

MEMS-VCSEL Array for Multiple Wavelengths

Pallavi Sarde

*Department of Electronics Engineering
GHRCE, Nagpur, Maharashtra, India-440016*

Wani Patil

*Department of Electronics Engineering
GHRCE, Nagpur, Maharashtra, India-440016*

Abstract- This paper describes the Vertical Cavity Surface Emitting Laser (VCSEL) wavelength engineering for use in high speed short reach systems which may include the wavelength expansion and integration and also the wavelength stabilization based on fully monolithic technologies. Optical sources in MEMS structure will be seen as a VCSEL. The optical thickness variation of the layers in a VCSEL changes the lasing wavelength. The advantages of VCSEL include simply fiber coupling, easy packaging and testing, and the ability to be fabricated in arrays. This paper deals with the development of highly strained GaAs quantum well (QW) VCSELs emitting multiple wavelength band. Also extended the emission wavelength of highly strained GaAs/GaAlAs QWs up to 1100 nm. A VCSEL array comprising several VCSELs arranged side by side on a common substrate. The demonstration a multiple wavelength VCSEL array on a patterned GaAs substrate covering a new wavelength window of multiple wavelength.

Keywords – vertical-cavity surface-emitting laser, Semiconductor lasers, laser array, micro electro-mechanical system, biomedical applications.

I. INTRODUCTION

MEMS-VCSEL is a type of semiconductor laser diode. VCSELs were first invented in the mid-1980's. The acronym VCSEL is pronounced 'vixel.' VCSEL technology has historically provided the most cost-effective optical link solution for high bandwidth applications and proven in recent years by their rapid adoption over edge-emitting lasers in the data communications market. The significant cost reduction afforded by the 1.3-micron VCSELs will make increased bandwidth more accessible and cost effective for the telecommunications and Internet infrastructure. Vertical cavity surface emitting lasers are being developed towards higher speed, higher operating temperature and higher efficiency to satisfy demands for higher interconnect capacity, higher interconnect density, and reduced power consumption in e.g. data centers and high performance computing systems. Optical injection-locking is proposed as a solution to these problems. It enhances the intrinsic component bandwidth and reduces frequency chirp considerably.

The first VCSEL was proposed in 1979 by Soda, Iga, Kitahara and Suematsu, but practically devices for CW operation at room temperature were not reported until 1988. The first semiconductor VCSEL was invented by Axel Scherer and Jack Jewell, two scientists at the AT&T Bell Laboratories. Today, VCSELs have replaced edge-emitting lasers in applications for short-range fiber optic communication such as Gigabit Ethernet and Fiber Channel.

MEMS, is a technology that in its most general form can be defined as miniaturized mechanical and electro-mechanical elements (i.e., devices and structures) that are made using the techniques of micro fabrication. The critical physical dimensions of MEMS devices can vary from well below one micron on the lower end of the dimensional spectrum, all the way to several millimeters. Likewise, the types of MEMS devices can vary from relatively simple structures having no moving elements, to extremely complex electromechanical systems with multiple moving elements under the control of integrated microelectronics. We required wavelength in the range of nm which a very small unit hence we used MEMS VCSEL.

This paper is intended to provide the basic knowledge necessary to understand VCSELs' benefits and limitations and at the same time to give an overview of some state-of-the-art performance data obtained experimentally. We start with basic studies of the laser cavity, such as active region and reflector properties, where essential differences to edge-emitting laser operation are underlined.

A vertical cavity surface emitting laser (VCSEL) is a specialized laser diode that promises to revolutionize fiber optic communications by improving efficiency and increasing data speed. Older laser diodes, called edge-emitting diodes, emit coherent light or infrared (IR) energy parallel to the boundaries between the semiconductor layers. In Edge emitting laser light emission through the cleaved edge of the laser. Edge emitters are difficult to integrate in large numbers. On the other hand, Surface emitting laser much smaller and can be integrated in large numbers on a substrate wafer, much easier to test individually while still on the wafer. The VCSEL has several advantages over edge-emitting diodes. The VCSEL is cheaper to manufacture in quantity, is easier to test, and is more efficient. The VCSEL cavity is very short, 100-1000 times shorter than that of a typical edge-emitting laser. There is typically only one Fabry-Perot (FP) wavelength within the gain spectrum; hence the FP wavelength (and not the gain peak) determines the lasing wavelength. The vertical cavity surface emitting laser has many potential advantages over the edge-emitting lasers. In addition, the VCSEL requires less electrical current to produce a given coherent energy output. The VCSEL emits a narrow, more nearly circular beam than traditional edge emitters; this makes it easier to get the energy from the device into an optical fiber.

