Company Overview
VCSELs at Vixar and OSRAM

Kevin Kruse, Phai Vue, Todd Schieffert | Summer 2019

Light is OSRAM
OSRAM Opto Semiconductors
Key locations and key markets worldwide

USA | NAFTA
Sunnyvale | Novi | Exeter
Headquarters NAFTA
• Sales and Marketing
• Application Centers
• LED Preproduct Production

Europe | EEM
Regensburg
Global Headquarters, R+D
• Chip Production
• OLED Production
• Sales and Marketing
• Application Centers

Asia | China
Hong Kong | Shanghai | Wuxi | Taiwan
Headquarters Asia Pacific
• LED Assembly, R+D
• Sales and Marketing
• Application Centers

Asia | Japan
Yokohama
• Sales and Marketing
• Application Centers

Asa | Malaysia
Penang | Kulim
GL Headquarters
• Chip Production
• LED Assembly
• R+D

NAFTA | Plymouth, MN
Headquarters Vixar
• VCSEL R+D
• Sales, Marketing and Application Engineering
• Foundry Operations
Vixar Historical Overview

Highly experienced VCSEL team; with expertise in device design, reliability and packaging
– Vixar combines the best design expertise with the most capable manufacturing partners

Company facts and financing
– Spinout from Honeywell in 2005 with headquarters in Minneapolis, MN
– Acquired by Osram July 2018

Scalable manufacturing for hundreds of millions of units per year
– In production on both 4” and 6” wafer platforms
– Both domestic and off-shore packaging capacity

VCSEL device and packaging technology for the sensor market
– Wavelengths from 670nm to 940nm
– Single-mode designs to high power arrays (>4W)
– Low cost surface mount packaging
– Custom subassemblies and optics integration
Technology and Operational Excellence

**VIXAR INC.**

- VCSEL Design expertise
- Design for reliability
- Dual outsourced manufacturing partners
- Packaging expertise

**OSRAM OS**

- High volume manufacturing expertise
- Experienced quality systems organization
- Internal Wafer and Packaging production
- Packaging expertise

Diversified VCSEL supply chain from EPI TO PACKAGE

Industry Leading EXPERTISE AND EXPERIENCE

UNIQUE BREADTH of technological expertise that provides optimal flexibility

Best economies of scale through LED technology synergies

THE WAY TO SUSTAINABLE GROWTH AND TECHNOLOGICAL LEADERSHIP
VCSEL Technology: Performance of Lasers with the Cost Structure of LEDs

VCSEL vs. Edge-Emitter

100% wafer level testing
~250K VCSELs per 6” wafer

VCSEL Advantages
- Wafer level testing
- Surface mount packaging
- Chip-on-board packaging
- 1D and 2D arrays
- Circular, low divergence beam
- High modulation rate
- Narrow spectrum
- High electrical efficiency
- High reliability
## The VCSEL advantage

<table>
<thead>
<tr>
<th></th>
<th>IRED</th>
<th>VCSEL</th>
<th>EEL (FP)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Optical Power</strong></td>
<td>Up to 4.5 W</td>
<td>0.1 W up to 6 W</td>
<td>Up to 120 W</td>
</tr>
<tr>
<td><strong>Beam quality</strong></td>
<td>Lambertian, Very wide divergence</td>
<td>Symmetric, Low divergence</td>
<td>Asymmetric, Medium Divergence</td>
</tr>
<tr>
<td><strong>Temperature stability</strong></td>
<td>0.25 nm/K</td>
<td>0.06 nm/K @ 850 nm</td>
<td>0.25 nm/K</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.07 nm/K @ 940 nm</td>
<td></td>
</tr>
<tr>
<td><strong>Spectral width</strong></td>
<td>20-30 nm</td>
<td>1-2 nm</td>
<td>1-2 nm</td>
</tr>
<tr>
<td><strong>Speckle</strong></td>
<td>Low</td>
<td>Low in an array</td>
<td>High</td>
</tr>
<tr>
<td><strong>Switching time</strong></td>
<td>Low speed</td>
<td>High speed</td>
<td>High speed</td>
</tr>
<tr>
<td><strong>Packaging</strong></td>
<td>Simple</td>
<td>Medium</td>
<td>Complex</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>Best</td>
<td>Good</td>
<td>Medium</td>
</tr>
</tbody>
</table>

