850 nm VCSEL for GI POF Links

Ramana Murty

Broadcom Inc.

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GI-POF based Optical Links

- GI-POF A4j characteristics will be defined in IEC at 850 nm, and some guidance on bandwidth for longer wavelengths is expected

- Goal for 802.3dh is to develop a link specification that enables a wide array of component suppliers – VCSEL, PD, IC, fiber, and optical elements

- This presentation is regarding reliability of 850 nm VCSELs

  A previous presentation on 850 nm 25G VCSEL reliability
  Laura Giovane, https://www.ieee802.org/3/cz/public/8_jun_2021/giovane_3cz_01_080621.pdf

850 nm VCSEL

- 850 nm VCSEL-based 25G links have been in use since 2014
- When it comes to reliability, one should distinguish between two aspects: wear-out life of the device, and random failure
- Wear-out life is established by accelerated aging tests

  Applications generally call for operation at either 70°C ambient or 85°C ambient.
  A minimum TT1%F of 10 years is required at these conditions [cw operation].

- Random failure is caused by manufacturing defects that slip through production

  Field experience over 100M 25 GBd transceivers shows a random failure rate below 1 FIT.

- Automotive mission profile calls for a total operating lifetime of 32000 hrs (3.7 years) with a temperature profile (slides 5 and 9)

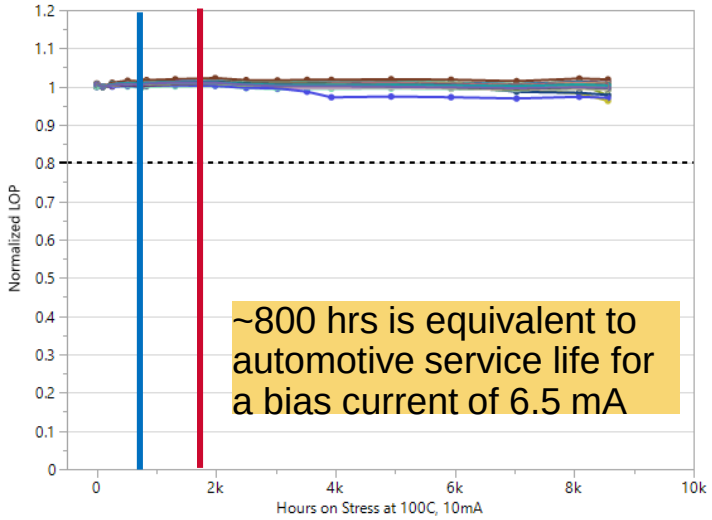
105°C ambient	1%
100°C	8%

  The automotive application is *adjacent* to the traditional high speed 850 nm VCSEL-based data links.

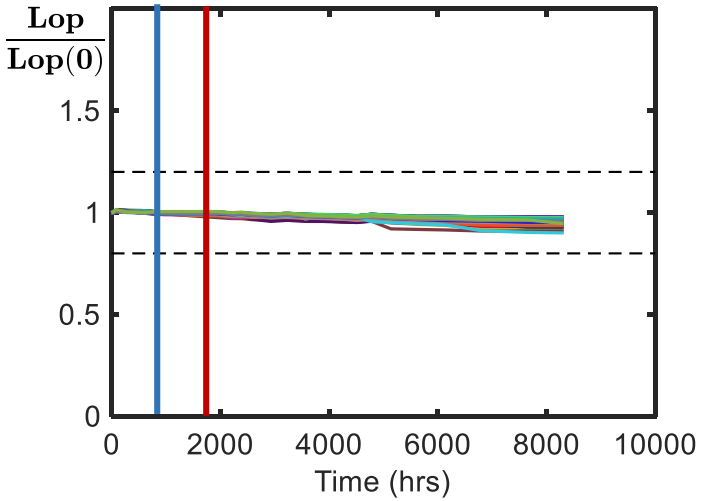
Accelerated Aging

- In estimating wear-out lifetime, a ΔT of 20K is assumed between ambient and VCSEL substrate
- Long term aging tests show that the wear-out life is several fold longer than automotive service life.

