Vixar Portfolio and Capabilities

Kevin Kruse, Phai Vue, Jill Oertel, Dominik Schulten | Spring 2020
Light is OSRAM
Agenda

1. Vixar Inc / OSRAM Company Overview
2. VCSEL Applications
3. VCSEL Portfolio
4. VCSEL Innovations
Vixar Inc. Overview

Headquarters: Plymouth, Minnesota, USA

Market leader across a diversified VCSEL product portfolio
- Wavelengths from 670 nm to 940 nm (extensible to 1000 nm)
- Single-mode designs to high power arrays (Power > 10W)
- Low cost surface mount packaging
- Custom subassemblies and optics integration

Manufacturing infrastructure and supply chain
- Scalable manufacturing for hundreds of millions of units per year
- In production on both 4” and 6” wafer platforms for cost-efficient manufacturing
- Both domestic and off-shore packaging capacity
- Maintain multiple sources of standard processes with the flexibility to customize die or package configuration

High performance, high volume VCSEL products

High quality, highly reliable VCSEL products

Robust dual and triple sourced supply chain

Best in class package options
Technological and operational excellence

**VIXAR INC.**
- ✓ VCSEL Design expertise
- ✓ Design for reliability
- ✓ Dual outsourced manufacturing partners
- ✓ Packaging expertise

**Technology and Operational Excellence**
- ✓ High performance, high volume VCSEL products
- ✓ High quality, high reliable VCSEL products
- ✓ Robust dual and triple sourced supply chain
- ✓ Best in class package options

**OSRAM OS**
- ✓ High volume manufacturing expertise
- ✓ Experienced quality systems organization
- ✓ Internal Wafer and Packaging production
- ✓ Packaging expertise
OSRAM Opto Semiconductors – Key Locations and 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

NAFTA | Plymouth, MN
Vixar
Headquarters Vixar
• VCSEL R+D
• Sales, Marketing and Application Engineering
• Foundry Operations
• Fully owned subsidiary

Asia | Malaysia
Penang | Kulim
GL Headquarters
• Chip Production
• LED assembly
• R+D
Vixar is Pioneering: VCSEL Technology Competence

Epitaxy

...to define the internal quantum efficiency

Chip Design

... to define the laser power, PCE and thermal performance

Package Solutions

... to define the light extraction efficiency and beam.
Agenda

1. Vixar Inc / OSRAM Company Overview
2. VCSEL Applications
3. VCSEL Portfolio
4. VCSEL Innovations
# VCSEL Targeted Markets & Applications

<table>
<thead>
<tr>
<th>Markets</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>Proximity Sensing, 3D Sensing (ToF / Structured Light), Illumination, LiDAR, Atomic Sensors, Safeguarding, Self Mixing</td>
</tr>
<tr>
<td>Mobile Devices</td>
<td>3D Sensing (ToF / Structured Light), Gesture/Facial Recognition, Biometric Metrology</td>
</tr>
<tr>
<td>Medical</td>
<td>Light therapy, 3D Sensing (ToF / Structured Light), Biometric Metrology</td>
</tr>
</tbody>
</table>
## 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 10 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 0.07 nm/K @ 940 nm</td>
<td>0.25 nm/K</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
Agenda

1. Vixar Inc / OSRAM Company Overview
2. VCSEL Applications
3. VCSEL Portfolio
4. VCSEL Innovations
## Standard Products – Chip

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>Number of Emitters</th>
<th>Part Number</th>
<th>Number of Junctions</th>
<th>Recommended Peak Power 100µS, 1% DC</th>
<th>Recommended Peak Power 5nS, 0.1% DC</th>
<th>Recommended Peak Power CW, 100% DC</th>
<th>Application Example(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>680 nm</td>
<td>1</td>
<td>V00146</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>7mW</td>
<td>Biosensing, Industrial Sensor, Light Therapy</td>
</tr>
<tr>
<td>795 nm</td>
<td>1</td>
<td>V00145</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>0.15mW</td>
<td>Atomic Clock, Magnetometer</td>
</tr>
<tr>
<td>850 nm</td>
<td>100</td>
<td>V00151</td>
<td>1</td>
<td>1.2W</td>
<td>9.5W</td>
<td>0.7W</td>
<td>Time of Flight (ToF), 3D Sensing, Gesture Recognition</td>
</tr>
<tr>
<td></td>
<td>281</td>
<td>V00027</td>
<td>1</td>
<td>6W</td>
<td>38W</td>
<td>3.5W</td>
<td></td>
</tr>
<tr>
<td></td>
<td>550</td>
<td>V00124</td>
<td>1</td>
<td>9W</td>
<td>52W</td>
<td>TBD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>770</td>
<td>V00029</td>
<td>1</td>
<td>12W</td>
<td>62W</td>
<td>6W</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>V00133</td>
<td>1</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>Long Range Sensing, LIDAR</td>
</tr>
<tr>
<td>895 nm</td>
<td>1</td>
<td>V00140</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>0.2mW</td>
<td>Atomic Clock, Magnetometer</td>
</tr>
<tr>
<td>940 nm</td>
<td>1</td>
<td>V00101</td>
<td>1</td>
<td>180mW</td>
<td>0.13W</td>
<td>18mW</td>
<td>Proximity Sensor</td>
</tr>
<tr>
<td></td>
<td>281</td>
<td>V00059</td>
<td>1</td>
<td>5.5W</td>
<td>38W</td>
<td>3W</td>
<td>Time of Flight (ToF), 3D Sensing, Gesture Recognition</td>
</tr>
<tr>
<td></td>
<td>550</td>
<td>V00081</td>
<td>1</td>
<td>8W</td>
<td>52W</td>
<td>4W</td>
<td></td>
</tr>
<tr>
<td></td>
<td>770</td>
<td>V00063</td>
<td>1</td>
<td>11W</td>
<td>62W</td>
<td>5W</td>
<td>Motion Control</td>
</tr>
<tr>
<td></td>
<td>2016</td>
<td>V00132</td>
<td>1</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>Long Range Sensing, LIDAR</td>
</tr>
</tbody>
</table>
### Ceramic-2835 Package Family

