Chapter 9
The Vertical-Cavity Surface-Emitting Laser
A Key Component in Future Optical Access Networks

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ABSTRACT
The proposal chapter aims at highlighting the tremendous emergence of the Vertical-Cavity Surface-Emitting Laser (VCSEL) in the FTTX systems. The VCSEL is probably one of the most important and promising components of the “last-leg” Optical Access Networks. To satisfy the bandwidth rise as well as the inexpensive design constraints, the VCSEL has found its place between the Light-Emitting-Diode (LED) and the Edge-Emitting-Laser (EEL) such as the DFB (Distributed-Feedback) laser. Hence, the authors dedicate a chapter to the promising VCSEL technology that aims to give an overview of the advances, the physical behavior, and the various structures regarding VCSELS. They discuss the VCSEL features and performance to weigh up the specific advantages and the weaknesses of the existing technology. Finally, diverse potentials of Optical Access Network architectures are discussed.

INTRODUCTION
For more than ten years, the access network market is attracted by the Vertical-Cavity Surface-Emitting Lasers well known as the acronym VCSEL.

Indeed, the numerous advantages of this component make the VCSEL technology suitable for access networks and today several studies have demonstrated the feasibility of various configurations of Optical Access Network (OAN) using the VCSEL Technology.

Above all, the VCSEL has been designed to achieve the need of the optoelectronic circuits planarization. Since its invention in 1977 by Prof. K. Iga (Iga, Koyama, Kinoshita, 1988), the VCSEL structure is in a state of constant progress (Iga, 2000; Koyama, 2006; Chow, Choquette, Crawford, Lear, Hadley, 2006) Today, a wide wavelength emission range (from the Green-blue band up to the infrared)
The Vertical-Cavity Surface-Emitting Laser is covered that enables the usage of these components in various applications, not only in the field of digital data communications (Gigabit Ethernet) but also in consumer applications; such as optical switching, laser printers, laser mice, high-density optical disks, display systems, etc. Thereof the VCSEL market is composed of various fields of application: automotive, computer, consumer, industrial, military/aerospace, telecom, biomedical where computer and consumers are major fields in the VCSEL market (Szweda, 2006). As we focus on the OANs, we will study the VCSELs emitting at 850, 1310 and 1550nm.

Even though these three varieties of VCSELs have really different structures and performance, the following features are distinctive to the VCSEL-technology:

- The vertical laser emission is perpendicular to the layers which makes easier the one and two-dimensional integration (1D and 2D VCSEL-array) according to the electrical packaging constraints.
- The VCSEL is the smallest commercial available semiconductor laser diode (LD) type.
- By combining the small size and the perpendicular to the structure emission, this component responds to the criterion of planarization that makes the VCSEL, the LD with the higher integration level
- The AL low volume (Quantum Well) involves sub-milliampere threshold current and low electrical power consumption.
- The small cavity size allows for a single-mode longitudinal emission.
- The VCSEL presents low thermal variation close to the room temperature (wavelength, threshold current).
- The serial fabrication reduces the cost and allows on-wafer testing.
- Due to its cylindrical geometry, the light-beam cross-section is circular.

All these reasons have led to the VCSEL growth market in a wide application range.

Firstly, we present chronologically the VCSEL emergence through the pioneer structures, the salient features which allowed the improvement of the VCSEL operation. That led to the presentation of the main 850nm VCSEL and the emerging 1300 and 1550nm VCSELs. This section also gives the main characteristics of these three types of components.

Secondly, the second section of this chapter introduces the VCSEL modeling based on coupled carriers and photons rate equations and the main characterization needed to be known before integrating the VCSEL into a system. This knowledge is important to avoid a drawback that could be encountered by the inadequate utilization of the device, notably due to the frequency increase in the optoelectronics circuits and electrical mismatch in integrated circuits.

The last section discusses the VCSEL utilization in diverse system configurations to generate a signal for the OAN such as VCSEL-Based Oscillator, Optical injection-locking, etc. Some network architectures are also presented: Radio-Over-Fiber Distributed Antenna Systems, Hybrid OAN.

PRESENTATION OF THE VCSEL

Even if the first VCSEL structure emitted at long wavelength (LW), it’s the 850nm GaAs-VCSELs which became the emerging technology in 2000. Today the 850nm VCSEL technology is the most competitive and reliable one (Ulm photonics company, 2008). All these advantages are due to the maturity of the AlGaAs/GaAs technology and the good performance of the structure: a Quantum-Well (QW) active layer (AL) between two Distributed Bragg Reflectors (DBR). Thus, due to the cost effectiveness linked to the massive VCSEL production, this device finds quickly its application in the 850nm short-distance Multimode fiber links giving an alternative to the LED.