100°C, 10 mA



130°C, 7.5 mA



Automotive mission profile service life

ΔT = 20K, Bias 6.5 mA

ΔT = 20K, Bias 7.5 mA

- Literature on long lifetime for 25G and higher speed 850 nm VCSELs

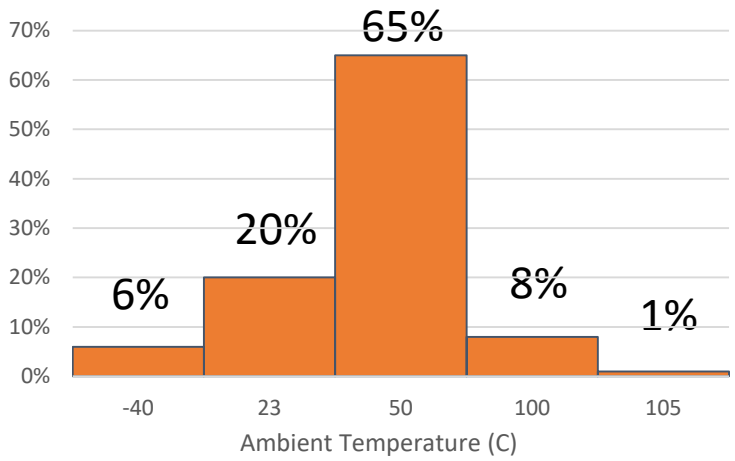
M. Hoser et al., Highly Reliable 106 Gb/s PAM-4 850 nm Multi-Mode VCSEL for 800G Ethernet Applications, OFC 2022 Paper TuD2.5

N. Ledentsov, Jr., Technical feasibility and reliability of quantum-dot 850-nm VCSELs operating up to and above 25 Gbaud with a high temperature stability beyond 150°C, https://www.ieee802.org/3/OMEGA/public/28_apr_2020/ledentsovJr_OMEGA_01_280420_VCSEL.pdf

Wear-out Lifetime

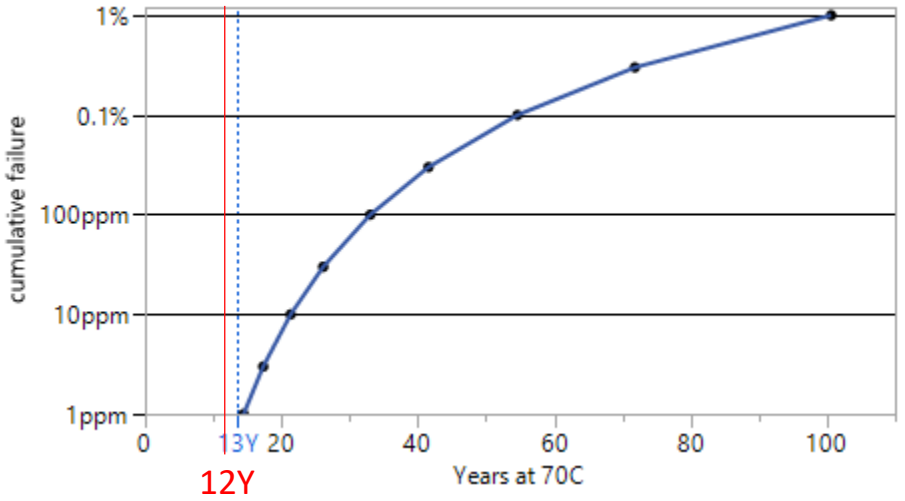
- Bias current of 6.5 mA is a sufficient for 25G operation at a VCSEL substrate temperature of 125°C.[1]
- Automotive mission profile is translated to equivalent number of years operation at 70°C.
- 850 nm VCSEL wear-out life meets the requirement for automotive service.