*Based on Vixar and OSRAM assessment*
Welcome to a spectrum of infinite possibilities
Target Applications

Biomedical
- 3D Medical Scanner
- Low Light Laser Therapy
- Biometric sensing

Automotive/Consumer
- Environmental Sensing
- Gesture recognition
- Facial recognition

Industry
- Sensors for automation
- Chip scale devices
- IR Illumination
# Selected Sensor Applications for VCSELs

<table>
<thead>
<tr>
<th>Application</th>
<th>Physical mechanism</th>
<th>Benefit Provided by VCSELs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensors/Scanning: Gesture recognition Proximity sensor 3D digital scanning / LIDAR</td>
<td>Structured illumination</td>
<td>High efficiency Compatibility with holographic elements</td>
</tr>
<tr>
<td></td>
<td>Time of Flight (ToF)</td>
<td>Short pulse widths</td>
</tr>
<tr>
<td></td>
<td>Modulated phase shift</td>
<td>High modulation rates</td>
</tr>
<tr>
<td>Illumination for IR cameras</td>
<td>CW Illumination</td>
<td>Narrow spectrum increases S/N ratio Arrays reduce speckle</td>
</tr>
<tr>
<td>Health/fitness sensors</td>
<td>Absorption spectroscopy</td>
<td>Narrow spectrum</td>
</tr>
<tr>
<td>Health/fitness sensors</td>
<td>Fluorescence spectroscopy</td>
<td>High speed</td>
</tr>
<tr>
<td>Proximity sensors</td>
<td>Reflected light intensity</td>
<td>High efficiency Beam directionality</td>
</tr>
<tr>
<td>Low light laser therapy</td>
<td>Light stimulates cells and facilitates delivery of oxygen to tissue</td>
<td>Narrow spectrum improves dose delivery Strong absorption coefficient overlap</td>
</tr>
<tr>
<td>Atomic sensors: Atomic clocks and magnetometers</td>
<td>Absorption at an atomic spectral level</td>
<td>Low power consumption High modulation frequency</td>
</tr>
</tbody>
</table>
Vixar – Product Portfolio

- Single Aperture
- Multi Aperture
- Power Arrays

Multiple Packaging Options
Standard Products – Single Aperture Die

**Single Spatial Mode (S)**
- Smallest aperture (~4 µm)
- Pure fundamental mode output
- Mode power ratio : >10 dB

**Gaussian Output (Q)**
- Small aperture (~6 µm)
- For an efficient gaussian output
- Mode power ratio : ~3 dB

**Multi-mode Aperture (M)**
- Large aperture (>10 µm)
- Optimized for max power output
- Non-Gaussian angular distribution

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>CW Output Power</th>
<th>Model Number</th>
<th>Package</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>&quot;S&quot; Series: Single Spectral and Spatial Mode VCSELs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>795</td>
<td>~0.1mW</td>
<td>I0-0795S-0000-A006</td>
<td>Die</td>
<td>Linewidth &lt; 100MHz, 795 +/-0.5nm</td>
</tr>
<tr>
<td>895</td>
<td>~0.1mW</td>
<td>I0-0895S-0000-A005</td>
<td>Die</td>
<td>Linewidth &lt; 100MHz, 895 +/-0.5nm</td>
</tr>
<tr>
<td><strong>&quot;Q&quot; Series: Gaussian Beam Shape VCSELs (Multi-Spectral Mode)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>670</td>
<td>1mW</td>
<td>I0-0670Q-0000-A002</td>
<td>Die</td>
<td>Improved Visibility Gaussian Beam</td>
</tr>
<tr>
<td>680</td>
<td>1.5mW</td>
<td>I0-0680Q-0000-A002</td>
<td>Die</td>
<td>Visible Gaussian Beam</td>
</tr>
<tr>
<td>940</td>
<td>3mW</td>
<td>I0-0940Q-0000-D001</td>
<td>PLCC-2</td>
<td>Invisible Gaussian Beam</td>
</tr>
<tr>
<td><strong>&quot;M&quot; Series: Multi-Mode, High Power VCSELs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>680</td>
<td>5mW</td>
<td>I0-0680M-0000-A002</td>
<td>Die</td>
<td>Visible, High Power Non-Gaussian Beam Shape</td>
</tr>
<tr>
<td>850</td>
<td>14mW</td>
<td>I0-0850M-0000-A002</td>
<td>Die</td>
<td>High Efficiency, High Power Non-Gaussian beam shape</td>
</tr>
<tr>
<td>940</td>
<td>14mW</td>
<td>I0-0940M-0000-A001</td>
<td>PLCC-2</td>
<td>High efficiency, High Power Non-Gaussian Beam Shape</td>
</tr>
</tbody>
</table>
## Standard Products – 850 nm Power Arrays

