasi Fermi levels, concept of strain and lasing characteristics like material gain, mode gain, anti-guiding factor gain compression, refractive index change and differential gain,

Chapter 4 compares the bulk heterostructures with nano-heterostructures. Energy band structure of bulk materials is discussed and the compositional dependence of ‘Ga’ is evaluated for the ternary heterostructures AlGaAs/GaAs and InGaAs/InP along with quaternary heterostructure InGaAlAs on GaAs and InP substrates.
Chapter 5 explores the lasing characteristics of step index SCH (separate confinement heterostructure) quaternary semiconducting heterostructure comprising of solitary quantum well of $\text{Al}_{0.15}\text{In}_{0.22}\text{Ga}_{0.63}\text{As}$ with a barrier of $\text{Al}_{0.2}\text{Ga}_{0.8}\text{As}$ and a cladding of $\text{Al}_{0.61}\text{Ga}_{0.39}\text{As}$ on GaAs substrate. In the subsequent part of this chapter yet another ternary semiconductor based lasing heterostructure comprising of single quantum well of $\text{In}_{0.45}\text{Ga}_{0.55}\text{As}$ with a barrier of $\text{Al}_{0.29}\text{Ga}_{0.17}\text{In}_{0.54}\text{As}$ and a cladding of $\text{Ga}_{0.48}\text{In}_{0.52}\text{As}$ grown on InP is surveyed. Apart from the lasing features like optical gain, modal gain, anti guiding factor, the energy band structure along with valence band (VB) and conduction band (CB) envelope functions and band offsets has been studied. Using theoretical simulation, the behaviour of quasi-Fermi levels in both the CB and VB have been determined. These properties have been studied in both the polarization modes namely Transverse Electric (TE) and Transverse Magnetic (TM) modes and their comparisions have been made.

Chapter 6 investigates the SQW quaternary semiconducting InGaAlAs/GaAs heterostructure and the ternary lasing heterostructure AlGaAs/InP based on GRIN SCH profile. The dependence of material gain on application of strain, well width alterations and temperature variations has been probed.

Chapter 7 examines the MQW heterostructure based on STIN-SCH profile of InGaAlAs/GaAs and AlGaAs/InP. The comparative study of the two heterostructures has also been drawn to scrutinize their usage in various optoelectronic applications.

Chapter 8 probes the MQW InGaAlAs/GaAs and AlGaAs/InP heterostructure based on graded index -SCH profile and its lasing properties. Effect of number of quantum wells and GRIN steps has been evaluated on material gain.

Chapter 9 is dedicated to the discussion, summary and conclusion of the two heterostructures.
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