VCSEL in Smartphone - Comparison 2019

Technology and Cost Comparison

LED report by Sylvain Hallereau
March 2019 – version 1
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Executive Summary

Today up to 3 VCSEL dies can be integrated in a smartphone. 3D recognition with the flood illuminator, the dot projector and a time of flight for the proximity sensor are based on VCSEL laser components. Already integrated in the flagship smartphone, these functions will quickly become widespread in all smartphones causing a sharp increase in demand for VCSEL.

This comparative review has been conducted to provide insights into the structures, technical and design choices of these component at the center of innovative functions. We analyzed and compared 4 Dot Projectors, 4 Flood illuminators and 2 Time of Flight systems, extracted the VCSEL dies and performed full physical analysis.

We present technological and economical comparisons of 10 VCSEL dies integrated by the main smartphone actors, Apple, Xiaomi, Huawei, Oppo, Lenovo in their flagship smartphones and the Intel RealSense. All the functions needing VCSEL are studied, Dot Projector, Flood Illuminator, Proximity sensor (Time of Flight). The components of the 3 main suppliers, Lumentum, Philips Photonic and ams (Princeton Optronics) are in the report.

Integration of the VCSEL in the smartphones are showed in the report. We base our analysis on full teardowns of the VCSEL dies to unveil the technological choices made by the different manufacturers. We also estimated the different participants in the supply chain. The combination of the two allowed us to simulate the cost of these different components.

This report contains a complete cost analysis and a cost estimation of the VCSEL. Finally, it features an exhaustive comparison between the studied samples, highlighting the similarities and differences and their impact on cost.
## VCSEL – Device Players and Functions

<table>
<thead>
<tr>
<th>VCSEL Manufacturer</th>
<th>System &amp; Smartphone</th>
<th>Mobile Manufacturer</th>
<th>Solution Integrator</th>
<th>Function</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philips Photonics</td>
<td>iPhone7</td>
<td>Apple</td>
<td>STMicroelectronics</td>
<td>Proximity/Ranging sensor</td>
<td>Time of Flight</td>
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<tr>
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<td>Huawei</td>
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<td>Structured light</td>
<td>Flood Illuminator</td>
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<tr>
<td>Princeton Optronics</td>
<td>RealSense</td>
<td>Intel</td>
<td></td>
<td>Structured light</td>
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<tr>
<td>Princeton Optronics</td>
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<td>Princeton Optronics</td>
<td>Mi8</td>
<td>Xiaomi</td>
<td>Mantis Vision</td>
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<td>Huawei</td>
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<td>Structured light</td>
<td>Dot Projector</td>
</tr>
<tr>
<td>Lumentum</td>
<td>Iphone X, XR, XS</td>
<td>Apple</td>
<td>ams Heptacon</td>
<td>Structured light</td>
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<tr>
<td>Lumentum</td>
<td>Oppo Find X</td>
<td>Oppo</td>
<td>Orbbec 3D depth</td>
<td>Structured light</td>
<td>Dot Projector</td>
</tr>
</tbody>
</table>
Company Profile – ams

**VCSEL highlights**

- **Traditional VCSEL players** but much smaller than Lumentum, Finisar or II-VI as they are a pure VCSEL player.
- Initially engaged in telecom and datacom applications, the company has rapidly shifted to other applications including material processing, security and surveillance cameras and now focuses on 3D sensing.
- The recent acquisition by ams in 2017 has further strengthened the position of Princeton Optronics in the 3D sensing area. This complements synergies with Heptagon acquired by ams in 2016 which specializes in illumination modules for sensing applications.
- In order to make the most of increasing volume opportunities for VCSELS for consumer applications from 2019 onwards, ams has recently invested $100M into a VCSEL manufacturing line in Singapore.
- Like Lumentum, ams has developed a virtual IDM model with IQE and AWSC in addition to internal manufacturing capacity. ams also has a 15% stake in HLJ and might use the company as a preferred partner.

