High Power VCSELs for 3D cameras

2019-10-17, EPIC meeting (Stuttgart)
Dr Julien Boucart, Senior Product Manager
II-VI Overview

“TWO SIX” Refers to groups II and VI of the Periodic Table of Elements

Core Competency
ENGINEERED MATERIALS

- **26,000** Worldwide Employees
- **70** Worldwide Locations
- **21** Countries
- **$2.6B** FY2019 Revenue (II-VI + Finisar)
Our Core & Growth Markets

Core Markets

- Industrial Lasers
- Aerospace & Defense

Growth Markets

- Optical Communications
- EUV Lithography
- 3D Sensing
- SIC for EV
- SIC for Wireless
Growth Application: 3D Sensing & LiDAR

- Components for 3D Sensing & LiDAR
  - Semiconductor Lasers: VCSELs & edge emitting lasers
  - Optics: Dual pass band filters, wide incidence angle mirrors

- Current market drivers: Face Biometrics
  - II-VI’s vertically integrated 150 mm GaAs compound semiconductor platform is one of the largest in the world

- Emerging applications: Augmented Reality, Automotive LiDAR
Increasing Wafer Diameter Enables Market Growth

Since 2006, 400M VCSELs shipped (Excludes 3D Sensing)

**Sensor applications**
- Motion Control
- Atomic clock
- Gas Detection

**Gas Detection**
- Display navigation
- Proximity sensors
- 3D Sensing / VR / AR
- Active optical cables
- Datacom
- 3D Sensing

**II-VI VCSEL**
Zurich, Switzerland

- 1994
- Since 2006, 400M VCSELs shipped (Excludes 3D Sensing)

**Market Size [Emitters/year]**
- $10^{12}$
- $10^{9}$
- $10^{6}$
- $10^{3}$

**Wafer Size [Inch]**
- 6”
- 4”
- 3”
- 2”

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Smartphones with 3D Sensing

VCSEL Demands TAM ($Million)

- Other consumer devices (tablet, TV, gaming)
- Mid-high-end Android (above $250)
- Apple

Source: Morgan Stanley Research Estimates

<table>
<thead>
<tr>
<th>Year</th>
<th>Devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>Huawei Mate 20 Pro Sep. 2018</td>
</tr>
<tr>
<td>2017</td>
<td>Oppo R17 Oct. 2018</td>
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<tr>
<td>2018</td>
<td>LG G8 Feb. 2019</td>
</tr>
<tr>
<td>2018</td>
<td>Samsung S10 5G Feb. 2019</td>
</tr>
<tr>
<td>2019</td>
<td>Huawei P-30 Mar. 2019</td>
</tr>
<tr>
<td>2019</td>
<td>Xiaomi Mi8 Explorer May 2018</td>
</tr>
<tr>
<td>2018</td>
<td>Oppo FindX Jun. 2018</td>
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<td>2018</td>
<td>Vivo NEX Jun. 2018</td>
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</tbody>
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iPhone X Sep. 2017
Xiaomi Mi8 Explorer May 2018
Oppo FindX Jun. 2018
Vivo NEX Jun. 2018

Source: Morgan Stanley Research Estimates

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# VCSELS for consumer

<table>
<thead>
<tr>
<th>Application</th>
<th>Power levels</th>
<th>Wavelength</th>
<th>Other Characteristics</th>
<th>Pictures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display Navigation</td>
<td>&lt;1mW</td>
<td>850nm</td>
<td>Single mode, polarization locked</td>
<td><img src="image1.png" alt="Picture" /></td>
</tr>
<tr>
<td>3D Sensing, indoor (IoT)</td>
<td>0.2-4W</td>
<td>850nm</td>
<td>Multimode array for ToF</td>
<td><img src="image2.png" alt="Picture" /></td>
</tr>
<tr>
<td>Proximity sensor, mobile</td>
<td>5-20mW</td>
<td>940nm</td>
<td>Single Mode or multimode</td>
<td><img src="image3.png" alt="Picture" /></td>
</tr>
<tr>
<td>3D camera, mobile</td>
<td>0.2-4W</td>
<td>940nm</td>
<td>Multimode array</td>
<td><img src="image4.png" alt="Picture" /></td>
</tr>
</tbody>
</table>
Next Generation High Power Single Mode VCSELs

