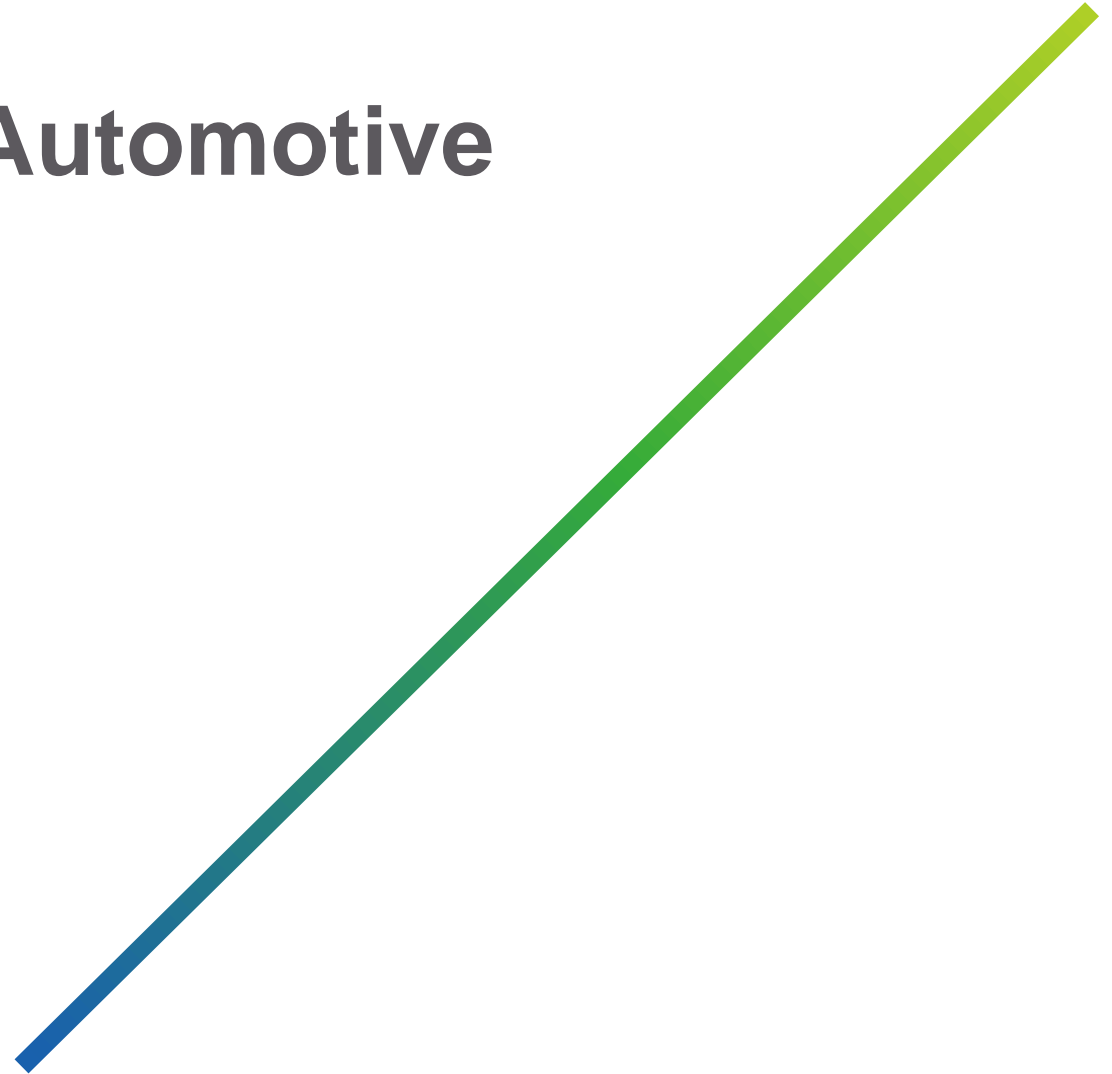




# VCSEL PIC solutions for Automotive LiDAR Applications

Dr. David Cheskis  
Product Line Director

11 January 2021



# Lumentum – World’s Leading Optical Solutions Provider

**\$1.68B** FY20\* revenue

**>5500** employees

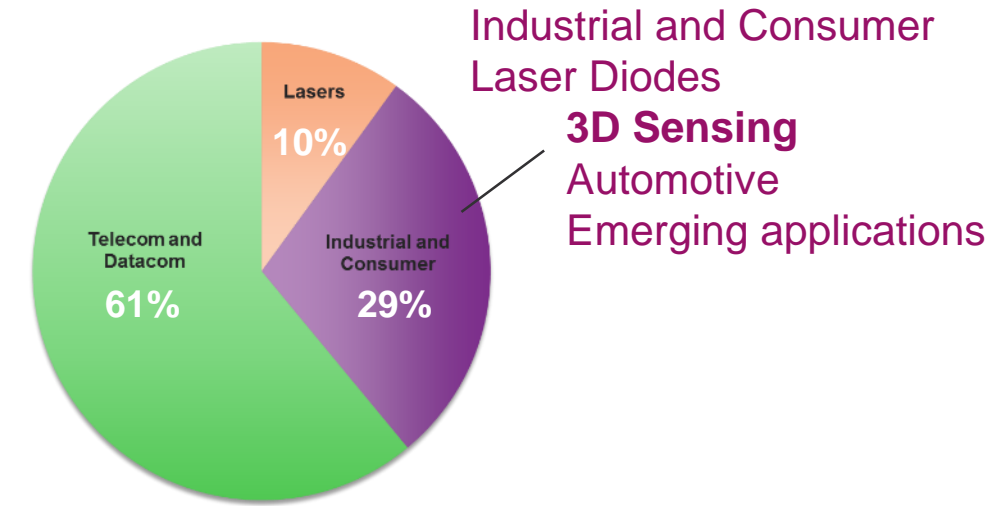
**>1800** patents

\*Fiscal year ended June 27, 2020

## Leadership positions:

- 3D sensing diodes
- Telecom transport and transmission
- 100G data center laser chips

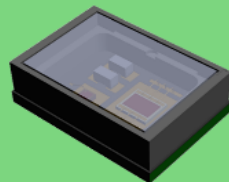
## Diversified Business



Largest global supplier of 3DS illuminators – several times over

**#1**

Develop innovative reference designs with eco-system



Integrated packages reference designs



Highest quality and reliability



Established high-volume, manufacturing infrastructure

# 3D Sensing: Past, Present, and Future Applications



Gaming, PC, various niche applications



Mobile front-facing for biometrics



World-facing for AR



Cabin monitoring



Consumer vehicle LIDAR

Non-mobile application AR/VR, Access Control, robot, interactive app



Robocars LIDAR

2010-2016

2018

TODAY

2022 - 2025

2017

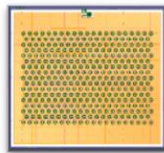
2019

2021

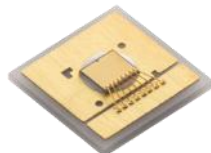
2026+



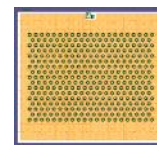
3DS EEL



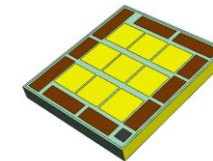
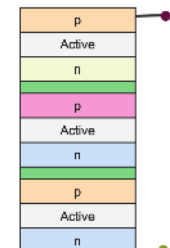
3DS VCSEL