The VCSEL technology became useful for a variety of medical, industrial, and military applications requiring high power or high energy. Examples of such applications are:

- Medical/cosmetics: laser hair removal, laser wrinkle removal
- Infrared illuminators for military/surveillance
- Pumping of solid-state lasers and fiber lasers
- Laser machining: laser cutting, laser drilling, laser ablation, laser engraving
- Integrated semiconductor VCSELs and PIN Photo detectors for sensing
- Integration of GaAs VCSEL with a silicon sensor.

II. DEVICE DESIGN

A. Structure –

A typical VCSEL consists of two oppositely doped distributed Bragg reflectors with a cavity layer between. In the center of the cavity layer resides an active region, consisting of multiple quantum wells. Current is injected into the active region of the structure. As the entire cavity can be grown with one step epitaxy, these lasers can be manufactured after that test on a wafer scale. This presents a significant manufacturing advantage in various field. The position of the layers with thickness variation to the center of the cavity is crucial for the resulting wavelength variation; the closer they are to the cavity center, the larger the wavelength change. This property lends to designs of wavelength-tunable VCSEL and multiple wavelengths VCSEL arrays.

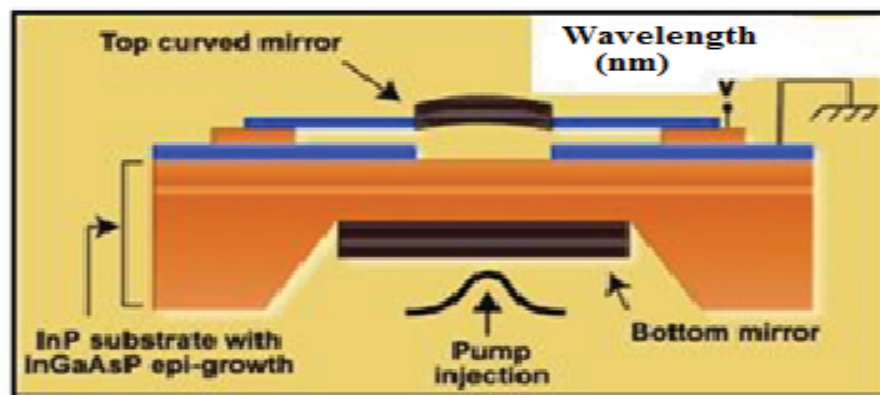


Figure 1. VCSEL Structure

B. Materials –

VCSELs however, can be tested at several stages throughout the process to check for material quality and processing issues. Additionally, because VCSELs emit the beam perpendicular to the active region of the laser as opposed to parallel as with an edge emitter, tens of thousands of VCSELs can be processed simultaneously on a three inch Gallium Arsenide wafer. Materials – GaAs has a natural wavelength emission of 873 nm, while InP emits a wavelength of 918nm. Furthermore, even though the VCSEL production process is more labor and material intensive, the yield can be controlled to a more predictable outcome. VCSELs have been constructed that emit energy at 850 nanometers (nm) and 1300 nm. These wavelengths correspond to energy in the near infrared portion of the electromagnetic spectrum. Optical fibers transmit energy most efficiently at wavelengths around 1550 nm. Materials used to manufacture VCSELs include gallium arsenide (GaAs), aluminum gallium arsenide (AlGaAs), and indium gallium arsenide nitride (InGaAsN). Particular interest with respect to fiber optical communication systems exists for those VCSELs that are emitting at wavelengths around 1.31 μ m or 1.55 μ m because of minimum dispersion or absorption, respectively, in silica fiber.

