10. Surface-Emitting Lasers

The surface-emitting laser began to be considered one of the crucial devices for the next generation of optoelectronics when advantage was taken of its high degree of parallelism. In this chapter, we review the concept of a vertical-cavity surface-emitting laser, mainly consisting of the GaInAsP/InP, GaAlAs/GaAs, and GaInAs/GaAs systems. Their ultimate performance and impact on the electronics industry will be discussed.

10.1 The Concept of Surface-Emitting Lasers

The importance of ultrahigh-performance semiconductor lasers is rapidly increasing along with the progress of large-capacity parallel light-wave communications, multi-access optical discs and optical computing. However, the present structure of cleaved semiconductor lasers still presents some problems. Among the difficulties yet to be solved, the following are included: the initial probe test of such devices is impossible before separating the wafer into chips, and the monolithic integration of lasers into optical circuits is limited due to the finite cavity length.

The Fabry-Perot resonator for a vertical-cavity Surface-Emitting (SE) laser is formed by two surfaces of an epitaxial layer with the light output emerging vertically from the surface [10.1]. This laser-structure scheme, if realized, would provide many advantages [10.2]; i.e., (i) the laser device is fabricated by a fully monolithic process, (ii) a densely packed two-dimensional laser array could be fabricated, (iii) the initial probe test could be performed before separation into chips, (iv) dynamic single-longitudinal-mode operation is expected because of its large mode spacing (≈ 100 ÷ 200 Å), (v) it is possible to vertically stack multiple-thin-film functional optical devices onto the SE laser, and (vi) a sharp, circular beam is achievable.
10.2 Structure and Characteristics

10.2.1 GaInAsP/InP Surface-Emitting Lasers

A GaInAsP/InP SE laser with a Circular Buried Heterostructure (CBH), strictly speaking, with a Flat-surface CBH (FCBH) has been fabricated [10.3]. This laser was manufactured by means of a successive, fully monolithic fabrication process utilizing a three-step Liquid-Phase Epitaxy (LPE) growth. The substrate is polished to 150 μm thickness, and on the n-type side a Au/Sn electrode is formed. Next, the substrate and etch stop layer are selectively etched off to form a short cavity (7 μm). The p-type side Au/Zn/Au electrode is then formed. Finally, a SiO₂/Au reflector is constructed by evaporation on the bottom of an etched well only.

The current/light output characteristic of a CBH SE laser device at 77 K under CW conditions has been measured [10.4]. The minimum threshold value was 6 mA. Pulsed operation has been obtained [10.5]; and CW operation has been achieved at room temperature for 1.3 μm devices.

Fig. 10.1. Schematic view of a Metal Organic Chemical Vapor Deposition (MOCVD) grown Circular Buried Heterostructure (CBH) GaAlAs/GaAs surface emitting laser.