<table>
<thead>
<tr>
<th>Apertures</th>
<th>0.5 W 850 nm</th>
<th>1 W 850 nm</th>
<th>2 W 850 nm</th>
<th>4 W 850 nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>150</td>
<td>225</td>
<td>281</td>
<td>770</td>
</tr>
<tr>
<td>I&lt;sub&gt;th&lt;/sub&gt;</td>
<td>700 mA</td>
<td>1300 mA</td>
<td>2500 mA</td>
<td>5000 mA</td>
</tr>
<tr>
<td>Efficiency</td>
<td>160 mA</td>
<td>300 mA</td>
<td>500 mA</td>
<td>800 mA</td>
</tr>
<tr>
<td>Efficiency</td>
<td>40 %</td>
<td>40 %</td>
<td>40 %</td>
<td>40 %</td>
</tr>
<tr>
<td>Chip size</td>
<td>0.62 x 0.62 x 0.15 mm</td>
<td>0.72 x 0.72 x 0.1 mm</td>
<td>0.87 x 0.87 x 0.15 mm</td>
<td>1.26 x 1.26 x 0.1 mm</td>
</tr>
<tr>
<td>Status</td>
<td>Available</td>
<td>Available</td>
<td>Available</td>
<td>Available</td>
</tr>
<tr>
<td>VX PN</td>
<td>K0-0850M-0000-00007</td>
<td>K0-0850M-0000-00041</td>
<td>K0-0850M-0000-00008</td>
<td>K0-0850M-0000-00017</td>
</tr>
</tbody>
</table>

*) Recommended operating condition 100us pulse width, 1% duty cycle, T = 25°C, pulse train of 5
All values are typical values
**Standard Products – 940 nm Power Arrays**

<table>
<thead>
<tr>
<th>Apertures</th>
<th>Current</th>
<th>Efficiency</th>
<th>Chip size</th>
<th>Status</th>
<th>VX PN</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5 W 940 nm</td>
<td>150 mA</td>
<td>40 %</td>
<td>0.62 x 0.62 x 0.15 mm</td>
<td>Available</td>
<td>K0-0940M-0000-00009</td>
</tr>
<tr>
<td>1 W 940 nm</td>
<td>225 mA</td>
<td>40 %</td>
<td>0.72 x 0.72 x 0.1 mm</td>
<td>Available</td>
<td>K0-0940M-0000-00010</td>
</tr>
<tr>
<td>2 W 940 nm</td>
<td>281 mA</td>
<td>45%</td>
<td>0.87 x 0.87 x 0.15 mm</td>
<td>Available</td>
<td>K0-0940M-0000-00011</td>
</tr>
<tr>
<td>3 W 940 nm</td>
<td>538 mA</td>
<td>44%</td>
<td>1.00 x 0.90 x 0.1 mm</td>
<td>Available</td>
<td>I0-0940M-0000-00023</td>
</tr>
<tr>
<td>4 W 940 nm</td>
<td>770 mA</td>
<td>42%</td>
<td>1.26 x 1.26 x 0.1 mm</td>
<td>Available</td>
<td>K0-0940M-0000-00018</td>
</tr>
</tbody>
</table>

*) Recommended operating condition 100us pulse width, 1% duty cycle, T = 25°C, pulse train of 5

All values are typical values
Product Packaging Technology

Vixar’s Standard Packages

Ceramic Package

PLCC Package

Custom Packaging Available

TO Cans

QFN Package

Die on MCB
VCSEL Ceramic Package – Diffusers

VCSEL die  Diffuser Package
Custom VCSEL Solutions

Custom Arrays & Packaging

Module integration – PD / TECs / ESD Diodes

Individual Addressability

Custom Die Layouts
Thank you.

For additional questions, please contact: Sales@vixarinc.com