



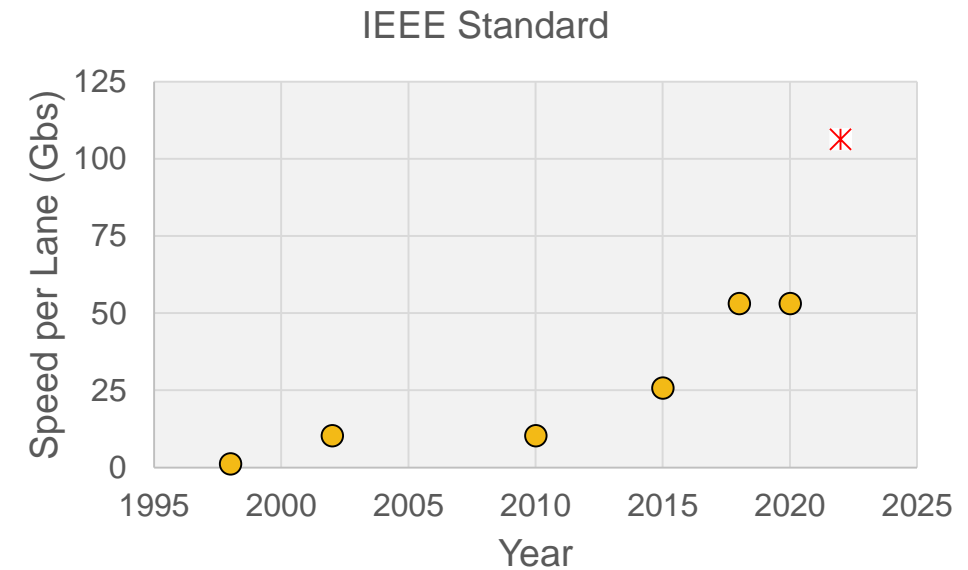
850 nm 25G VCSEL Reliability

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IEEE 802.3cz Task Force
8 June 2021

850nm Datacom Deployment History

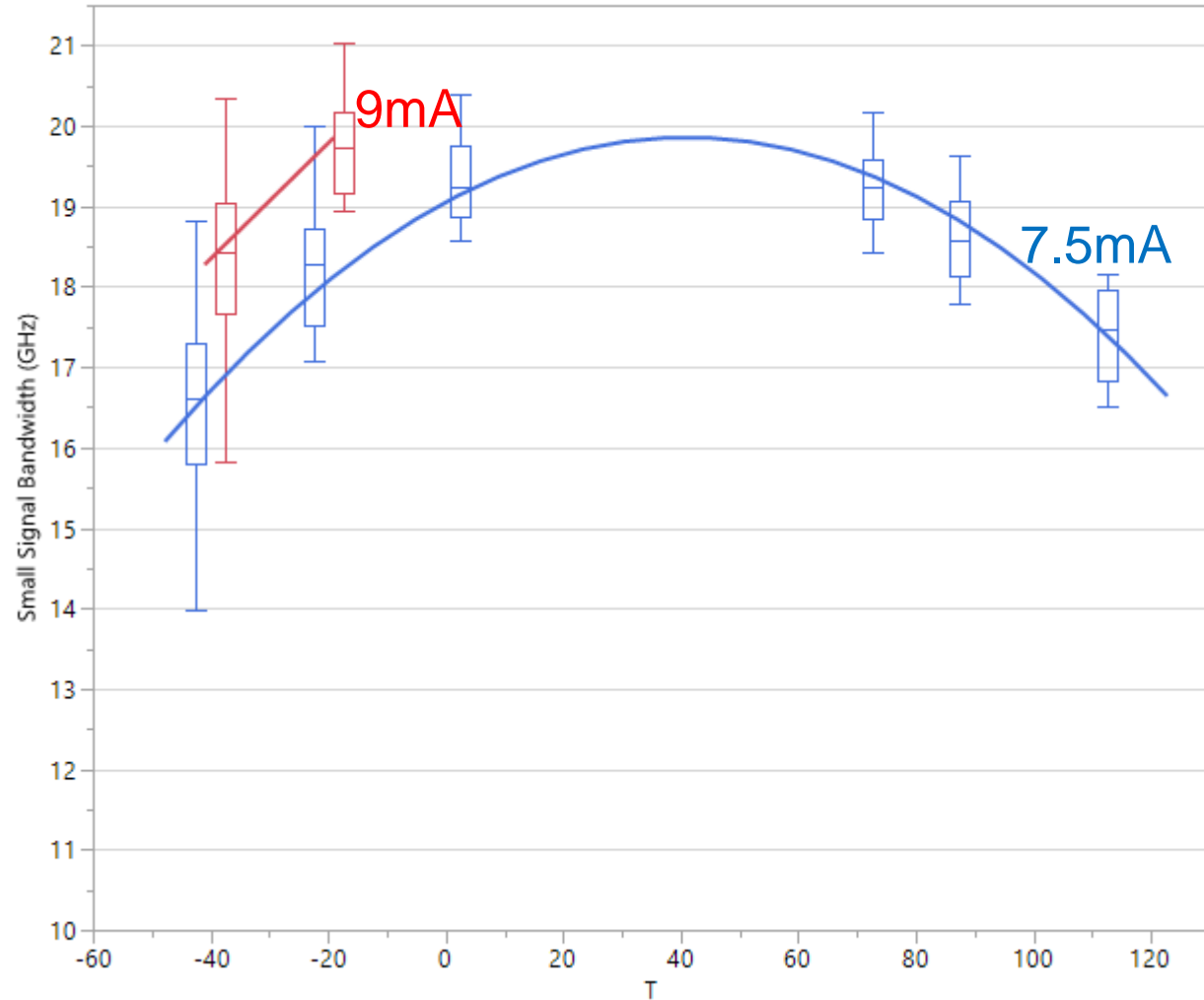
- Over 20Y of high volume 850nm VCSEL production from multiple vendors serving multi-mode data communication market on glass fibers
- Bit rate increasing x10 every 10Years
- 25Gb/s IEEE 802.3bm standard release in 2015
 - Over 100M 25Gb/s channels deployed
- 50Gb/s IEEE 802.3cd standard release in 2018
 - Over 20M 50Gb/s channels deployed
- 100Gb/s IEEE 802.3db standard expected to be released in 2022