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>Number of Emitters</th>
<th>Part Number 1</th>
<th>Part Number 2</th>
<th>Part Number 3</th>
<th>Number of Junctions</th>
<th>Optics</th>
<th>Eye Safety Feature</th>
<th>Recommended Peak Power</th>
<th>Recommended Peak Power</th>
<th>Recommended Peak Power</th>
<th>Application Example(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>850 nm</td>
<td>281</td>
<td>V00024</td>
<td>V00056</td>
<td>V00075</td>
<td>1</td>
<td>60° x 45° Diffuser</td>
<td>None</td>
<td>5W</td>
<td>7W</td>
<td>2.5W</td>
<td>Time of Flight (ToF)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V00028</td>
<td>V00061</td>
<td>V00128</td>
<td></td>
<td>60° x 45° Diffuser</td>
<td>Monitor Photodiode</td>
<td>5W</td>
<td>7W</td>
<td>2.5W</td>
<td>3D Sensing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V00100</td>
<td>V00079</td>
<td>V000065</td>
<td></td>
<td>60° x 45° Diffuser</td>
<td>None</td>
<td>10W</td>
<td>12W</td>
<td>6W</td>
<td>Gesture Recognition</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>V00105</td>
<td>V000128</td>
<td></td>
<td>72° x 58° Diffuser</td>
<td>None</td>
<td>12W</td>
<td>62W</td>
<td>6W</td>
<td>Motion Control</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V00075</td>
<td>1</td>
<td>60° x 45° Diffuser</td>
<td>None</td>
<td>10W</td>
<td>52W</td>
<td>4.5W</td>
<td>Long Range Sensing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V00130</td>
<td></td>
<td>72° x 58° Diffuser</td>
<td>None</td>
<td>10W</td>
<td>52W</td>
<td>4.5W</td>
<td>LiDAR</td>
</tr>
</tbody>
</table>

### Ceramic-XXXX Package Family (Coming Soon)

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>Year</th>
<th>Status</th>
<th>Number of Junctions</th>
<th>Optics</th>
<th>Eye Safety Feature</th>
<th>Recommended Peak Power</th>
<th>Recommended Peak Power</th>
<th>Recommended Peak Power</th>
<th>Application Example(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>850 nm</td>
<td>2016</td>
<td>Coming Soon</td>
<td>1</td>
<td>No Diffuser</td>
<td>Monitor Photodiode</td>
<td>TBD</td>
<td>-</td>
<td>TBD</td>
<td>Long Range Sensing</td>
</tr>
<tr>
<td>940 nm</td>
<td>2016</td>
<td>Coming Soon</td>
<td>1</td>
<td>No Diffuser</td>
<td>Monitor Photodiode</td>
<td>TBD</td>
<td>-</td>
<td>TBD</td>
<td>LiDAR</td>
</tr>
</tbody>
</table>
# Standard Products – PLCC Package

