CHAPTER 1

Introduction

1.1 Background

The laser diode is a semiconductor device consisting of a forward-biased p-n junction. Electron-hole recombination in the depletion region of the p-n junction provides the photon, and the cleaved facets perpendicular to the junction plane provides the optical feedback (by forming a resonant cavity) - the two necessary ingredients for any laser.

In the early of laser era, it was suggested [1] that laser diode performance might be improved if a layer of one semiconductor material were sandwiched between two cladding layers of another semiconductors that has a relatively wider bandgap and lower refractive index. Such a device composing of two dissimilar semiconductors is commonly referred to a *heterostructure laser*, in contrast to single semiconductor devices which are labeled as *homostructure laser* which were reported the lasing action in the first time. Both of these structures are shown schematically in Fig.1.1a.

Heterostructure lasers are further classified as *single-heterostructure (SH)* or *double-heterostructure (DH)* devices depending on whether the active region, where lasing occurs, is surrounded on one or both sides by cladding layer of higher bandgap. The use of a heterostructure, however, required a careful matching of lattice constant of the two semiconductors. Gallium-arsenide (GaAs) and aluminium-gallium-arsenide ($Al_xGa_{1-x}As$) are the most generally used materials less than 0.1% lattice mismatch [2,3].

It is obvious that the laser diode is practical, compact, coherent light source, low power operation and capable of ultrafast direct modulation [4]. In present, the laser diode is performing a major role for numerous electronics devices, such as, in home appliances - compact disc players, in highly-precise measurement equipment, and in conventional fiber-optic communication systems. Most applications require the high output light, the optical mode stabilization and the resultant single-optical mode oscillation. This has been made possible by deeper understanding of the waveguiding mechanism of the heterostructure laser and the design of proper device structures, in all three optical mode directions - along the cavity (*longitudinal*), perpendicular (*transverse*) and parallel (*lateral*) directions to the junction plane.