850nm 25G VCSEL Characterization

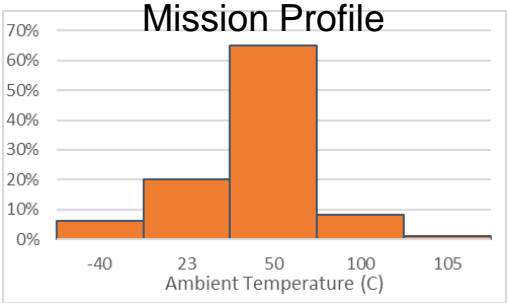
Bandwidth Performance Over Temperature

- 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.

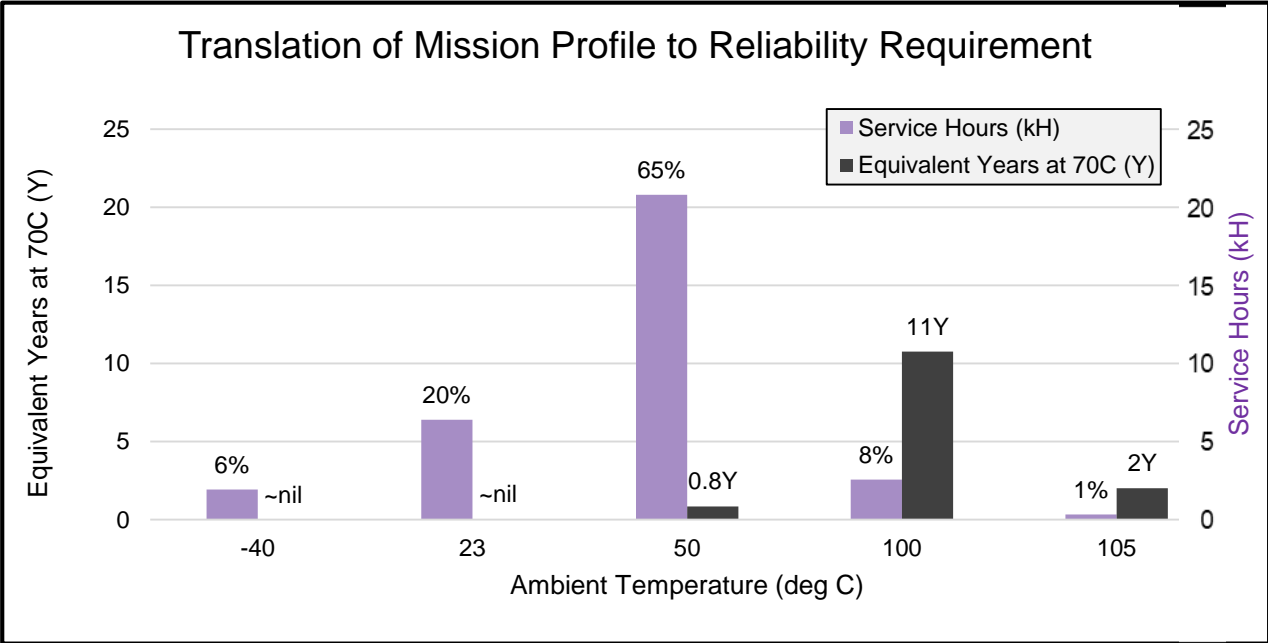


850nm 25G VCSEL Reliability Requirement

	Data Center	Automotive
