

EPIC ONLINE TECHNOLOGY MEETING ON VCSEL MANUFACTURING AND APPLICATIONS

June 07, 2021 Phil Worland – Founder, President and CEO





BANDWIDTH10, LTD.

COMPANY PROFILE

- Founded in February 2011 from a team out of Berkeley and industry veterans
- Design center in Berkeley CA
- Operations in Berkeley and San Jose (CA), and Zhongli (Taiwan)
- Manufacturing in North America and Asia
- New fabrication and packaging facility in Taiwan
- 55 employees worldwide
 - 30% of them with 10+ years in optoelectronics/semiconductors
 - Core team: 11 PhDs from top US, EU and Chinese universities
- VCSEL wafer capacity ~100 million lasers per year
- Sales team on the ground in Germany, China and USA







PATENTED HCG-VCSEL TECHNOLOGY

Bandwidth 10 is bringing revolutionary wavelength tunable Vertical Cavity Surface Emitting Laser (VCSEL) technology to the market, delivering cost-effective tunable solutions that are out of reach with conventional technologies



- HCG= High Contrast Grating
- Bandwidth10 patented design
- Monolithic growth and integrated fabrication process
- Electrostatic MEMS tuning controlled by voltage
- Fast and continuous wavelength tuning (sweep)
- GaAs and InP substrates available
- Flexible platform for all wavelengths from 720nm to 1700nm







HCG-VCSEL RELIABILITY

WEAR OUT

- Less than 25% drop in output power was observed after over 11,000 hours of stress in a wear-out study with 5 groups of 12 parts being biased at various currents.
- The range of bias caused the junction temperature for the 5 groups to range from 134C to 190C.
- Applying the corresponding acceleration factors based on derived activation energy of 0.7eV, this corresponds to < 10% wear-out in 340,000 hours or **about 39** years at operating conditions.





FIT CALCULATION

- 155 parts from 2 lots operated at 85°C for ~18,500 hours at a typical drive current of 15 mA, measured at room temperature at intervals
- Output power is reasonably constant within expected small variations in power due to room temperature variations over 18454 hours under 85C stress
- For the actual 3.5 million device-hours so far with just one failure, we can thus predict a FIT = 270 with a 90% confidence level, using E_a =0.35eV for random failures; the FIT = 141 with 60% confidence level.



HCG-VCSEL TARGET APPLICATIONS

Features by wavelength			Applications								
Wavelength	Tuning range	CW Pout at 20°C TEC Temperature	FBG Sensors	Gas Sensors	Swept source	ост	Medical Imaging	Optical seed lasers	FMCW LIDAR / range finder	Optical communications	OTDR (telecom)
1060nm	50 nm	0.5 mW			•	•	•	•			
1550nm	10 nm	1.0 mW	•	•	•		•	•	•	•	
1654nm	4 nm	1.0 mW		•	•					•	•

BW10 VCSEL Common features

- Single mode VCSEL
- High modulation bandwidth 10G
- Mode-hop free
- Swept-tuning up to 500 kHz TO and TOSA with integrated TEC
- TOSA with integrated isolator
- TOSA with LC Fiber receptacle
- Pigtailed TOSA with PM or SM fiber

Example of application: **medical OCT**







TO-can



1060 nm GaAs VCSEL swept source for next generation **optical coherence tomography (OCT)**

Demonstrated performance (in cooperation with a partner company and a research institute): Swept source: Bandwidth10 1060nm tunable VCSEL (Product model number: BW10-1060-T-PxFA), Tuning range 60nm Optical amplifier: SOA with 15dB gain Scan speed: 200KHz A-Scan Image depth: 12mm



Pigtailed TOSA





Drive and Control electronics





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THE EPIC QUESTIONS

What can BW10 do for you?

- Deliver cost-effective swept-tunable solutions that are out of reach with conventional technologies
- Flexibility in design and wavelength choice
- Offer complete solutions with the laser ranging from TO and TOSA packages including drive and control electronics.

What can you do for BW10?

- Cooperation on integrated solutions (beam steering, amplification, ...) for the forthcoming mainstream applications
 - Chip level
 - Subassembly level
- Identify target specification for ground-breaking applications



THANK YOU

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BACK UP SLIDES



Wear-out Lifetime Prediction

Product: TO 1550nm

Experiment: Expt46C-MFG15 after 11,000 stressed hours (MFG15 manufactured at Luxnet fab), responsible Ghulam Hasnain

Description: Wearout study of 60 pcs. in 5 bias groups, intermediate results of 202105

Prediction: Weibull++, 1dB/2dB degradation, 90% confidence level, exponential/lognormal distribution, Ea=0.7eV

Author: Thomas Käßemodel Date: 6/1/2021

Power degradation (points) with exponential fit (lines) and 1dB/2dB limits (dotted lines).



Time [u]	Fail [%]				
time (y)	1dB	2dB			
5	8.3E-15	0.0E+00			
10	7.5E-10	5.6E-14			
15	1.8E-07	4.0E-11			
20	5.0E-06	2.5E-09			
30	2.8E-04	4.4E-07			
50	1.3%	8.9E-05			
75	10.3%	0.2%			
100	29%	1.6%			
125	51%	5.1%			
150	69%	11.4%			
250	98%	52%			
400	100%	86%			

E-il [9/]	Time [y]				
Fair [20]	1dB	2dB			
TT0.1%F	35.7	67.9			
TT1%F	49.0	94.2			
TT10%F	75.2	146.4			
TT25%F	95.9	188.1			
MFT	124.3	245.8			
MFT : Median Failure Time (50% of					



Numbers in the tables are actually based on 7,500h readouts. Latest numbers after 11,000h support these, with slight shift towards longer lifetime expectation.







RELIABILITY

Reliability FIT Declaration

This declaration applies to the products listed below:

Product Number:

BW10-1550-T-TO BW10-1550-T-T7 BW10-1550-T-PSFA BW10-1550-T-PPFA

Product Family Name:

Tunable VCSEL TO-can Tunable VCSEL TOSA Tunable VCSEL pigtail TOSA

FIT - Random failures during useful life

TVCSEL	Bias	Ea	609	%CL	90%CL			
			λ [FIT]	MTTF [y]	λ [FIT]	MTTF [y]		
30°C	15mA	0.35eV	141	812	270	422		

 $\label{eq:linear} \begin{array}{l} \lambda \mbox{ [FIT]: Failure rate, in FIT (failures per 1*10^9 operational hours)} \\ MTTF [y]: Mean time to failure, in years \\ xx%CL: Statistical confidence level, in % \\ T_{VCSEL}: VCSEL temperature \end{array}$

The predictions are based on over 3.5 Mio stressed TO device hours, equivalent to over 14 Mio equivalent device hours, with 1 failure observed. Prediction methods as described in Telcordia SR-332 were applied. Calculations were made most conservatively, taking the sum of total equivalent device hours vs. sum of total failures from all test groups into account. This declaration is made after careful data examination and to the best of our knowledge.