VCSEL on Carrier



Multi-Junction VCSEL

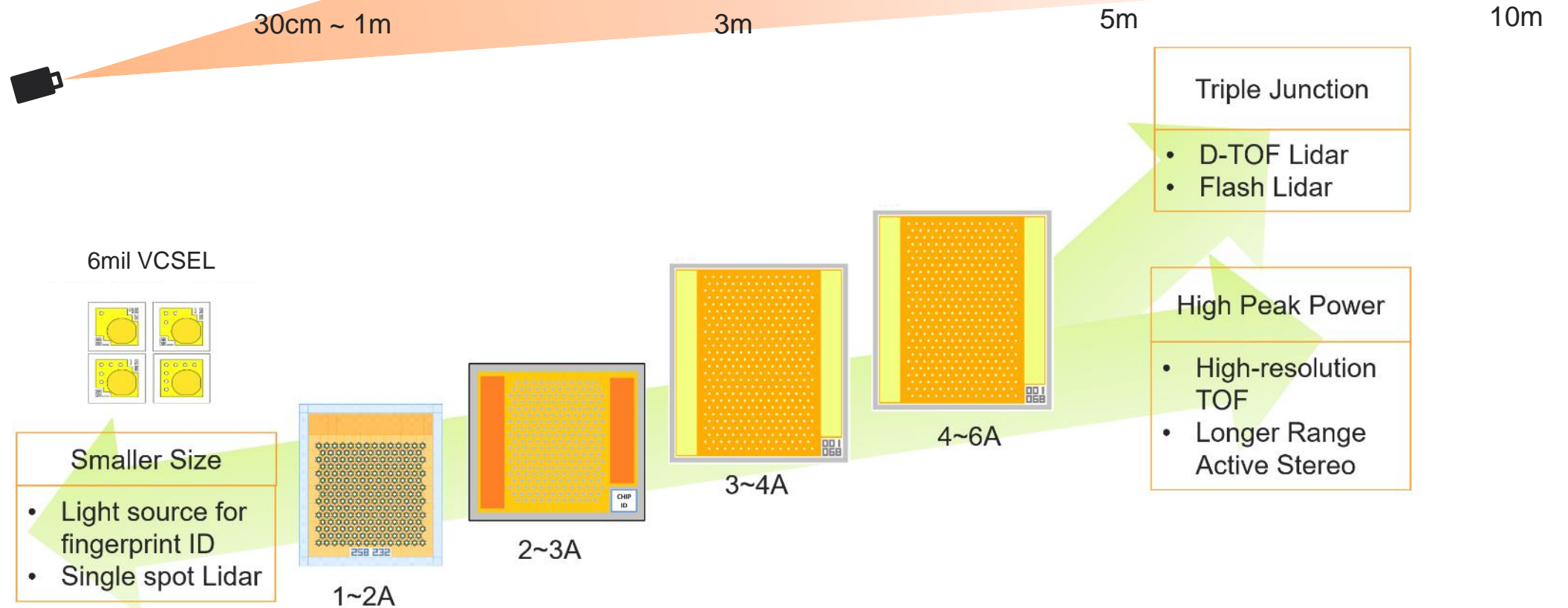


Addressable Arrays

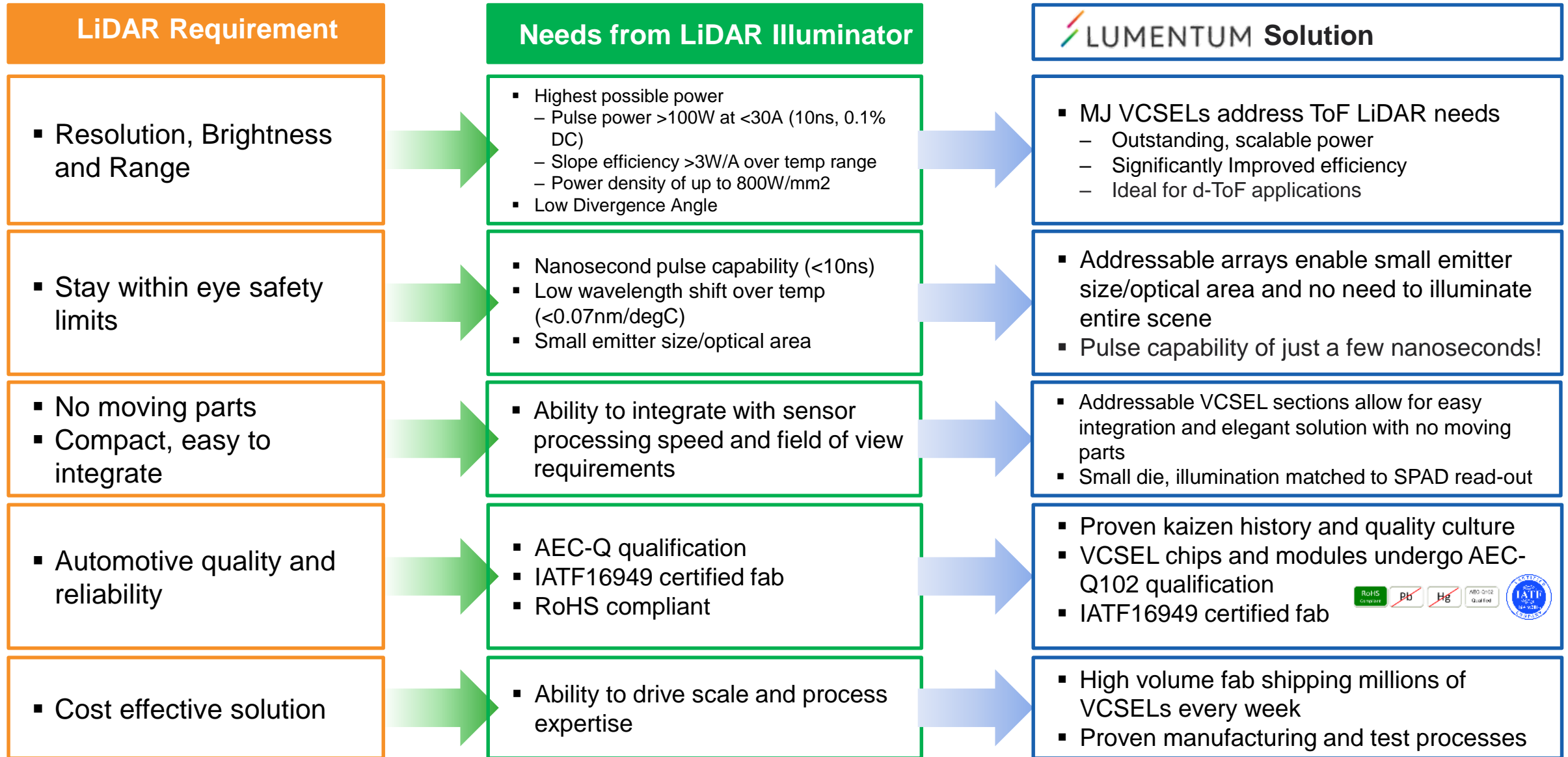
Long Wavelength, More integration

# Lumentum TOF VCSEL Product List for Consumer Market

	Products Offering, VCSEL chips for Flash i-ToF						
<b>Power Level</b>	<b>2.3W</b>	<b>2.4W</b>	<b>2.9W</b>	<b>3.2W</b>	<b>4.3W</b>	<b>5.1W</b>	<b>8.4W</b>
