# High Power VCSELs for non-hermetic time-of-flight modules

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## Agenda

- AFBR-S50 CW ToF Module series
- ToF Module System partition
- CW ToF optics scaling (distance, FoV, peak power)
- VCSEL technology baseline
- VCSEL reliability
- VCSEL scaling for higher peak powers
- VCSEL at Broadcom (Avago): Summary



## AFBR – S50: Sensor Family for Short Range Industrial Flash LiDAR

TOF Sensor:	AFBR-S50MV85G	AFBR-S50LV85D	AFBR-S50MV85I	AFBR-S50MV68B
Target	Medium	Long	Short - Medium	Medium
Range (black):	- 10m	- 30m	- 5m	- 10m
Laser Light Source:	850nm	850nm	850nm	680nm (red)
Illuminated FOV:	4.5°x4.5°	1.5°x1.5°	12.4°x6.2°	<1°x1°
Illuminated Pixels:	7-16 (32)	1 (32)	All 32	1 (32)



drop-in Presence, Distance, Motion compatible

Navigation & Collision Avoidance

Visible "point"

Same platform - different integrated optics to choose optimum distance, Pixelcount and FoV



## AFBR – S50: System partition







100mA in TX driver & 100pA in integrated detector and RX circuit 9 decades smaller signal current in RX **180dB** attenuation in ~2mm spacial distance! Patented structures used as shielding Fully transparent analog and digital test layer for deep probing Distance resolution in mm range under extreme ambient light conditions



## **Optics scaling for a given pixel sensitivity**

Sensitivity of -75dBm with 20ns pulses\* using correlation ToF + APD !

- 1. Max. distance (left axis)
  - 6mm Rx lens
  - 9 illuminated Pixels
  - 60mW peak emission
  - →10m max. distance
- 2. Field of View FoV (right axis)
  - 6mm Rx lens
  - f-number: f/0.9
  - detector size: 0.45mm x 0.45mm
    diagonal FoV = 6.6°
  - \* ~3 photons per pulse!







## **VCSELs for ToF Sensors**

Key attributes of high power VCSELs for ToF sensor applications:

- Emission in the near infrared, 800 1000 nm, suitable for low cost Si detectors.
- Rapid response with sub-ns turn on / off.
- Stable over temperature operation.
- Long lifetime under CW and pulsed operation.
- Circular beam, small emission diameter.
- 1D and 2D arrays for high aggregate power.
- On wafer testing.





# **Reliability of High Speed Data Communication VCSEL**

#### Solid field reliability track record

Shipping since 2013

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- Over 20 Million VCSELs shipped
- Over 100 Billion Estimated Device Hours Accumulated
- < 1FIT –channel field return</p>

#### Wearout life far exceeds 10 years at elevated temperatures



## VCSEL design with max. reliability for (CW) TOF

- Scaling of Datacom VCSEL to higher slope efficiency and peak currents
- Emission area <80um & stable far field properties
- Rise times << 300ps for stable Time-Of-Flight reference timing</li>
- for direct TOF: Pulse widths of <5ns, peak currents of ~1A</li>
- for CW TOF typical drive signals are burst-like (mixture of high and low DC), peak currents of ~80mA
- Pauses and average power to meet eye safety class 1
  Drive Signal







### **Farfield properties**

- CW and long pulses show strongest widening
- Shorter pulses / low Duty Cycle / high Peak currents with the tendency to saturate
- Stable farfields require defined indexguiding, limited aperture diameters



larger peak currents and lower Duty Cycles further help to reduce farfield variations



#### Gen 1



100°C, 28 mA 90 devices each from three wafers Gen 1 Three wafers (PKVRA8239 A, B, E)



85°C, 85% RH, 15 mA 40 devices each from three wafers Gen 1 Three wafers (PKVRA8239 A, B, E)



## Gen 2: Optimization for higher (peak) power



85°C, 250 mA 200 ns pulse width

2% duty cycle

20 devices each from two wafers

Gen 2

Two wafers (PKVRC1228A, D)





## **VCSEL** at Broadcom

- Broadcom is a leader in manufacture of high speed data communication VCSEL
- Complete in house R&D and manufacturing capability
- Over 20 years of high volume VCSEL manufacturing experience
- Track record of doubling bit rate every 3 years
- Proven reliability and low FIT rate for demanding data center applications





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