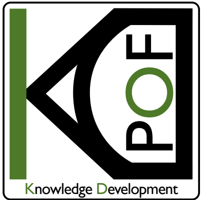
VCSEL reliability

Results for data-center mission profile

Rubén Pérez-Aranda, KDPOF
David Ortiz, KDPOF

IEEE 802.3cz Task Force - 22nd June 2021

Introduction



- In [4] and [7] it was stated that:
  - 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.

- This contribution will demonstrate that these results are very consistent with the reliability results that can be extracted from the same wearout reliability models used for reliability assessment in automotive mission profiles

Reliability results of [1, 2, 3]

Reliability parameters

Operation	Operation total time (h)	87360	Reliability model	Wear out Ea (eV) @ T_J	1.180
	Service life (years)	15		Wear out n @ T_J	1.640
	Oxide aperture diam. (um)	7.0		TTF x%, location	50.0
	I_{OP} (mA) max	7.5000		Log-normal σ', ln (hours)	0.5
	J_{OP} (kA/cm²)	19.50		J_0 (kA/cm²)	19.50
	J_{OP} (mA/um²)	0.19		T_{J0} (ºC)	193
	ΔT_{AS} (ºC)	5.0		TTF_0 x% (hours)	965
VCSEL model fitting	R_{JS} (K/W) @ room Ts reference	1950		Arrhenius C factor (hours) @ T_J	2.200519E-08
	R_{JS} factor	100 %		Qe	1.6022E-19
	R_{JS} (K/W) @ room Ts	1950		K_B	1.3806E-23
	R_{JS} room Ts (ºC)	20.0		Qe/K_B	1.1605E+04
	R_{JS} Exponent	1.067		ºC to Kelvin	273.15
	R_{JS} Current fitting p0	0.01754	VCSEL model fitting	P_{DIS} poly-fitting p11	-0.006889
	R_{JS} Current fitting p1	0.9636		P_{DIS} poly-fitting p02	-5.203E-05
	P_{DIS} poly-fitting p00	-0.3481		P_{DIS} poly-fitting p21	0.0001612
	P_{DIS} poly-fitting p10	1.291		P_{DIS} poly-fitting p12	3.641E-05
	P_{DIS} poly-fitting p01	0.01552		P_{DIS} poly-fitting p03	1.736E-15
	P_{DIS} poly-fitting p20	0.05763			

- Temperature consideration: T_S = 70ºC, 100% of the time
  - Pessimistic in any case
- 10 years of continuous operation is considered
- < 1 FIT
- < 1 DPPM

Reliability result

	Temperature profile							Failure rate						
	Percentage	Operation time per Temperature (h)	T_A (ºC)	T_S (ºC)	R_{JS} (K/W)	P_{DIS} (mW)	T_J (ºC)	TTF x% (hours)	$TTF_{5\,FIT}$ (hours)	Equivalent time in max T (hours)	Log-normal mu', ln (hours)	Failure-rate wear out (FIT)	Failure-rate maverick (FIT)	ppm
T0	100 %	87360	65	70.0	2526.3	11.76	99.7	1.500E+06	128283	87360.00	14.2211			
Cummulative	100 %	87360								87360.00	14.2211	0.0009	0.0	0.0759

Reliability results of [4]

Reliability parameters

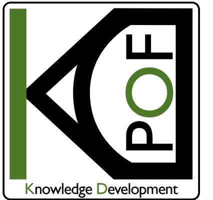
Operation	Operation total time (h)	87360	Reliability model	Wear out Ea (eV) @ T_J	1.150
	Service life (years)	15		Wear out n @ T_J	8.210
	Min oxide aperture diam. (um)	7.0		TTF x%, location	1.0
	I_{OP} (mA) max	7.5000		Log-normal σ', ln (hours)	0.8
	J_{OP} (kA/cm^2)	19.50		J_0 (kA/cm^2)	19.50
	J_{OP} (mA/um^2)	0.19		T_{J0} (ºC)	95.0
	ΔT_{AS} (ºC)	5.0		TTF_0 x% (hours)	873600
VCSEL model fitting	ΔT_{SJ} (ºC) @ 7.5mA	25.0		Arrhenius C factor (hours) @ T_J	6.155275E+00
				Qe	1.6022E-19
				K_B	1.3806E-23
				Qe/K_B	1.1605E+04
				ºC to Kelvin	273.15

- Temperature consideration: T_S = 70ºC, 100% of the time
  - Pessimistic in any case
- 10 years of continuous operation is considered
- < 1 FIT
- < 1 DPPM

Reliability result

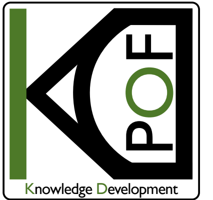
	Temperature profile					Failure rate						
	Percentage	Operation time per Temperature (h)	T_A (ºC)	T_S (ºC)	T_J (ºC)	TTF x% (hours)	$TTF_{5\,FIT}$ (hours)	Equivalent time in max T (hours)	Log-normal mu', ln (hours)	Failure-rate wear out (FIT)	Failure-rate maverick (FIT)	ppm
T0	100 %	87360	65	70.0	95.0	8.736E+05	109856	87360.00	15.5415			
Cummulative	100 %	87360						87360.00	15.5415	0.00749	0.0	0.65453

Conclusions



- Field experience reported in [4] and [7] is consistent with the wear out reliability results obtained using the same models for reliability assessment in automotive mission profiles
- This analysis also shows that the automotive mission profile (operation time 32 kH) is much more restrictive even considering that in data-center applications the VCSEL operates in max temperature the 100% of the operation time (88 kH)
- Using the same reliability model it was shown in [5] and [6] that 850nm 25G VCSELs are not sufficiently reliable for automotive applications unless the operation current is reduced, i.e. ~5 mA

References



- [1] R. Pérez-Aranda, “Reliability constrained link budget assessment for 25 and 10 Gb/s,” Dec 2020, [Online], Available: https://www.ieee802.org/3/cz/public/22_dec_2020/perezaranda_3cz_02a_221220_reliability_linkbdget.pdf
- [2] R. King, “A comparison between 850 nm and 980 nm VCSEL for automotive datacom,” November 2020, [Online], Available: https://www.ieee802.org/3/cz/public/nov_2020/king_3cz_01_1120.pdf
- [3] R. King, “VCSEL design for automotive datacom Experimental results for 980 nm versus 850 nm,” https://www.ieee802.org/3/cz/public/may_2021/king_3cz_01a_0521.pdf
- [4] L. Giovane, “850 nm 25G VCSEL Reliability,” June 2021, [Online], Available: http://www.ieee802.org/3/cz/public/8_jun_2021/giovane_3cz_01_080621.pdf
- [5] R. Pérez-Aranda et al., “VCSEL reliability comparison,” June 2021, [Online], Available: https://www.ieee802.org/3/cz/public/8_jun_2021/perezaranda_3cz_01b_080621_vcsel_reliability.pdf
- [6] R. Pérez-Aranda et al., “VCSEL reliability comparison Annex: possible cause behind results of [4],” June 2021, [Online], Available: https://www.ieee802.org/3/cz/public/15_jun_2021/perezaranda_3cz_01_150621_vcsel_reliability_annex.pdf
- [7] L. Giovane et al., “850 nm VCSEL for Automotive Applications,” June 2021, [Online], Available: https://www.ieee802.org/3/cz/public/15_jun_2021/giovane_3cz_01_150621.pdf

Thank you!