**Supply chain highlights**

Source: Yole Développement
STMicroelectronics ToF - Package Opening

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Package Opening Overview

Package Opening – SEM View
Intel RealSense - VCSEL Lens Modules Cross Section

VCSEL Integration
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Philips Photonics - VCSEL Die – Cross-Section
Princeton Optronics - VCSEL Front-End Cost

Wafer (Epitaxy + Metal Layer)

- wafer with epitaxy
- Clean Room Cost
- Equipment Cost
- Consumable Cost
- Labor Cost
- Yield loss Cost

Front-End Cost
### DOT Projector VCSEL Comparison

<table>
<thead>
<tr>
<th>Dot Projector VCSEL</th>
<th>Die Area (mm²) (mm x mm)</th>
<th>Cavity Array (mm²) (mm x mm)</th>
<th>Cavity Number</th>
<th>Cavity Area (µm²)</th>
<th>Cavity Diameter (µm)</th>
<th>Cavity Density (cavity per mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xiaomi Mi 8 Explorer</td>
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<tr>
<td>Apple Iphone X</td>
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<tr>
<td>Oppo Find X</td>
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<tr>
<td>Huawei Mate 20Pro</td>
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Related Reports

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**PACKAGING**
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- SP18438 - Mantis Vision’s 3D Depth Sensing System in the Xiaomi Mi8 Explorer Edition
- SP18437 - Xiaomi MI 8 Explorer Teardown
- SP18434 - Orbbec’s Front 3D Depth Sensing System in the Oppo Find X
- SP18404 - Intel RealSense D435_en relecture
- SP18383 - STMicroelectronics Proximity & Flood Illuminator iPhone X - Version 2
- SP17376 - iPhone X - Heptagon - DOT Projector
- SP17326 - STMicroelectronics ToF Sensor iPhone 7 Plus
- SP17305 - Lenovo Phab2Pro - Google Tango project - Time of Flight

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**ADVANCED PACKAGING**
- VCSELs – Technology, Industry and Market Trends 2018
- 3D Imaging & Sensing 2018

**ADVANCED PACKAGING**
- VCSEL Patent Landscape
Today, up to three VCSEL dies can be integrated in a smartphone. 3D recognition with the flood illuminator; dot projector; and time of flight (ToF) for the proximity sensor are all based on VCSEL laser components. Already integrated in flagship smartphones, these functions will quickly find a home in all smartphones, causing a sharp increase in VCSEL demand.

This comparative review, conducted by System Plus Consulting, provides insights into the structures, technology, and design choices related to these components, which are at the center of innovative functions. Four dot projectors, four flood illuminators, and two ToF systems have been analyzed and compared; the VCSEL dies have been extracted and full physical analyzed.

This report offers technological and economical comparisons of 10 VCSEL dies integrated by the major smartphone manufacturers (Apple, Xiaomi, Huawei, Oppo, and Lenovo) in their flagship smartphones, and by Intel in its RealSense product suite. Moreover, the report covers all of the functions that require VCSEL, including dot projector, flood illuminator, and proximity sensor (ToF). The components from the three key suppliers - Lumentum, Philips Photonic, and ams (Princeton Optronics) - are also included in the report.

This report shows the integration of the VCSEL in smartphones, and, based on the analysis of full teardowns of the VCSEL dies, System Plus Consulting reveals the technological choices made by the different manufacturers. Also, the various supply chain participants have been estimated. The combined knowledge gleaned from these two groups allows System Plus Consulting to simulate the cost of these different components. This report contains a complete cost analysis and a cost estimate of the VCSEL. Additionally, it features a full comparison of the studied samples, highlighting their similarities and differences and their impact on cost.
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- VCSEL Epitaxy Comparison
- VCSEL Die Comparison
- VCSEL Cost Comparison

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---

## LINKED REPORT

**VCSELs – Technology, Industry and Market Trends 2018 – Market and Technology Report by Yole Développement**

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