Due to the integration of the BTJ, the VCSELs are slightly thicker at the center ($\Delta L / L_{eff} \gg 1\%$) wherefore the boundary conditions of the optical field yield an efficient wave-guiding that is of comparable magnitude to that of steam-oxidized GaAs-based VCSELs. The AlGaAs/GaAs material system is known to be well suited for direct modulation of laser diodes for high-speed communication systems at 1.55 μ m. Therefore the BTJ VCSELs, which utilize this material in the active region, show excellent intrinsic modulation characteristics. In conjunction with the low series resistances that are typical for the BTJ concept, transmission at 10Gbit/s is feasible.

VCSELs at wavelength of 750 to 850 nm are based AlGaAs and GaAs. GaInAsP-InP VCSELs with wavelength of 1300 to 1700 nm, where fibers have lower attenuation and dispersion. GaInNAs/GaAs structure 1150 nm are currently investigating.

These devices employ a thin strained AlGaAs multiple quantum well active region integrated with a fully oxidized GaAs/AlxOy bottom mirror and a suspended dielectric top mirror. In common VCSELs the upper and lower mirrors are doped as p-type and n-type materials, forming a diode junction.

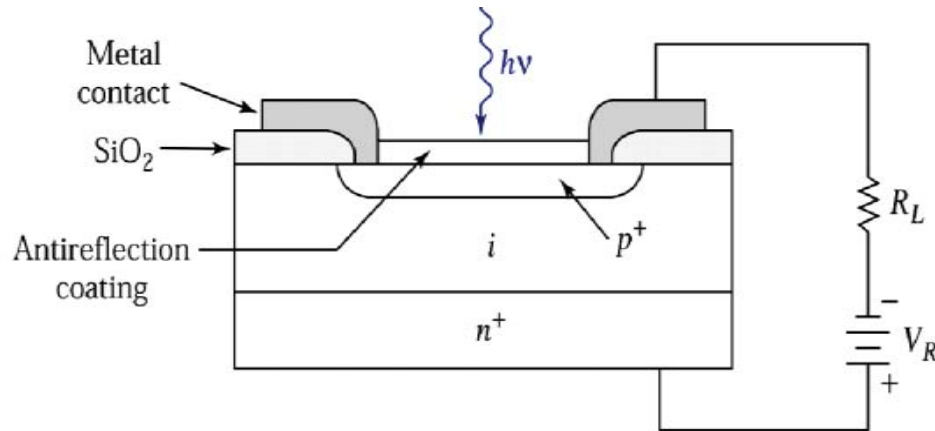


Figure 2. VCSEL Circuit Diagram

PIN diode constructed by sandwiching an intrinsic (pure) semiconductor between heavily doped p+ and n+ semiconductor. An anti-reflecting coating is applied at the top face of the pin diode to received light radiation and ovoid secondary emission.

Operation: A PIN diode operates under what is known as high-level injection. In other words, the intrinsic "i" region is flooded with charge carriers from the "p" and "n" regions. Its function can be likened to filling up a water bucket with a hole on the side. Once the water reaches the hole's level it will begin to pour out. An ideal PIN diode acts as a variable resistor controlled by dc current. The leakage current of a good PIN diode is so low (<1 nA).

The total current through the photodiode is the sum of the dark current and the photocurrent, so the dark current must be minimized to maximize the sensitivity of the device.

Photovoltaic mode : When used in zero bias or photovoltaic mode, the flow of photocurrent out of the device is restricted and a voltage builds up.

Photoconductive mode : In this mode the diode is often reverse biased. Compared to forward bias, this dramatically reduces the response time at the expense of increased noise, because it increases the width of the depletion layer, which decreases the junction's capacitance. The reverse bias induces only a small amount of current along its direction while the photocurrent remains virtually the same. Although this mode is faster, the photoconductive mode tends to exhibit more electronic noise.

Avalanche photodiodes have a similar structure to regular photodiodes, but they are operated with much higher reverse bias. This allows each photo-generated carrier to be multiplied by avalanche breakdown, resulting in internal gain within the photodiode, which increases the effective responsivity of the device.

II. RESULT ANALYSIS

The analysis was obtained from VCSEL model with different cavity size. The stack of the different materials which forms distributed bragg reflector when we applied 5V to the conductor plates(metal) of the VCSEL then we obtained following simulation results.