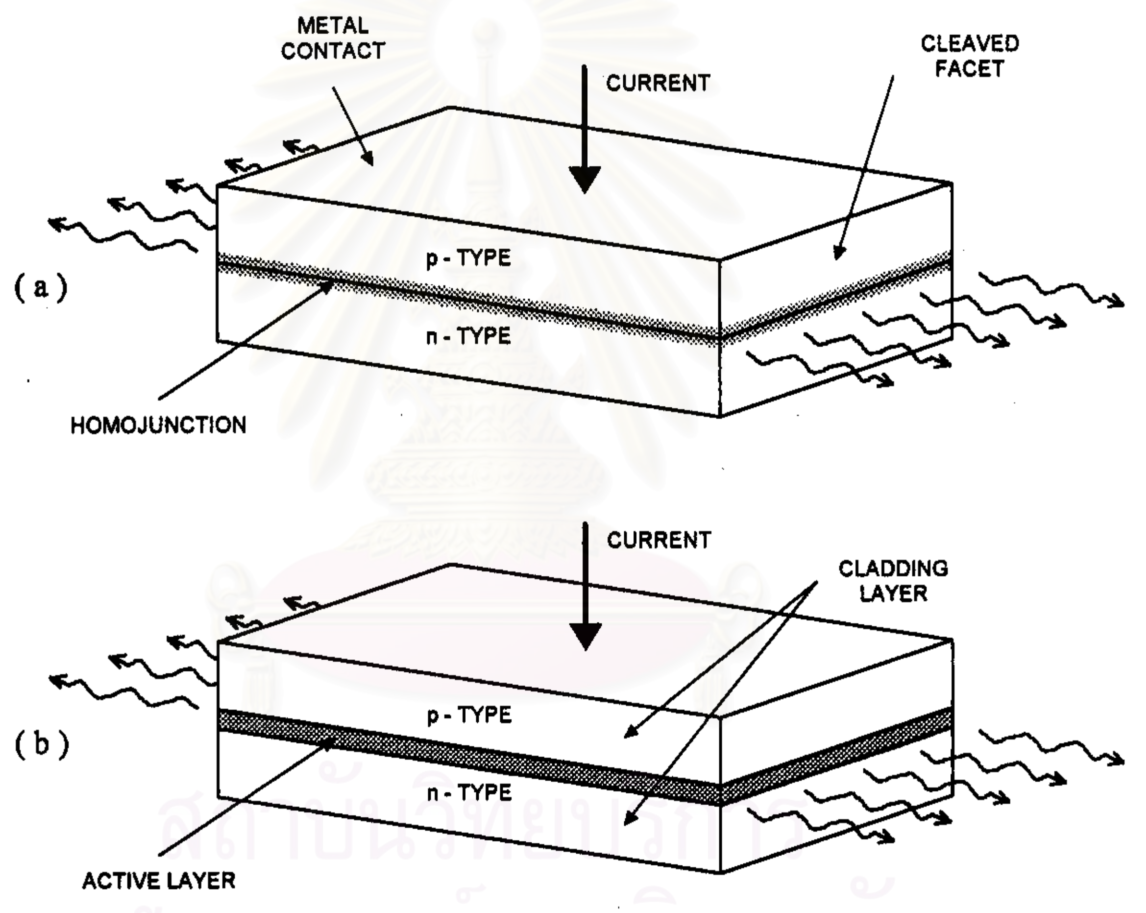

Fig. 1.1 Schematic illustration of (a) homostructure and (b) double-heterostructure laser diode. The dotted area represents the depletion region in the vicinity of the homojunction. The shaded area shows the thin (~0.2 μm) active layer of a semiconductor material whose bandgap is slightly lower than that of the surrounding cladding layer

The most commonly used analysis technique for dielectric waveguide laser is *effective refractive index approximation* [5-10]. The method combines the bulk refractive indices in each layer of the heterostructure to an approximate value called *effective refractive index* (n_{eff}). *Confinement factor* (Γ) [10] is a quantity that plays an important role for the laser because it represents the fraction of laser mode energy within the guiding layer that is available for interaction with the injected charge carriers and photons, in other word, it means the ratio of the guiding laser energy to the overall energy generated by the carriers.

The most industrially popular and practical structure, ridge waveguide, have been selected for the thesis scheme. Transverse confinement of both electron and photon is obtained by the heterostructure, while lateral confinement can be achieved by the ridge structure. Then the ridge waveguide laser diode can provide high-power single-spot beam and fundamental mode stability with less power consumption, The ridge, fabricated by one epitaxy growth, is more easy and convenient that is very worthwhile for its advantageous performance.

1.2 Objective

The thesis aims to provide a comprehensive account of the study on optical confinement of ridge waveguide heterostructure for laser diode application. The study covers the theoretically optical guiding mechanism representing by effective refractive index (n_{eff}) and confinement factor (Γ) and their simulations in various laser diode structures. Ridge waveguide laser diode fabrication, composed of wet-chemically etching, is done to evaluate the advantageous performance in both electrical and optical of ridge waveguide heterostructure laser diodes.

1.3 Overview

The literature is organized as follows. It first chronologically describes the structures of various laser diodes in chapter 2 including their advantages and disadvantages. Then the nature of optically confining mechanism occurring in a laser diode is introduced in chapter 3 which also presents the effective index approximation and its applications in transverse and lateral analyses. Subsequently, the examinations of three transverse and a lateral structures corresponding to the ridge are the purpose of chapter 4. Their simulation results are submitted in the functions of residual thickness *(t)* and ridge width *(w)* which are the two designing parameters used in ridge waveguide manufacturing. After the designing process is determined, the fabrication process is performed. Chapter 5 provides the details of laser diode fabrication process which is composed of 8 major steps. Next, the characteristics of fabricated devices are reported and also be discussed in chapter 6. Finally, chapter 7 is reserved for thesis conclusion.