<table>
<thead>
<tr>
<th>PLCC2-3020 Package Family</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Wavelength</td>
</tr>
<tr>
<td>680 nm</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>850 nm</td>
</tr>
</tbody>
</table>
New Product Preview – 940nm 10W VCSEL Performance Demonstration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Units</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold Current</td>
<td>( I_{th} )</td>
<td>A</td>
<td>-</td>
<td>1.5</td>
<td>-</td>
</tr>
<tr>
<td>Operating Voltage</td>
<td>( V_f )</td>
<td>V</td>
<td>-</td>
<td>2.0</td>
<td>-</td>
</tr>
<tr>
<td>Optical Operating Power</td>
<td>( L_{op} )</td>
<td>W</td>
<td>-</td>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>% Power Drop from 60°C to 105°C</td>
<td></td>
<td></td>
<td></td>
<td>70%</td>
<td></td>
</tr>
<tr>
<td>Power Conversion Efficiency</td>
<td>PCE</td>
<td>%</td>
<td>35</td>
<td>40</td>
<td>-</td>
</tr>
<tr>
<td>Beam Divergence</td>
<td>FWHM</td>
<td>°</td>
<td></td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Operating Peak Wavelength</td>
<td>( W_{Lpeak} )</td>
<td>nm</td>
<td>930</td>
<td>940</td>
<td>950</td>
</tr>
</tbody>
</table>

Chip available in Q1 2020
Package in Q2 – Q3 2020
Agenda

1. Vixar Inc / OSRAM Company Overview
2. VCSEL Applications
3. VCSEL Portfolio
4. VCSEL Innovations
**Multijunction VCSEL design**

**Motivation:**
- Increase gain volume by periodically stacking active regions in cavity
- Carrier regeneration in tunnel junctions → increased slope efficiency
- Re-optimize gain & loss in cavity for net efficiency improvement
- Trade off voltage and current for driver compatibility (faster rise time)

**Challenges:**
- Requires low resistance & low absorption tunnel junction
- Precise layer tuning to align QWs and TJ with standing wave

**Design Features:**
- Top emitting VCSEL with backside cathode
  - Oxide aperture confinement
  - p- and n-type AlGaAs DBRs
  - Strained InGaAs MQWs
- Low resistance n+/p+ tunnel junction

Compatible with high volume fabrication:
- n-type GaAs substrates
- MOCVD grown epi
- 6-inch wafer processing

---

Single, double, triple junction 940nm comparison

Peak performance comparison:

<table>
<thead>
<tr>
<th>Design</th>
<th>PCE (%)</th>
<th>Power (mW)</th>
<th>Voltage (V)</th>
<th>Slope Eff. (mW/mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td>52%</td>
<td>5.0</td>
<td>1.9</td>
<td>1.1</td>
</tr>
<tr>
<td>Double</td>
<td>59%</td>
<td>10</td>
<td>3.3</td>
<td>2.10</td>
</tr>
<tr>
<td>Triple</td>
<td>60%</td>
<td>17</td>
<td>4.6</td>
<td>3.15</td>
</tr>
</tbody>
</table>

- Single 10um aperture VCSEL characterization
  - Continuous wave, room temp operation
  - Slope efficiency and voltage scale with junctions
    - 2.1 W/A → 160% DQE
    - 3.15 W/A → 240% DQE
  - Higher power & higher efficiency achieved
    - 60% PCE for triple junction VCSEL
VCSEL array performance (single, double, & triple junction)

**Fabricated VCSEL array die for high power**
- 0.9 x 0.9 mm chip footprint
- 361 apertures (10µm diameter)

**LIV Comparison**
- Operating condition: 100µs pulse width, 1% duty cycle, T=20°C
- Peak efficiency of 53.3% at 2.5W & 5W (double and triple junction)
  - Peak slope efficiency: 2.1 W/A & 3.0 W/A
  - > 10W power at I=4A
Short pulsed operation

- High power pulsing experiments conducted with GaN-FET based driver
- Triple Junction VCSEL array driven with 3.6ns pulses, 0.1% duty cycle
  - Peak pulse power of 147W recorded for 64 A peak current
  - No rollover observed (power limited by driver)
- Equivalent irradiance: 281W/mm²
  - Emission area: 0.77 x 0.68 mm²
Innovations! Narrow Beam divergence for structured light

- New epi wafers available with low beam divergence.

<table>
<thead>
<tr>
<th></th>
<th>Wavelength</th>
<th>Spectral width</th>
<th>Conversion Efficiency @ 45°C</th>
<th>Wavelength shift</th>
<th>Beam Divergence (1/e²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Epi</td>
<td>940±5nm</td>
<td>&lt;1.5nm</td>
<td>&gt;38%</td>
<td>&lt;0.07nm/C°</td>
<td>&lt; 26°</td>
</tr>
<tr>
<td>New Epi</td>
<td>940±5nm</td>
<td>&lt;1.5nm</td>
<td>&gt;35% to 36%</td>
<td>&lt;0.07nm/C°</td>
<td>&lt; 22° (average 18°)</td>
</tr>
</tbody>
</table>
Custom VCSEL Solutions

Custom Arrays & Packaging

Module integration – PD / TECs / ESD Diodes

Individual Addressability

Custom Die Layouts
VCSEL Ceramic Package – Diffusers

VCSEL die

Diffuser Package

X-Cross Section Beam Divergence

Y-Cross Section Beam Divergence
Thank You

Website: vixarinc.com

Email: sales@vixarinc.com

Phone: (952) 656-7000