- **Applications**
  - Proximity sensors
  - Other 3D sensing illumination

- **Low beam divergence**
  - Simpler optics
  - Reduced jitter

- **Simple power scaling by number of emitters**
  - 3mW of single mode power per emitter

- **Small chip size (150x150x150µm3)**
  - Compact cost effective illumination

- **940nm emission wavelength**
  - Outdoor operation
3D Cameras Time Of Flight requirements on the illumination

1. High modulation speed
2. High power conversion efficiency
3. Narrow wavelength spread
4. Reliable laser sources
5. Accurate beam shaping
Fast speed modulation

- Modulation speed allows greater depth resolution
- VCSEL chip is intrinsically fast
- Limitations will come from assembly / driver setup
- Low duty cycle allows for high peak power

Simulation without wire bonds

$f_{3dB}=4GHz$

$37W (60W/mm^2)$ at 50ns, 0.01% D.C.
Single Emitter Short Pulse Operation

Single Emitter: Pulsed (1ns / 100kHz)

LI curves from two chips

Optical Pulse

Electrical Pulse

<table>
<thead>
<tr>
<th>Current (mA)</th>
<th>Vpp (V)</th>
<th>Rise time (ps)</th>
<th>Fall time (ps)</th>
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<tbody>
<tr>
<td>3</td>
<td>2</td>
<td>18.1</td>
<td>57.6</td>
</tr>
</tbody>
</table>

3mA – multi pulse

100ps pulse / 1ns period
High Power Conversion Efficiency

- Higher PCE allows longer battery life in mobile phones
- Chip delivers up to 47% PCE at 25°C and 42% at 60°C
Wavelength Consideration

- **850nm versus 940nm:**
  - 850nm: high efficiency from sensors, generates red glow
  - 940nm: no red glow, less interference from sunlight, but detectors suffer from lower QE
  - 1550nm is an “eye safe” wavelength, sources and sensors are high costs.

- **VCSEL light sources allow narrower band pass filters to better system performance**

<table>
<thead>
<tr>
<th>Wavelength</th>
<th>Non visible</th>
<th>Laser Efficiency</th>
<th>Sensor efficiency</th>
<th>Eye Safety</th>
<th>VCSEL Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>850nm</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>940nm</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1550nm</td>
<td>+ +</td>
<td>-</td>
<td>-</td>
<td>+ +</td>
<td>-</td>
</tr>
</tbody>
</table>

*Lower sunlight interference at 940 nm*
Beam Shaping

- Optical elements need to provide uniform illumination for the application
  - Low high frequency noise
  - Steep FOI to match FOV
    - Requires low divergence VCSELs
  - Angle emphasis to match illumination
  - Good 0\textsuperscript{th} order suppression
    - Could favor MLA vs DOE
  - Low cost
  - Robust performance: environment and mechanical
    - Issues for polymer based vs glass based

DOE type diffusor showing 0\textsuperscript{th} order transmission

MLA type diffusor showing no 0\textsuperscript{th} order transmission
**High Reliability Lasers**

**DATACOM**

**FIT Rate**
- 33,000 hours at 90 C, 6 mA
- > 200M true cum. dev hours
- < 10 FIT at stress from 2 fails

**Environment**
- 4000 h 85C/85%
- Zero Failures

**Wear-out**
- 28G Multi-cell layout: Ea=1.2, n=2.7
- 70°C/7mA operation: TT1%Fail: 151years

**3D SENSING**

**Wafer Release**
- Hundreds of thousands of devices from a production subset
- Device failure rate: 0 DPPM
- Emitter failure rate: < 40 FIT

**Environment (selection)**
- Humidity: Pass
- Op / Non-op Heat soak: Pass
- Temperature cycling: Pass
- High temperature storage: Pass
- ESD: Pass
Outlook

Applications

Wearables

FACE RECOGNITION

FACE TRACKING

EMOTION TRACKING

HEALTH MONITORING

INDOOR MAPPING

Application:...towards a complete and seamless VR and AR experience

Flickr: BrotherUK, Creative Commons
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MATERIALS THAT MATTER