850 nm 25G VCSEL Reliability

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850nm Datacom Deployment History

- Over 20Y of high volume 850nm VCSEL production from multiple vendors serving multi-mode data communication market on glass fibers
- Bit rate increasing x10 every 10 Years
- 25Gb/s IEEE 802.3bm standard release in 2015 – Over 100M 25Gb/s channels deployed
- 50Gb/s IEEE 802.3cd standard release in 2018 – Over 20M 50Gb/s channels deployed
- 100Gb/s IEEE 802.3db standard expected to be released in 2022
• Intended for extended temperature range 0-85°C
• Recommended bias is 7.5mA and
• Small signal bandwidth exceeds 17GHz
• Bandwidth at 115°C is greater than 16GHz
• At -40°C bandwidth decay can be increased by increasing bias without concern for reliability.
850nm 25G VCSEL Reliability Requirement

- 25G 850nm Datacom VCSELs are specified and designed for 10 years of continuous use (24x7x52x10=88kH) at constant substrate temperature.

- Assumptions to translate automotive mission profile and service life to reliability requirement:
  - Total vehicle operating time: 32kH
  - Mission temperature profile: >90% of operating time is below 50C!
  - Acceleration model for 25G VCSEL (Ea=1.15eV)
  - VCSEL substrate is 10degC hotter than ambient

- 32kH Automotive service life/mission profile corresponds to ~13Y at 70C (substrate)
**Extended Temperature 25G 850nm VCSEL Characteristic**

**Wearout Lifetime**

- Equivalent of ~13Y of life at 70C (substrate) required for automotive application
- Extended Temperature Datacom VCSEL specified at >10Y at 85C and >40Y wearout life at 70C
  - Characteristic TT1%F 25G VCSEL is ~100 Years at 70C (substrate)
  - Extrapolation shows low-level cumulative failure at 13Y, 70C that corresponds to automotive mission life corresponds to <1ppm
- 850 nm 25G VCSELs are capable of performing in automotive application for duration of service life
High Temperature Operating Life

- Long-term aging (over many years) show that 850nm VCSELs are robust for automotive mission profile
  - >4000 channels with cumulative >30MH without failure
- Negligible degradation for VCSELs in stress for extended high temperature operating life after 10kH!
- 32kH mission profile/service life equivalent at 7.5mA bias shown by blue vertical line

### Temperature-Ambient

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Current (mA)</th>
<th>Mission profile %</th>
<th>Total Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>-40°C</td>
<td>7.5</td>
<td>6%</td>
<td>1.9kH</td>
</tr>
<tr>
<td>23°C</td>
<td>7.5</td>
<td>20%</td>
<td>6.4kH</td>
</tr>
<tr>
<td>50°C</td>
<td>7.5</td>
<td>65%</td>
<td>20.8kH</td>
</tr>
<tr>
<td>100°C</td>
<td>7.5</td>
<td>8%</td>
<td>2.6kH</td>
</tr>
<tr>
<td>105°C</td>
<td>7.5</td>
<td>1%</td>
<td>0.3kH</td>
</tr>
</tbody>
</table>

Mission profile/service life
Field Experience

Over 100M 850nm 25GBd VCSEL channels deployed for Data Centers

Field experience

< 1 DPPM (channel)
< 1 FIT (channel)
Summary

- 850nm 25Gbps VCSELs have sufficient bandwidth to perform over wide temperature range -40C to 115C
- Analysis of automotive service life and mission profile shows that 850nm VCSELs exceed expectation
- 25Gb/s 850nm VCSEL Technology has proven performance and field reliability for data centers
  - Multiple high-volume vendors
  - Low field FIT rate with deployments since 2014
- Using 850nm VCSELs for automotive application will leverage high-volume/complete multi-vendor technology and manufacturing eco-system
  - Photodiodes, ICs (laser driver, TIA) and OM3/OM4 fiber
- Proven capability to extend to future higher bit rate generations