# Chapter 3
# Improved Design of Vertical Cavity Surface Emitting Laser for 3D Sensing in Internet of Things Applications

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## ABSTRACT

*Internet of things (IOT) and Vertical Cavity Surface Emitting Laser (VCSEL) future can be seen together, since VCSEL technology-based 3D sensors are introduced for IoT applications. The improved VCSEL structure design with fixed wavelength using a thermally actuated cantilever structure is presented. This improved structure of VCSEL will help us in realizing athermal VCSEL. In athermal VCSEL the dependency of VCSEL on temperature will be much less because it will not require temperature controllers. Realizing fully temperature-independent VCSEL (i.e., athermal VCSEL) is still a challenge but we can reduce it to some extent. In this chapter, recent diversification of application of VCSEL technology from data communication to sensing has been discussed. This proposed VCSEL structure may give us an opportunity to improve the VCSEL technology. Therefore, smart 3D sensors based on VCSEL will help in making internet of things applications more reliable and will directly or indirectly serve the concept of smart homes and smart cities.*

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## INTRODUCTION

Kenichi Iga invented Vertical Cavity Surface Emitting Laser (VCSEL) in 1977. From that point of time VCSEL come up a long way and diversified their applications from data communications to upcoming 3D sensing technology for Internet of Things (IoT) purposes. Earlier VCSEL was used as an optical source for data communication in optical fibers, as infrared illuminators for military or surveillance. VCSEL also became popular in medical science. VCSEL based printers are also very common. Nowadays VCSEL based 3D sensors are hitting the market. By 2023, VCSEL market is expected to reach United States Dollar (USD) 3.89 billion, which is USD 1.78 billion in present scenario given by Report buyer (2018).

In 1999, Kevin Ashton formulated the term 'Internet of Things', in a presentation to Proctor and Gamble. FurtherArik Gabbai (2015) observed IoT concept in between 2008-2009. IoT is all about Big data, analytics, cloud computing, software, and sensors. The sensor is one of the crucial components for realizing the concept of IoT in reality. Sensors play a very pivotal role in various applications of IoT. In IoT, devices totally rely on sensors because sensors sense everything in the environment, collect data which is further processed for continuing the work or for making decisions manually or automatically by the application itself. In order to fulfill the requirement of IoT, every device is made smart such as smart T.V., smart mobiles, smart tablets, smart computers or any portable device with internet access. Further development and innovation of smart devices will contribute to the development of IoT only. One important characteristic of smart device is its strong sensing ability and object recognition. These smart devices with the strong sensing capability can be employed anywhere in vehicles, airports, railway station, libraries, buildings, shopping malls, schools, colleges, roads, etc. Installing smart devices wherever possible will contribute to the intelligent applications of IoT. IoT applications use a plethora of sensors among which VCSEL based 3D sensors in the future can replace multiple sensors.

Devices are made smart when the sensors are made smart. Keeping in view of smart sensors, 3D sensors are realized by using VCSEL as optical source by various smartphone brands. According to Evangeline H (2018), Apple released the latest iPhone X smartphone with 3D sensing technology based on sensors. These 3D sensors are not used for just face recognition but also for sensing the environment. iPhone X used VCSEL technology for proximity sensing and face identification. Now other smartphone brands are planning to integrate 3D sensors based on VCSEL in their upcoming smartphone release. In 2018 Xiaomi launched Xiaomi Mi8, Oppo launched Oppo Find X phone. By 2019, other smartphone brands like Huawei, Vivo, and Samsung are believed to integrate VCSEL for making more efficient 3D sensors in mobile phones.

Rising adoption of VCSEL technology for 3D sensing is not just limited to mobile phones only, but can also be realized in tablets, PCs and notebooks, gaming, automotive, drones and above all for the application of smart homes and smart cities in IoT. Jabil (2019) gives that for IoT applications like smart home, 3D sensors are employed for safety and security purposes, as 3D sensors can sense 2D or 3D gesture. For realizing smart cities in IoT, VCSEL based sensors can be employed in parking and museum or in the retail industry for safety and security purpose. The concept of smart home and smart cities can be envisioned with the innovation of VCSEL based smart sensors employed in every possible device of home or city. The idea of smart home can be visualized when every electronic or non-electronic object like T.V, refrigerator, A.C., lighting, microwave, oven, or flowering pots etc. can communicate with each other and can be controlled manually or automatically.