Advanced VCSEL for High Temperature Operation

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→ Introduction
→ Reliability of the devices
→ LIV study
→ Optimal currents and modulation voltage
→ 10Gb/s eye diagrams at 105°C at 3 mA
→ Multi-rate operation
→ Expected lifetime at 10 Gb/s at 105°C
**SPEED**

- **10 Gbps**
  - Cameras
  - Displays
  - Data Sharing

- Up to 10 Gb/s at 105°C
- Electromagnetic interference is not relevant for optical links

Expect to have few, if any, needs for speeds greater than 1 Gbps but less than 10 Gbps

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**AUTOMOTIVE ENVIRONMENT**

Voltage Requirements


Environmental Requirements

- See 802.3 Clause 96.9
- Max ambient temperature of 105°C

EMC Considerations

- Not all frequencies have strict Radiated Emissions limits
- Consider using frequencies whose multiples fall into these “Open” bands
- Even a 59th harmonic can be an issue if the limit line is low
Key issue: Reliability

VCSEL lifetime decreases with current increase
VCSEL lifetime decreases with temperature increase
For high temperature operation low current density is needed to ensure reliability
Only VCSELs reliable at very high current density may be suitable for 10G reliable operation at 105°C
1 mA (6 µm aperture): $f_{\text{3dB}} \sim 8$ GHz, 10 Gb/s operation

1 mA at room temperature is enough for 10 Gb/s ($\sim 3.6$ kA/cm²)
850 nm VCSEL studied: Accelerated Ageing

- Wafer level tests: 600 chips. Tested at 3 currents each at 3 temperatures
- 30 thousand years extrapolated to 1% failure at RT at 18kA/cm² (5mA)
- Lifetime increases as \( \sim 1/\text{(current)}^7 \)
- Lifetime decreases 30000-fold by temperature increase to 105°C

VIS chips studied: Long run reliability

- >6000h at 95°C (>0.7 years)
- 18 kA/cm² (6 µm aperture)
- 25Gb/s – compatible at 95°C

References on ageing studies of VIS chips:

„Accelerated aging of 28 Gb s⁻¹ 850 nm vertical-cavity surface-emitting laser with multiple thick oxide apertures“


Eye diagrams at 10Gb/s

- 25°C: 4 mA, 5 mA, 7 mA, 9 mA
- 105°C: 4 mA, 5 mA, 7 mA, 9 mA

30GHz linear receiver (not optimal for 10G eyes)

→ No significant change in the eye diagram 5 – 9 mA
→ Peak-to-peak modulation voltage 0.3V is too high at 105°C
Eye diagrams at 10Gb/s

At small currents, small modulation voltage is applied to avoid signal distortion due to the reaching of the laser threshold current.

- 105°C 4 mA, V_{pp} = 0.3 V
- 105°C 3 mA, V_{pp} = 0.15 V
- 105°C 3 mA, V_{pp} = 0.075 V

30GHz linear receiver (not optimal for 10G eyes)

⇒ At small currents, small modulation voltage is applied to avoid signal distortion due to the reaching of the laser threshold current.
Different bit rates and receivers

30GHz linear receiver (evaluation of the optical eye)

105°C 3 mA  Vpp=0.15V  5 Gb/s

VIS 40G ROSA
35GHz limiting TIA
(evaluation of electrical eye)

105°C 3 mA  Vpp=0.15V  10 Gb/s

→ Reliable electrical eye at 10 Gb/s 3mA 105°C
→ Devices, which passed the qualification test are studied
→ 10 Gb/s performance at 105°C at moderate current density (10 kA/cm²)
→ Lifetime increases as ~1/(current)⁷: at 3mA lifetime increases 36-fold over the 5mA lifetime

→ 36 years of the estimated lifetime to 1% failure at 10Gb/s at 105°C
→ The design is optimized for the range of up to 85°C. Several approaches can be applied to improve temperature stability further to 105°C