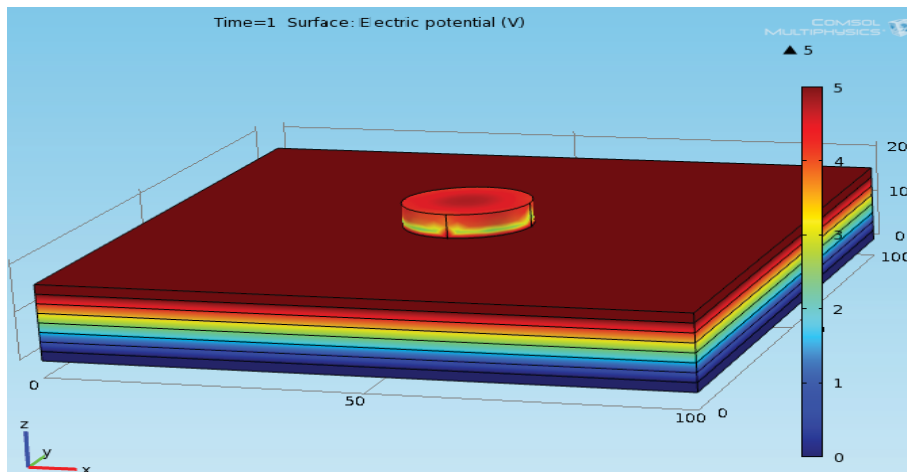


Figure 3. VCSEL Device Model

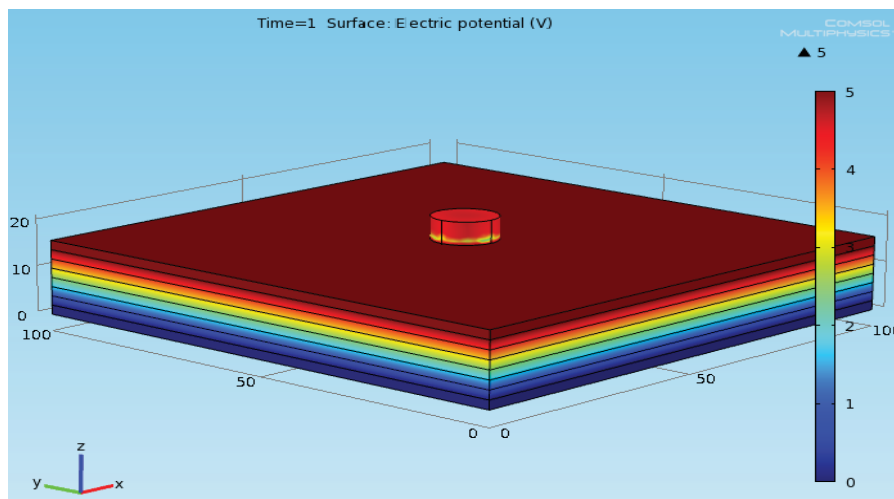


Figure 4. VCSEL Device Model

Fig 3 shows that the Voltage is 4.5391 V in the cavity as we applied 5V to the circuit. Similarly, Fig 4 shows that the voltage is 4.4463 V inside the cavity. From the simulation results, it is observed that by increasing the size of the cavity voltage drop is increased. Hence we have to keep the narrow cavity to achieve the better emission of beam.

IV. CONCLUSION

The analysis were obtained by using Comsol Multiphysics. If cavity is big, it implies emission is spreaded over and we cannot observe the emission properly. Hence we require small Cavity size for getting large wavelength.

V. FUTURE SCOPE

Application of array is to pump the lasers. With the help of array we will achieve the better emission of light beam. In Array, a very fine beam of wavelength can be achieve. We will able to obtained more than one wavelength beam of emission at the same time which will be useful in various biomedical applications. Multiple wavelengths can be obtained from a single device which would be very economical.

VI. ACKNOWLEDGEMENT

The authors are grateful to VNIT College, Nagpur for the provision of Authorized Version of Comsol Multiphysics software, because of which the analysis of the project work could be carried out successfully. Special thanks to Raisoni college of Engineering, Nagpur because of which this project could be compiled successfully.

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