Ambient Temperature	0-70C –commercial 0-85C –extended Most of time near max temperature	Wider: -40C-105C Temperature Profile
Service Life (VCSEL on hours)	88kH=10Y	32kH=3.6Y



- 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)**

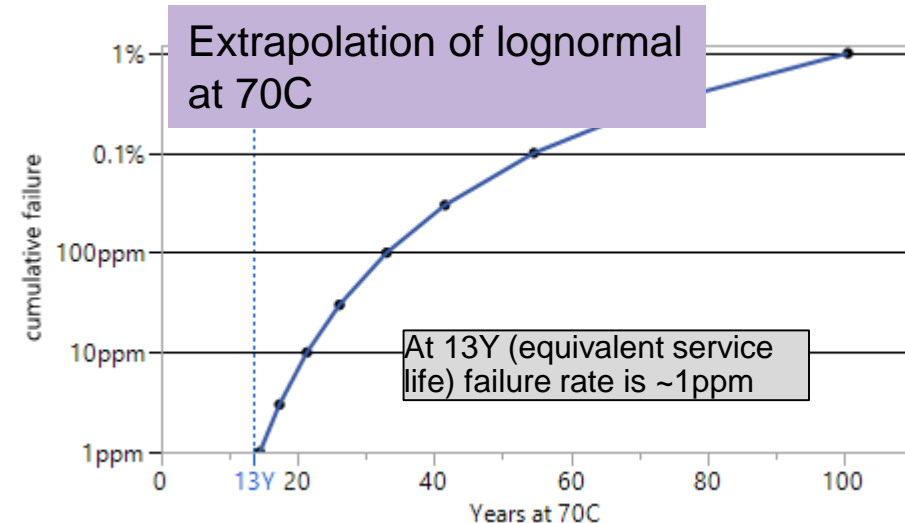
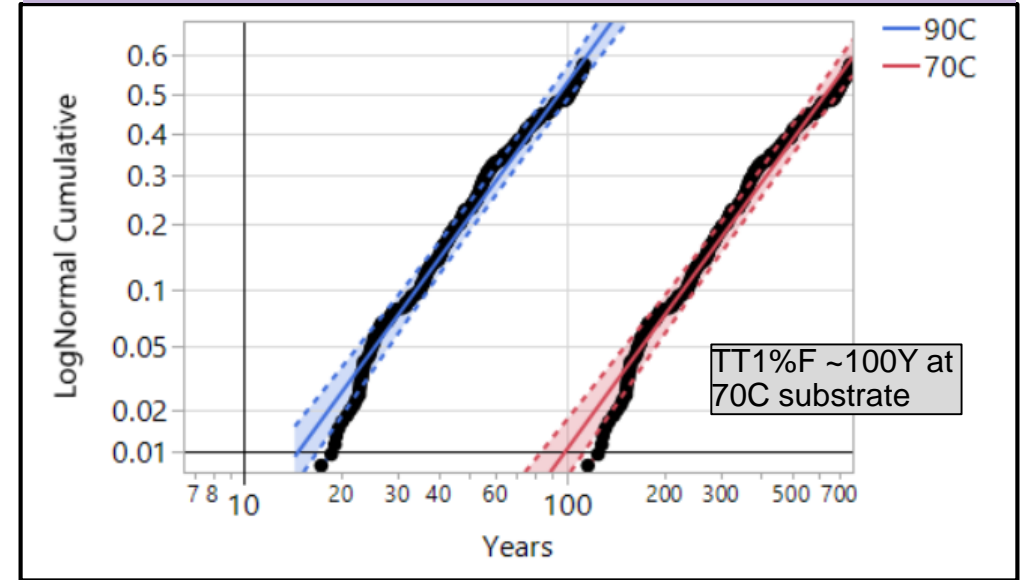