Automotive mission profile[2]



Total: 32000 hrs (3.7 years)

Extrapolation of lognormal at 70°C



Operating Condition	Equivalent number of years at 70°C
ΔT = 20K, Bias 6.5 mA	12 years

1. Ramana Murty, https://www.ieee802.org/3/cz/public/sep_2021/murty_3cz_01_0921.pdf
2. R. King, https://www.ieee802.org/3/cz/public/nov_2020/king_3cz_01_1120.pdf

Failure Rate

850 nm 25 GBd VCSELs are widely deployed in data centers.

- Field experience: Over 100M 850nm 25GBd VCSEL channels deployed for Data Centers

  Field experience

  < 1 DPPM (channel)

  < 1 FIT (channel)

- Wear out failure mode is not observed in the field.
- Accelerated aging tests determine the parameters of the wear out failure mode.

Low random failure rate is more important in the field. How do you establish low random failure rate?

1. Failure modes have low activation energy; not easy to accelerate in a lab test (GR-468 Ea = 0.35 eV)
2. Demonstrating values below 10 FIT requires massive testing, or many years of field experience.

Summary

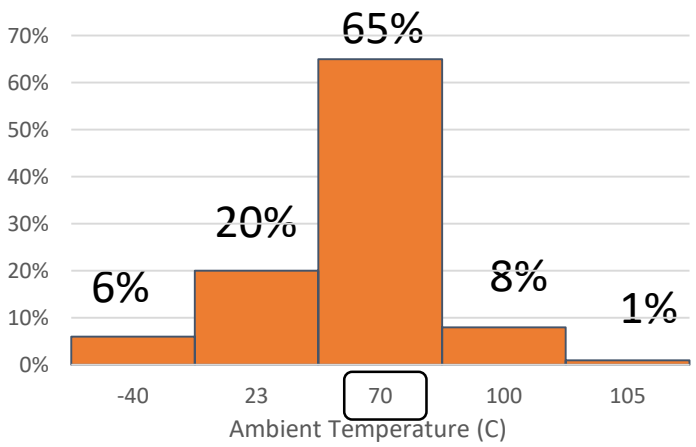
850 nm VCSELs have been proven in the field and are available today.

- 25 GBd VCSELs have sufficient wear-out lifetime to operate over the automotive temperature range.
- Low field FIT rate in data center applications over 8 years.
- Using 850 nm VCSELs for automotive application will leverage the established high volume, multi-vendor manufacturing eco-system.

Appendix

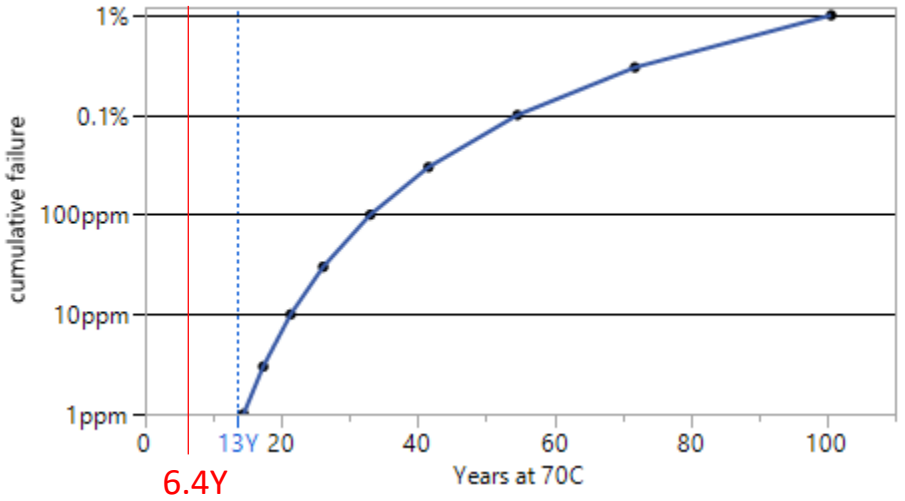
Wear-out Life: A second mission profile

Automotive mission profile[1]



Total: 12000 hrs (1.4 years)

Extrapolation of lognormal at 70°C



Operating Condition	Equivalent number of years at 70°C
ΔT = 20K, Bias 6.5 mA	6.4 years