<b>Operating Voltage</b>	2V	1.6V – 2.4V	1.7V – 2.3V	1.75V – 2.3V	3.5V-3.7V	1.75V – 2.3V	4.3V – 5.0V
<b>Die Size</b>	880*850 um2	780*680 um2	980*880 um2	950*850 um2	870*830 um2	1170*960 um2	980*880 um2
<b>Bond Pad Type</b>	Single	Dual	Dual	Dual	Single	Dual	Dual
<b>Junction</b>	1J	1J	1J	1J	2J	1J	3J



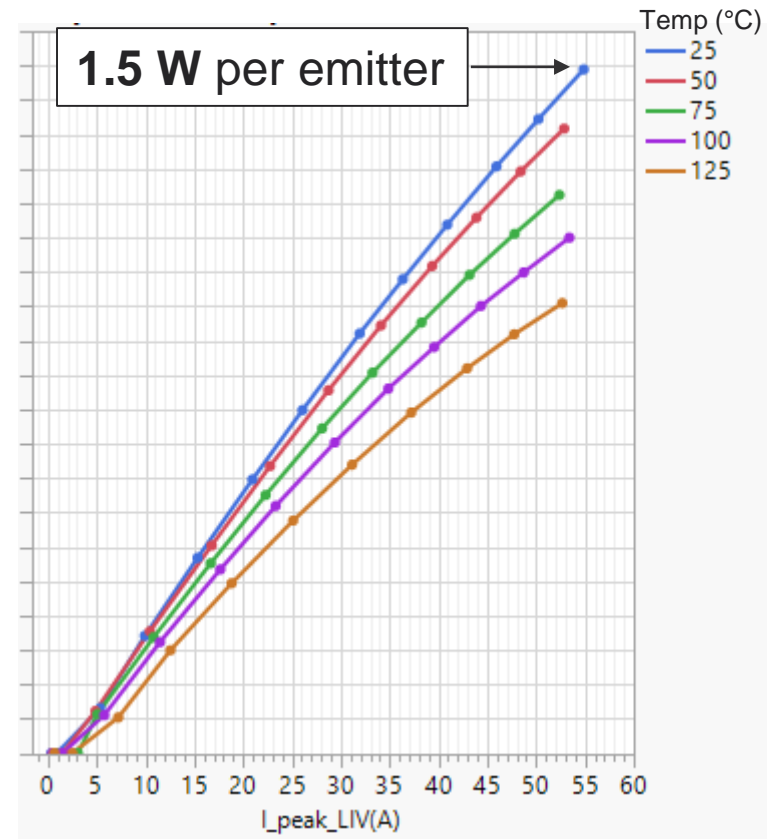
# Challenges for the ToF LiDAR Illuminator