Extended Temperature 25G 850nm VCSEL Characteristic

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

Wearout lifetime of 850nm 25G Extended Temperature VCSEL

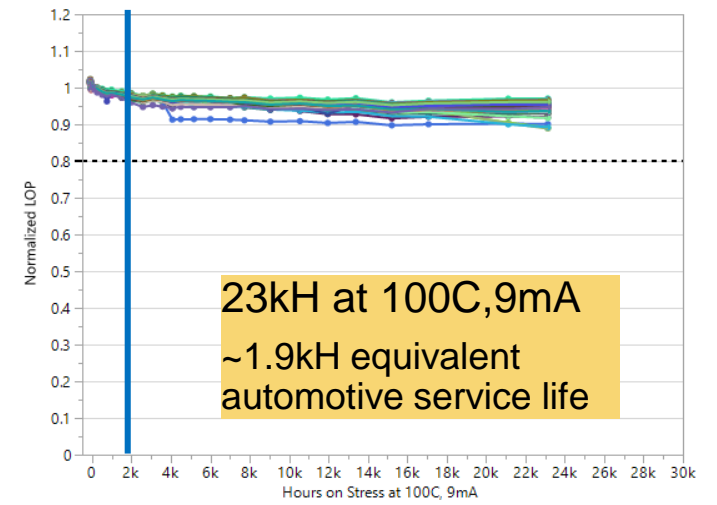
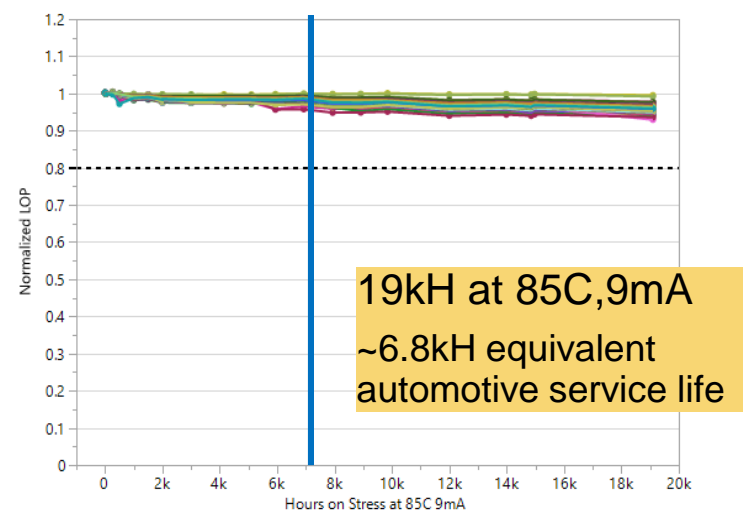
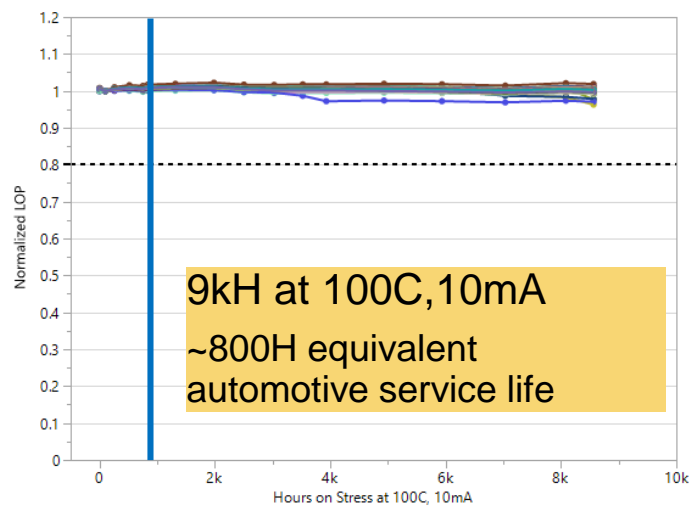


High Temperature Operating Life

- 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	Ibias (mA)	Mission profile %	Total Time
-40°C	7.5	6%	1.9kH
23°C	7.5	20%	6.4kH
50°C	7.5	65%	20.8kH
100°C	7.5	8%	2.6kH
105°C	7.5	1%	0.3kH

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