# Lumentum Multi-Junction VCSEL Technology

- More junctions -> More photons (higher output power) for the same input current
- For TOF, overall efficiency (WPE) of both the VCSEL chip and driver significantly improved vs. single junction
- Lower current of 2J, 3J benefit iTOF (50% duty-cycle, within <0.2 ms bursts, overall DC < 10%)
- Ideal solution for d-ToF application (e.g. few nsec pulse width, <0.1% to 2% DC)
  - 100 mW to 2 W/emitter (depending on size, pulsing condition)
  - High power density (20 W/ mm<sup>2</sup> to 1 kW / mm<sup>2</sup>)



100W's of power from small VCSEL chips <1 mm<sup>2</sup>

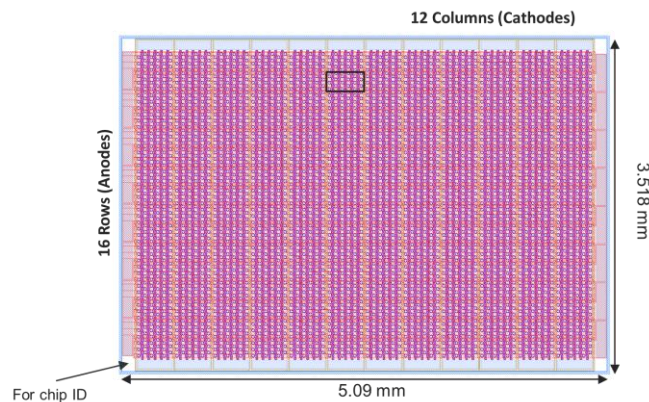
# Matrix Addressable VCSEL PIC Arrays

## 1D Addressable Array:

Illuminate all "1s", then all "2s", "3s", etc.

1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4

**1D addressable:** Good for SPAD with linear readout, but (for automotive designs) requires long, narrow, high resistance rows

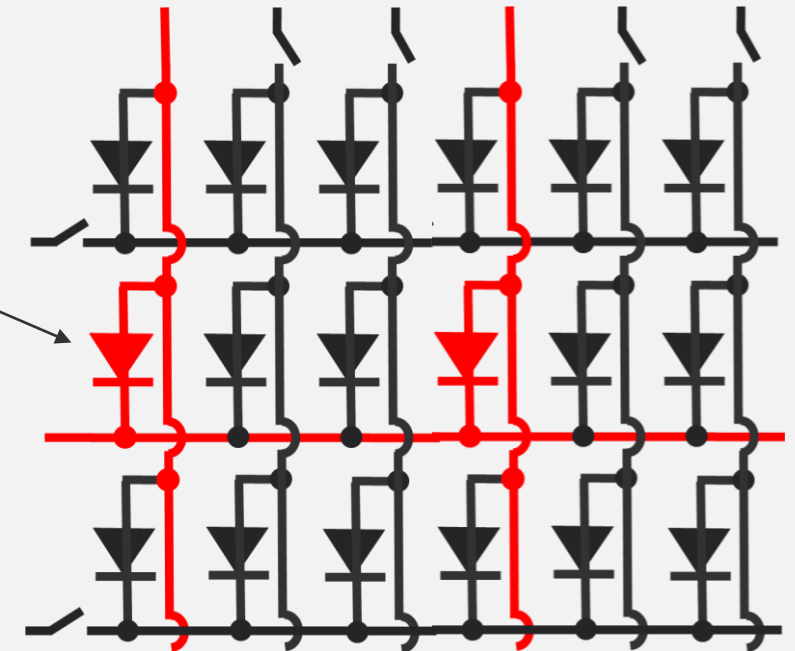


**Matrix addressable:** Requires SPAD with block readout, but avoids high resistance, narrow rows

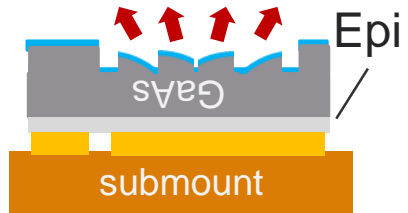
## Matrix Addressable VCSEL Array:

1	1	2	2	1	1	2	2
3	3	4	4	3	3	4	4
1	1	2	2	1	1	2	2
3	3	4	4	3	3	4	4

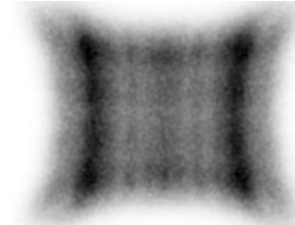
Sub-Array:  
>=1  
emitters



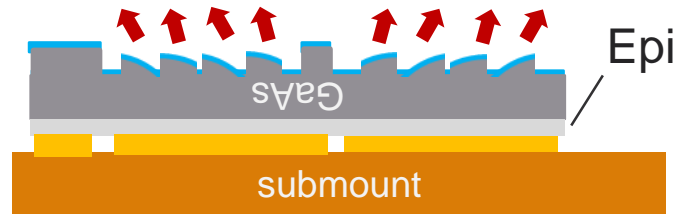
# Bottom Emitting Integrated Optics Configurations



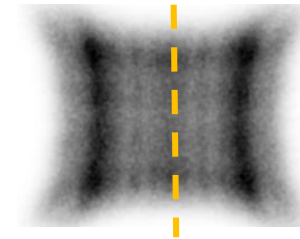
No External optics



Single section,  
Full FOV

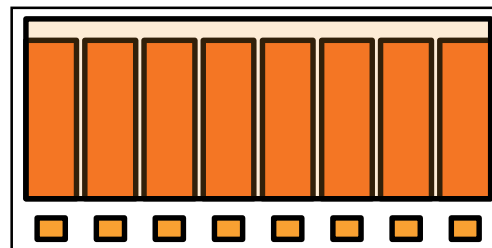
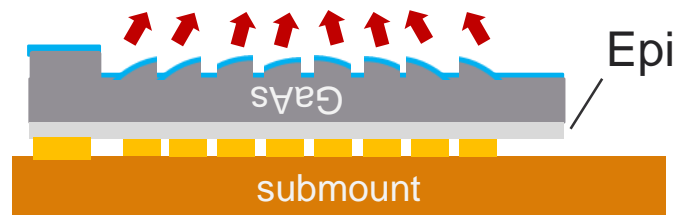


No External optics

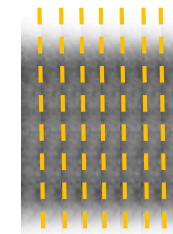


Two section,  
Half FOV each section

 External lens to reduce divergence



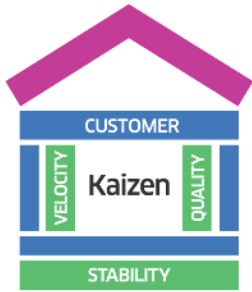
Common anode



8 section,  
1/8<sup>th</sup> FOV each section

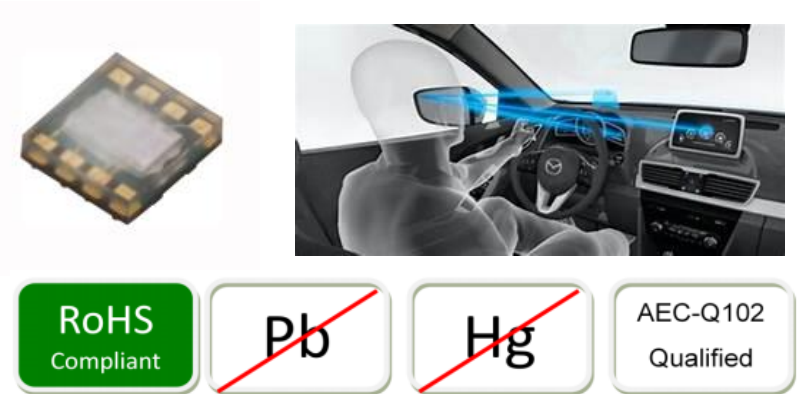


# Reliability



- Lumentum's **Kaizen** quality culture
- Submarine proven fiber optical component history
- >900M units of VCSEL chips shipped, zero field failures!

- VCSEL module for automotive in-cabin applications **completed AEC-Q102 qualification**
  - Qualified in a packaged solution



- **IATF 16949-2016 certified** VCSEL fab

# Summary

- The latest generation of high-power, multi-junction VCSEL chips are the light sources of choice for automotive ToF LiDAR architectures
- Addressability of individual emitter sections allows a perfect match of the emitter to available and future detector devices
- VCSEL development has advanced rapidly as high-volume applications drive innovation and infrastructure
- Lumentum is focused on expanding its automotive VCSEL portfolio
- Ecosystem partners are established for module integrators, detector solutions, and electronic integration



**Thank you!**

